Advances in Military Geosciences

Aldino Bondesan
Judy Ehlen *Editors*

Military Geoscience: A Multifaceted Approach to the Study of Warfare

Springer

Advances in Military Geosciences

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Contents

Chapter 1
Military Geoscience: A Multifaceted Discipline

Aldino Bondesan and Judy Ehlen

Contents

Abstract Military geoscience is defined as the application of geology and geography to the military sphere. Geology was first taught in military academies in the mid-nineteenth century, although military geologists and geographers were not employed by Western nations as such until the First World War (WWI). These were few in number, and their use was significantly increased during the Second World War, particularly in Germany. Academic interest developed primarily after WWI and has increased since, resulting in a series of conferences, beginning in 1994. These conferences, 13 in number, initially stressed military geology, but beginning in 2000, military geography and conflict archaeology, among other subjects, were incorporated. The International Association for Military Geosciences was established in 2013 and now sponsors biennial International Conference on Military Geoscience (ICMG) throughout the world. A book series was established by Springer in the same year. This volume is the seventh in that series and contains papers spanning time from 490 BC into the twenty-first century based on presentations given at the 13th ICMG in June 2019 in Padua, Italy. Emphasis is placed on

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Italian military geoscience research dealing with WWI, although other topics are also addressed.

Keywords Military geoscience · Military geography · Military geology

1.1 Military Geoscience: What Is It?

Galgano and Rose (2020, p. 648) define military geoscience as a discipline "…focused on employing the broad scope of the earth sciences to support military operations: from direct tactical support of combat operations to an extensive spectrum of strategic activities." Furthermore,

> Modern military operations rely on a wide range of land-, air-, sea-, and space-borne intelligence and knowledge of dynamic terrain processes and conditions. In addition, the study of geo-based environmental science is critical to both the sustainable management of military reservations and installations, as well as the evaluation of how terrain and environmental conditions may impact military equipment and operations. (https://link.springer.com/bookseries/15030)

Armies have historically made use of geology, geography, and geomatics as tools to gain greater control of the battlefield and to better understand the territorial contexts in which military operations are carried out as well as the placement of logistical facilities. Many countries have set up military geological offices to meet these various demands in peace time and during war; most geoscience tasks are carried out today by the Corps of Engineers belonging to each army.

Military geoscience encompasses a wide-ranging and very open set of disciplines that address military activities within a geological, geographical, or, more generally, spatial, geological and geographical context. Examples include engineering geology, hydrogeology, geospatial sciences, terrain analysis, archaeology, historical geography, geomorphology, environmental science, geophysics, human geography, cartography and GIS, climatology, and cognate disciplines. "Military geography" and "military geology," however, are the terms normally used to describe the combination of all these disciplines as applied to the military art.

Military geography is generally recognized in its broadest sense as the application of geographic principles to military affairs or military problems. It can be considered a sub-discipline of geography including all its branches: physical geography (e.g., geomorphology, hydrology), human geography, and geomatics. Military geography is also concerned with global issues of interest not only to the military but also to academic researchers and politicians, helping them to understand the geopolitical sphere through the militaristic lens (O'Sullivan and Miller 1983; Collins 1998; Palka and Galgano 2005; Galloro 2007; Galgano and Palka 2011).

Military geology is defined as the application of the earth sciences to such military concerns as terrain analysis, water supply, and foundations and construction of military emplacements and buildings, roads, and airfields. The definition may also be extended to the search for global geo-resources such as oil, water, and strategic minerals. Over time, military geology has increased in scope to include historical analysis and forensic investigations, giving new perspectives to military historical studies (Underwood and Guth 1998; Rose and Nathanail 2000; Ehlen and Harmon 2001; Doyle and Bennet 2002; Caldwell et al. 2004; Rose 2014; Galgano and Rose 2020).

In recent years, without regard to country, military geologists now include individuals with a wide variety of expertise, not only geologists and cartographers but also seismologists and other geophysicists who provide support for nuclear test monitoring and carry out geophysical prospecting and counterbattery actions through seismic survey, among other undertakings. Paleontologists, petrologists, and soil scientists undertake forensic geology studies. Engineering geologists, rock mechanicians, and statisticians study rock properties, including the properties of weathered material, and their variability, which are important with respect to water supply and underground excavation, and deal with site characterization. Soil scientists also study the properties of weathered material. In addition, experts in multispectral, hyperspectral, and other forms of remote sensing and computer specialists, especially those dealing with geographic information systems, are also involved (Harmon et al. 2014).

Academic researchers have paid particular attention to reconstructing battles and military operations, often in cooperation with conflict archaeologists and historians. In this sense, the military geosciences are often in between hard science and the humanities. Much international research is devoted to modern and contemporary warfare (e.g., Bulmer 2019), but many studies address warfare from previous periods using modern techniques and methods of analysis such as remote sensing (e.g., Guth and Scott 2020). Analysis of historical data related to geological settings has significantly improved the understanding of war events, command decisions, and operational results (Rose and Pareyn 2003). In addition, great interest has recently developed with respect to the legacy of war, especially the impact of war in terms of morphological transformation, urban and infrastructural change, social evolution, and pollution (e.g., Doyle 1998; Ehlen and Harmon 2001). Results from military geoscience studies also help to spread knowledge through museums (e.g., the Venetian Great War Memorial (*Memoriale Veneto Grande Guerra*) in Montebelluna, Italy; the Overlord Museum – Omaha Beach in Normandy, France), expositions, and historical parks (e.g., Gettysburg National Military Park in Pennsylvania, USA; the El Alamein Battlefield’s Historical Park, Egypt).

1.2 Military Geoscience: A Brief History

The decisive outcomes of land battles throughout history have been dictated in large part by the terrain and environmental setting. The military geological perspective is a natural concept deeply connected to the act of war and dates back to the dawn of civilization. Geology *ante litteram*[1] has supported military activities since prehistory, although only as an empiric experience by the first primitive fighters. History is full of examples where knowledge of the terrain has been crucial in military operations, for example, Thermopylae (480 BC), Hannibal crossing the Alps (218 BC), Teutoburg (9 AD), and Agincourt (1415).

Geology became a regulated discipline in military organizations during the eighteenth century when all major empires began producing military topographic maps. Frequently, early geologists performed military service but never as geologists, although some applied their geological knowledge to the military art. Napoleon was the first commander to include geographers and geologists in his expeditionary forces during his invasion of Egypt in 1798 (Rose 2005).

The first treatises on military geography were published in the first half of the nineteenth century, for example, Theophile Lavallee's *Geographie physique, historique et militaries* in 1836 and Albrecht von Roon's *Physical description of Europe's military regions* in 1837. During the second half of the century, military geography and military geology become recognized autonomous disciplines. There are numerous texts on the military applications of geology used when the subject was introduced in military schools. As an example, geology was taught at the British Royal Military Academy east of London at Woolwich, from 1848, and at Sandhurst (now The Royal Military Academy Sandhurst), southwest of London in Camberley, from 1858. In Italy, the military academies adopted military geography textbooks starting from 1850 (e.g., Mini 1850; Goiran 1880; Porro 1898; Bianchi 1918; Deambrosis, 1924). The first strategic geographical studies were performed by Perrucchetti (1874, 1878, 1884) on the Alpine fronts.

During the nineteenth and much of the twentieth centuries, geologists in uniform and academics or applied geologists were employed by various armies for operational tasks. They performed basic terrain analysis to assist in assessing the movements of troops and vehicles, located access routes, found construction materials, analyzed slope stability and rock excavation characteristics, and mapped surface and subsurface hydrology (Underwood and Guth 1998; Rose and Nathanail 2000; Ehlen and Harmon 2001; Caldwell et al. 2004; Nathanail et al. 2008; Häusler and Mang 2011; Rose and Mather 2012; Harmon et al. 2014; McDonald and Bullard 2016; Bergerat et al. 2018; Häusler 2018; Rose et al. 2019b, Smit and Bezuidenhout 2019).

During the First World War (WWI), geologists were embedded in armies with this specific role for the first time. British and American Armies employed few geologists as such, a total of 12 for the two armies combined, but the German Army had about 200 geologists on military duty (Rose et al. 2019a). The Russians deployed an unspecified number and the French and Italians had none. These geologists were mainly occupied with water supply, trench construction, and mine warfare. Many Italian academics served in uniform, but not as military geologists, although Italy made extensive use of geological studies, in particular for the design and

[1] Translation: before writing (before the term existed)

management of field works (trenches and shelters) and mine warfare along the Alpine front, where mining engineers and geologists played a fundamental role. After the war, some of the most important Italian university professors who fought in the Alps wrote papers on the relations between war and geology (e.g., Craveri 1916; Sacco 1916, 1917; Gortani 1919; Fossa-Mancini 1920, 1926; Anselmi 1921; Abbolilto 1936). Only Germany maintained a formal military geology organization between the two world wars.

By the Second World War (WWII), military geology was a well-developed science, with hundreds of geologists employed in special military branches in the armies of many countries, such as Germany (von Bülow et al. 1938; Häusler and Willig 2000; Häusler 2003, 2018), Great Britain (Rose et al. 2000), and the United States (Terman 1998). About 400 German military geologists served in the field as members of specialist military geology teams, outnumbering those of any other nation. There were just three British military geologists who served mainly as staff officers at headquarters and fewer than 90 Americans who were primarily civilians located in Washington, DC, at the US Geological Survey (Rose et al. 2019a). In Italy, geological tasks were accomplished by the Military Geological Department (*Reparto Geologico Militare*) as part of the Corps of Engineers and by the Italian Geographical Institute (*Istituto Geografico Militare*) and other colonial units deployed in North and East Africa.

Following WWII, some national European military units were reduced to small teams with reserve army status (the United Kingdom, Italy). In Germany, the geological survey was abolished, to be reestablished in 1956. In the United States, the Military Geology Branch at the US Geological Survey became the Military Geology Unit. It is still active but significantly reduced in numbers and under another name (Terman 1998; Leith 1997; Leith and Matzko 1998). There was also a diminished interest in academia, mainly for ideological reasons, with a renewal in interest among the military and academics beginning with the Gulf War in the early 1990s.

Today in Italy, geologists are part of the Army Select Reserve (*Riserva selezionata*) in the Corps of Engineers, although with a very limited involvement in international missions. Military geoscience in Italy is not yet independently integrated into a fully recognized thematic strand as in many other nations. The relatively few academic papers turn to historical reconstruction under the lens of the geographer or geologist, typically as secondary to the main research interests of the scholars.

The Italian Society of Military Geography and Geology (*Società Italiana di Geografia e Geologia Militare* (SIGGMi)) and the Italian Society of Military History (*Società Italiana di Storia Militare*) are the only national organizations dealing with military geoscience, although the latter is devoted to a broader focus on history. They gather geologists, geographers, and historians around research projects and disseminate scientific information in books and at exhibitions and conferences; many members of SIGGMi are simple enthusiasts or amateur scholars who participate in the social and scientific life of organizations.

Among the main projects of SIGGMi is the El Alamein Project (Bondesan et al. 2009; Bondesan 2012; Bondesan and Vendrame 2015) started in 2008, which aims to preserve the Egyptian battlefield through field research, mapping, and trench restoration. The ARCA project is devoted to the collection of aerial photographs and maps of the WWI front line involving the University of Padua and other research institutions (Bondesan and Scroccaro 2016).

1.3 The International Association for Military Geoscience

The International Association for Military Geoscience (IAMG) was founded by the registrants at the 10th International Conference on Military Geoscience (ICMG) in Aviemore, Scotland, in 2013. An informal organization existed prior to this time, beginning with a one-day symposium in 1994 at the Geological Society of America (GSA) Annual Meeting in Seattle, Washington, under the auspices of GSA's Engineering Geology Division (Rose 2018). The first book of military geoscience papers, *Military Geology in War and Peace* (Underwood and Guth 1998), resulted from this symposium.

The IAMG is free to join and seeks members interested in all aspects of the military geosciences and associated fields. As stated on the Association's website (http://militarygeoscience.org/), "The main purpose of the Association is to encourage and support research and publication in military geosciences in general, more particularly through the organization of the biennial ICMG (usually alternating between North America and Europe)." Although not directly associated with the IAMG, smaller meetings, special sessions, and symposia on the theme of military geoscience are now often held at national or regional geography and geology conferences.

The first conferences were embedded into meetings of the geological societies in the United States (1994), England (1996), and Canada (1998). Beginning in 2000 at the conference in Greenwich, England, however, the scope was broadened to include presentations on military geography and archaeology. Midweek excursions and post-conference field trips were initiated at Greenwich, and these have become a major part of each conference. They provide opportunities for participants to visit very special sites linked with the military geosciences, especially in an historical perspective. Since 2003, the ICMGs have been held autonomously as five-day single events in the United States (2003, 2011, 2015), Canada (2007), Europe (2005, 2009, 2013, 2019), and South Africa (2017). Most conferences have resulted in publication of a book or proceedings, creating, over time, a collection of special volumes specifically dedicated to the military geosciences.

1.4 Advances in Military Geosciences

Advances in Military Geosciences, a book series published by Springer (https://link.springer.com/bookseries/15030), was established in 2013 at the 10th ICMG in Aviemore, Scotland. The series explores interactions between current and historical

Table 1.1 The *Advances in Military Geosciences* series (series editors: A Bondesan, P Doyle, J Ehlen, F Galgano, and EPF Rose)

Authors	Year	Title
Rose EPF (ed)	2020	German Military Geology and Fortification of the British Channel Islands During World War II
Guth PL (ed)	2020[a]	Military Geoscience: Bridging History to Current Operations
Galgano F (ed)	2019	The Environment-Conflict Nexus: Climate Change and the Emergent National Security Landscape
Hippensteel S	2019	Rocks and Rifles: The Influence of Geology on Combat and Tactics During the American Civil War
Pearson S, Holloway JL, and Thackway RM (eds)	2018	Australian Contributions to Strategic and Military Geography
McDonald EV and Bullard T (eds)	2016[a]	Military Geosciences and Desert Warfare: Past Lessons and Modern Challenges

[a]Volumes hosting ICMG papers

military operations and the geosciences, e.g., geography, geology, geophysics, soil science, ecology, hydrology, glaciology, and atmospheric sciences, as well as conflict archaeology. *Advances in Military Geosciences* hosts single-authored and multiauthored books as well as edited volumes. This volume is the seventh in the series and the third consisting of selected papers from ICMGs (Table 1.1).

1.5 The 13th International Conference on Military Geosciences, Padua, Italy

This Conference was held from Monday 24 June to Friday 28 June 2019 in northern Italy, at the University of Padua, the second oldest university in Italy and which will celebrate its 800-year anniversary in 2022. The venue was the magnificent Aula Magna of the Palazzo del Bo (Fig. 1.1), first mentioned in a document dating from 1399 and where Galileo Galilei taught from 1592 to 1610. The conference was organized on behalf of the IAMG by the Department of Historical and Geographic Sciences and the Ancient World (DiSSGeA) of the University of Padua and the Italian Society of Military Geography and Geology (SIGGMi).

The conference theme was "Peace Follows War: Geosciences, Territorial Impacts and Post-conflict Reconstruction," but it was also open to many other topics. About 100 people participated; there were 66 oral presentations and posters and three keynote lectures (Bondesan et al. 2019). The presentations were open to students and local citizens who could follow lectures and take part in events and museum visits without paying the registration fee.

Mid-conference excursions took participants to islands in the Venetian lagoon, with its fortifications (Fig. 1.2) and museums, and to the WWI front line between the Kingdom of Italy and the Austro-Hungarian Empire along the Piave River, with

Fig. 1.1 The sixteenth-century Aula Magna "Galileo Galilei" in Palazzo del Bo, University of Padua. (Photo by Massimo Pistori)

Fig. 1.2 The Fort of Sant'Andrea in the Venetian Lagoon. The fort protected the entrance to the lagoon from the Lido inlet. It was built by Michele Sanmicheli between 1545 and 1550 and completed in 1571 by Francesco Malacrida on the remains of previous defensive works and is a part of the lagoon defensive system (photo by Didier Descouens; Wikimedia Commons, CC BY-SA 4.0)

Fig. 1.3 Italian WWI trench on the Monte Piana karst plateau in the Dolomites on the front line immediately in front of Austro-Hungarian emplacements. Monte Piana is on the border between the Veneto Region and Alto Adige/Südtirol (South Tyrol) Province

visits to the battlefield and WWI memorials and museums, in particular, to the brand-new Venetian Great War Memorial (*Memoriale Veneto Grande Guerra*). Short visits were also made to the 3rd Army Museum and the fourteenth-century Scrovegni Chapel (*Cappella degli Scrovegni*), which is decorated with frescos by Giotto, both in Padua.

A post-conference field trip, "Italian Alps from WWI to Cold War," took place from Saturday 29 June to Thursday 4 July 2019 in the Dolomites and Classical Karst region of the Italian Alps (Fig. 1.3). Participants visited the battlefields, emplacements, museums, memorials, and cemeteries in the Italian Alps and on the Piave front line. The tour included the Marmolada Glacier, a WWI "White War" site (one of the many high-mountain theaters of war in the Alps – up to 3400 m asl), mine warfare sites, old fortresses and modern bunkers, military tunnels, military museums, and the *Sacrario di Redipuglia*, the largest war memorial and military cemetery in Italy. Most of the battlefields were in the Dolomites, a UNESCO World Heritage Site and probably the most famous mountains in the Alpine range.

1.6 From Marathon to the Twenty-First Century: An Overview

The 17 selected research papers in this volume, based on presentations made at the 13th ICMG, explore different issues within Military Geoscience. Although this monograph focuses mainly on the events that characterize the twentieth and twenty-first centuries, concentrating on Italy in WWI, the papers span a time frame from 500 BC into the twenty-first century. They are grouped into three periods – pre-twentieth century, world wars, and twenty-first century – and, for the most part, are in chronological order. The authors are primarily academics, but serving and retired military officers are also included among their number. They are civil engineers, geologists, geographers (both physical and human), cartographers, and archaeologists. This heterogeneous composition reflects the progressive widening of competences and disciplines under the umbrella of military geosciences that began at the conference in Greenwich in 2000.

We begin in Chap. 2 with an interesting analysis of the Battle of Marathon that took place in Greece in 490 BC. Fuhriman and Ridgeway present a new interpretation of the battle using GIS-aided visualization techniques and demonstrate how the topography of the battlefield was a valuable and irreplaceable ally for the Greeks, enabling victory over the Persian forces. This shows once more how the terrain contributes to the outcome of a battle.

Moving forward almost 2000 years, we find ourselves along the English Channel in Chap. 3. Ehlen addresses English artillery forts built as a result of perceived threats of invasion from France during the reign of Henry VIII and in the mid-Victorian period, strongly relating them to geological and geomorphological evolution in terms of position, construction techniques, and materials as well as to advances in artillery technology and naval tactics.

Landscape is a result of the overlapping of natural processes and human action. Most of the time, people are not aware that what they are seeing is a military landscape, one that has been shaped by centuries of warfare. An interesting case study is Monte Baldo, located in northeastern Italy between Lake Garda and the Adige River. According to Premi in Chap. 4, this forbidding mountain ridge exhibits a military landscape through time, marked by boundaries, posts, routes, and fortifications starting from the eighteenth century and extending through the Second World War.

Training and test sites are integral parts of the issues related to the military geosciences and the art of war. During WWI, they were present in every belligerent country. In France, training camps were commonly occasional facilities, situated to the rear of the front line, reproducing the spatial and architectural structures of trench networks on the front line. In Chap. 5, Brenot et al. describe discovery of about 20 previously unknown or forgotten sites in northern France using 1948 aerial photographs and an unusual postcard database. Postwar agricultural reparcelling of the land has erased almost all traces of these facilities except in wooded areas.

Loosing traces of war due to human activities or natural processes is a common situation, sometimes occurring very quickly after battle. Conflict archaeology, which uses traditional archaeological techniques, combined with an advanced digital/remote sensing approach, may lead to better understanding of burial processes and help in the investigation of and, when possible, restoration of the prewar landscapes that recover the archaeological record. This process is described in Chap. 5 in which Magnini et al. present their comprehensive multiscale study of two Austro-Hungarian trench systems along the northern Italian Front, one located in Millegrobbe, Trento, and the other, part of the *Winterstellung* line in Rotzo, Vicenza, through the use of remote sensing techniques, field surveys, and microinvasive excavations.

"Gentlemen, we may not make history tomorrow, but we shall certainly change the geography" (Lytton 1921, p. 97). British General Charles Harington uttered these words as tunneling units working beneath German lines in WWI were about to undertake one of the largest explosions of the war at Hill 60 near Ypres in Belgium. In total, the British tunneling units detonated about 750 mines along their 160 km front line, and the Germans responded with 700 (Strachan 2000). On the Italian Front, the Dolomites were the area most affected by tunnel warfare. Thirty-four large mines were exploded between 1916 and 1918, often beheading mountain peaks or reshaping cliffs and slope deposits. In Chap. 7, Macini and Samurri describe miners and sappers of the Italian Corps of Engineers reconstructing methods, engineering concepts, technical innovations, and strategies of the Corps itself. As is well known, warfare usually results in advanced technological improvements and inventions: the authors describe a large number of drills and other devices used in tunneling, including geophones and recording "microseismophones" developed during this period, all precursors of modern oil and gas seismic exploration.

Military maps play a fundamental role in each conflict. No modern war could be fought without strategic and tactical maps, and their historical study is today aided by GIS technology. In Chap. 8, Dai Prá et al. address WWI military maps preserved in the Historical Archives of the Italian 3rd Army in Padua (which was visited by participants and hosted the poster session during the conference), describing the map corpus, its typological classification, and digital processing through georeferencing and data vectorization of troop movements on the battlefields. In Chap. 9, Plini et al. identify the locations of the places of war where Italy was involved during WWI (i.e., along the border between the Austro-Hungarian Empire and the Kingdom of Italy, in the Middle East and North Africa) by the use of a Web GIS. In Chap. 12, Häusler deals with the terrain analysis and thematic military maps produced for the Eastern Front by German and Austrian military geologists during WWII. Maps were often attached to military geologic reports which provided insight into terrain characteristics for the attacking and retreating German Armies. Toward the end of WWII, five agencies of the German Reich provided military geoscientific information for the Adriatic theater (Häusler, Chap. 13) regarding water supply, off-road trafficability maps, the location of aggregate for construction of fortifications, and support to *Organisation Todt* (the German construction agency) in the preparation of defensive lines crossing the northern Italian Apennines and the Alpine Wall between Italy and Austria.

Chapter 10 addresses Italian prisoner of war (POW) camps in South Africa and the living conditions of prisoners. A detailed account of Zonderwater POW Camp, established on the featureless plains of the Highveld, is given by Smit. Zonderwater was the biggest detention camp built by the Allies during WWII and hosted more than 100,000 Italian soldiers captured by the British on the North and East African Fronts from April 1941 to January 1947. A review of available literature and archival material combined with fieldwork and personal interviews was used to investigate this underexplored piece of South African and Italian history.

As previously noted, the European Theater during WWII involved fighting in mountainous areas. This required the US Army to construct a military installation for training soldiers in Alpine and mountain warfare. In Chap. 11, Doe and Czaja describe the establishment of Camp Hale, located in the Colorado Rocky Mountains, from 1942 to 1944 where the 10th Light Division (Alpine), later the 10th Mountain Division, conducted rigorous training, including military skiing, mountaineering, altitude training, and the use of pack mules and sled cargos. Today, the site has been memorialized, and there is a proposal before the US Congress for it to become the first American National Historic Landscape.

As noted above, today Military Geoscience has evolved to include, among other research areas, post-conflict stability operations, territorial conflicts, the use of strategic resources, and global security issues on land, air, and sea. In Chap. 15, Galgano considers contemporary security threats on the high seas by maritime piracy. This has become a global problem in the international security scenario. East Africa, the Gulf of Guinea, and South and Southeast Asia are the regions mostly affected by pirate attacks. He attributes the rise in international piracy that began in 2008 in Somalia to poor governance in these maritime states and a fundamental disconnect between international and domestic law and law enforcement. In Chap. 16, Blaine describes the geography of resource-driven territorial controversy in the South China Sea, one of the world's busiest waterways, which results from China's interpretation of the Law of the Sea regarding the innocent passage through its vast territorial claims in the region. The increase in tension and hostilities is becoming more pervasive and concerning and could easily lead to military confrontation if no suitable solution is found.

Modern conflict theaters are analyzed in their military geological aspects by Stewart (Chap. 14) and Bulmer (Chap. 17). Stewart describes his experiences with the sustainable development projects of the US Army Agribusiness Development Teams within local communities in Afghanistan. Several community-led projects are described. Through the use of multi-temporal satellite imagery, project sustainability was assessed between 2009 and 2019. The overall impact of the projects was considered positive; about 80% have either been maintained within the original scope of work or the original concept. Bulmer describes different kinds of emplacements, i.e., trenches, observation towers, cut-and-cover hardened tunnels, and underground facilities, in the Afrin Region of Syria constructed by Kurdish militia. Geological, technological, and economic issues of military works are compared and evaluated. These emplacements were initially effective against Syrian forces and their affiliates, but in the long run could not stand up to a modern military utilizing combined airstrikes, artillery, armor, combat engineering, and ground assaults.

Lastly, in Chap. 18, Teichmann presents a forward-looking account of the Austrian approach to Military Geoscience, considering the operational challenges and trends in modern warfare. What is worth noting is that more and more globalization requires interoperability between units, technological advancements, data digitalization, and remote sensing. The high complexity of today's modern missions requires an all-encompassing approach, full cooperation, and quick sharing of information.

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References

Abbolito E (1936) Il contributo della geologia alla guerra. Rivista di Fisica, Matematica e Scienze Naturali, y. 10, ser. 2, n. 6 (28 March 1936)

Anselmi R (1921) La geologia nell'arte militare modernissima. Atti della Società Ligustica di Scienze Naturali e Geografiche 31:57–71

Bergerat F, Gaviglio P, Gély JP et al. (eds) (2018) 14–18, La terre et le feu: géologie et géologues sur le front occidental. Co-édition AGBP - COFRHIGÉO - SGN., Paris and Lille, (dir.) with Mém. hors-série no. 10 de l'AGBP

Bianchi (1918) Geografia descrittiva del teatro delle operazioni di guerra italiane: studio compilato ad uso dei corsi allievi ufficiali di complemento. Istituto Geografico De Agostini, Novara

Bondesan A (2012) The El Alamein Project: research, findings and results between history and military geography. In: Edwards J (ed), El Alamein and the struggle for North Africa, international perspectives from the twenty-first century. American University Press, Cairo, pp. 113–136

Bondesan A, Scroccaro M (eds) (2016) Cartografia militare della Prima Guerra Mondiale. Cadore, Altopiani e Piave nelle carte topografiche austro-ungariche e italiane dell'Archivio di Stato di Firenze. Archivio di Stato di Firenze-Regione Veneto-Grafiche Antiga, Crocetta del Montello

Bondesan A, Vendrame T (2015) El Alamein. Rivisitazione del campo di battaglia tra mito e attualità. Cierre Edizioni, Verona

Bondesan A, Craig D, Pantaloni M et al. (eds) (2019) Peace follows war: geosciences, territorial impacts and post-conflict reconstruction. Abstracts, 13th International Conference on Military Geosciences. Società Geologica Italiana, Roma

Bondesan A, Fabbrucci L, Facco L et al. (2009) The historical GIS for the reconstruction of the battlefield of El Alamein (Egypt, 1942) through remote sensing and analysis of military historical cartography. Geoitalia 2009 - VII Forum di Scienze della Terra 9-11 September 2009, Rimini. Epitome 3:1083–1088

Bulmer MH (2019) Geological considerations of contemporary military tunneling near Mosul, northern Iraq. In: Rose EPF, Ehlen J, Lawrence UL (eds) Military aspects of geology: fortification, excavation and terrain evaluation. Special Publications, 473. The Geological Society, London, pp. 241-265

Caldwell DR, Ehlen J, Harmon RS (eds) (2004) Studies in military geography and geology. Kluwer Academic Publishers, Dordrecht

Collins JM (1998) Military geography for professionals and the public. Potomac Books, Washington DC

Craveri M (1916) La conoscenza geologica del terreno nella guerra moderna. Bollettino della Società Geologica Italiana 35:43-79

Deambrosis (1924) L'insegnamento della geografia alla Scuola di Guerra. IX Congresso Geografico Italiano, Genova, 29-30 aprile 1924

Doyle P (1998) Geology of the Western Front, 1914–1918. Geologists' Association Guide 61. Geologists' Association, London

Doyle P, Bennett MR (eds) (2002) Fields of battle: terrain in military history. Kluwer Academic Publishers, Dordrecht

Ehlen J, Harmon RS (eds) (2001) The environmental legacy of military operations. Reviews in Engineering Geology XIV. Geological Society of America, Boulder

Fossa-Mancini E (1920) Geologia militare in tempo di pace. Giornale di Geologia Pratica 15:16-20
Fossa-Mancini E (1926) Storia della geologia militare. Giornale di Geologia Pratica 20:37-110
Galgano F (ed) (2019) The environment-conflict nexus. Climate change and the emergent national security landscape. Springer Nature, Cham
Galgano FA, Palka EJ (eds) (2011) Modern military geography. Routledge, New York
Galgano FA, Rose EPF (2020) Military geoscience. In: Alderton DHM, Elias S (eds) Encyclopedia of Geology (2nd edn). Elsevier, Oxford, vol 6, pp. 648-659
Galloro G. (2007) La geografia nelle operazioni militari. Montedit, Milano
Goiran G. (1880) Lezioni di geografia militare esposte ai signori ufficiali allievi della scuola di guerra. Scuola di Guerra di Torino, Torino
Gortani M (1919) La geologia e la guerra di posizione. Atti della Società Italiana per il Progresso delle Scienze, X riunione (Pisa, April 1919)
Guth PL and Scott DD (2020) The battle of Big Hole (Montana, USA, 1877): history, archaeology, GIS and military terrain analysis. In: Guth PL (ed) Military geoscience. Bridging history to current operations. Springer Nature, Cham, pp. 21-39
Guth PL (ed) (2020) Military geoscience. Bridging history to current operations. Springer Nature, Cham
Harmon RS, Baker SE, McDonald EV (eds) (2014) Military geosciences in the twenty-first century. Reviews in Engineering Geology XVI. Geological Society of America, Boulder
Häusler H (2003) Wehrgeologie im nordafrikanischen Wüstenkrieg (1941-1943). Milgeo 13, Bundesministerium für Landesverteidigung, pp 1–135
Häusler H (2018) "Sonderkommando Dora": special military geoscientific unit of the German Counter-Intelligence Service in North Africa, 1942. Scientia Militaria, South African Journal of Military Studies 46(1):37-57
Häusler H, Mang R (eds) (2011) International handbook military geography, 2 volumes. Arbeitsgemeinschaft Truppendienst, Vienna, pp. 510–513
Häusler H, Willig D (2000) Development of military geology in the German Wehrmacht 1939-45. In: Rose EPF, Nathanail CP (eds) Geology and warfare: examples of the influence of terrain and geologists on military operations. The Geological Society, London, pp. 141-158
Hippensteel S (2019) Rocks and rifles. The influence of geology on combat and tactics during the American Civil War. Springer Nature, Cham
Leith W (ed) (1997) Reports and maps of the Military Geology Unit, 1942–1975. Open File Report 97–175. US Geological Survey, Reston
Leith W, Matzko JR (1998) Recent activities in military geology at the U.S. Geological Survey. In: Underwood JR, Guth PL (eds) Military geology in war and peace. Reviews in Engineering Geology XIII. Geological Society of America, Boulder, pp. 139-143
Lytton N (1921) The Press and the General Staff. Collins, London
McDonald EV, Bullard T (eds) (2016) Military geosciences and desert warfare: past lessons and modern challenges. Springer Science+Business Media, New York
Mini (1850) Geografia e storia militare dell'Italia, ossia Breve corso di studj geografici e storici sulla penisola e sull'arte della guerra tra gl'Italiani da' tempi più remoti ai giorni nostri. Firenze
Nathanail CP, Abrahart RJ, Bradshaw RP (eds) (2008) Military geography and geology: history and technology. Land Quality Press, Nottingham
O'Sullivan P, Miller Jr JW (1983) The geography of warfare. Croom Helm, London
Palka EJ, Galgano FA (2005) Military geography: from peace to war. McGraw-Hill Education, New York
Pearson S, Holloway JL, Thackway RM (eds) (2018) Australian contributions to strategic and military geography. Springer Nature, Cham
Perrucchetti G (1874) Il Tirolo, saggio di geografia militare. Voghera Cargo tipografo, Roma
Perrucchetti G (1878) Teatro di guerra italo-svizzero: studio di geografia militare. Tipografa Roux e Favale, Torino
Perrucchetti G (1884) Difesa dello Stato. Tipografa Roux e Favale, Torino
Porro C (1898) Guida allo studio della geografia militare: compendio delle lezioni di geografia militare (parte generale) esposte agli ufficiali allievi della scuola di guerra. Utet, Torino

Rose EPF (2005) Napoleon Bonaparte's invasion of Egypt 1797-1801 the first military operation assisted by both geographers and geologists – and its defeat by the British. Royal Engineers Journal 119:46-53

Rose EPF (2014) Military geology. In: Reference Module in Earth Systems and Environmental Science. https://doi.org/10.1016/B978-0-12-409548.09141-7

Rose EPF (2018) The International Association for Military Geosciences: a history to 2017. Scientia Militaria: South African Journal of Military Studies 46:19–35. https://doi.org/10.5787/46-1-1222

Rose EPF (ed) (2020) German military geology and fortification of the British Channel Islands during World War II. Springer Nature, Cham

Rose EPF, Mather JD (eds) (2012) Military aspects of hydrogeology. Special Publications, 362. The Geological Society, London

Rose EPF, Nathanail CP (eds) (2000) Geology and warfare: examples of the influence of terrain and geologists on military operations. The Geological Society, London

Rose EPF, Pareyn C (2003) Geology of the D-Day landings in Normandy, 1944. Geologists' Association Guide 64. Geologists' Association, London

Rose EPF, Ehlen J, Lawrence UL (2019a) Military use of geologists and geology: a historical overview and introduction. In: Rose EPF, Ehlen J, Lawrence UL (eds) Military aspects of geology: fortification, excavation and terrain evaluation. Special Publications, 473. The Geological Society, London, pp. 1-29

Rose EPF, Ehlen J, Lawrence UL (eds) (2019b) Military aspects of geology: fortification, excavation and terrain evaluation. Special Publications, 473. The Geological Society, London

Rose EPF, Häusler H, Willig D (2000) Comparison of British and German military applications of geology in world war. In: Rose EPF, Nathanail CP (eds) Geology and warfare: examples of the influence of terrain and geologists on military operations. The Geological Society, London, pp. 1007-1040

Sacco F (1916) La geologia e la Guerra. Saggi di Astronomia Popolare 6:8-9

Sacco F (1917) I minerali e le guerre. La Miniera Italiana 1:31-32

Smit H, Bezuidenhout J (eds) (2019) Contemporary military geosciences in South Africa. SUN Press, Cape Town

Strachan H (2000) The Oxford illustrated history of the First World War. Oxford University Press, Oxford

Terman MJ (1998) Military Geology Branch of the U.S. Geological Survey from 1945 to 1972. In: Underwood JR, Guth PL (eds) Military geology in war and peace. Reviews in Engineering Geology XIII. Geological Society of America, Boulder, pp. 75–81

Underwood JR, Guth PL (eds) (1998) Military geology in war and peace. Reviews in Engineering Geology XIII. Geological Society of America, Boulder

von Bülow K, Kranz W, Sonne E (1938) Wehrgeologie. Quelle and Meyer, Leipzig

Part I
Pre-twentieth Century

Chapter 2
Visualizing the Impacts of Topography: A Geographic Perspective of the Battle of Marathon

Chris Fuhriman and Jason Ridgeway

Contents

Abstract In 490 BC, Athenian General Miltiades routed Datis' numerically superior Persian invasion force on the Plain of Marathon, Greece. Although Greek scholar Herodotus' account of the battle is relatively bereft of tactical detail, subsequent scholars have produced an enormous body of speculative literature on the subject. Employing a GIS-aided visualization of the battlefield, we examine the key geographic factors which may have impacted tactical decisions made by Miltiades and Datis. We suggest that Miltiades, in elongating his phalanx formation, stretched the Greek front lines across the valley between Mounts Kotroni and Agrieliki, leaving no space for the Persian cavalry to maneuver along the Greek flanks. Additionally, the Greek camp was positioned slightly higher on the sloping coastal plain, rendering Miltiades' famous running approach to contact the Persians a downslope maneuver. This effectively closed the gap between the Greek and Persian forces more rapidly, diminishing the effects of the Persian archers and cavalry. We conclude that the topography of the battlefield afforded the Athenians and their allies an advantage that neutralized the greatest strengths of the Persian army—its cavalry and archers—even though the Persians had chosen the Plain of Marathon specifically for its suitability for cavalry operations.

Keywords GIS · Military geography · Topography · Battle of Marathon

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2.1 Introduction

The Battle of Marathon in 490 BC is one of the oldest examples of a military engagement about which historical writings provide the detail required for a case study. The earliest account of the battle can be found in the writings of Herodotus, a traveler and scholar whose histories provide us with a contemporaneous record of events in the Eastern Mediterranean between the fifth and sixth centuries BC. Primarily from Herodotus, we know the following: the approximate number of troops at the battle, their equipment, the relative positions of the armies before the battle, the sequential flow of the battle, and the decisive results (Lloyd 1881). However, there is no consensus in the literature regarding the veracity or even the plausibility of those details—a debate centered on the point that Herodotus was neither a participant nor an observer of the battle, but wrote his account several years later based on interviews with participants. Many scholars believe Herodotus and his sources embellished the story and exaggerated some of the details, leaving room for speculative discussion (Doenges 1998). The purpose of this chapter, however, is not to debate Herodotus's credibility. Rather, we seek to explore a previously neglected factor which took center stage in the Battle of Marathon—the geographic characteristics of the battlefield itself. The archaeological evidence supports a wide range of possibilities, but that evidence is beyond the scope of this study (for a detailed discussion, see Rhodes 2013). Further, the goal here is not to provide a deterministic approach to the battle, but to offer an explanation via battlefield visualization of the choices Datis and Miltiades made in choosing the Plain of Marathon initially, positioning their formations on the plain, and carrying out their tactical plans at the time of battle.

A 3D visualization of the landscape as it is today, created using NASA's SRTM elevation data set and ArcGIS Pro, sheds new light on the Battle of Marathon and in the process bolsters the plausibility of Herodotus's narrative. Our assumption that the present-day topography of the Marathon Plain and surrounding hills has changed very little since the time of the battle is supported in the scientific literature. Pavlopoulos et al. (2006) concluded that tectonic uplift rates of 0.4–0.5 millimeters per year at Marathon over the past 2000 years have effectively canceled out the rise in sea level during that period, resulting in a relatively stable coastal environment. Furthermore, Tucker et al. (2011) report the weathering rates of the Mesozoic limestone to be between 0.005 and 0.03 millimeters per year, totaling between 12.5 mm and 75 mm since the battle occurred. We therefore assume with confidence that the topographic properties of the battle site have changed insignificantly since the Pleistocene (van Andel et al. 1990).

2.2 Historical Context

By the fifth century BC, the Persian Empire stretched from the Indus River to the Balkans. But dissent and unrest on the Empire's western frontier commanded the attention of the Persian king, Darius. By 499 BC, Ionian Greeks had grown weary of Persian rule and sought to overthrow the Persian provincial governors known as satraps (de Souza et al. 2004). The Greek cities of Eretria and Athens pledged their support to their Ionian counterparts, sending 25 ships to aid in the revolt (Fig. 2.1; Herodotus 2008). The Persians quelled the uprising by the end of 493 BC, and Darius sought to punish Eretria and Athens for their participation. Capturing and subjugating these two Greek cities would underscore Persian dominance in the region and simultaneously open the door to westward expansion of the empire. Darius sent his generals Datis and Artaphernes to carry out his plan, while he remained at his palace in the Persian capital, Susa (modern-day Iran) (Krentz 2010).

After resupplying in Samos and taking control of the Cyclades, an island group in the Aegean between modern-day Greece and Turkey, Datis advanced to Karystos and Eretria (Fig. 2.1; Herodotus 2008). Darius now controlled the sea path to southern Greece, which enabled the Persians to stage their invasion of Attica, the province in which Athens is located, resupply with food and water, and gather more conscripts (Krentz 2010). The conquest of the Cyclades was not achieved by

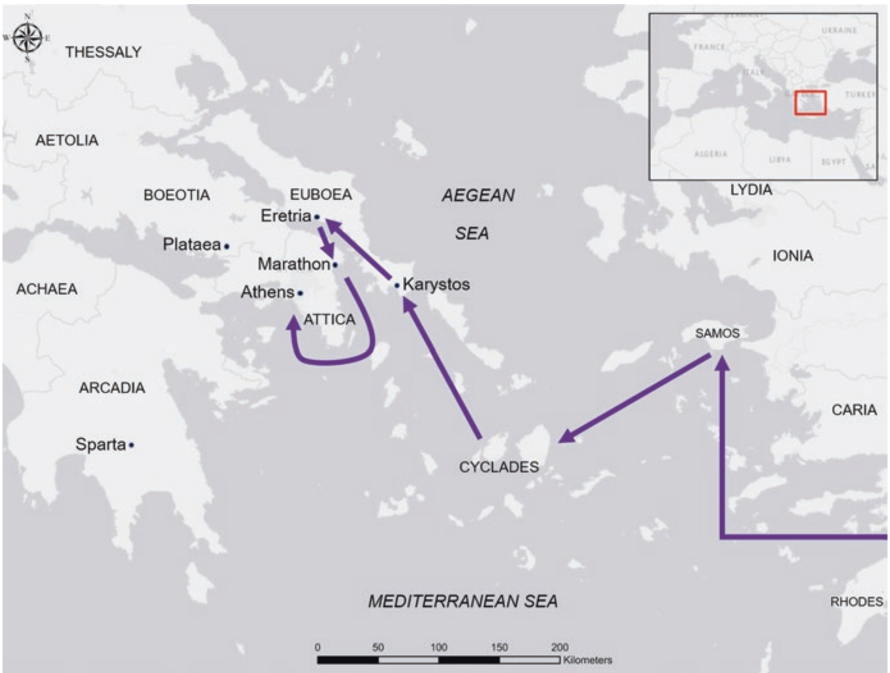

Fig. 2.1 The Persian invasion route in 490 BC

military action alone, however. The Persian's preferred method of conquest was diplomacy via emissaries and gifts of earth and water to the king—an official sign of subservience. Accompanying Datis was Hippias, the former Athenian tyrant who proposed Marathon as the initial landing site. The presence of Hippias on Datis' expedition indicates the Persians hoped for and even favored a diplomatic solution to their arrival in Athens. Hippias convinced Darius that at least some of the leadership in Athens would welcome his return and that he need only set foot on the beach at Marathon to begin the peaceful restoration to his former post in Athens. Had Darius assumed that Athens would engage in military action, Hippias's presence on the expedition would have been unnecessary. He could have easily arrived as the newly appointed satrap of Athens after the Persians defeated the Greeks in battle. As diplomacy was Persia's first choice, Hippias made the voyage with the invasion force, and it was he who suggested Marathon as a landing site and battlefield (Herodotus 2008).

2.3 The Greeks Decide to Fight: Geographic and Tactical Factors

The Persian Army's strength lay in its cavalry and its archers (Fragos 2011). Accordingly, Persian commanders sought battlefields with physical characteristics that favored their capabilities and tactics. They needed an invasion site in mountainous Attica where cavalry could be employed against the Greek defenders. They also needed a site which could be easily resupplied from Eretria. Marathon was not the only site which favored cavalry operations, nor was it the only one near Eretria, but it was the location that offered the best combination of the two landing requirements (Krentz 2010). Schinias Beach at Marathon had a long, gentle slope for easy landing and disembarking (Fig. 2.2). The bay was protected from wind and waves by Kynosoura Point which sheltered the ships in mooring. There was adequate grazing and fresh water for the horses, and the wide coastal plain was advantageous ground for both cavalry and archers. Having landed there with his father's invasion force decades earlier, Hippias was undoubtedly familiar with these geographic factors and advised Datis on the merits of the site (Krentz 2010).

The news of the fall of Eretria put Athens on high alert. Athenian sentries, watching the seas for the impending invasion, reported the arrival of the Persian fleet at Marathon to the politicians in Athens. The Greeks had three options: fight the Persians at Marathon, fight the Persians on the road(s) to Athens, or fortify the city of Athens and defend against a siege (Fragos 2011). Greek general Miltiades argued for the first option (Herodotus 2008). He knew that the Plain of Marathon accommodated cavalry operations but would also accommodate his phalanx—the classic Greek military formation that deployed infantry armed with shields and spears in closely spaced files. Neither the road to Athens nor the city itself provided a suitable area to assemble this formidable Greek battle formation. Miltiades believed the

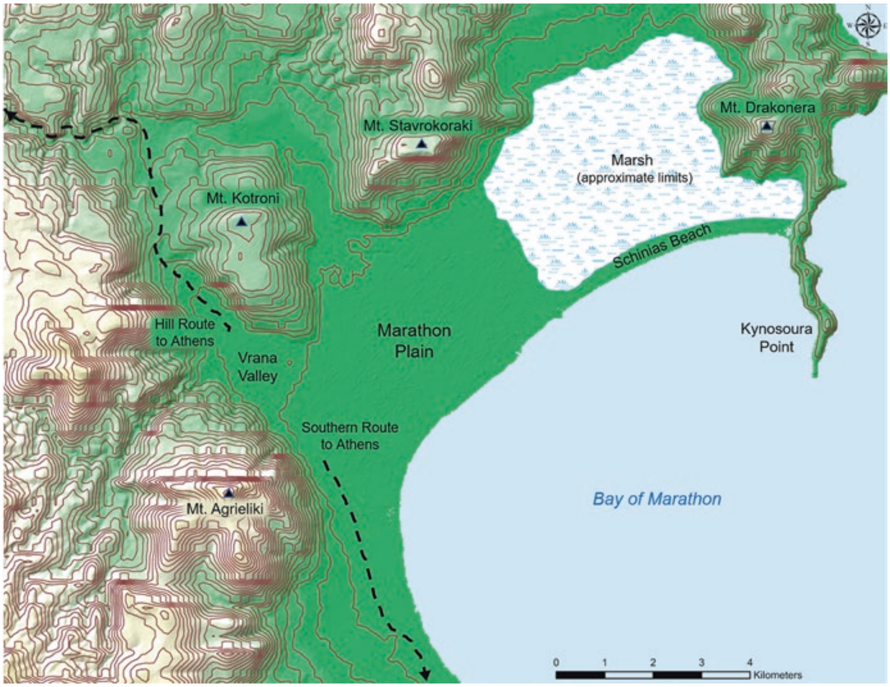

Fig. 2.2 A physical map of Marathon. The contour lines are at 20-m intervals as derived from NASA's SRTM data set

Greeks stood a chance against the Persians if they could maintain the order of the phalanx in battle (Herodotus 2008; Fragos 2011). Moreover, Miltiades was leery of placing the Greek Army inside the walls of Athens. Fortifications were lacking, and the political climate was divided. If the siege began to wear on the Athenians, those who still supported Hippias could betray the city, ending the siege from the inside. Athens would then fall to Datis in the same manner as Eretria had a few days before (Fragos 2011).

After considering their circumstances, the ten Greek generals were divided evenly, five in favor of meeting the Persian Army at Marathon and five in favor of surrendering as a vassal state (Herodotus 2008). The Greek system had a tiebreaker vote built in for this very reason. The War Archon, who served as the Athenians' chief military officer and was selected by lot on a rotational basis, could cast an eleventh vote to break the deadlock. At the time, Callimachus held the post of War Archon (Herodotus 2008), and Miltiades convinced him that the stakes were too high to lay down their arms. Callimachus cast the deciding vote in favor of battle. The 10,000-man Athenian Army thus marched to the Plain of Marathon where they were joined by 1000 soldiers from the allied city of Plataea (Krentz 2010).

The number of soldiers on each side in the battle remains a contentious affair among historians, as do several other key details. A common theme in Marathon literature is that the Greeks deliberately diminish their own numbers while overinflating the Persian numbers to make the victory seem more astounding in the historical record. The most recent works on Marathon continue to reflect this conflict: Fragos (2011) insists the Athenians marched 9000—10,000 hoplites (armed soldiers) to battle, whereas Krentz (2010) proposes 20,000. Both agree the Persian force was between 16,000 and 24,000, a figure based on the 600 Persian triremes (oar-powered warships) that Herodotus reported in his account of the invasion force (Sekunda 2002). In this chapter, we align with Fragos (2011), who based his calculus on the obligation for each of the ten tribes in Athens to supply 1000 hoplites when the vote for war passed the council of generals. It is reasonable to assume that Datis would have invaded with sufficient combat power to contend with the expected collective resistance of 20,000 hoplites from Athens, Sparta, and Plataea. In any case, the dimensions of the Plain of Marathon (10 km long and 3 km wide) would provide maneuver space for both invaders and the defenders (Sekunda 2002).

Miltiades was no stranger to the Persian war machine. Having fought *for* Darius on a previous expedition into Europe, he had gained firsthand knowledge of the Persian battle order, tactics, and logistics systems (Krentz 2010). He witnessed the lethal combination of cavalry and archers and he understood their weaknesses. Miltiades knew that if he could negate the effects of the Persian cavalry and archers, his phalanxes could cut through the lightly armored Persian infantry. But he also knew that he must wait for the right moment. As the Persians arrived at Marathon, the Athenians sent a messenger to request the aid of Sparta. But citing a religious law, Sparta would not send an army until the full moon (Herodotus 2008). The Athenians and Plataeans stalled in their defensive positions, but Miltiades reached the point where he could wait no longer for the Spartans to arrive. His army would receive no further support, so he seized the initiative. Most scholars agree that Miltiades's tactical decisions led to the Greek victory. A few even mention his superior use of terrain in passing, but all fail to explicitly address the connection between his tactics and the topography (Hammond 1968; van der Veer 1982; Krentz 2010; Fragos 2011). By visualizing the topography of the battlefield using a three-dimensional map of the terrain, we give Miltiades a geographic context for his tactical decisions.

2.4 Visualizing the Battlefield Environment

Because the Athenians had advance warning, the Persians were still establishing their positions on the Plain of Marathon when Miltiades arrived with his forces (Krentz 2010). He therefore had the luxury of selecting the most favorable defensive position from several possible locations on the western portion of the plain. Miltiades's force likely arrived at Marathon via the southern route, which was more navigable for a large army, even if it was almost 5 km longer than the difficult hill route to the north (Fig. 2.2; van der Veer 1982). Upon entering the plain, Miltiades needed to establish camp in a place that would both protect his formation and allow him to achieve his objective: to defend Athens by destroying the Persian Army. A three-dimensional view of the battlefield environment reveals one location which allowed Miltiades to protect his force and defend Athens—the Vrana Valley (Fig. 2.3). Herodotus (2008) tells us Miltiades, upon viewing the Persian formation, stretched his own front line to match that of the enemy before the attack began. Without adjustment, the original Greek line would have stretched approximately 1375 m, as the front for each of the ten tribes was 125 m, plus another 125 m for the Plataeans. With adjustment, the line was most likely 1600 m wide (Fragos 2011).

Curiously, 1600 m is the exact distance between the base of Mount Agrieliki on the south and Mount Kotroni on the north where the Vrana Valley opens into the Plain of Marathon (Figs. 2.2 and 2.3). Whereas there were the obvious benefits of stretching the Greek line to match the Persians, it makes more sense if the ends of the formation were protected. Miltiades chose the Vrana Valley not only because it blocked the hill route to Athens, but it offered him the natural protection of high ground on each flank—terrain that would prohibit the use of the Persian cavalry. Additionally, from this position, he could cover the southern route to Athens. The Persians would expose their flank if they attempted to march past the mouth of the Vrana Valley to reach the southern route. The other possible defensive position is the valley between Mount Kotroni and Mount Stavrokoraki (Figs. 2.2 and 2.3). This location's disadvantages add up quickly. First, the valley is wider (1900 m) at its mouth, than the Vrana Valley, which would force Miltiades to stretch his

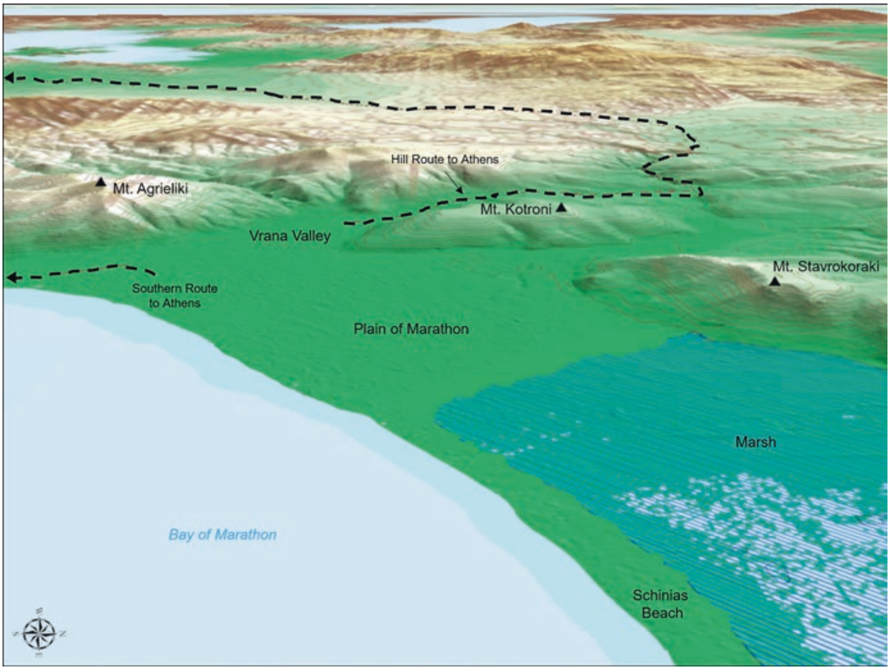

Fig. 2.3 Three-dimensional topographic map of the battlefield

already-thinned formation even more. It also tapers dramatically to the northwest, down to a width of 900 m over a short distance, making a possible retreat very difficult. Second, this valley is farther from the hill road to Athens and sits at the widest extent of the Plain of Marathon. The effect is reduced coverage for both routes to Athens and a less desirable defensive position. Miltiades found in the Vrana Valley a defensive position which blocked one route to Athens and covered the other route, rendering the Persian cavalry useless.

Having addressed the problem of Persian cavalry, Miltiades faced the next challenge: what to do with the deadly Persian archers. Once again, topographic analysis gives context to Miltiades's tactical decision. Many scholars discount Herodotus's report that the Greek formation ran to meet the Persian front line, presumably to pass rapidly through the archers' effective target area (Krentz 2010, citing Delbrück 1887 as the first to question Herodotus's claim). This widespread skepticism was based largely on the distance that had to be covered (about 1500 m) while running with the heavy armor of a hoplite; there is no quarrel with the idea that running would reduce exposure to Persian arrows. Krentz (2010) goes to great lengths to dispel the notion that Greek soldiers would be incapable of running 1500 m with full armor and immediately engage in combat. He provides numerous modern examples citing the physiological possibility of accomplishing such a feat. Still, Krentz misinterprets one important detail: the direction of the Greek charge. He places the Greek line between Mount Stavrokoraki (left flank) and the bay (right flank), oriented to the northeast (Fig. 2.2). A charge of that orientation and direction would be mostly level and, in some places, even slightly uphill—not ideal for attacking at a run. Our proposed position (Fig. 2.4), however, favors the runner. On a southeasterly line from the mouth of the Vrana Valley to the shoreline, a runner drops more than 19 m in elevation. Any decline is noticeable when burdened with a full combat load; a 19-m decrease over approximately 1600 m of horizontal distance (a downward grade of approximately 1%) should not be discounted. Krentz's (2010) insistence (adjusted for location) on the veracity of Herodotus's account of the running charge now has further justification in the topography of the Plain of Marathon: the Greeks ran downhill.

Whereas the initial Greek defensive position discouraged the employment of Persian cavalry (Fig. 2.4), the running charge would have also negated the cavalry's battlefield advantage. Persian cavalry required prior notice to prepare the horses and riders for battle (Doenges 1998). Datis likely would not have kept his cavalry on alert as the standoff continued, especially given the defensive position of the Greeks, who for several days could not be lured out into the plain (Krentz 2010). A running phalanx would have been able to cover the 1500 m between the front lines in a shorter amount of time than was required to prepare the horses (Shrimpton 1980). By the time the phalanx engaged the Persian infantry, the cavalry would have been far less effective and arguably no longer required (Krentz 2010). Miltiades's tactical decision to approach the Persian front line at a run effectively negated both Persian advantages.

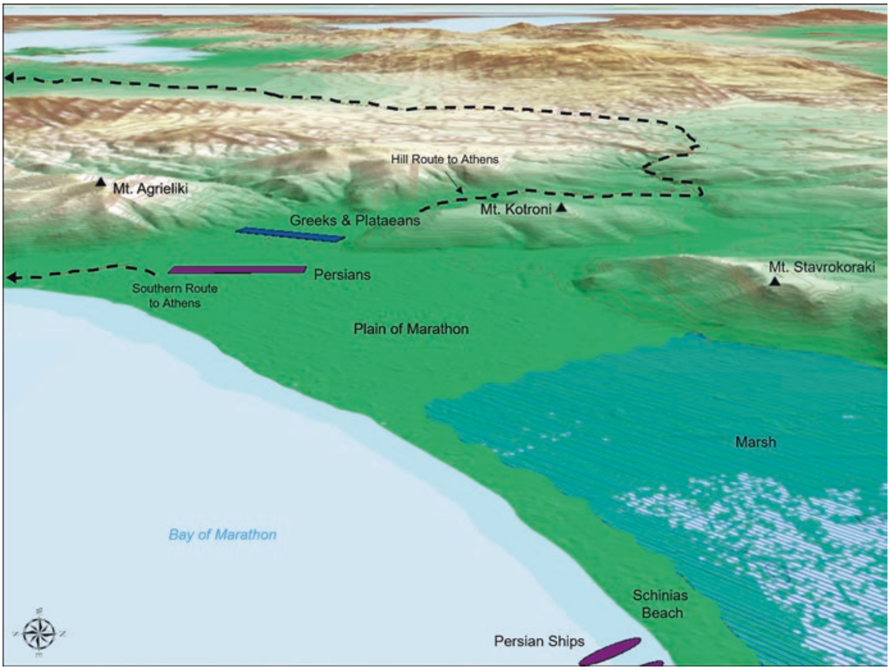

Fig. 2.4 The front lines of the Greeks and the Persians at Marathon

2.5 Conclusions

A three-dimensional view of the battlefield affords us a unique vantage point in understanding how the Battle of Marathon unfolded and how the Greek Army was able to rout the Persian army. Considering that Miltiades could select the initial defensive position, it makes perfect sense that he would choose a location that would help prevent the Persians from taking Athens. To that end, he had to find a location from which his army could cover both roads to Athens and in which it would have maximum security against the Persians. Viewing the battlefield in 3D reveals the most likely position Miltiades selected to meet his military objective. Furthermore, his position at the mouth of the Vrana Valley gave his army a downslope approach to the Persian front line, rendering Herodotus's account of the running charge more plausible. Thus, Miltiades used the topography to his advantage in nullifying the efficacy of the Persian cavalry and diminishing the importance of the Persian archers. With their two greatest combat multipliers reduced, the Persians faced the Greek phalanx with only lightly armored infantry. The result was a massacre—6400 Persians were killed in battle, whereas only 192 Athenians perished. Combining topography with tactics at Marathon, Miltiades defeated a numerically superior enemy which had previously never lost a battle to a Greek army (Krentz 2010).

References

De Souza P, Heckel W, Llewellyn-Jones L (2004) The Greeks at war: from Athens to Alexander. Osprey, Oxford

Delbrück H (1887) Die Perserkriege und die Burgunderkriege. Walther and Apolant, Berlin

Doenges NA (1998) The campaign and Battle of Marathon. Historia: Zeitschrift für Alte Geschichte 47(1):1–17

Fragos F (2011) Without cavalry: battle of Marathon (490 BC) 2500 years. Strategic Publications, Athens

Hammond NGL (1968) The campaign and the battle of Marathon. Journal of Hellenistic Studies 88:13–57

Herodotus (2008) The histories (trans: Waterfield R). Oxford University Press, Oxford

Krentz P (2010) The battle of Marathon. Yale University, New Haven

Lloyd WW (1881) The battle of Marathon: 490 BC. Journal of Hellenic Studies 2:380–395

Pavlopoulos K, Karkanas P, Triantaphyllou M et al. (2006) Paleoenvironmental evolution of the coastal plain of Marathon, Greece, during the Late Holocene: depositional environment, climate, and sea level changes. Journal of Coastal Research 22(2):424–438

Rhodes PJ (2013) The battle of Marathon and modern scholarship. Bulletin of the Institute of Classical Studies 124:3–21

Sekunda N (2002) Marathon 490 BC: the first Persian invasion of Greece. Osprey, Oxford

Shrimpton G (1980) The Persian cavalry at Marathon. Phoenix 34(1):20–37

Tucker GE, McCoy SW, Whittaker AC et al. (2011) Geomorphic significance of postglacial bedrock scarps on normal-fault footwalls. Journal of Geophysical Research 116: F01022

van Andel T, Zangger E, Demitrack A (1990) Land use and soil erosion in prehistoric and historical Greece. Journal of Field Archaeology 17(4):379–396

van der Veer JAG (1982) The battle of Marathon: a topographic survey. Mnemosyne 4(35):290–321

Chapter 3
Defending Britain's Soft Underbelly: Invasion, Fortification and Geology Near Portsmouth, Hampshire

Judy Ehlen

Contents

Abstract The artillery forts along the English Channel owe their origins to Pleistocene megafloods that drowned the river valleys feeding into the pre-Pleistocene Channel River. The Channel coast consists mainly of cliffs, so only these deep-water estuaries could be used for invasions. The most important fortified area was Portsmouth in Hampshire where the coastline consists of spits, beaches, lagoons, marshes and islands. The bedrock is Eocene sands and clays that form terraces. Cretaceous chalk is located behind and above the terraces. This paper addresses artillery forts built as a result of invasion threats during the reign of Henry VIII and in the mid-Victorian period. The Henrician forts are located on the shingle spits and beaches and the Palmerston forts, on higher-ground surrounding Portsmouth. The Henrician forts are low, stone-built structures constructed for coastal defence; the Palmerston forts were built of brick and soil to defend against land attack. These differences mainly reflect the fast-developing advances in artillery technology and naval tactics that began in the 1840s. The Henrician forts were decommissioned in the mid-twentieth century, but some of the Palmerston forts live on and have been retained in military ownership into the current century, but not as artillery forts.

Keywords Coastal defence · Portsmouth · Sixteenth-century artillery forts · Nineteenth-century artillery forts

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3.1 Introduction

The English Channel, England's soft underbelly, is approximately 560 km long and 240 km at its widest point. It connects the Atlantic Ocean to the North Sea and extends from the Isles of Scilly, 45 km off Land's End in Cornwall, to the east coast of Kent just north of Dover (Fig. 3.1). At this point, England is a mere 33 km from France and the rest of Continental Europe. The Channel formed in the Late Pleistocene, at the end of the Devensian glaciation (~10,000 BP), as a result of two megafloods (Gupta et al. 2007; Collier et al. 2015) that occurred when the land bridge between England and the Continent was destroyed and the Channel river system to the south was engulfed. This resulted in rising sea levels and the drowning of river valleys along the entire coastline. Many of these valleys are now estuaries with deep-water channels ideal for anchorages, harbours and dockyards. Because much of the coastline between them consists of high, vertical cliffs, the estuaries and their associated beaches and spits are prime landing sites for invading forces.

Britain has been invaded over 30 times throughout its history, beginning with Julius Caesar's invasion of Kent in 55–54 BC. Few invasions, however, occurred along the English Channel. The best known of these are Roman invasions in 43 AD near Chichester in Sussex and at Poole Harbour in Dorset, William of Normandy's invasion in 1066 near Pevensey in Sussex, and in 1688 the invasion of William of Orange, who became King William III, at Torbay in Devon. Threats of invasion, though, have been far more frequent, and many of these were along the Channel. This paper addresses the local geology in the Portsmouth, Hampshire, area and the fortifications that were built there as a result of invasion threats during the reign of Henry VIII between 1539 and 1545 (Henrician or 'Device' forts, so called due to the order given by Henry to construct them being a 'Device') and during the mid-Victorian period between 1853 and 1872 (Palmerston forts; Lord Palmerston was Prime Minister at the time).

Fig. 3.1 The English Channel. (Modified from Google Earth Pro; image: Landsat/Copernicus 2020)

3.2 Portsmouth and the Solent

The Portsmouth area is extensive and complex (Fig. 3.2) due to its diverse local geology and the number and types of fortifications. Cretaceous chalk occurs to the north, and the immediate area around Portsmouth is underlain primarily by Eocene sands and clays that form a series of terraces caused by fluctuating sea levels during the Pleistocene (SCOPAC 2012). The Solent, which separates the English mainland from the Isle of Wight, was at one time a river flowing east and southeast into the Channel River, but the megafloods that transformed this river into the English Channel also submerged the Solent River and its major tributaries, e.g. Southampton Water (SCOPAC 2012; West 2017). During the Holocene (between 8600 and 6800 BP), the land bridge that separated the western parts of the Solent River from the Channel was breached, and the Solent was opened to the sea at both ends (SCOPAC 2012); the Hampshire coast became a complex of salt marshes, beaches, spits and islands. With the Isle of Wight protecting the Solent to the south, the deep-water channel in the Solent itself, and the drowned river valleys leading to Portsmouth and Southampton, the area was an ideal site for dockyards and thus a likely location for foreign invasions. For these reasons, it was heavily fortified. Although blockhouses, batteries and earthen fortifications were present prior to the Tudor period, this paper will address only the Henrician and mid-nineteenth-century structures – three Device forts and seven Palmerston forts.

Fig. 3.2 Portsmouth and the Solent. (Modified from Google Earth Pro; Data: SIO, NOAA, US Navy, NGA, GEBCO; image © 2020 Terrametrics)

3.3 Henrician Forts (1539–1545)

Prior to the 1530s, coastal defence structures were rare; coastal defence was the responsibility of local lords and communities, and it was political developments on the Continent that led to Henry VIII's decision to build a series of new forts along the coast of England. In 1533, Henry broke with the Catholic Church by having his marriage with Catharine of Aragon annulled because she failed to produce a male heir. Her nephew, Charles V, the Holy Roman Emperor and King of Spain, took the annulment as a personal slight. At the time, however, Spain and France were at war, so no retaliatory action was taken. In 1535, Henry ordered dissolution of the monasteries, further exacerbating the situation. He was excommunicated in 1538 by Pope Paul III, a close ally of both France and Spain, and at about the same time, the two Catholic powers signed a peace treaty which further heightened tensions and made an invasion of England more likely. As a result, Henry sent out commissioners to assess the strength of existing coastal defences. This assessment revealed that these defences were inadequate and recommended that 36 forts be built. They were to be built at strategic locations extending from South Wales, along the English Channel, and up the east coast of England as far north as Hull in Yorkshire. The locations were chosen based on vulnerability, i.e. the forts were to be sited to protect vulnerable landing places, harbours and anchorages. Because of proximity to the Continent, most were built along the English Channel. Twenty-one have survived into the twenty-first century.

The Henrician artillery forts were new and different. Although artillery had been in use in Britain since the fourteenth century (Harrington 2007), the Device forts were the first to be constructed specifically for the use of artillery and on a national scale. These were low, squat structures built of stone with very thick walls (Fig. 3.3) surrounded by moats. Such forts had been promoted on the Continent from the 1520s, but awareness of these new forms was slow to develop in England (Harrington

Fig. 3.3 Deal Castle, Kent, a typical low-profile, thick-walled Henrician fort viewed from the beach

2007). The new forts were constructed in two phases, the first between 1539 and 1544 and the second in 1544 and 1545. Phase 1 forts have round keeps; rounded, semicircular bastions; and rounded parapets (Fig. 3.4a). The rounded shapes were intended to deflect incoming artillery fire and reduce ricochet. Phase 2 forts were built in *trace-italienne* style, popular on the Continent at the time, with angular bastions; this configuration significantly improved flanking fire (Fig 3.4b). Some have square keeps and others none at all.

The keeps in both types of fort are two or three stories high, including a basement, and are mostly small, ranging from 14 to about 20 m in external diameter (Fig. 3.5). Although adjacent to the sea, the basements must have been dry because they were used for storage of food, gun powder and other supplies. Gun ports and embrasures were purpose-built for the first time; prior to construction of the Device

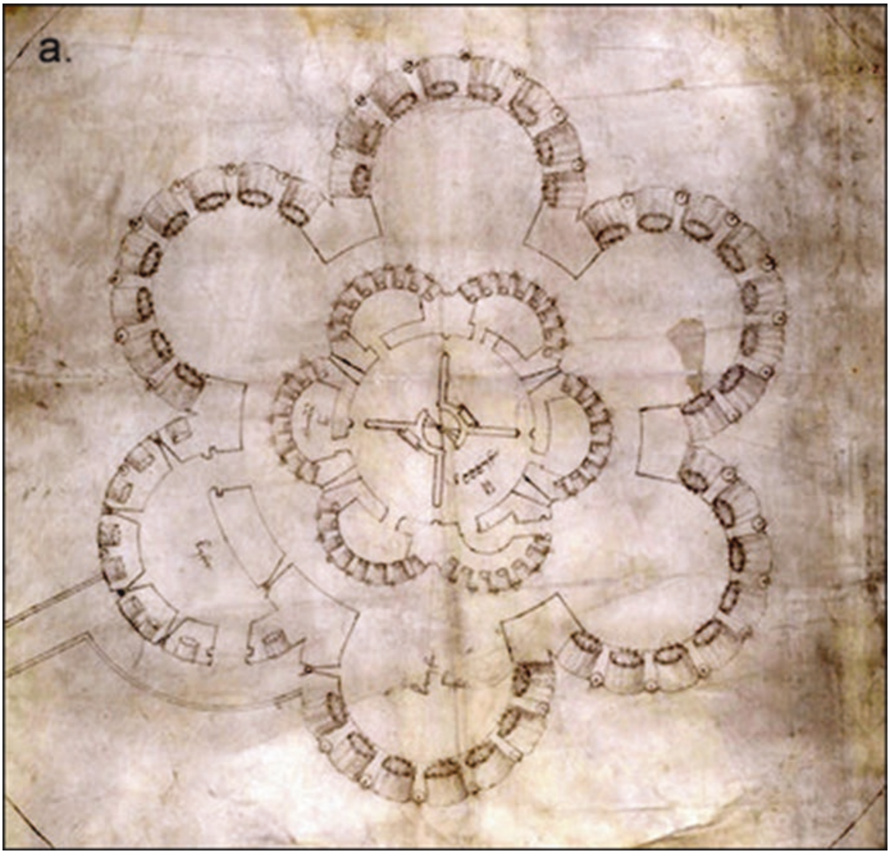

Fig. 3.4 Plan views of Device forts. (**a**) A 1539 drawing of Deal Castle, Kent, a Phase 1 fort. (Wikimedia Commons, original source http://www.bl.uk/onlinegallery/onlineex/unvbrit/d/001cotaugi00001u00067000.html) and (**b**) an 1813 drawing of Southsea Castle, Portsmouth, Hampshire, a Phase 2 fort. (Wikimedia Commons, original source http://www.fortified-places.com/southsea/image8.jpg)

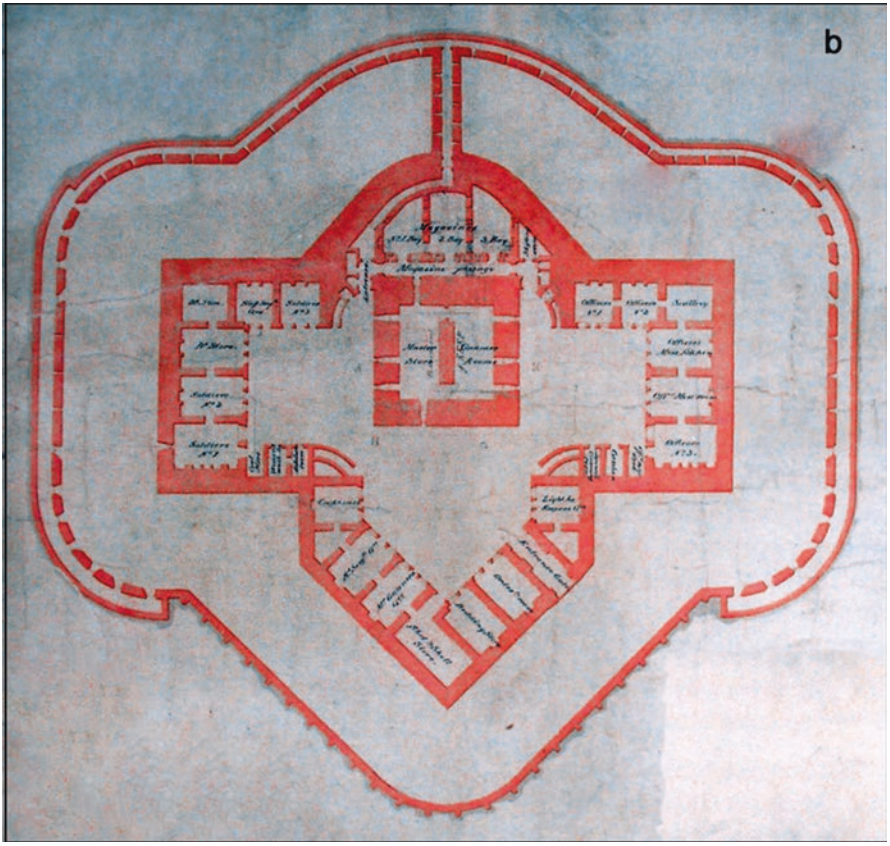

Fig. 3.4 (continued)

forts, gun ports had merely been knocked through existing walls (Harrington 2007). Guns, typically cannons, demi-cannons and culverins along with the smaller sakers, minions and falcons, were mounted on gun platforms on the keep roofs, occasionally on the upper floor(s) of the keep, and on the bastions. The number of guns varied between 11 and 36. Although primarily for coastal defence, some forts also had offensive capabilities. Some also had extensive, associated earthworks and bulwarks, no longer extant (Harrington 2007).

During the reign of Henry VIII and for some time thereafter, English (and later British) military thinking assumed any invasion from foreign soil would be met and turned back at sea and that naval battles would be merely supplemented by coastal fortifications. Additional forts and batteries were constructed along the Solent over time, but these were also primarily for coastal defence; only some had land-facing guns. However, Portsmouth and Gosport, its neighbour on the west side of the harbour, had been protected against land attack by earthen ramparts and water defences since the twelfth century (Moore 2011).

Fig. 3.5 The keep at St Mawes Castle, a Device fort near Falmouth in Cornwall

The three Henrician forts are located at particularly strategic locations to protect Portsmouth harbour and the dockyard – Hurst Castle at the western entrance to the Solent protecting the Needles Passage, Calshot Castle at the mouth of Southampton Water and Southsea Castle at the tip of Portsea Island, upon which the city of Portsmouth is located, at the eastern end of the Solent protecting the Spithead Anchorage (Fig. 3.2). Calshot Castle, built between 1539 and 1540, and Hurst Castle, built between 1541 and 1544, are Phase 1 forts, but Southsea Castle, built in 1544, is a Phase 2 fort. All three are virtually at sea level, reflecting the limited capabilities of mid-sixteenth-century artillery. The following sections describe the castles as built in the sixteenth century.

3.3.1 Calshot Castle

Calshot Castle is located on a shingle spit at the entrance to Southampton Water where the deep-water channel is close to shore (Fig. 3.2; Coad 2013a). Calshot Spit is thought to have resulted from coastal erosion during the early to mid-Holocene sea level rise (SCOPAC 2012). There is a lagoon and marsh behind it. The bedrock is the Middle Eocene Barton Group, which consists primarily of clay and fine-grained sand (BGS n.d.; Hopson 2001; West 2017).

The Castle is built of limestone, likely to be from the Upper Jurassic Portland Stone Formation from the Isle of Portland in Dorset, sourced from nearby Beaulieu and Netley Abbeys[1] (HE 1996a; Coad 2013a). This famous white building stone is quarried from the thick-bedded middle member, the Portland Freestone. The three-story, cylindrical keep is 15.5 m in diameter and 10.5 m tall, making it one of the smaller Device forts (Fig. 3.6; Harrington 2007). There is a gatehouse and a small courtyard surrounding the keep with a 16-sided curtain wall and a flared stone apron above the stone-lined moat, also 16-sided. The elevation in the courtyard is 6 m. Coad (2013a) notes that any well water at Calshot was likely brackish and that water was probably brought in from elsewhere and stored in tanks in the keep basement. The keep has two tiers of guns, one on the second floor with 18 gun ports and the second on the roof with eight embrasures. There are 15 embrasures in the curtain wall; there are no bastions. In addition, there is space for three guns in the gatehouse (HE 1996a; Harrington 2007; Coad 2013a). Calshot was allowed to decay until 1774 when general repairs were made to the structure. After the Napoleonic Wars, it was used as quarters for coastguards. Quick fire (QF) guns were mounted in the 1890s and early twentieth century when the Castle underwent its last modernisation. The area served as a sea plane base from 1931 until 1953. English Heritage has since restored the Castle to its nineteenth-century appearance (Coad 2013a).

Fig. 3.6 Calshot Castle, one of the smallest Device forts, viewed from the south. The building on the left side is the gatehouse and is separated from the keep (right) by a courtyard

[1] After the monasteries were dissolved in the late 1530s, many were destroyed, and the stone was often reused in new construction.

3.3.2 Hurst Castle

Hurst Castle (Figs. 3.2 and 3.7) was built to protect the Needles Passage, the western entrance to the Solent. It is located on Hurst Spit, at an elevation of about 3 m, only 1200 m north of the western end of the Isle of Wight. The spit is 2.25 km long, early to mid-Holocene in age, and is composed primarily of Pleistocene flint that has been transported from Christchurch Bay to the west by longshore drift (SCOPAC 2012; West 2020). It is thought to have originated as a barrier island that was subsequently pushed inland (SCOPAC 2012). The spit, particularly in front of the Castle, is progressively eroding (West 2020). In fact, part of the sea-facing wall of the east wing of the Castle collapsed into the sea during a storm on 26 February, 2020 (Anon 2021). A lagoon and marsh are located behind the spit. The bedrock is the Upper Eocene Headon Hill Formation of the Solent Group which consists of clay, silt and sand (BGS n.d.; Hopson 2001; West 2017).

The Tudor Hurst Castle is built of limestone and the nineteenth-century wing batteries of Cornish Granite (West 2020). The limestone is likely to be Portland stone, probably sourced from Beaulieu Abbey a few miles to the north. It is a typical Device fort with a 12-sided, two-story keep (~20 m in diameter, 18 m tall) with basement, surrounded by a courtyard, an outer curtain wall with three semicircular bastions and a moat. Water for the garrison was stored in cisterns in the basement (Coad 2013b). The castle was designed for all-round defence with 71 gun ports and embrasures on six levels, but only about 20 guns were mounted upon completion (Coad 2013b). The northwest bastion is somewhat unusual in that it is two stories high and has gun positions on both floors – four on the ground floor and two on the first floor – as well as embrasures on the roof. The other two bastions have two levels of gun positions (Cantwell 1985; HE 1997; Harrington 2007; Coad 2013b).

Fig. 3.7 Hurst Castle. The Device fort is centred between the two mid-Victorian wing batteries. (From Google Earth Pro; Data: SIO, NOAA, US Navy, NGA, GEBCO; image © 2020 Terrametrics)

Hurst Castle, like the other Device forts, was mostly neglected and allowed to fall into disrepair in the seventeenth and eighteenth centuries. New batteries were added, and the keep was rebuilt during the Napoleonic Wars (Coad 2013b), and it was further updated later in the nineteenth century with alterations to the bastions, curtain walls and moat. The Napoleonic batteries were replaced with the brick casemated wing batteries still present today (Fig. 3.7), and the Castle was rearmed in the 1870s with more powerful weapons. These guns were in turn replaced with QF guns during World War I when Hurst served as part of Fire Command Needles. This role recommenced during World War II with the addition of more QF and anti-aircraft guns. It was placed under care and maintenance in 1954 (Coad 2013b) and is now managed by English Heritage.

3.3.3 Southsea Castle

Southsea Castle is a Phase 2 fort (Fig. 3.4b) located at the southernmost tip of Portsea Island. It protects the eastern entrance to the Solent and the Spithead Anchorage next to the deep-water channel leading to Southampton and Portsmouth harbours and the Portsmouth dockyard (Fig. 3.2). It is situated on a shingle barrier beach probably created as early as the mid-fifteenth century (SCOPAC 2012) at an elevation of about 2 m. The bedrock forming Portsea Island is the Middle Eocene Bracklesham Group, which consists primarily of clays, silts and fine- or medium-grained sands (BGS n.d.; Hopson 2001; West 2017).

The Castle keep is constructed primarily from the Upper Eocene Bembridge Limestone (‘Binstead stone’) from the Isle of Wight (Colenutt 1892); the curtain wall is also limestone but Upper Jurassic to Lower Cretaceous Purbeck stone from the Isle of Purbeck in Dorset. The keep is square with two rectangular gun platforms on either side and two angled bastions on the front and rear (Fig. 3.8), an example of the trace-italienne style (Anon 2019a). The keep is surrounded by a ten-sided, angular curtain wall and a dry ditch. The bottom of the ditch is at sea level. A courtyard separates the keep from the bastions. Water was obtained from a well constructed of chalk blocks located in the courtyard. During the Dutch Wars of the late 1660s, a *glacis* (an open, grassy slope) and a new gun platform for 30 guns were added north of and outside the original fort. Thereafter, Southsea was neglected but remained garrisoned until 1759 when it was badly damaged by an explosion. Major upgrades were made during the Napoleonic Wars including, in 1814, modification of the keep roof to form a gun platform with four embrasures. New batteries were added east and west of the Tudor fort during the mid-nineteenth century. At some time during its history, probably during the early nineteenth century, brick reinforcement was added to the keep interior and on the bastion walls facing the courtyard. The brick was made locally in Eastney in military brickworks. Southsea Castle served a coastal defence function in both world wars and was bombed with incendiaries several times during World War II. Decommissioned in 1956, the Castle, owned and restored by the City of Portsmouth, serves as a local tourist attraction (Anon 2019a).

Fig. 3.8 Southsea Castle, a Phase 2 fort constructed in the trace-italienne style. The battery wings on either side of the Tudor fort were added in the mid-nineteenth century. (Modified from Google Earth Pro; image © 2020 Terrametrics)

3.4 Palmerston Forts (1853–1874)

Both military and political considerations led to this second period of artillery fort construction on a national scale. After the fall of Napoleon in 1815, tensions between France and England waxed and waned, but the two countries managed to remain on friendly terms most of the time. However, when Louis-Napoleon became President of France in 1848 and shortly thereafter took the title of Emperor Napoleon III, tensions rose. Conflict in the Crimea in the 1850s brought the two countries together as allies against Russia, but soon after this war ended in 1856, French military involvement in Italy and Austria brought things to a head once more. Furthermore, the 1859 expansion of the harbour at Cherbourg to form a naval base immediately across the Channel suggested an invasion could be imminent (Saunders 2002; Lawrence 2018). There was no firm evidence that military preparations for invasion were ongoing (Saunders 2002), but a Royal Commission, set up in 1859 and reporting in 1860, advised the Prime Minister, Lord Palmerston, that existing coastal defences were inadequate and obsolete. This led to the Defence Act of 1860 which authorised construction of modern fortifications, particularly in the Portsmouth area. The Commission report noted that it was impractical to defend the entire coastline and recommended that the new forts be built in the most vulnerable, strategic locations, many of which were previously protected by Device forts.

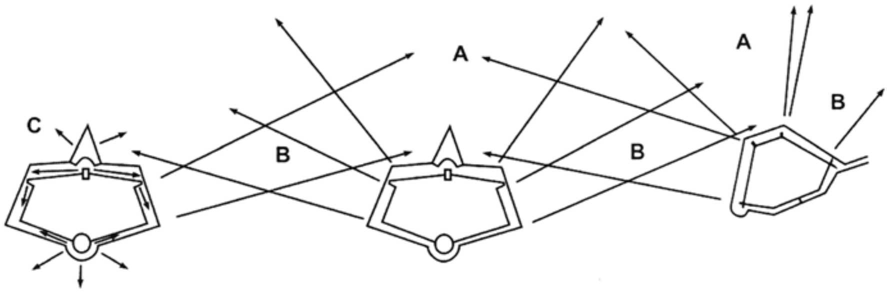

Fig. 3.9 The Prussian 'system' of fortification showing interlocking fields of fire. A = Frontal, from the main ramparts. B = Crossfire, from the flanks. C = Local, from caponiers and keep. (Modified from Moore (2011); used with permission from David Moore)

Like the Device forts, the Palmerston forts were artillery forts. Influenced by developments in fortification on the Continent, they were built using the 'Prussian system', in which self-contained, polygonal forts independent of one another were constructed in a line with interlocking fields of fire (Fig. 3.9; Moore 2011). Some 70 Palmerston forts and batteries were eventually built. They were significantly larger than previous fortifications, covering hectares rather than square meters – Fort Nelson at Portsmouth, for example, covers nearly 8 hectares (Mitchell and Moore 2015).

These new forts were most often built on high ground, and most had no coastal defence capabilities, as they were intended for thwarting attacks from land. It was thought that an invading force could land elsewhere, move inland and then attack the dockyards from the rear, so protection was needed for attacks from this direction. Like the Device forts, the Palmerston forts had low profiles and were often built into the ground to make them less obvious targets. The forts were surrounded by deep, wide ditches or moats below wide, usually casemated, ramparts upon which the guns were to be mounted (Fig. 3.10). The siege at Sebastopol during the Crimean War (1853–1856) showed that soil or sand provided much better protection from heavy artillery fire than stone or brick. Experience during the American Civil War at Fort Pulaski, GA, in 1862 and at Morris Island, SC, in 1863, provided more evidence that this was the case (Hippensteel 2019; Norris 2000; Henderson 2019). Thus, the ramparts in the Palmerston forts were constructed of soil and chalk excavated from the ditches, and casemates were covered with soil. *Caponiers*, casemates constructed in the ditches, were positioned at the corners of the forts to allow flanking fire along the ditches. There are usually two or three in each fort. Large barrack blocks formed the back sides of the forts behind the gorge (ditch); the entrance gatehouses were also located at the rear. The central areas consisted of large parade grounds (Fig. 3.11) often containing free-standing buildings; magazines, connected to the barrack block and caponiers by tunnels, were located below the parade grounds. Early Palmerston forts retained a keep above the gorge to serve as a haven of last resort, but in later forts, the barrack blocks performed this function.

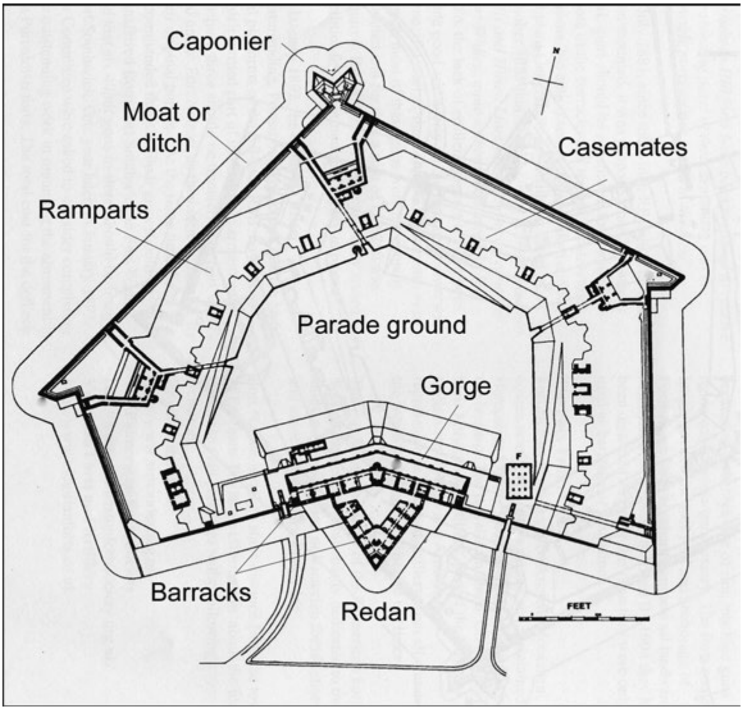

Fig. 3.10 Plan view of a Palmerston fort showing typical features. (Modified from Mitchell and Moore (2015); used with permission from David Moore)

The number of heavy gun positions in each ranged from about 30 to 55, and most also contained mortar batteries. Because of funding problems, construction was spread over approximately 20 years, and long before they were completed, the perceived French invasion threat had waned. They were thus not fully armed when completed. Armament was finally received in the mid-1880s or 1890s but in smaller numbers and of different types than originally planned (Mitchell and Moore 2015).

3.4.1 The Gosport Advanced Line

Work on the five forts that became the Gosport Advanced Line across the harbour from Portsmouth (Forts Gomer, Grange, Rowner, Brockhurst and Elson[2]) began in 1853 (Fig. 3.12; Moore 2011). Their guns were land-facing, with the exception of Fort Gomer which also had guns positioned for coastal defence (Moore 2011), and all five were surrounded by moats. Their polygonal, D-shaped designs (Fig. 3.10)

[2] Technically, Forts Gomer and Elson are not Palmerston forts because construction began on them before the Royal Commission reported in 1860.

Fig. 3.11 Parade ground at Fort Brockhurst, Gosport, Hampshire, with casemated barracks on the left below the ramparts

were experimental (Moore 2011). The designs of the forts, however, were not appropriate for the new rifled guns available at the time they were completed in 1863 (UKFD n.d.), and the line was considered too close to the dockyard to adequately protect it – modern, long-range guns could simply fire over them (Moore 2011), so the Gosport Advanced Line was virtually obsolete by the time construction was completed.

Fort Brockhurst Fort Brockhurst (Figs. 3.12 and 3.13) is located on Lower Eocene London Clay (BGS n.d.; Hopson 2001; West 2017). Construction began in 1858. It was built of red brick likely to be 'Fareham Red' made from the local London Clay. The elevation of the parade ground is only about 8 m, just slightly above the surrounding terrain, but the tops of the ramparts are about 9 m higher (Moore 2011). Fort Brockhurst was the highest of the Gosport Advanced Line forts. Although polygonal in shape, it retains one feature of the earlier Device forts – a moated, circular keep, about 26 m in diameter. The keep, however, is not in the centre of the fort, but is located at the rear, to serve as a refuge of last resort, and the gorge wall runs into the middle of it (Moore 2011). The ramparts are also surrounded by a moat, and there are three caponiers. There are two ramps leading up from the parade ground to the ramparts for moving heavy artillery. An earthwork *redan* (a V-shaped construction exterior to a fort) flanked by a glacis is located in front of the main caponier in the centre of the main rampart (UKFD n.d.; HE 1996b). Water was apparently obtained from wells – water pumps are located within the keep and the parade ground (Moore 2011). Fort Brockhurst was designed to hold 45 heavy guns

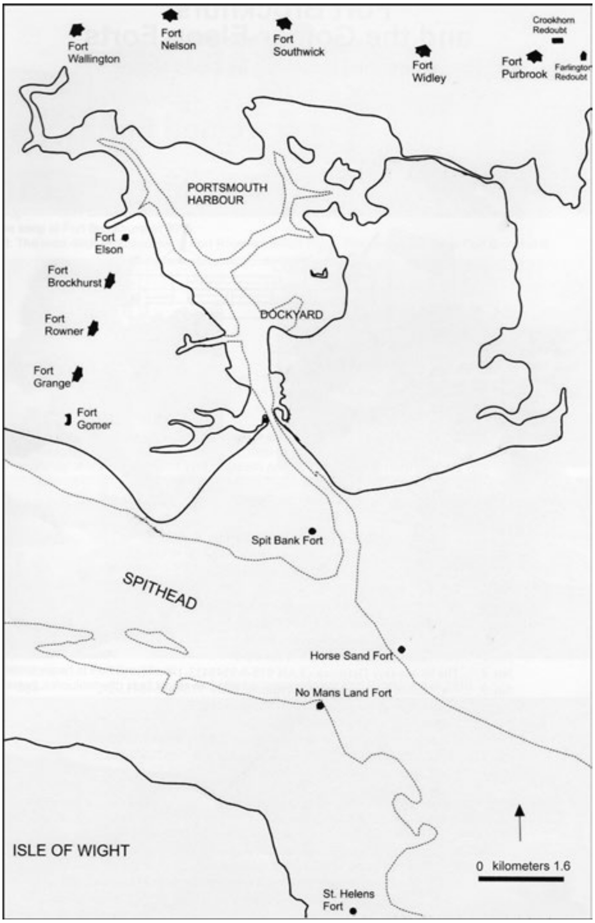

Fig. 3.12 The forts of the Gosport Advanced Line are on the left, and those comprising the Northern Approaches are at the top. The two redoubts which were intended to anchor the east end of the Northern Approaches are in the upper right. The four Spithead forts are located at the bottom in the Spithead Anchorage. The dotted lines mark the boundaries of the deep-water channel in the Solent. (Modified from Moore (2011); used with permission from David Moore)

on the ramparts, 20 light guns in the keep (Coad 2018), additional light guns in the caponiers and four 13-in mortars on the parade ground (Moore 2011, 2017), but it was not fully armed until the 1890s (UKFD n.d.; HE 1996b; Moore 2017). These guns were eventually removed, and by 1902, Fort Brockhurst was armed only with two machine guns. After 1900, it was used as an army barracks, and during World War II, it served as quarters for regiments protecting a nearby aerodrome. After the war, it served as a demobilisation centre for returning troops; it was decommissioned in 1957 (Moore 2011). Fort Brockhurst was sold to English Heritage in 1962 and is currently used as a repository for artefacts from other English Heritage properties.

Fig. 3.13 Fort Brockhurst, Gosport Advanced Line. Note the round, Henrician-style keep (1), the caponiers in the moat (2), the earthen redan (3) and the ramps leading from the parade ground to the ramparts (4). (Modified from Google Earth Pro; image Landsat/Copernicus 2020)

3.4.2 The Northern Approaches

A second line of five forts (Forts Wallington, Nelson, Southwick, Widley and Purbrook) was constructed north of Portsmouth on Portsdown Hill, a 11.3-km-long, east-west trending, chalk ridge about 8 km north of the dockyard (Fig. 3.12; Mitchell et al. 2015). The eastern end of the line was intended to be protected by two redoubts, Crookhorn and Farlington, but only Crookhorn Redoubt was completed (Mitchell et al. 2015). The forts, constructed using the 'Prussian system', are about 1.8–2.3 km apart with interlocking fields of fire.

The bedrock is the Portsdown Chalk Member of the Upper Cretaceous Upper Chalk, a soft white chalk with flints (BGS n.d.; Hopson 2001; West 2017). Portsdown Hill itself is an anticline with a steeply dipping south flank, immediately above which is the line of forts (Hopson 2001). The highpoint of the ridge, at Fort

Southwick, is about 124 m. The land also drops off to the north, but much less steeply. As noted previously, the forts are only partly above ground and are virtually invisible from the north, the direction from which attack was expected. All that can be seen from this direction are the grassy slopes of the ramparts which look like a natural continuation of the surrounding terrain (HE 1971; Mark Sellwood, 2019, personal communication). Vegetation and buildings were removed to the north to improve lines of sight (Mark Sellwood, 2019, personal communication). The water supply for all five forts was stored in tanks at Fort Southwick and was sourced from Farlington at the east end of the ridge (Mitchell et al. 2015).

Fort Nelson Fort Nelson (Figs. 3.12 and 3.14), at an elevation of 84 m, is hexagonal in plan and surrounded by a ditch. It is built of 'Fareham Red' brick made from the London Clay, Portsdown Chalk and flint excavated from the ditch and soil (UKFD n.d.; HE 1971; Mitchell and Moore 2015; Lawrence 2018). The inner wall of the ditch is constructed of flint and brick (Fig. 3.15), and the outer wall, which has slumped, is formed of soil-covered chalk. The ditch is dry because it was not possible to keep water in a moat excavated in fractured chalk. There are three caponiers. The north caponier is two stories high and 'M'-shaped, with two pairs of casemates, one facing east and the other west; the other two caponier*s* have only one pair. Hand-excavated tunnels in the chalk connect the caponiers with the magazine below the central parade ground and with the barrack block at the rear. The *terre-plein*, a wide level platform on the ramparts behind a parapet, was designed to mount 30 heavy guns. There are also 48 gun positions on the flanking ramparts.

Fig. 3.14 Fort Nelson, Northern Approaches. Note the 'M'-shaped north caponier. (From Google Earth Pro; image Landsat/Copernicus 2020)

Fig. 3.15 The flint and brick inner wall of the ditch surrounding Fort Nelson

Mortar batteries for three cast iron, 13-in mortars each are located behind each caponier. The ramparts are formed of chalk excavated from the ditch covered with soil; as at Fort Brockhurst, ramps were provided to move the guns up from the parade ground. A *chemin de ronde* (a raised walkway behind the parapet) with firing steps is present except on the gorge wall. The barrack block is behind the gorge, replacing the keeps of the earlier Gosport Advanced Line forts as a refuge of last resort (UKFD n.d.; HE 1971; Mitchell and Moore 2015). A redan protects the barrack block from the rear.

Fort Nelson wasn't fully armed until the 1890s (UKFD n.d.; Moore 2017). It was declared obsolete around the turn of the twentieth century and was disarmed in 1904, after which it was used primarily as a barracks (Mitchell and Moore 2015). It was altered extensively in 1938 to house a magazine for anti-aircraft ammunition (UKFD n.d.), and in World War II, it served as a Royal Artillery training facility as well as a barracks and ammunition depot. Fort Nelson was abandoned in 1950 and sold in 1979 to Hampshire County Council who restored it. It is now leased to the Royal Armouries Museum of Artillery.

Fort Widley Fort Widley (Figs. 3.12 and 3.16) is constructed of the same materials as Fort Nelson, 'Fareham red' brick (Mark Sellwood, 2019, personal communication), chalk and flint, but is higher in elevation, at 102 m above sea level. Like Fort Nelson, it is hexagonal in plan but is symmetrical on a north-south axis. There is a

Fig. 3.16 Fort Widley, Northern Approaches. (From Google Earth Pro; image Landsat/Copernicus 2020)

flint- and brick-walled dry ditch on three sides; chalk excavated from the ditch was used to form the ramparts. There are three two-story caponiers; those on the north-east and northwest corners are double. There is a large parade ground in the centre with ramps leading up to the ramparts, a chemin de ronde with firing steps, and the barrack block is located at the rear, behind the gorge wall outside of and below the ramparts. The main armament was to be mounted on the ramparts, 21 guns in all, but no guns were in place until 1893 (UKFD n.d.; HE 1969; Mitchell et al. 2015). It was disarmed in 1907 and served as a Royal Artillery barracks until 1939. During World War II, it had a variety of uses – as an 'Action Post, Fire' in 1941, as a Royal Engineers Bomb Disposal Unit from 1941 and to house prisoners of war for a short time (UKFD n.d.). During the Cold War, the magazine beneath the parade ground was converted to a Civil Defence command centre. Fort Widley is now a riding and equestrian establishment.

3.4.3 The Spithead Forts

In addition to the two lines of forts that surround Portsmouth Harbour, four small forts (No Mans Land, Horse Sand, Spit Bank and St Helens) were constructed on shoals in the sea bed in the Spithead Anchorage on the edges of the deep-water channel (Fig. 3.12). Construction began in 1861 and was completed by 1880 (Anon 2005). The bedrock consists of Eocene sands with some clay (West 2017). At St Helens Fort, water was raised by pump from 152 m below the seabed and stored in cisterns (HE 2000). Similar arrangements can be assumed for the other three forts. All four forts were armed through World War II; their armament was removed in 1948 (HE 1999a, b, c, 2000).

No Mans Land and Horse Sand Forts No Mans Land and Horse Sand Forts (Fig. 3.12) are identical, fully armour-plated, circular in plan each with a basement and two gun floors, and originally each had a lighthouse on the roof. They are about 61 m in diameter above the water line and 73 m in diameter at the base. They rest on foundations of 8-ton cast concrete blocks with inner and outer casings of brick and are filled with shingle capped by a 3-m-thick concrete slab. The walls at the base are 18 m thick (HE 1999a, b). The walls above the foundations are granite (Saunders 2002). Each has 24 gun positions on the lower gun floor and 25 on the upper floor. They were armed through World War II when they served as naval signalling stations (HE 1999a, b). Both were released by the military in 1987. No Mans Land was initially converted to a private residence and then became a high-security conference centre and finally, after 2009, a luxury hotel (UKFD n.d.). Horse Sand Fort was abandoned until 2009, after which it was also converted into a luxury hotel (Anon 2019b).

Spit Bank Fort Spit Bank Fort (Figs. 3.12 and 3.17) is also circular in plan with a diameter of 45 m above the water line but has only one gun floor above the basement, and it was only armoured on the front. The foundations are the same as for No Mans Land and Horse Sand Forts but are 49.4 m in diameter at the sea bed with 14.6-m-thick walls. The walls of Spit Bank Fort above the water line are also granite (Saunders 2002). Fifteen gun casemates face landward, and nine, in an armour-plated gallery, face towards the sea. Its lighthouse is still extant (HE 1999c).

Fig. 3.17 Spit Bank Fort viewed from Southsea Castle looking south towards the Isle of Wight

Although abandoned in 1956 with the demise of coastal artillery, it remained in military hands until 1982 when it was sold and converted into a museum. After 2012, it became a luxury hotel (Anon 2019b).

St Helens Fort St Helens Fort (Fig. 3.12) is oval in plan, and like Spit Bank Fort, it only has a basement and one gun floor and is only armour-plated on the front. The foundations, 45.7 m in diameter, are different from the other three Spithead forts, consisting of cement and back-filled iron caissons, filled with poured concrete (HE 2000). Above the foundations, the walls are Roche stone from South Yorkshire, Portland stone from the Isle of Wight, both limestones, and Bramley Falls stone from the Millstone Grit series in Yorkshire, a coarse-grained sandstone (HE 2000). It initially had 15 casemated gun positions, with four additional guns in turrets on the roof, but by 1880, only one gun remained, and it had to be moved to the back of the fort due to settlement of the foundations (HE 2000). Like Spit Bank Fort, St Helens Fort remained in military hands until the early 1980s when it was sold to a private buyer for a residence but has since been abandoned (UKFD n.d.).

3.5 Concluding Remarks

The Henrician and Palmerston forts owe their origin to the Pleistocene megafloods that formed the Channel and drowned the river valleys feeding into the Channel and Solent Rivers. Their positions vary depending primarily upon the naval and artillery technologies of the period in which they were built although their existence was primarily due to political considerations. Because most of the Channel coast consists of cliffs, only deep-water estuaries could be used for invasions from the Continent. Furthermore, particularly during Tudor times, ships needed safe anchorages in rough weather, a common feature along the Channel, so forts were built to protect them for this reason as well.

Most of the 36 Henrician forts are located at low elevations, on beaches or spits, primarily because of the short range of the guns in use at the time – large guns, such as culverins, had effective ranges of little more than 1700 yards (about 1550 m) and smaller ones, such as falcons and sakers, had effective ranges of only 400 and 500 yards, respectively (about 360 and 460 m) (Norris 2000). The guns mounted in these new artillery forts differed little from those in use in the past (Norris 2000). The forts were only expected to be used in rare circumstances to attack enemy ships before they could land or attack ships in the harbour – battles were assumed to be carried out only at sea, and at that time, the English Navy ruled the waves.

In the mid-nineteenth century when the 70 Palmerston forts were built, these vulnerable harbours and anchorages still required protection from potential invasions, but developments in armour-plating and ship propulsion beginning in the 1850s – existing smoothbore muzzle-loaders took too long to load and fire and could thus not keep up with the new steam-powered vessels as they passed by, for instance – as well as innovations in artillery manufacture and metallurgy, made the earlier forts, Forts Gomer and Elson, completed by 1860, and their smoothbore armament obsolete.

Construction of the later forts of the Gosport Advanced Line, Forts Grange, Rowner and Brockhurst, began in 1858 and was completed in 1863. The forts were positioned west of existing earlier fortifications partly because of growth of the city of Portsmouth, but also because of the increased fire power, accuracy and range of the new rifled weapons that became available in the early 1860s. These guns were primarily 64-pdr converted smoothbore muzzle loaders with a range of 4000 yards (about 3660 m) (Moore 2017). According to Moore (2011, p. 4):The Commission [The Royal Commission of 1859] decided that where there was a direct line of sight from the enemy to a target, a distance of 8,000 yards had to separate them. The distance from the Elson Gomer Line [Gosport Advanced Line] to the dockyards is 4,000 yards. As our artillery was then capable of commanding a distance of 8,000 yards it meant that the enemy could not bombard the dockyard at a distance of less than 12,000 yards…

Neither topography nor geology thus played a role in positioning the forts of the Gosport Advanced Line.

This was not the case, however, for the forts of the Northern Approaches where both geology and the new weapons played significant roles. As noted previously, Portsdown Hill is a chalk anticline that rises steeply above Portsmouth – about 80 m over a horizontal distance of 600 m. The change in elevation north of the ridge crest is much more gradual but effectively camouflages the forts behind their ramparts from enemy fire. Construction of these forts began later than for the forts on the Gosport Advanced Line, and by the time they were armed in the late 1880s and 1890s, rifled breech loaders, with their greater ranges, higher accuracies and ease of firing, were the weapons of choice (Moore 2017). The 7-in Armstrong rifled breech loader, for example, had a range of 4000 yards (about 3660 m), virtually the same as a converted 64-pdr muzzle loading smoothbore but was much easier to load and faster to fire (Moore 2017). The dockyard was thus well protected from any enemy guns that might be positioned on the crest of Portsdown Hill 8 km away (Mitchell and Moore 2015).

Construction materials also changed, and this was reflected in the Palmerston forts. Damage inflicted on fortifications in the Crimea and the American Civil War showed that stone and brick forts were unable to withstand fire from the new, more powerful, rifled guns so soil or sand was used to better protect them. The ramparts in the Palmerston forts, constructed of soil and chalk, thus replaced the stone parapets of the Device forts, and soil-covered casemates were constructed in the ramparts for accommodation and on the terreplein for better protection of the guns.

Both Henrician and Palmerston forts were upgraded to handle the fast-developing late nineteenth-century innovations in naval warfare and artillery, such as the QF guns used to defend against torpedo boats and anti-aircraft guns during the two world wars, but by the mid-twentieth century, all the forts were deemed obsolete. The Henrician forts are all tourist attractions owned by English Heritage or municipal authorities, but some of the Palmerston forts have been retained in military ownership, but not as artillery forts, into the current century. Ironically, the ports and harbours along the English Channel, with their forts designed to protect against foreign invasion, became the main embarkation points for British, Canadian and American troops for the D-Day landings and the Battle of Normandy in 1944, the largest seaborne invasion in history.

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References

Anon. (2005) History of the Solent Forts. http://www.royalnavalmuseum.org/info_sheets_solent-forts.html. Accessed 10 August 2019

Anon. (2019a) Southsea Castle. http://castlesfortsbattles.co.uk/south_east/southsea_castle.html. Accessed 21 January and May 2019

Anon. (2019b) Solent Forts. https://solentforts.com/about/solent-fort-history/. Accessed 10 July 2020

Anon. (2021) Storm prompted wall collapse at Henry VIII's Hurst Castle. https://www.bbc.co.uk/news/uk-england-hampshire-56222543. Accessed 27 February 2021

British Geological Survey (BGS) n.d. The BGS lexicon of named rock units. https://www.bgs.ac.uk/BGS/. Accessed from October 2018 through May 2019

Cantwell A (1985) The Needles defences. Fort 13:69–88

Coad JG (2013a) Calshot Castle, 2nd edn. revised. English Heritage, London

Coad JG (2013b) Hurst Castle. English Heritage, London

Coad JG (2018) Fort Brockhurst. English Heritage, London

Colenutt GW (1892) The Bembridge Limestone ("Binstead Stone") of the Isle of Wight. Proceedings of the Hampshire Field Club & Archaeological Society 2(2):167–180. http://www.hantsfieldclub.org.uk/publications/hampshirestudies/digital/1885-99/Vol_2/Colenutt_pt2.pdf. Accessed 13 May 2019

Collier JS, Oggioni F, Gupta S et al. (2015) Streamlined islands and the English Channel mega-flood hypothesis. Global and Planetary Change 135:190–206

Gupta S, Collier JS, Palmer-Felgate A et al. (2007) Catastrophic flooding origin of shelf valley systems in the English Channel. Nature 48:342–345

Harrington P (2007) The Castles of Henry VIII. Osprey Publishing Ltd., Oxford

Henderson, SW (2019) American coastal defence Third System forts: how geomorphology and geology dictated placement and influenced history. In: Rose EPF, Ehlen J, Lawrence UL (eds) Military aspects of geology: fortification, excavation and terrain evaluation. Geological Society of London Special Publication 473, p 61–82

Hippensteel S (2019) Rocks and rifles. The influence of geology on combat and tactics during the American Civil War. Springer Nature Switzerland AG, Cham

Historic England (HE) (1969) Fort Widley. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1387128. Accessed 18 October 2018

Historic England (HE) (1971) Fort Nelson. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1350616. Accessed 18 October 2018

Historic England (HE) (1996a) Calshot Castle: a 16th century artillery castle. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1014619. Accessed 30 October 2018

Historic England (HE) (1996b) Fort Brockhurst. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1013401. Accessed 19 October 2018

Historic England (HE) (1997) Hurst Castle and lighthouse. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1015699. Accessed 19 October 2018

Historic England (HE) (1999a) Horse Sand Fort. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1018588. Accessed 18 August 2019

Historic England (HE) (1999b) No Man's Land Fort. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1018589. Accessed 18 August 2019

Historic England (HE) (1999c) Spitbank Fort. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1018587. Accessed 18 August 2019

Historic England (HE) (2000) St Helen's Fort. Historic England National Heritage List for England. https://historicengland.org.uk/listing/the-list/list-entry/1017370. Accessed 18 August 2019

Hopson PM (2001) Geology of the Fareham and Portsmouth district: sheet description for the British Geological Survey 1:50000 series sheet 316 and the mainland portion of sheet 331 (England and Wales). British Geological Survey, Keyham, Nottingham. http://pubs.bgs.ac.uk/publications.html?pubID=B06084. Accessed October 2018

Lawrence M (ed) (2018) Fort Nelson souvenir guide. Royal Armouries Museum, Leeds

Mitchell G, Moore D (2015) Fort Nelson – A history and description. Solent Paper No. 9. David Moore, Gosport

Mitchell G, Cobb P, Moore, D (2015) Fort Nelson and the Portsdown Forts. Solent Papers No. 3. David Moore, Gosport

Moore D (2011) Fort Brockhurst and the Gomer-Elson Forts. Solent Paper No. 6. David Moore, Gosport

Moore D (2017) Arming the forts – The artillery of the Victorian land forts. David Moore, Gosport

Norris J (2000) Artillery – a history. Sutton Publishing Ltd., Stroud

Saunders A (2002) The Solent Forts – the preliminary arguments. Fort 30:22–42

Standing Conference on Problems Associated with the Coastline (SCOPAC) (2012) Quaternary history of the Solent System. https://www.scopac.org.uk/sts/solent.html. Accessed December 2018

Victorian Forts and Artillery (UKFD) (n.d.) United Kingdom fortification data. http://www.victorianforts.co.uk/data.htm. Accessed October 2018 through May 2019

West IM (2017) Solent estuaries – introduction: Geological Field Guide. http://southampton.ac.uk/~imw/Solent-Introduction.htm. Accessed December 2018 through March 2019

West IM (2020) Hurst spit, barrier beach of the West Solent, Hampshire and Milford-on-Sea: Geology of the Wessex Coast. http://www.southampton.ac.uk/~imw/Hurst-Castle-Spit.htm. Accessed 14 June 2020

Chapter 4
Fortress Monte Baldo: A Military Landscape Between Nature and War

Francesco Premi

Contents

Abstract Monte Baldo, a mountain ridge located in Northeastern Italy between Lake Garda and the Adige River, is a unique geohistorical location linking the Germanic world and the Mediterranean area. It exhibits the typical characteristics of a military landscape and has done so since the beginning of the eighteenth century continuing through the Second World War. The aim of this paper is twofold: (1) to unfold the natural landscape of Monte Baldo into a new perspective and (2) to reconfigure Monte Baldo as a military landscape where signs of its military history are clearly marked.

Keywords Monte Baldo · Military landscape · Modern Age · Italian unification · World wars

4.1 Introduction

Monte Baldo, the southernmost mountain group in the pre-Alps, rises to a height of 2218 m and stands northwest of the city of Verona (Fig. 4.1). A long, serrated ridge, it is bounded by Lake Garda to the west, the Val Lagarina (the southern end of the Val d'Adige) to the east and the Loppio Valley to the north. To the south, it is

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Fig. 4.1 Monte Baldo (northeast Italy) and its physical boundaries

bounded by the area extending from the southern end of Lake Garda to the Caprino Plain and to the Morainic Amphitheatre of Rivoli Veronese (Figs. 4.2 and 4.3). Projecting southward, uniquely in the Alps, Monte Baldo forms an asymmetrical bastion, steeply sloping on the western side, whereas the eastern side is divided into a system of ridges, valleys, plateaus and natural terraces. These have favoured human settlement in the heart of Monte Baldo since ancient times (Turri 1998; Villa 2010).

Because of these very different environments, Monte Baldo has two aspects, a natural space that is still wild and an area shaped by humans. It is imprinted with many marks of history, some of which are more obvious than others. Whereas its special natural features have attracted scholars to Monte Baldo since the sixteenth century,[1] in modern times, the mountain itself has become an object of interest, especially as a border area and link between the northern European and Mediterranean worlds. Over the centuries, this location on the boundary would progressively endow it with the features and characteristics of a military landscape, with traces going back to ancient times.

[1] The first investigations and publications on the natural features of Monte Baldo were by botanists Francesco Calzolari (1522–1609) and Giovanni Pona (1565–1630). They provide a large amount of useful information on both the progressive evolution of the natural landscape of Monte Baldo, called by later Italian and foreign naturalists *hortus Italiae* (the Garden of Italy) and even *hortus Europae* (the Garden of Europe), and its territorial organisation in past times.

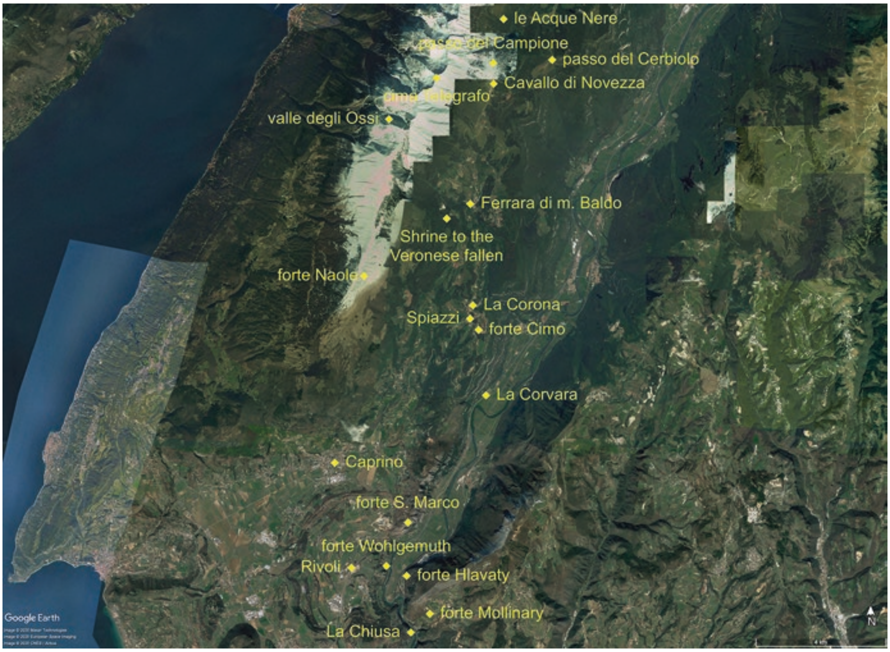

Fig. 4.2 The southern sector of Monte Baldo with places mentioned in this paper

Fig. 4.3 The northern sector of Monte Baldo with places mentioned in this paper

We can define a military landscape as one formed by the build-up and superimposition of traces of military activity over the medium and long term. These traces may be real, such as physical or documented remains, but can also be intangible, such as testimonies of those engaged in military activities in the area. These testimonies are primarily by soldiers but are also by civilians who suffered war in various ways and describe their experiences from their various and differing points of view. A military landscape should be considered a cultural landscape in that it incorporates 'minor but morphologically and visually important functional elements' (Pinchemel and Pinchemel 1996, p. 37) having a specific place in the history of an area (Woodward 2004, 2005, 2014a, b). The particular attention to the relationship of diverse observers with the territory and to testimonies that are different by nature, age and origin as well as the integration and overlap between written, photographic and cartographic sources strengthen even more the role of the above-mentioned functional elements in the landscape. Thus, the interaction of material traces in an area, perceptions, narratives, military cartography and official documents will help us more effectively delineate the military landscape of Monte Baldo.

4.2 A Mountain on the *Limes Veneticus*

There are, in the area of Monte Baldo, ancient, ephemeral, but noteworthy, traces of minor but important functional elements that hold a particular role in the history of the region. These can be seen both as an unavoidable route for those who attempted to cross the heights of Monte Baldo and as the impassable route alongside the Ossi Valley. 'Bones Valley' (*ossi* is the Italian word for bones) is a craggy and detrital area on the western side of Monte Baldo, often mentioned by its first visitors, the sixteenth-century botanists.

Venetian historian Marin Sanudo, who wrote about this area in 1483 (his chronicle was published much later, however, in 1847), suggested an attractive explanation for this by establishing a link between the place names and the episodes of fighting which had actually taken place in more than one part of the Monte Baldo area over the centuries. So, if as early as the fifteenth-century people were assuming that Monte Baldo had been the scene of terrible battles, this needs to be followed up and investigated more thoroughly to see how the military role of the mountain arose and was shaped over time.

The starting point is the so-called *Almagià* map, a fifteenth-century document that has recently provoked a heated argument among scholars over its standing as a military map (ASVe 1438). This status is confirmed above all by the accuracy and care with which aspects, such as routes and castles, were depicted together with references to place names relating to strategic sites (e.g. La Corona, San Marco and Corvara). These would become symbols of the military landscape of Monte Baldo over the centuries (Varanini et al. 2014).

However that may be Monte Baldo's military connotations relate to its special features as a border area in the pre-Alps, originating in the nature and form of its particular physical relief, shaped by mountains and rivers. It is a kind of hinge between two different geopolitical realities that have led to the formation and development of a major, although imaginary, border wall across its slopes and along its ridges. It is a substantial, almost real, wall, despite rare physical demarcation between transalpine and Mediterranean civilisations, in an area inviting friction and conflict.

The imaginary frontier wall on Monte Baldo, which probably already existed as a *limes* (limit or boundary) in Roman times, was consolidated in the fifteenth century when the dominions of the Scaligeri family expanded into the Val d'Adige and the surrounding mountains. This is evidenced by the border line 'that runs across Monte Baldo and the Lagarina valley, starting at the top of the Altissimo di Nago and ending on Monte Sparavieri in Lessinia' (Zumiani 2011, p. 9), almost coinciding with the present boundary between Veneto and Trentino-Alto Adige. However, in the centuries immediately following, with the border lines already established, Monte Baldo also inherited their inherent disputes. In an attempt to resolve these, prominent stone boundary markers were erected, on the assumption that they might resolve any additional disputes arising (Fig. 4.4).

This sense of a frontier wall, whose line has remained almost unchanged for a long time, can be understood with the help of seventeenth- and eighteenth-century maps of the area. The *Topographiam veronensis agri* (Topographic map of the Veronese region; IGMa 1625) shows the boundary in the Val d'Adige up to Borghetto, although only as a mere line, confirming the territorial division in the earliest of modern times. Some places frequently arising in the Monte Baldo military area, such

Fig. 4.4 Stone boundary marker at Cerbiolo pass

as La Corona, Ferrara and Brentonego, are indicated by name. But it is above all on *Tophografia della Frontiera del Veronese co' gli Austriaci* (Topographic map of the border between the Veronese region and Austria; ASVr 1713) that the borderline is clearly shown, with alongside it 'two lines of posts, a first forward line, a second drawn back because of the snow' (ASVr 1713, caption) marked in different colours designed to prevent smuggling, indicating the strategic localities shown on the fifteenth-century *Almagià* map: La Corona, San Marco and Corvara.

The early eighteenth century proved to be a turning point in the way that the Monte Baldo area was viewed and its landscape conceived; its importance as a border guard was confirmed. It is during this time that the mountain became, so to speak, decked with new manifestations of military activity that, together with its inherent qualities, its unchanging natural features such as the passes and man-made works such as roads and boundaries, helped to build its military character. For the Monte Baldo area, the century opened with the passage of 'a column of the army of the Duke of Vendôme that descended on Brentonico after having burned down Ferrara' (Gorfer 1993, p. 49) at the start of the War of the Spanish Succession.[2] At the outbreak of war in 1701, the French and Spanish troops commanded by French Marshal Nicolas de Catinat began military operations in the area to thwart the Habsburgs by preparing some entrenched positions on Monte Baldo. In 1703, troops of the Holy Roman Empire, commanded by Prince Eugene of Savoy, were lined up against the French and Spanish under the orders of the Duke of Vendôme who, in planning to occupy Trentino, intended to join up with the Bavarian troops who had occupied the Tyrol from the north. This is a time when Monte Baldo was regarded as a valuable access route from the south towards the Holy Roman Empire, especially through the natural gaps of the Cerbiolo, Cavallo and Colma di Novezza passes (Fig. 4.5) and the Campione pass.

Maps relating to the French invasion of Trentino in 1703 provide direct evidence of these events. In a letter to his sovereign, King Louis XIV, Vendôme sets out in some detail his intentions to proceed with the troops along both sides of Lake Garda, at the head of one of the two army corps:

> [from Ferrara] I would if I could climb Monte Baldo, to take the fortifications that the enemies have made between this mountain and the Adige in the vicinity of Borghetto from behind. Your majesty will be able to see all this on the map that I have had the honour of sending you. If I succeed, I will then try to strike towards Torbole, to join up with the body that will have passed down the other side of the lake. (Bressan 1994, p. 205)

[2] The War of the Spanish Succession (1701–1714) was caused by conflicting claims to the Spanish throne after the death of childless King Charles II of Habsburg Spain. The accession to the Spanish throne of Philip V Bourbon, grandson of King Louis XIV of France, antagonized England, Holland and the Holy Roman Emperor Leopold I, who had claimed the succession on behalf of his son. War in Europe broke out with the Grande Alliance (Holland, England, the Holy Roman Empire and most of the German states) against France, Spain and Bavaria. Portugal and Savoy, initially allied to France, joined the Alliance in 1703; Hungary joined the opposite front in 1703. From a military point of view, the most pre-eminent commanders were the Duke of Marlborough and Eugene of Savoy for the Alliance and the Duke of Vendôme, Maximilian II Emanuel and Ferenc Rákóczi on the French-Bavarian side.

Fig. 4.5 Cavallo di Novezza was a key point for the control of the routes, and not just during the War of Spanish Succession

Unfortunately, loss of the map mentioned by Vendôme prevents us from reconstructing the proposed route and from locating the enemy fortifications between the Adige and Monte Baldo at Borghetto. However, another document (as yet unpublished) can help in this respect: the *Carte de partie du Trentin & du Veronois dans la quelle sont Marquez les retranchemens faits par les Imperiaux dans la presente année 1703 au long de l'Adige tant en deça qu'en dela de cette Rivierre et a la partie Septentrionale des bords du Lac de Garde* (Map of part of Trentino and Veronese in which are marked the entrenchments made by the Imperials in the present year 1703 along the Adige both below and beyond this River and in the northern part of the shores of Lake Garda; IGMb 1703). This map, which is full of information about the routes followed by the French forces and the positions of major defensive works in the Val d'Adige, is unfortunately of little help in locating fortifications in the area of the mountain. Although it clearly shows those in the valley bottoms between Avio and Borghetto and the upper lake between Riva and Torbole, there is no mention of fortifications at higher altitudes on the slopes of Monte Baldo. The border line, however, is clearly marked, together with the same place names relating to sites of military interest shown on the fifteenth-century *Almagià* map – La Ferrara, La Corona, La Croara, San Marco.

On conclusion of the Italian stage of the War of the Spanish Succession and as part of an ambitious project to redefine the border between the Austrian House of

Habsburg and the Venetian Republic, the Congress of Rovereto in 1753 put an end to the long-standing border disputes, albeit with some difficulties with regard to some points of particular military importance, such as the passes. The result was a jagged boundary line, along which new boundary markers were placed to mark the defensive wall of Monte Baldo; this boundary line is well represented on the detailed 1790s *Mappa dei confini tra il Trentino e il Veronese sul monte Baldo* (Map of the border between Trentino and Veronese on Monte Baldo; ACAv 1790), now kept in the town hall of the village of Avio in Trentino.

These boundary markers are the same as those mentioned by French officer and geographer Jean Jacques Germain Pelet in 1803 in a report intended for the French Army, which has remained unpublished until recent times when it was discovered (Dal Corso and Salgaro 2004). This is a treatise on regional military geography, written before the term was coined. It is an essential reference for study of the military landscape of Monte Baldo at the turn of the nineteenth century.

Monte Baldo's involvement in the 1796–1797 Italian campaigns of the French Revolutionary Wars (led by General Napoleon Bonaparte), which can be followed in the 1803 account by Lieutenant Pelet, brought about the extensive use of the network of tracks for the passage of troops and a need to protect passes and borders with the construction of new fortifications. At stake was control of a mountain hinge, the key to the north-south corridors of the Adige and Lake Garda areas.

For Monte Baldo, the Napoleonic wars represented the beginning of a stormy historical period that would leave further traces, constructions and passages in the book of the military landscape that had been emerging for centuries. The geographical nature of the region would have decisive repercussions on the outcome of battles, and at the same time the countenance of the area would be marked by the presence and activity of troops, as attested by the *Descrizione Geografica, Militare e Politica dell'Italia, di Napoleone Bonaparte* reported by Martino Cellai (1864). Once again, the practicability of routes was a determining factor in the conduct of military operations on the slopes of the mountain, and it was these (virtually unchanged from previous centuries) which focused the first actions of the French against the Austrians in a place now known as a military icon because of its strategic importance – La Corona (Fig. 4.6).

Lieutenant Pelet refers to entrenchments built by French General Joubert at La Corona in January 1797. Joubert also placed outposts towards Monte Baldo and Ferrara before abandoning the position to regroup on the Rivoli Plain, where the situation definitively came under French control (Dal Corso and Salgaro 2004). In the armistice signed on 18 April 1797, the borders were redefined, and the Monte Baldo area was declared neutral territory. To re-emphasise the strategic importance of the Monte Baldo area in subsequent different geopolitical circumstances, it should not be forgotten that Bonaparte himself was aware of it; a document sanctioning the handing over of the Tyrol and Trentino from France to Bavaria signed in Innsbruck on 11 February 1806 states that 'for military reasons Napoleon held onto the extreme lower end of the Trentino, the parishes of Ala, Avio and Brentonico, part of the district of Mori' (Corsini 1963, p. 72).

Fig. 4.6 The Church of Madonna della Corona, a devotional temple and a military icon

4.3 A Static Front

In the course of the *Risorgimento,*[3] Monte Baldo, defined by famous Italian, Nobel Prize poet Giosuè Carducci as 'the father mountain' (Carducci 1877, p. 40), continued and strengthened its strategic role and was once again the scene of clashes. The annexation of the Veneto to the Kingdom of Italy in 1866 brought about a radical change, and the border that ran along the ridges and slopes of the mountain took on a new meaning and gave rise to the creation of an area that became progressively more militarised, conceptually and physically. This was partly due to new construction spanning the nineteenth and twentieth centuries, such as the Austrian forts Wohlgemuth, Hlavaty, Mollinary and Chiusa and the Italian forts San Marco, Cimo Grande and Naole (Fig. 4.7; see Premi 2015). The culmination came with the outbreak of the First World War, which also saw the front halt along this border line – it became a static front precisely because of the bulwark nature of Monte Baldo.

[3] *Risorgimento* (the Italian word for 'resurgence') designates the process (approx. 1848–formally 1866) that unified the different states on the Italian peninsula into a single state, the Kingdom of Italy. During this process, at least three military milestones can be identified in the First, the Second and the Third so-called 'Wars of Independence' (1848–1849, 1859, 1866), fought by the Kingdom of Sardinia (later, Kingdom of Italy) primarily against Austria, which ruled major parts of northeast Italy.

Fig. 4.7 Remains of Fort Naole, with Monte Baldo ridge in the backwards

However, despite this immobility, it was the First World War which left the most tangible and permanent marks of a military landscape on Monte Baldo.

Awareness of the military role of Monte Baldo has therefore been a more or less constant companion to the history of its landscape, at least from the beginning of the Modern Age in the late fifteenth century. We can regard this awareness as implicit until the seventeenth century, explicit but not substantial between the eighteenth and nineteenth centuries and explicit and substantial from the early twentieth century, that is, when military geography began to be specifically discussed by high commands and in military academies.

Although reading about the area through the accounts of military engineers (primarily the 1803 document by Lieutenant Pelet) helps to foster understanding of the complexity of the landscape problems in the eighteenth century, to complete the definition of Monte Baldo as a military landscape, we must focus attention on another specific text, one unique of its kind. Exactly a century after Pelet, the periodical 'Rivista Militare Italiana' published an essay *La regione del Baldo e dei Lessini. Descrizione geografico-militare* (Prata 1903), a true work of military geography specifically relating to Monte Baldo. Written by Major Prata of the 65th Italian infantry regiment, the text is perhaps the first work on Monte Baldo in which the military perspective is explicitly stated even in the title and whose content reflects the general tenor of essays of this kind published between the late nineteenth and early twentieth centuries. The work of Prata, which describes 'the imposing mountain massif' (Prata 1903, p. 4) of Monte Baldo, is innovative especially because of his attention to the geological aspects of the area and the strategic function of the mountain. He comments that the strategic importance of Monte Baldo in 'addition to the inherent qualities of its terrain, mainly depends on its constituting the apex of the great Trentino salient, together with the land between Oglio and Garda, formed by the political border and penetrating into the heart of the provinces of Lombardy and Veneto' (Prata 1903, pp. 35–36). Almost explicitly following the theories set out by Italian generals Giovanni Sironi (1873) and Carlo Porro (1898), Prata researches and examines 'in a special way all those landforms and objects that may have an influence on military operations' (Sironi 1873, p. 1) and analyses various geographical elements, in particular the nature of the ground, and links them to tactical and logistical issues.

A few years later, from being Europe's 'playground' (Armiero 2013, p. 93), the Alps turned into a theatre of war. Even the *hortus Europae* did not escape this destiny: in the initial pre-World War I period, in fact, Monte Baldo had already become the subject of military geography studies, among which, in addition to the previously mentioned work by Prata, the most important is *Guida Militare n. 12: Trentino* (Battisti 1914). Cesare Battisti was an Italian-Austrian geographer, socialist politician and later Irredentist officer in the Italian Army.[4] The *Guida* was published anonymously by the Italian Ministry of War to document the conditions of roads, paths, bridges and rivers beyond the Austrian border. At the start of the conflict, Monte Baldo was a bulwark well-guarded by fortifications built by Italians and Austrians towards the Val d'Adige between the nineteenth and twentieth centuries, continuing their function of dissuading any possible penetration along the north-south route. The area involved in the first actions of the war can be identified in the lines held by troops in the area. In the Verona area, trenches from the First World War overlap and sometimes merge with the pre-existing fortifications of 1848 (Gondola 1985). In the Trentino, a defensive line was created by the Italians in the summer of 1915 along the ridge extending from Altissimo towards the southern slopes of the Loppio Valley, providing excellent points for observation of the upper Garda and Val Lagarina, and as such, susceptible to radical transformations for the needs of war (Fig. 4.8; Bertè 1990).

It was Cesare Battisti, in letters sent from positions on Monte Baldo in 1915, who pointed out the weighty military impact on the environment. The changes are clear to see to those familiar with the mountain, and despite his role as a fighter, Battisti did not lose the observant eye of a geographer with respect to the impacts inflicted by war on 'his' landscape:

> When the war is over, we will find everything changed ... Here war has a much darker and more tragic aspect than in the high mountains; here it is not just a war of soldiers against soldiers, it is a bestial fury against everything, against property, against the defenceless, against the land itself…. (Battisti 1915, p. 290)

The unit involved in the initial fighting on Monte Baldo was the Alpine battalion Verona, which, after crossing the border at Passo Campione, entered enemy territory to reach the Austrian positions and strengthen the new defensive line. Also involved alongside the Verona was the Lombard Volunteer Motorcycle battalion, which included futurist avant-garde artists such as Umberto Boccioni and Filippo Tommaso

[4] The Italian irredentist political and cultural movement (late nineteenth–early twentieth century) supported the incorporation of the territories of Trentino, Trieste and other areas along the Adriatic coast with an Italian ethnic presence within the boundaries of the Kingdom of Italy.

Fig. 4.8 World War I Italian trench at Punta delle Redutte

Marinetti, who, in lulls in the fighting, wrote down their impressions of military life (Daly 2013). Boccioni, in 1915, provides an overall view of the military landscape of the area in drawings and notes presented as a series of snapshots: ‘landscape, action, objects, feelings, trees, Malga Casina, Dosso Mosca, fleeing Austrians, bayonet in the mouth’ (Boccioni 1915 p. 112). Marinetti, too, in sketches and notes, captures his perception of the environment, at the same time perceived as a theatre stage and a narrator itself: although from an unusual point of view, he draws attention to the presence of elements of a militarised landscape such as trenches and communication trenches (Ferro and Ferro-Francesconi 2000). The new scars inflicted on the mountain by war are clear to see from the scanty observations of these futurist soldiers, a sensitivity to the natural environment – that of the Futurists – which is decidedly atypical, but one which evidences a clear awareness of the transformation of the mountain landscape affected by military operations (see Premi 2016).

4.4 From War to Memory

On the southern ridges of Monte Baldo, not far from Bocchetta di Naole, a monument today commemorates the fallen soldiers of the war of liberation in 1943–1945, not just the partisans but also the men and women who ‘gave them strength and assistance’, as engraved on the memorial stone. This simple memorial cautions that while the First World War represented a turning point in the build-up of the military landscape on Monte Baldo, it was not, however, its culmination. This should be sought in the dramatic events of the Second World War. To add the missing pieces to the mosaic sketched out so far, we have to investigate the time of World War II, which, although with different impacts and in different ways, still affects the Monte Baldo area.

In 1944, Nazi-Fascist raids of the German occupants, supported by their allies of the Italian Social Republic from the plains of Verona and the Val d'Adige, gradually pushed northwards and intensified, especially in the foothills of Monte Baldo, where guerrilla warfare became established (what is now called asymmetrical warfare). In this new context, the mountain routes acquired a governing role over both the outcome of the fighting and the survival of those engaged in it as well as those in support operations (Martini 2015). Resistance on Monte Baldo began in the summer of 1944 when the Command of the Ateo Garemi partisan division assessed the possibility of extending its organisation into the mountains of Verona to counter Germans along the main communication routes between Italy and Germany: the Val d'Adige and eastern Garda area. The brigade active on Monte Baldo, the Avesani, was responsible for sabotaging connections between Italy and Germany. Once again, the Monte Baldo area was being viewed and examined from a strictly military point of view, and it is interesting to note that some relatively recent features have now been set as concrete reference points for a true military landscape. Of particular significance is the reuse by the Germans of fortifications built in World War I; this had already happened in the past, for example, in the case of the Fortino, built during the War of the Spanish Succession in 1703 and recovered by the Austrians during the First War of Independence in 1848, and other positions.

In the latter days of April 1945, peace was being spoken of in Europe, but fighting was still continuing on the eastern side of Lake Garda. Diaries kept by American soldiers tell the story of these last military operations, and among these is the war diary of Captain David R. Brower of the 86th Battalion of the US 10th Mountain Division (Brower 2013). Brower's reactions to his first encounter with the Navene and Monte Baldo areas are particularly striking; his notes do not differ much from the gloom and unease felt at varying times in the past by other travellers when faced with this dark and forbidding landscape. Brower notes that what previously seemed to be landscapes illustrated 'in Italian tourist posters, with very steep mountains and castle ruins towering over the countryside below' had given way to images of gardens ravaged by grenade craters and uprooted trees (Brower 2013, p. 142). This is a view of change in the environment and landscape not dissimilar to that of Austrian Kaiserjäger Lieutenant Felix Hecht, who, between the end of 1916 and the beginning of 1917, pointed out the contrast between war and the beauty of the landscape and noted the devastating impact of war on the area:

> It is a very sad spectacle to see so many fine evergreen bushes obstructed by grids linked to electricity, rose gardens crossed by trenches, villas with loopholes ... Here, by contrast, war takes on the face of death, destroying everything beautiful with a violent hand. (Menegus 1989, pp. 79–80)

4.5 Conclusions

This so well-described transformation process deserves to be explicitly revealed to today's observers, too, in order not to risk the downsizing of the war on something obvious, common, familiar or even easy to rule. The military landscape, on Monte Baldo as elsewhere, retains its memorial, cultural and experiential power only if it still transmits even the most terrible and obscene aspects of the battles. Reading the landscape through a variety of written sources, even the most private and intimate testimonies, together with the official documents, can contribute to this purpose: as we have tried to demonstrate, there are in fact aspects in the construction of a landscape that can only be told in words and that cannot be found in the cartographic or photographic element.

Over the centuries, war has shaped and remodelled the nature of Monte Baldo, creating new features from time to time, and sites that have sadly become famous for battles that later became places for remembrance (Fig. 4.9), 'consecrated by tradition to play an active part in preserving identifying or founding aspects' of the past (Salvarani 2008, p. 2). When such features accumulate in an area and if they are still visible and understandable, so they become part of people's collective memory and themselves become landscape: because a landscape 'exists only once it is dis-vealed by a glance' (Augé 2004, p. 41).

Fig. 4.9 Monte Baldo shrine, dedicated to the Veronese fallen in the First and Second World Wars

References

Archivio Comunale di Avio (ACAv) (1790) Mappa dei confini tra il Trentino e il Veronese sul monte Baldo. 1.1.14–3

Archivio di Stato di Venezia (ASVe) (1438) Carta dell'Almagià (o Carta dei Frari). Miscellanea Mappe, dis.

Archivio di Stato di Verona (ASVr) (1713) Tophografia della Frontiera del Veronese co' gli Austriaci. Comune, n. 23

Armiero M (2013) Le montagne della patria. Einaudi, Torino

Augé M (2004) Rovine e macerie. Il senso del tempo. Bollati Boringhieri, Torino

Battisti C (1914) Guida militare n. 12: Trentino. Ministero della Guerra – Corpo di Stato Maggiore, Venezia

Battisti C (1915) Lettera a Giovanni Pedrotti da Loppio 24 dicembre 1915. In: Monteleone R, Alatri P (eds) (1966) Epistolario di Cesare Battisti. La Nuova Italia, Firenze, p 290

Bertè T (1990) Gli acquedotti militari italiani della seconda linea difensiva, sulla sinistra Adige della prima Guerra mondiale. I Quattro Vicariati e le zone limitrofe 34(68):60–66

Boccioni U (1915) Diario di guerra. In: Di Milia (ed) Umberto Boccioni: diari. Abscondita, Milano, p 112

Bressan L (1994) Lettere originali circa l'invasione dei Francesi del 1703. In: Bressan L, Gobbi D, Farina M (eds) L'invasione francese del Trentino. Comprensorio della Valle dell'Adige, Trento, p 183–239

Brower DR (2013) Remount Blue. Dalla Linea Gotica al Lago di Garda 1944-1945. Museo Storico Italiano della Guerra, Rovereto

Carducci G (1877) Odi barbare. Zanichelli, Bologna, p. 40

Cellai M (1864) Fasti militari della Guerra dell'indipendenza d'Italia dal 1848 al 1862. Tipografia degli Ingegneri, Milano

Corsini U (1963) Il Trentino nel secolo decimo nono. Arti Grafiche R. Manfrini, Rovereto

Dal Corso M, Salgaro S (eds) (2004) Monte Baldo 7bre 1803: la relazione di J.J.G. Pelet. Cierre, Sommacampagna

Daly S (2013) The Futurist mountains: Filippo Tommaso Marinetti's experiences of mountain combat in the First World War. Modern Italy 18(4):323–338

Ferro T, Ferro-Francesconi L (2000) Sul Monte Baldo in trincea con i Futuristi. In: Ferro T, Ferro-Francesconi L (eds) Visti sul Garda. Zanetti, Montichiari, p 226–232

Gondola VS (1985) Il Baldo Orientale nella storia. Bertani, Rivoli V.se

Gorfer A (1993) Un paesaggio tra Alpi e Prealpi. Cierre, Verona

Istituto Geografico Militare (IGMa) (1625) Topographiam veronensis agri. Biblioteca, Coll. Bianconi, n. 145

Istituto Geografico Militare (IGMb) (1703) Carte de partie du Trentin & du Veronois dans la quelle sont Marquez les retranchemens faits par les Imperiaux dans la presente année 1703 au long de l'Adige tant en deça qu'en dela de cette Rivierre et a la partie Septentrionale des bords du Lac de Garde. Nuovo Archivio, inv. 9161

Martini U (2015) Presentazione. In: Club Alpino Italiano (ed) I sentieri per la libertà. Solferino, Milano, p 9

Menegus O (1989) La prima Guerra Mondiale sul Monte Baldo. Moschini, Rovereto

Pinchemel P, Pinchemel G (1996) Dal luogo al territorio. Franco Angeli, Milano

Porro C (1898) Guida allo studio della Geografia Militare. Utet, Torino

Prata A (1903) La regione del Baldo e dei Lessini: descrizione geografico-militare. Rivista Militare Italiana 8(10)

Premi F (2015) Il Monte Baldo tra natura e guerra: definizione ed evoluzione di un paesaggio militare. Dissertation, Alma Mater Studiorum Università di Bologna

Premi F (2016) I segni della Grande Guerra: iconemi militari sul monte Baldo. In: Ferrandi G, Gorfer G (eds) Uomo – territorio. Scritti di etnografia e paesaggio. Aurora, Trento, p 206–209

Salvarani R (2008) Il paesaggio come fonte per la storia del territorio: l'uso della fotografia aerea. In: Crippa MA, Zanzottera F, Boemi MF (eds) Le terre dei folli. Bamsphoto, Montichiari, p 77–86

Sanudo M (1847) Itinerario di Marin Sanuto per la terraferma veneziana: nell'anno MCCCCLXXXIII. Tipografia del Seminario, Padova

Sironi G (1873) Saggio di geografia strategica. Candeletti, Torino

Turri E (1998) Il paesaggio come teatro. Marsilio, Venezia

Villa M (2010) Un'autostrada del paleolitico. Altrestorie 32:5–7

Woodward R (2004) Military geographies. Blackwell, Malden-Oxford

Woodward R (2005) From Military Geography to militarism's geographies: disciplinary engagements with the geographies of militarism and military activities. Progress in Human Geography 29(6):718–740

Woodward R (2014a) Military landscapes: agendas and approaches for future research. Progress in Human Geography 38(1):40–61

Woodward R (2014b) Looking at military landscapes: definition and approaches. In: Bellais R (ed) The evolving boundaries of defence: an assessment of recent shifts in defence activities. Emerald, Bingley, p 141–155

Varanini GM, Postinger CA, Lazzarini I (2014) Il territorio veronese, trentino, mantovano. In: Lodi S, Varanini GM (eds) Verona e il suo territorio nel Quattrocento. Cierre, Sommacampagna, p 61–109

Zumiani D (2011) Presentazione. In: Laiti I, Fasoli L. Il confine fra la Casa d'Austria e la Repubblica di Venezia sul Monte Baldo e nella Vallagarina. Comunità Montana del Baldo, Verona, p 9

Part II
World War

Chapter 5
The Practice of Trench Warfare: Training Sites in the Aube Region of France (Champagne), 1914–1919

Jérôme Brenot, Yves Desfossés, Robin Perarnau, Marc Lozano, and Alain Devos

Contents

Abstract The objective of this research is to provide new archaeological insights into World War I (WWI) training trench sites in France. These training areas, situated to the rear of the front line, illustrate how the military command prepared soldiers, physically and mentally, before they were sent to the front. The training areas reproduced the spatial and architectural organization of trench networks and thereby allowed soldiers to become familiar with the battlefield topography.

WWI training camps have never been studied extensively in France, although their presence is occasionally reported in the literature. They were in fact more

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numerous than archival records indicate, a function of the fact that they were created in an opportunistic and temporary way. To date, no archaeological or geohistorical research has been undertaken to determine their actual distribution, and this paper is a first step in developing this. To identify and map their traces in the landscape, the Pays d'Othe of the Aube region (Champagne) was studied using aerial photography flown in 1948. About 20 sites were discovered, indicating the high intensity of military occupation in the region between 1914 and 1919. Agricultural reparcelling, which began in the 1950s, has erased almost all traces of these remains.

Keywords Training trenches · Rear front line · Champagne-Ardenne · Pays d'Othe · WWI archaeology

5.1 Introduction

An important component of training camps in World War I (WWI) are the training trenches – or practice trenches – which were built to train new soldiers to construct this defensive architecture (Cocroft 2013; Cocroft et al. 2015; Brown 2017), as well as allowing them to understand how to live, move, and shoot in the static war and even providing psychological training. These particular terrains, the subject of this study, are generally located within or close to military areas but were also created in civilian areas during the conflict. The training camps have been studied for a long time in countries that were located far from the front, especially in the United Kingdom (Smith 2010; Saunders 2017). In these cases, it is possible to measure the degree of imagination of the builders to best reproduce the architectural features of the trenches. Heritage inventories have been done (Historic England 2020; Historic Environment Scotland 2020), highlighting the very high density of training trench sites in the British Isles (Fig. 5.1). They are also well documented in the United States, where about 100 camps were created (e.g., Hunt, 1918; Spickelmier, 1987).

In France, WWI training trenches constitute a relatively little documented field of the daily life of an infantryman: no archaeological or geohistorical research has been undertaken to determine their actual distribution within the country. Training trenches cannot be documented through military archival investigations, because they were created in an opportunistic and temporary way around infantry cantonment areas. They were mainly developed because of the saturation of the military camps and the need for quartering and training new troops within the regions near to the front line (*Zone des Armées*) but also to the rear of the front (*Zone de l'intérieur*).

Today, a dozen of these training trench sites (Fig. 5.2) are known through fortuitous discoveries as a result of archaeological operations or surveys conducted by local associations (e.g., Gauthier, 2013). Only one of these sites, in the South West France close to Bergerac, was the subject of an archaeological investigation (Ballarin et al. 2005). In that instance, the remains of a training trench site for the 108th Infantry Regiment were initially interpreted as defensive structures from religious wars in the sixteenth century.

In the Champagne-Ardenne region, only three sites are known, thanks to an historical analysis (Dry and Seurat 2018); they are located close to the city of Troyes.

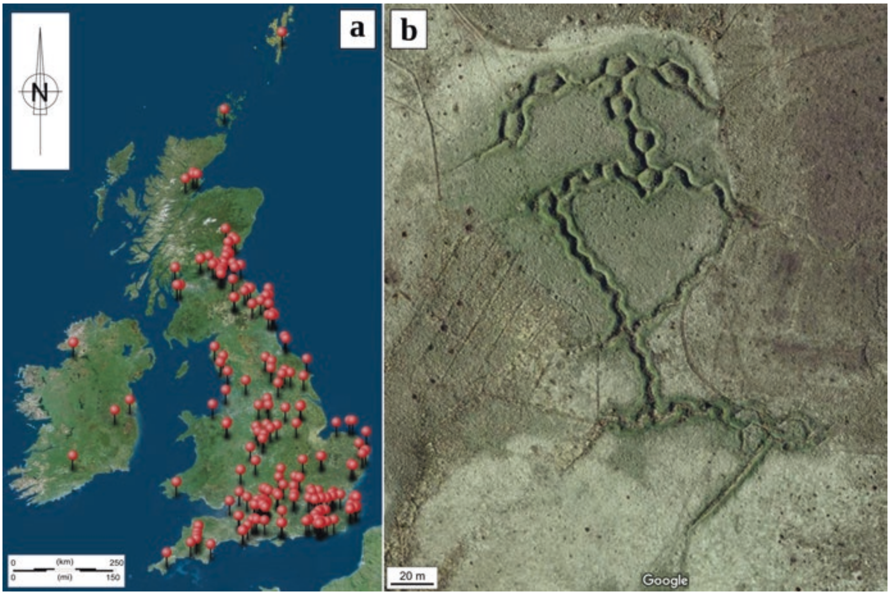

Fig. 5.1 (**a**) Locations of British training trench sites. (Modified from https://www.openstreetmap.org). The reconstituted "front" represents about 500 sites, compiled from available British Heritage databases (Historic England 2020; Historic Environment Scotland 2020); Irish and Welsh site compilation is non-exhaustive. (**b**) Aerial view (scale of about 1:2000) of twenty-first-century preserved practice trenches on pasture land at the Otterburn site, Northumberland (aerial photo: Google Earth 2020). This site is approximatively 1 hectare

Fig. 5.2 Locations of the known French training trench sites mentioned in archaeological and historical literature (red stars). The area studied is located in the Aube, in the south of the Champagne-Ardenne region, and is outlined in black; the mean WWI front line is shown by a red line

In this study, we investigated the Aube department, in the south of the Champagne-Ardenne, to quantify and analyze the training camp network established during WWI. The question raised is the apparently low number of training trench sites in France compared with other countries.

5.2 The Study Area

The study area is located in the department of Aube where the main city is Troyes (Fig. 5.3). From a geological point of view, the Aube region extends over two cuestas of the Paris Basin and is composed of Jurassic limestones in the southeast and Cretaceous clays and chalks in the rest of the department. The area is crossed by two main rivers, the Seine and the Aube. The study area, the Pays d'Othe, corresponds to an area of raised topography consisting of the residual Pleistocene Clays-with-Flints formation overlying Cretaceous chalks (Petit et al. 2018). This cuesta extends over an area 60 km long and 20 km wide, and elevations range between 150 and 280 m. It is mainly forest-covered.

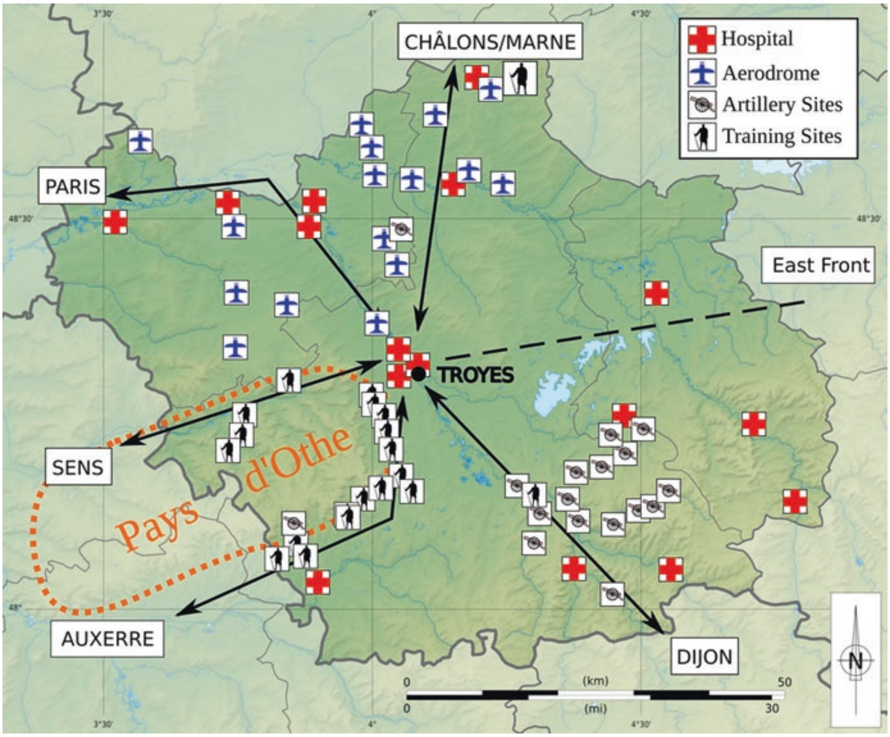

Fig. 5.3 Military areas in the Aube department during WWI. The main transport routes are represented by black arrows. The study area, the Pays d'Othe, is bounded by a dashed orange line. The training sites located in the Pays d'Othe discovered through this study were abandoned after the war. (Compiled from Framery (2016), Dry and Seurat (2018), and this study)

The Aube region, which was under military authority during WWI, is known to have served as a logistical hub between the rear area and the front line (Dry and Seurat 2018). Troyes is the main transportation hub linking the main cities of the rear area (e.g., Paris, Sens, Auxerre, Dijon) with cities closer to the front line (e.g., Reims, Châlons/Marne, Verdun). Both rail and road networks serve the area, permitting movement of military units, equipment, and supplies. The intensity of the military occupation is illustrated by about 50 sites for soldiers (Framery 2016; Dry and Seurat 2018): military hospitals, airfields concentrated in the northern part of the department, artillery camps in the southeast, and three previously identified training trench sites, Mailly-le-Camp, Bourguignons, and Sommeval.

The largest site, developed around the village of Mailly-le-Camp, is located at the northern limit of the department. It is a military camp of about 10,000 hectares created at the beginning of the twentieth century. During WWI, this camp was located about 60 km from the front line. Aerial photographs, especially those from a mission flown in 1938 at a scale of about 1:20,000, show a constellation of training trench areas (Fig. 5.4). The air photos show that trench replicas were built with

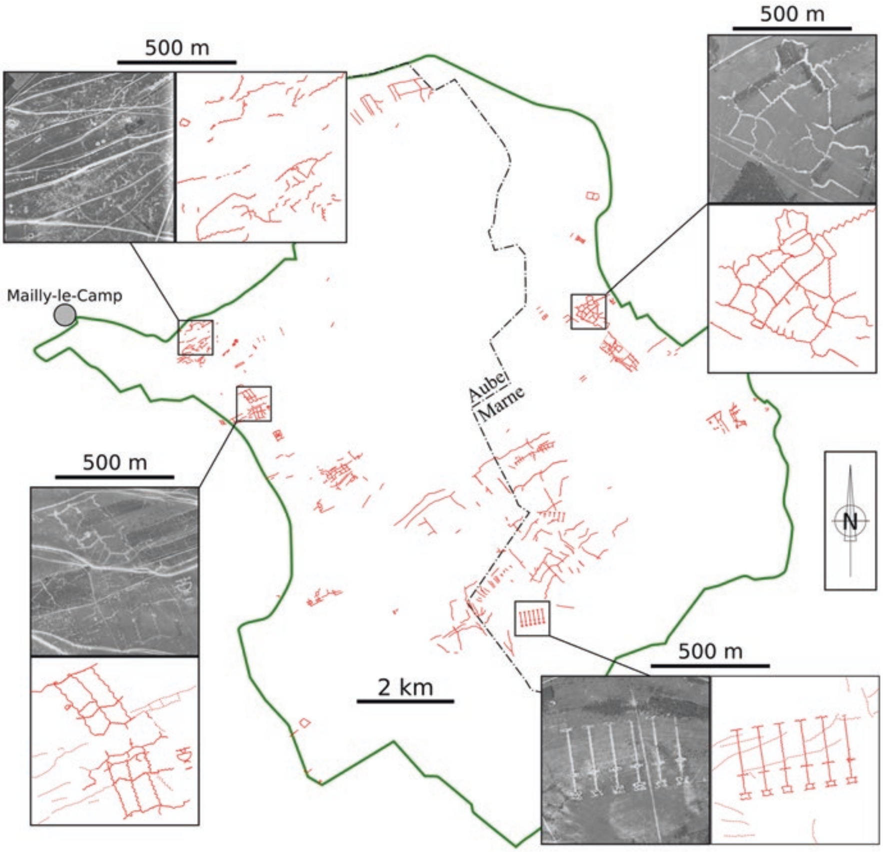

Fig. 5.4 Trench networks within the military camp of Mailly-le-Camp (delimited by a green line) identified by interpretation of aerial photographs flown in 1938 at a scale of about 1:20,000. (Aerial photos: IGN 2020)

great variability in dimensions and morphologies, ranging from small infantry trenches and defensive works to gigantic battlefields of several square kilometers. However, it is impossible to be precise as to when these trenches were built because this camp had been used since 1902.

5.3 Methodology

To measure the archaeological impact of the military occupation, two databases were used. First, vintage postcard databases were used to circumscribe the study area within the Pays d'Othe. Due to the high density of the military camps as early as 1914, the Pays d'Othe served as a place to lodge infantry troops being transported to the front. This presence is evidenced by the large number of postcards produced at the time by civilian/professional photographers (Fig. 5.5). Hundreds of these postcards, from public and private collections, were examined in order to establish concentration areas in the Pays d'Othe and the presence of soldiers hosted in some villages.

Second, a 1948 airborne photographic mission was used. There are about 235 stereo aerial photographs, each covering about 12 km^2 (IGN 2020). This survey offers a complete overview at a scale of 1:25,000 of the Pays d'Othe with a good spatial resolution (±1 m). It was therefore possible to look for the presence of camps in an area of about 700 km^2. It is relatively easy to distinguish and to map trench

Fig. 5.5 Examples of daily life in some Pays d'Othe villages from WWI postcards. (**a**) Civilians, NCO (Cavalry?), and soldiers dressed in work clothes in front of a bicycle shop in Bouilly, circa 1914. (**b**) Civilians and infantry soldiers in a street in Palis, winter 1916/1917. (**c**) Civilians and Armée d'Afrique soldiers (probably Algerian *Tirailleurs*) in a street in Sormery, circa 1917–1919. (**d**) Civilians and infantry soldiers in front of a restaurant-grocery shop in Chamoy, circa 1916–1919

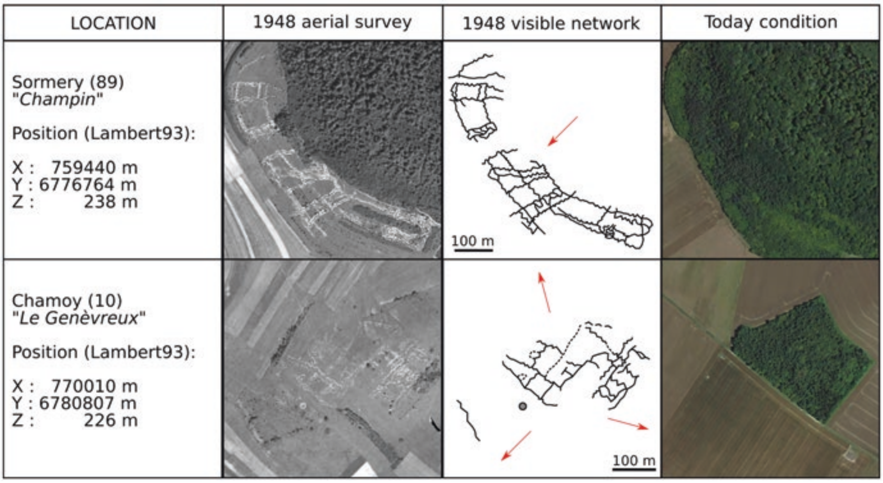

Fig. 5.6 Examples of training sites identified on the 1948 1:25,000 scale aerial photographs showing location, view in 1948, trench network visible in 1948, and the condition today for two sites. Slope is indicated by red arrows pointing downhill. North is at the top of the maps and images. (Aerial photos: IGN 2020)

networks using aerial photo interpretation techniques. Trenches are visible due to white-colored banks that contrast with gray-colored vegetation (Fig. 5.6). They are mostly located on grasslands at the edge of forest plots. In 1948, the remains were still visible, 30 years after the end of their use. Today, they are mostly invisible, either leveled under tillage or hidden within forest cover.

5.4 Results

5.4.1 Trench Site Inventory

The military settlement in the Pays d'Othe has been mapped, and it is thus possible to study both the degree of preservation of its remains and its evolution over time. Firstly, the presence of soldiers has been identified in at least 26 of the villages using the postcard database (Fig. 5.7). These villages served as quarters for soldiers and are mainly located along the roads and railways linking Troyes with the cities of Sens and Auxerre. Secondly, 17 sites can be clearly seen on the 1948 aerial photography; two are not clearly visible or are uncertain (Saint-Phal and Souligny, cf. Fig. 5.7). These training areas are very close to the villages (1 or 2 km distant at most) on the edge of the clayey plateau that constitutes the Pays d'Othe. They vary in size from one (Saint-Benoît-Sur-Vanne) to several dozen hectares (Mesnil-Saint-Loup), with different morphologies, and seem adapted to different exercises and therefore to different types of fighting units (Fig. 5.8). According to the trench geometry, they seem to correspond to the complex defense systems that were developed as of the end of 1915 (Taborelli et al. 2017).

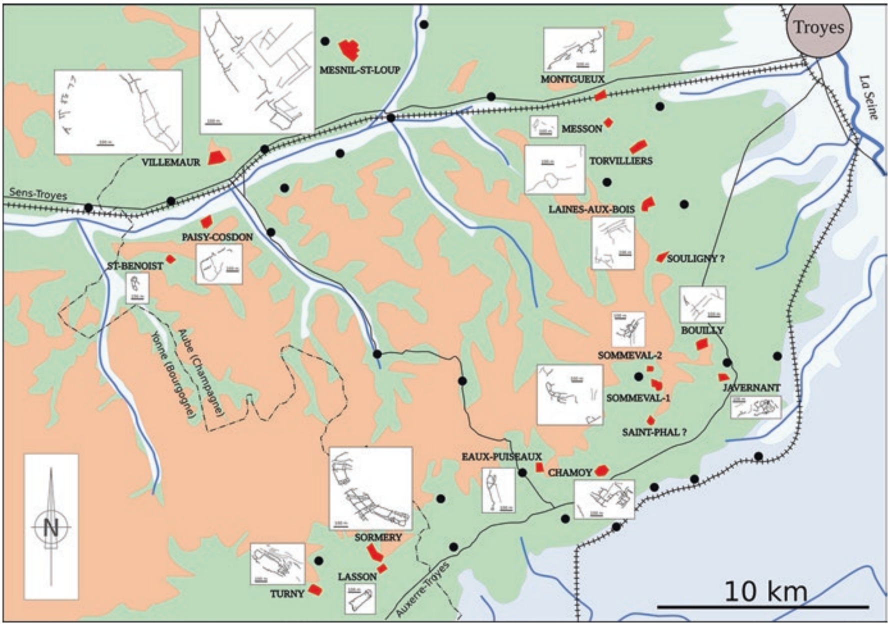

Fig. 5.7 Location of training sites (red polygons) and cantonment villages (black dots) in the Pays d'Othe. The detailed trench network visible in 1948 is shown for each site. The high relief Pays d'Othe is shown in pale orange and corresponds to the clayey plateau. The chalky hillslopes below the plateau are shown in pale green area. (Geological map: modified from IGN 2020)

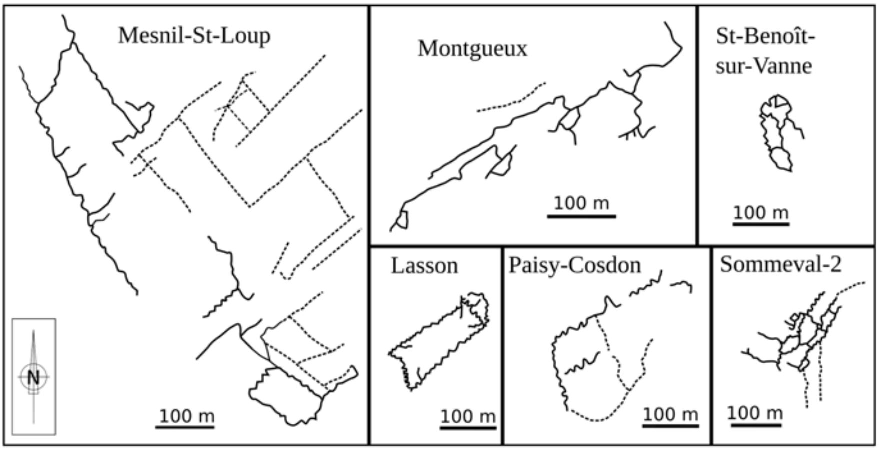

Fig. 5.8 Examples of training trench sites in the studied area. Trench networks seem to be related to different types of training, e.g., infantry or trench artillery, as illustrated by large, linear, and parallel networks (e.g., the Mesnil-Saint-Loup site) or smaller bastions with a dense and complex network (e.g., the Lasson site)

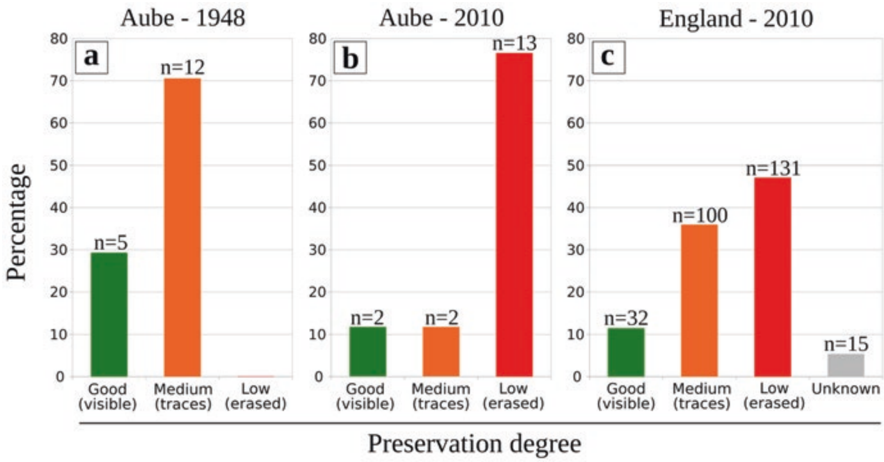

Fig. 5.9 (**a** and **b**) Preservation evolution between 1948 and 2010 in Aube. (**c**) The situation in England in 2010

Using these results, we have compared the degree of preservation and its evolution between 1948 and today (Fig. 5.9). In 1948, only five among the 17 identified sites are clearly visible in the Pays d'Othe landscape: the embankments and trenches can be distinguished. Twelve were already partially reworked by plowing or backfilling. More than a half century later (in the 2010s), only four sites are barely visible, whereas 13 (i.e., 80%) are completely leveled by plowing. Today only two of these sites are preserved, beneath forest cover, with the trench and embankment relief still visible. In comparison, half of the WWI English training trench sites ($n = 278$) are well preserved up to now. Their location in military areas could explain this difference due to the absence of post-WWI tillage.

5.4.2 Archaeological Evidence

Although today no training site is visible in its entirety, it is nevertheless possible to describe how they were implanted in the rural landscape of the Pays d'Othe, thanks to the only known photograph of a training area (Fig. 5.10a). It was taken in 1917 by a civilian photographer and represents a view of the Sommeval 2 site (cf. Fig. 5.7 for location), located a few hundred meters from the village (some houses are in the foreground). The training site is located at the midpoint of the slope between clayey plateaus covered by forests and the hillslope bottoms containing colluvial deposits (Fig. 5.10b). This intermediate topographic position is observed for almost all of those recorded in the Pays d'Othe. This typical position is explained by the calcareous substratum of low quality for agriculture that offers plots which could easily be requisitioned from the farmers by the military command. This substrate is the same

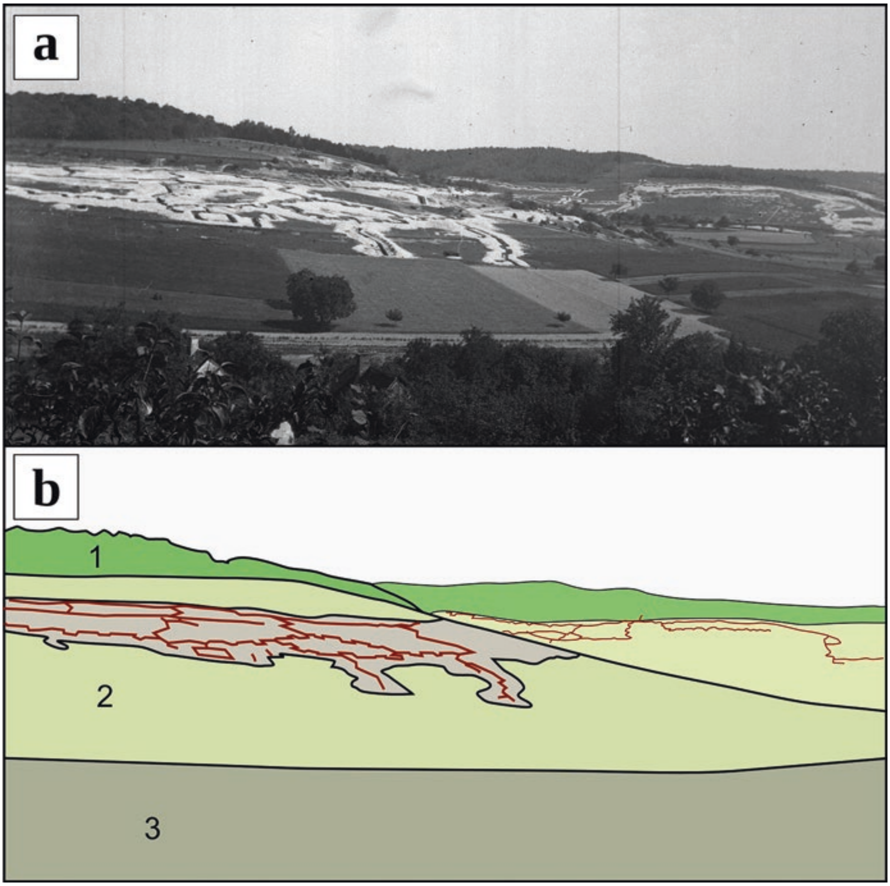

Fig. 5.10 (**a**) Photograph of the Sommeval 2 training terrain in 1917 (used with permission from A Hourseau). (**b**) Drawing showing the forest plateau over residual clays (1), ploughed chalky hillslopes (2), and Sommeval town developed on the lower slopes (3). Note the intensity of earth removal (chalk) within the landscape

as that of the Champagne front line, from Reims to Argonne. Thus, the soldiers trained in the same geological conditions as those of the trenches to which they were to be sent.

One century later, there is almost nothing left of these sites in terms of geoarchaeological and landscape heritage. However, many material and memorial traces have been found through other archaeological sources. Firstly, numerous letters and postcards describe the material conditions of villagers cohabiting with soldiers. In particular, civilians describe the military activity (noise from shooting and explosions) in the surrounding fields. This could explain why civilians thought they could hear the artillery of the front, despite being located hundreds of kilometers away from the frontline battlefields.

Secondly, many traces, such as frescoes and graffiti, can also still be found on walls of public and private buildings (Fig. 5.11), indicating the ephemeral passage

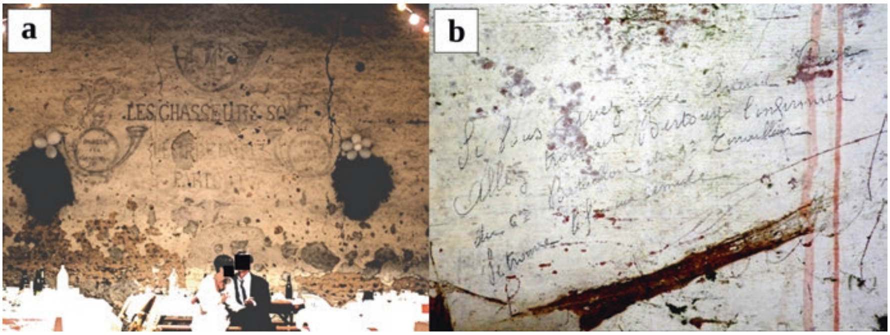

Fig. 5.11 Examples of inscriptions still visible in the Pays d'Othe. (**a**) On a wall in a barn in Aix-en-Othe, a fresco extols the merits of the 16th Battalion of Chasseurs, their motto being "Chasseurs are first everywhere." (**b**) Inscription in the abandoned public washhouse in Villeneuve-au-Chemin, where dozens of graffiti are more or less legible; here is written: "If you've got the clap [gonorrhoea], go see the [soldier] *Bertouy* nurse from the 6th Battalion of the 9th Tirailleurs [Algerian Battalion], he will have the cure"

of soldiers through the villages. Whereas some are the usual inscriptions referring to fighting units (e.g., Desfossés et al., 2008), some evoke the soldiers' daily life and the interactions with the civilian population.

5.5 Conclusions

This survey of a small area to the rear of the front line revealed the presence of about 20 previously unidentified training trench sites, representing more than all the sites previously known in France. They are indicative of the necessity to create realistic training structures for new units before sending them to the front. In France, tens or even hundreds of training areas of this type were built around garrison centers and around the rear area cantonments after the first months of the war. The temporary nature of these training sites and their improvised status has left almost no traces in the military literature. Obsolete at the end of the conflict, the trenches were quickly infilled or leveled although they were still visible in the landscape of the 1940s. Today, only diffuse traces of trenches can be found in forest areas or during prospecting and archaeological operations. This study points out the primary need to create an inventory of training trench sites in France.

Finally, this study demonstrates that a local analysis reveals fairly quickly the intensity of military occupation, from both archaeological and sociological points of view. For many years, hundreds and probably thousands of soldiers were stationed in the villages emptied of their men of fighting age. The construction of the training trenches affected the entire country, yet they totally disappeared after the war. The geohistorical and archaeological documentation of the military structures of the rear area also documents the trench war perception of the young recruits and the civilian population.

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References

Ballarin C, Casagrande F, Laborie Y (2005) Camp militaire de "Pombonne, La Brunetière-Sud" Bergerac (Dordogne). Rapport final de fouille archéologique, INRAP Grand Sud-Ouest, Pessac

Brown M (2017) First World War fieldworks in England. Discovery, Innovation and Science in the Historic Environment, Historic England Research Report Series 61

Cocroft W (2013) Trenches of the Home Front. English Heritage Conservation Bulletin 71:4–5

Cocroft W, Schofield J, Appleby C (2015) The Home Front in Britain 1914-1918. CBA Practical Handbook 22. Council for British Archaeology, Oxford

Desfossés Y, Jacques A, Prilaux G (2008) L'Archéologie de la Grande Guerre. Éditions Ouest-France/INRAP, Rennes

Dry L, Seurat H (2018) L'Aube, base arrière d'une guerre mondiale. In: Cazauban É, Pottier O (eds) Troyes, l'Aube, la Guerre (1914-1922), Les Éditions de la Maison du Boulanger, Troyes, p 91–97

Framery D (2016) Quelques camps d'entraînement dans la campagne auboise. In: Humbert J-L, Terrillon J-C (eds) L'Aube dans la Grande Guerre, 1914-1918. Société Académique de l'Aube, Troyes, p 23–30

Gauthier A (2013) Les Sablonnières (Chambon-sur-Cisse, Loir-et-Cher), un site historique méconnu en forêt de Blois. Bulletin du Groupe d'études locales d'Onzain et ses environs Issue 75

Historic England (2020) First World War fieldworks gazetteer. https://historicengland.org.uk/content/docs/research/fww-fieldworks-gazetteer-pdf. Accessed 7 June 2020

Historic Environment Scotland (2020) First World War site inventory. https://canmore.org.uk/site/search/. Accessed 7 June 2020

Hunt F (1918) Blown in by the draft: camp yarns collected at one of the Great National Army cantonments by an amateur war correspondent. Doubleday, Page and Company, Garden City, NY

Institut Géographique National (IGN) (2020) French airborne photographic database. https://remonterletemps.ign.fr/. Accessed 7 June 2020

Petit C, Dandurand G, Deborde G et al. (2018) L'environnement des sociétés néolithiques et protohistoriques autour de Lavau. In: Dohrmann N, Riquier V (eds) Archéologie dans L'Aube, des premiers paysans au prince de Lavau. Snoeck, Ghent, p 40–51

Saunders B (2017) Barry Buddon First World War training trenches. Archaeological evaluation: data structure report, Wessex Archaeology, Salisbury

Smith N (2010) Old Oswestry, Selattyn and Gobowen, Shropshire: analysis of earthworks. English Heritage Archaeological Survey, Research Department Report Series 82

Spickelmier R (1987) Training of the American soldier during World War I and World War II. Army Command and General Staff College, Fort Leavenworth, KS

Taborelli P, Devos A, Laratte S et al. (2017) Typologie et organisation spatiale des «polémoformes» de la Grande Guerre révélées par l'outil Lidar et les Plans Directeurs. Application à la Champagne et à l'Argonne. Revue de Géographie Historique 10. http://rgh.univ-lorraine.fr/articles/view/88/Typologie_et_organisation_spatiale_des_polemo_formes_de_la_Grande_Guerre_revelees_par_l_outil_LiDAR_et_les_Plans_directeurs_Application_a_la_Champagne_et_a_l_Argonne. Accessed 14 Dec 2019

Chapter 6
A Digital and Archaeological Perspective of the World War One Veneto-Trentino Front Line Trench Systems in Northern Italy

Luigi Magnini, Giulia Rovera, Armando De Guio, and Giovanni Azzalin

Contents

Abstract Since the end of the First World War, material remains of the conflict have undergone progressive transformations. In the last decades, conflict archaeology has contributed to the investigation of these remains using a scientific approach.

We present the results of a comprehensive study of two Austro-Hungarian trench systems along the northern Italian Front, one located in the area of Millegrobbe, Trento, and the other, part of the Winterstellung in Rotzo, Vicenza. Our aim is to determine the conservation rate of the trench portions still present in the test sites and to investigate the natural and anthropic contributions in the processes of obliteration of the WWI infra(structures) and the restoration of the pre-war landscape.

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Methodologically, the study was carried out with different degrees of impact: noninvasive, remote sensing techniques (applied to both case studies) and (semi) automatic recognition of the visible war-related traces (only in Millegrobbe); field surveys to verify the reliability of the remotely sensed investigations and the preservation of the structures (both case studies); and microinvasive excavations (only for the Winterstellung) to identify the pre- sin- and postdepositional processes of natural and man-made origin that caused the heterogenous degree of preservation of the investigated structures.

Keywords First World War · Remote sensing · Formation processes · Archaeological survey · Object-based Image Analysis · Trenches

6.1 Introduction

The archaeology of the First World War (WWI) represents one of the most active and studied specialized domains (spatially, temporally, and functionally) within conflict archaeology. This interest has translated into numerous and different methodological approaches to the study of the First World War, in particular, those related to material culture (e.g., Saunders 2003, 2012; Schofield 2005; Saunders and Cornish 2014), archaeological excavations and surveys (e.g., Fraser and Brown 2007; De Guio and Betto 2008; Robertshaw and Kenyon 2008; Desfossés et al. 2009), physical anthropology (e.g., Hunter and Cox 2005; Le Bailly et al. 2012; Gaudio et al. 2013), geophysical prospecting (e.g., Doyle 1998; Masters and Stichelbaut 2009), and remote sensing (e.g., Stal et al. 2010; Gheyle et al. 2016; Mlekuž et al. 2016; Stichelbaut et al. 2016; Magnini et al. 2017a).

The use of archaeological methods and techniques is significantly changing the perspective from which WWI is perceived, not only as a chronicle of major events, global implications, or military tactics but also as a historic moment made up of countless small stories related to each social actor involved in the conflict. The landscape itself has become a central character, as it retains traces of the natural and man-made changes caused by the conflict and allows us to reconstruct in a diachronic perspective what preceded, what happened during, and what followed the war.

During the four years of conflict, both tactical and technical innovations strongly contributed to the formation of a new way of waging war which was continued during the Second World War. The wide range of these innovations, such as aerial fighting and trench warfare, had a considerable impact on the landscape. It is possible to follow this evolution using an archaeological approach, not only from the perspective of armaments but also from their impact on the landscape. In fact, the impact of the conflict has left deep scars still in "the healing phase" and created complex palimpsests of war-related traces still partially in incipient formation in the archaeological record. The study of the formation processes on the archaeological record of WWI represents a unique opportunity for studying, not only the natural and anthropic processes of modification/obliteration of contexts but also the mental processes underlying these changes.

The aim of this research is to study the entrenched system along the Alpine front line between the Kingdom of Italy and the Austro-Hungarian Empire using a multi-scale approach, and test a set of innovative methods derived from the most recent archaeological literature (Gheyle et al. 2018; de Matos-Machado et al. 2019; Van den Berghe et al. 2019). Specifically, our investigation focused on two areas: the first one is part of the entrenched system in the Millegrobbe area (Trento), involved in the war events in the first days of the conflict, and the second is part of the *Winterstellung* (Winter Position) defensive line, between the "Gibraltar" stronghold and the protohistoric site of the Bostel, in the municipality of Rotzo (Vicenza) (Fig. 6.1).

The study was carried out by adopting a three-step protocol to minimize time consumption, archaeological remains collection (no-collection policy), and warscape destruction (minimum tillage). Each of the three steps corresponds to an increased investigation scale and an increasingly invasive impact on the ground: whereas the analysis of small-scale remote sensing data causes no impact on the WWI remains, surface surveys and topographic mapping on a medium scale create a minimal impact. Finally, large-scale excavations or half-sections have a medium impact on the archaeological record.

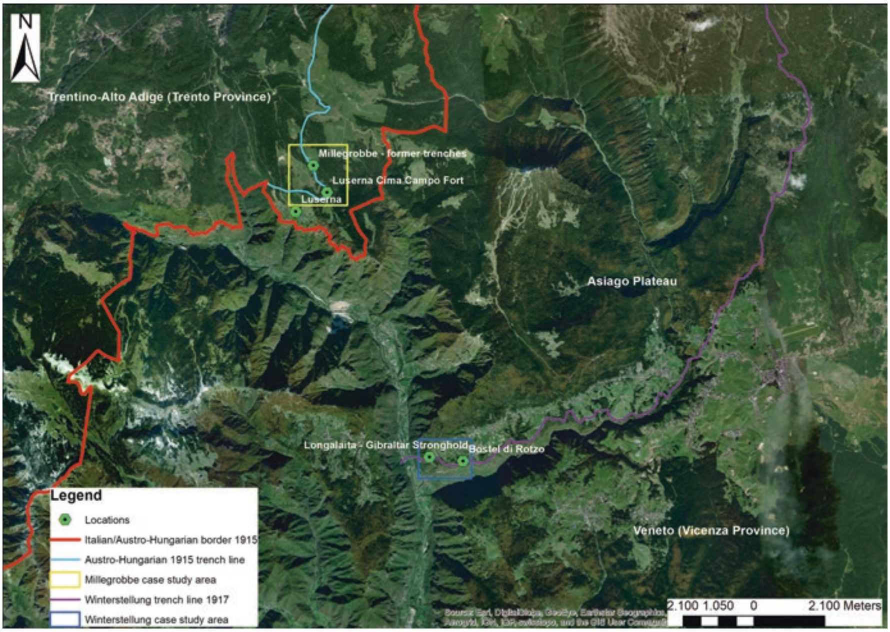

Fig. 6.1 Location of the study areas in Northern Italy

6.2 Archaeological and Historical Context

The front line between the Kingdom of Italy and the Austro-Hungarian Empire was mainly located in Alpine territory (at least from 1915 to 1917) (Fig. 6.1) and because of this, the war structures had to be adapted to the conformation of the terrain (Eliseo 2013). The Italian-Austro Hungarian border separates the Trentino-Alto Adige region from the Veneto region (Fig. 6.1), and here, both national armies had permanent fortresses in the valleys, on the plateaus, and in the mountain passes. In 1915, military operations focused mainly on overcoming these fortifications, and field attacks were almost completely excluded from the strategies of both armies.

The conflict between Italy and the Austro-Hungarian Empire officially began on 25th May 1915 in Luserna, when the Austro-Hungarian Luserna Cima Campo fort, known among the Italian troops as "the Almighty," and the nearby entrenched lines of Millegrobbe were attacked by Italian artillery with no less than 5000 shells fired in just three days. After initially collapsing, the Austro-Hungarian Army reorganized, and in the following months obtained more powerful artillery, e.g., the famous Škoda 305 mm and 420 mm siege howitzers, and managed to conquer first Verena fort, then Campolongo fort, and in a short time, most of the other Italian positions (Liber et al. 1988). Despite numerous battles, from that moment on, the positions of the two armies remained almost unchanged until the arrival of the first snow.

By 1916, the strategy had changed, and the biggest battle ever fought in the Italian mountains was launched by Austria's Chief of Staff, Conrad von Hötzendorf. *Operation Frühjahrsoffensive* (Spring Offensive), also called the *Strafexpedition* (Punitive Expedition), was a massive offensive against the Italian forces that lasted from 15 May 1916 to the end of June that same year. During the Strafexpedition, the Austro-Hungarian Army threatened to overrun the Venetian plain to the south (Thompson 2008). The operation took place on the plateaus and in the valleys of the Veneto and Trentino regions (Fig. 6.1). The first phase of the offensive was fast and effective, pushing the Italians to a defensive position on the southern edge of the Asiago Plateau (Fig. 6.1). There were direct battles between the two sides throughout the plateau, but in mid-June, the Italian Army managed to overwhelm the repeated Austro-Hungarian attacks and started their counteroffensive, slowly regaining ground (Acerbi 1992). The Austro-Hungarian forces retreated from their advanced positions and deployed on the Winterstellung, the defensive line they had started building during the initial stages of their advance. The Austro-Hungarian Army maintained this position until the end of the war in November 1918 (Offelli 2006). The Winterstellung was an important Austro-Hungarian defensive line built between 1916 and 1917. It is a defensive trench system that cuts across the Asiago Plateau, defining the new border between Italy and the territory conquered by the Austro-Hungarian Empire in 1916 (Fig. 6.1). It forms an uninterrupted line connecting fortified strongholds and other defensive systems to each other.

The Winterstellung represents an exceptional work that compensated for the complexity of mountain warfare. It is one of the most imposing defensive systems on the northern Italian Front. It holds a dominant position on mountain slopes and plateaus which facilitated observation of the enemy and was at the same time easily defensible (Vergara et al. 2019; Vergara and Bondesan 2020; Magnini and Bettineschi 2021). In addition, it was equipped with structures including trench lines, underground tunnels, cave shelters, emplacements, barracks, and the associated logistical support infrastructure (Balbi 2015). The trenches were about 1.5 m deep and were dug in either soil or the bedrock. They had ramparts about 50 cm high that consisted of soil sacks or drystone walls; the front trenches were protected by barbed wire and other obstacles. Because of its defensive strength and strategic position, the Italian troops never managed to break through the Winterstellung.

Trenches are one of the symbolic elements of WWI and are intrinsically linked to another war innovation of that period, intense shelling. The construction of kilometers of trenches and the subsequent shelling have indelibly marked the landscape. During the first months of the war, military commanders ordered the excavation of continuous trench lines for very large areas: for example, 760 km of trenches were built between the English Channel and the Swiss border (Keegan 1998). Often, the excavation of these structures during the initial stages of the war affected an already present and complex palimpsest of archaeological evidence, sometimes with devastating results, as in the case of the Winterstellung, where the trench that runs along the entire southeast side of the protohistoric site of Bostel di Rotzo has removed most of the archaeological structures present along the limits of the town (De Guio and Betto 2011a). In other cases, however, they helped to expose important stratigraphic windows that have been exploited for the study of otherwise undetectable buried contexts (De Guio and Betto 2005). The way the entrenched system looked varied according to the environmental conditions, the morphological features, the tools, and the time available to the troops for construction.

6.3 Applied Methods

The identification and study of both emergent and non-monumental war infrastructures (the so-called everyday life and death structures) and the material culture on the front line were carried out using noninvasive or microinvasive archaeological methods as noted above. Contemporary landscapes are characterized by a complex evolutionary process, whose palimpsestic traces can be extremely difficult to distinguish. Digital remote sensing techniques have intrinsic object/pattern/scenery recognition capabilities and an extremely high predictive and discriminatory potential that can improve the comparability of analytical data, reduce data processing times and avoid errors, and preconceptions that can influence classical archaeological photo interpretation (Halliday 2013). In this respect, machine learning techniques have had a very strong impact in recent years, not only in archaeological applications but in all areas of landscape analysis (Traviglia and Torsello 2017; Davis 2018).

A fundamental aspect of remote sensing recognition of archaeological traces is a solid understanding of the different types of structures and the possible formation processes (natural/anthropic and pre/sin/postdepositional) of the archaeological record (De Guio et al. 2015). Alongside these new remote sensing methodologies, it is important to maintain systematic control of the evidence identified both automatically and through traditional photo interpretation methods, especially in the field of archaeology. Above all, this is necessary because of the incompleteness of the archaeological record and the different formation processes underlying the surface traces (Schiffer 1972). Most of the interpretative issues related to remote sensing concern the equifinality[1] and multifinality[2] of the evidence and the seasonality of the data acquisition (Magnini and Bettineschi 2019). In fact, in many cases, as the seasons vary, the visibility of the traces can change, as does their type (e.g., negative or positive crop/vegetation marks). This aspect derives largely from the different use of the soil, the soil moisture, and the type of vegetation that allows identification of the buried structures (Magnini et al. 2019). For example, traces left by shelling are usually characterized by negative morphological anomalies with positive grass marks and low reflectance (Magnini et al. 2017a). However, in the case of anthropic interventions such as drainage remediations, diametrically opposite effects are induced with the almost total absence of negative morphological anomalies and above all, negative grass marks.

These specific aspects must also be taken into consideration during field surveys to validate the remotely sensed interpretation and to collect information about the location, distribution, and organization of WWI residual evidence (ground truth). Half-section digs, exposed stratigraphic windows, and micro-stratigraphic excavations were also fundamental to study the postdepositional impact of the war-related features after a century of pedogenetic processes (see e.g., Hupy and Shaetzl (2006, 2008) on ‘bombturbation’). Half-section is a peculiar “then/now” excavation technique optimized for subsequent exposition (in terms of ‘public archeology’). This procedure, based on the most recent theoretical-methodological trends, aims to present, not only to specialist users but also to a wider public, the most effectively illustrative models of an archaeological site in its formative and deformative manifestation (depositional and postdepositional processes). The technique consists, simply, in saving and leaving in its present state of abandonment a part of the deposit to return to the public three distinct and spectacular “information surfaces”: (a) the excavated part (with original functional plans), (b) the part not excavated (abandonment), and (c) the connective interface between the two, that is, the stratigraphy (De Guio 2018).

[1] Equifinality accounts for similar morphogenetic outcomes derived from different archaeological entities at a certain point of their formation and transformation processes.

[2] Multifinality refers to all the possible morphogenetic outcomes of single archaeological entity, and is connected with the variability of the environmental contexts and the human-nature interactions which shaped that specific entity over the millennia.

6.4 Millegrobbe Case Study

The test area (Fig. 6.1), called "former trenches," extends from the road that leads to Malga Millegrobbe[3] to the wooded area east of the pastures. This location is characterized by a restored trench section and by the presence of numerous other trench sections that are partly buried, partly covered by trees, and partly visible, as well as by the strong presence of shell craters. Except for this example of selective and "memorialist" conservation, most of the structures have undergone a gradual process of obliteration due to natural causes in marginal areas not yet affected by urbanization, as well as anthropic ones especially in areas of high social and economic development. The different states of conservation of the trenches require a greater effort for mapping using (semi)automatic recognition methods (de Matos-Machado et al. 2019; Dolejš et al. 2020), and their study is even more demanding in the case where different portions of the same trench have very different residual characteristics.

Originally, these structures were long and narrow ditches dug into the ground with variable shapes (depending on the geomorphology, the nationality of the army, and the function), about 2 m deep and just as wide that extend from a few meters to several kilometers in length (Eliseo 2013). At present, however, these characteristics are only partially useful to effectively map this type of structure due to the postdepositional transformations mentioned above. Moreover, the presence in the test area of evidence with a high degree of equifinality/multifinality such as modern roads, paths, and mule tracks, requires an approach focused not only on morphological and formal characteristics but also on relational ones (Magnini and Bettineschi 2019).

6.4.1 Object-Based Image Analysis Classification

In this first study area, Object-Based Image Analysis, a very adaptable digital classification method, was applied to (semi)automatically identify the war-related features. The approach allows the creation of a specific and exportable rule set for each type of archaeological structure using textural, relational, spectral, and morphometric characteristics.

The most difficult part in the creation of a rule set for the trenches is addressing the different outcomes that a single archaeological structure can have. In order to overcome this issue, we adopted a three-step workflow that allowed us to explore the qualitative and quantitative classification potential of the method. First, we created a specific rule set for each different postdepositional outcome of the trench based on the conservation state visible on the images. Second, we carried out a field survey to verify the correspondence of each class with distinct formation processes

[3] 'Malga' in Italian is a complex of traditional alpine structures where animals and shepherds live during the summer months.

and the related state of conservation. And third, we merged the different classes into a single class to quantify the overall impact of the trench on the landscape.

Because of the dense woodland in the study area, the high resolution (1 × 1m) LIDAR-derived Digital Terrain Model (DTM) of the Autonomous Province of Trento was chosen for the landscape analysis. Four different DTM visualization techniques – the positive openness (Fig. 6.2a), the negative openness (Fig. 6.2b), the local relief model (LRM; Fig. 6.2c), and the sky-view factor (SVF; Fig. 6.2d) – have been applied to enhance and highlight the concave micromorphology, making it easier to identify specific archaeological objects such as the trenches (Kokalj and Hesse 2017; Burigana and Magnini 2018).

One of the most informative visualization techniques for delineating both concave and convex features from a digital model is "openness" (Doneus 2013). Openness is obtained using the mean of the zenith (positive openness) or the nadir (negative openness) angles along at least eight directions from each point of the model. The area affected by the algorithm calculation is defined by the user through the definition of a maximum search radius (Yokoyama et al. 2002).

The LRM increases the visibility of surface micromorphologies regardless of the angle of illumination by removing small-scale landscape morphologies. This model assumes that archaeological structures are generally characterized by a slight morphological discontinuity of a positive or negative nature (depending on the type of

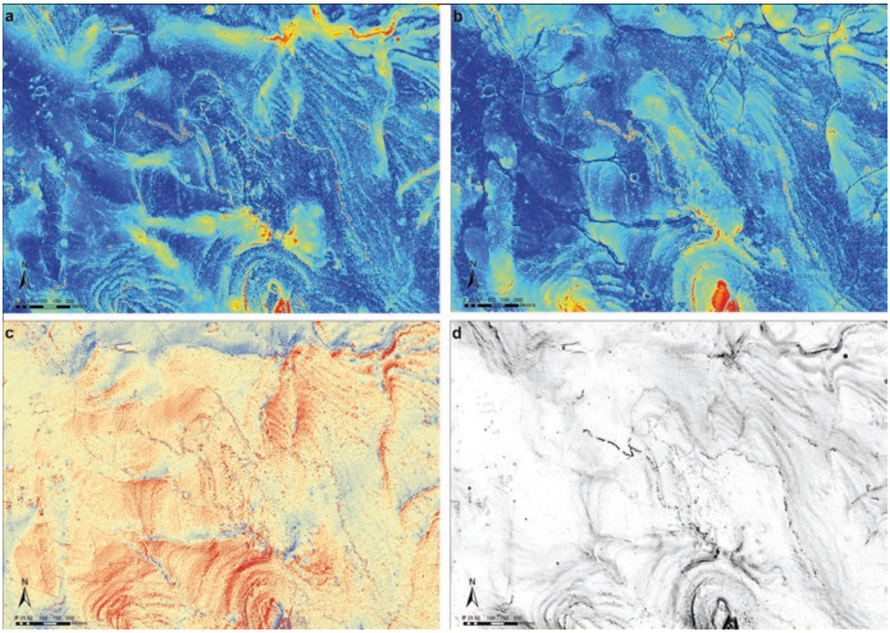

Fig. 6.2 Millegrobbe former trenches area (1.16 × 1.65 km). (**a**) Positive openness visualization of DTM with 1 m resolution. (**b**) Negative openness visualization of DTM with 1 m resolution. (**c**) LRM visualization of DTM with 1 m resolution. (**d**) SVF visualization of DTM with 1 m resolution. (DTM: Creative Commons License – Assignment 2.5 Italy) (http://creativecommons.org/licenses/by/2.5/it/legalcode))

evidence) with respect to the surrounding terrain. With the application of LRM, it is possible to overcome the problem of landscape morphology by extracting the small elevations on a local scale typical of the archaeological landscape (Hesse 2010).

Another very useful DEM enhancing technique is the Sky-view Factor. This method consists of quantifying the part of the sky that is visible at each point of the model. The computation is based on the vertical elevation angle of the horizon, the number of search directions (from 8 to 32 directions depending on the maximum search radius), and the maximum search radius (a large radius exposes large relief features, a small radius exposes more detailed features) (Zaksek et al. 2011).

The four visualization techniques of the DTM were then analyzed using an object-based approach which, following the first phase of segmentation, allowed objects of interest to be classified with a user-defined rule set. For the first phase, we applied a multi-resolution segmentation that, through a bottom-up approach, allowed a more accurate definition of the image-object with respect to geo-objects (or archaeo-objects in our case) by setting a scale parameter consistent with the size of the structures to be classified (Lang 2008; Magnini and Bettineschi 2019). Without going into the technical aspects of the rule set, the morphological characteristics of the trenches, already well highlighted by the four images, were used to classify the three different recognizable states of conservation of the trench (Fig. 6.3).

The first class (Fig. 6.3, yellow), located in the western part of the image in an area of open fields, has all the typical characteristics of the WWI trenches, and

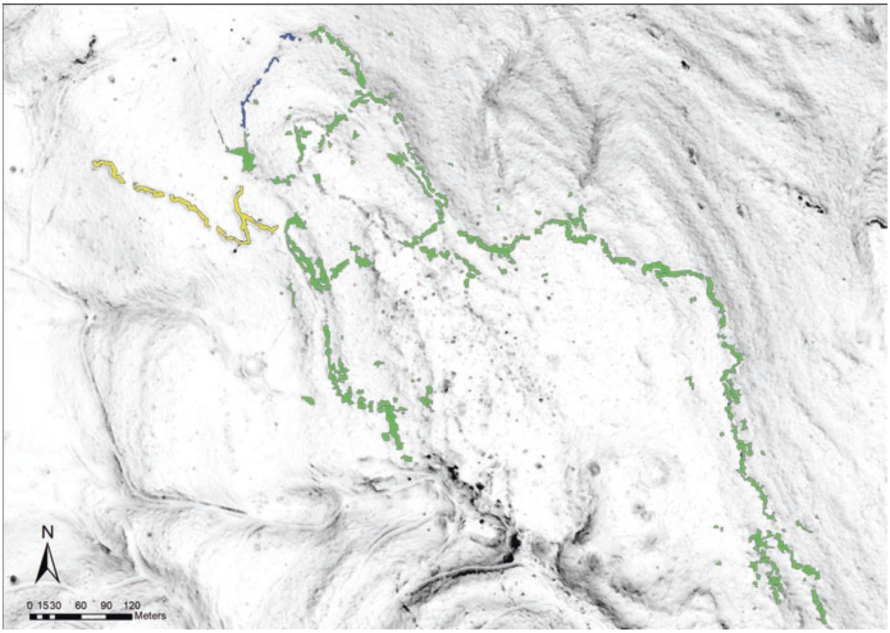

Fig. 6.3 Millegrobbe former trenches area. SVF visualization with object-based image analysis classification of the three different postdepositional outcomes of the trench. Yellow indicates the first class interpreted as restored trench; blue, the second class, interpreted as obliterated trench; and green, the third class, interpreted as abandoned trench

therefore, classification was quite easy. Less recognizable are the traces in the northern part of the area where the trench is barely perceptible in the images. Moving eastwards, where the vegetation begins, the visibility of the trench increases but is partial and fragmented. A specific rule set was created for each of these sections from some common features such as small dimensions and more or less slight depression of the ground. The second class (Fig. 6.3, blue) is limited to a short section in the northwest of the investigation area, connecting the first class with the third class which is covered by trees. Its regularity allowed us to make the best use of the length/width ratio to classify the traces visible on the DTM. The third class (Fig. 6.3, green), on the other hand, is characterized by a high degree of fragmentation that limits the continuity characteristics of the trench – there are more than 20 fragments in this class. Originally, it must have been a long, continuous structure that ran for several kilometers. Today, it appears to be subdivided into several segments that are generally close to each other. Although separated, the closeness of the segments to each other made it possible to recognize the trend and the direction. The rule set took this noncontinuous configuration into account, using the proximity relationship between the individual sections of the structure for classification.

6.4.2 Field Survey and Evaluation of Results

Following the (semi)automatic classification of the trenches, the test area was investigated through a systematic field survey to assess the reliability of the classification, as well as to discern the causes of the different postdepositional outcomes of the trenches. We also used the ground survey, which took place on 28 October 2018, to cross-validate the results and systematically monitored a large part of the trench route. Starting from the western portion of the trench, classified as first class and shown in yellow on Fig. 6.3, the survey followed the path of the trench first northwards and then, after turning east below the vegetation, checked the state of conservation of the structure in the forest. The field survey confirmed the presence of three different post-depositional outcomes for the same trench. The first class (Fig. 6.4a2, yellow) is the restored part of the trench (Fig. 6.4a1). It is very limited (200 m) and is located near the tourist routes.[4] It is the only portion that is clearly visible even on digital aerial photographs (De Guio et al. 2015) and preserves the morphological and dimensional characteristics typical of trenches that are also recognizable on the digital model.

The second class (Fig. 6.4b2, blue) identifies part of the trench that is almost completely obliterated (Fig. 6.4b1). This class is spatially limited (150 m) to the open field area and is in direct continuity with the restored portion. This segment has probably been subjected to voluntary anthropic obliteration, and only a small morphological difference in height that is barely large enough to be seen both on the

[4] There is a small road used during the summer by tourists for walking and cycling. Local people who have some economic activities in the area, such as pastures or timber exploitation, use this road, too. During the winter, it is part of a cross-country ski and dog sledge route.

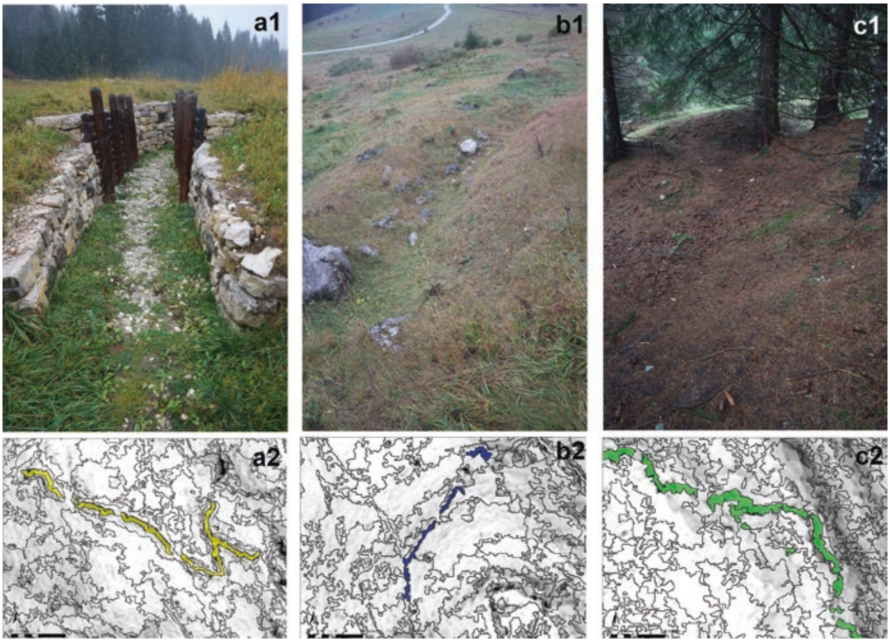

Fig. 6.4 Millegrobbe, former trenches area: comparison between the results of the semi-automatic classification (**a2**, **b2**, and **c2**) (300 × 210 m) and the ground-truth survey (**a1**, **b1**, and **c1**) of the trench. Each ground photo shows the actual state of preservation of each of the three classes. The ground images were taken in the areas shown on the corresponding classified image below. Yellow indicates the first class interpreted as restored trench; blue, the second class interpreted as obliterated trench; and green, the third class interpreted as abandoned trench

ground and the DTM is preserved. It is, therefore, possible to hypothesize, but not verify, that the first class should also have been in this condition before the restoration work.

The third class (Fig. 6.4c2, green) is entirely covered by not excessively dense vegetation (Fig. 6.4c1). It is the largest class and runs in two directions for a length of several kilometers. The first branch starts from the easternmost vertex of the restored trench and trends in a N/NW-S/SE direction. The second branch, trending NW-SE, begins at the northernmost point of the obliterated trench and extends along the entire eastern edge of the investigated area, taking advantage of the raised position. Both branches have the same morphological characteristics; they are only partially obliterated by natural processes and only the parts of the trench not affected by the presence of vegetation remain visible both on the ground and on the DTM. The interruptions are caused by the collapse of the walls of the trench and by the growth of vegetation on these collapses. In general, the trench parts of the third class have a shorter average length than the ones in the other two classes and are rather variable in-depth, ranging from 1.2 to 1.5 m.

Even in very diversified conditions, the reconnaissance effectiveness of LIDAR data in forest-covered areas, the specific visualization techniques to increase the visibility of morphological evidence, and the object-oriented approach have allowed rapid, effective mapping in this study area. This is in accordance with the diachronic semantic models proposed by the authors, minimizing bias and subjective interpretation errors.

6.5 The Winterstellung Case Study

The targeted analysis of this warscape was carried out in a limited area in the south-western part of the Asiago Plateau, specifically, in the municipality of Rotzo (Fig. 6.1, blue rectangle). This small village is located on the northern side of the Assa Valley, and, as a result of the Strafexpedition, was occupied by the Austro-Hungarian Army. The Italian forces were on the southern side of the valley. The study area was affected by events related to the Strafexpedition and thus, involved a pervasive anthropic impact in the mountainous landscape resulting from the establishment of a series of military infrastructures, the most important of which is the Winterstellung line (Stenghele 2010).

After years of conflict, the landscape changed considerably, but the scars of war were deeply impressed throughout this Alpine area. Local communities on the Asiago plateau, starting from the end of the war, began to deconstruct the mountains from the war system and some trench lines, emplacements, and shell craters were covered up to obliterate the signs left behind by the war (De Guio and Betto 2011b).

6.5.1 Remote Sensing and Cartographic Analysis

Much of the land is covered by the Winterstellung, which extends from Bostel, a protohistoric village to the Gibraltar stronghold (the western limit of the municipality of Rotzo; see Fig. 6.1), is thickly wooded. Unfortunately, a LIDAR-derived, high-resolution DTM, which would allow the ground to be "seen" through the trees, was not available and our interest, therefore, shifted to other types of data, such as time series digital aerial images and historical maps. It was only possible to carry out a partial analysis of the structures on aerial photography, so targeted field surveys including GPS mapping, with the double function of mapping the areas covered by vegetation and verifying the traces identified by remote sensing, were relied upon. GIS vectorizations of historical maps were used for cross-validation of the reliability of the image analysis and the GPS survey. Four military maps were used, three of which were British (updated on 24/06/1918, 22/08/1918, and 28/08/1918) and one, Austro-Hungarian (revised on 06/06/1918). The most recent one, the British map dated 28/08/1918 at a scale of 1:10,000, marked the course of the Winterstellung as it was known by the Italian and British Armies (Bondesan and Scroccaro 2017).

Table 6.1 The digital aerial images (Regione del Veneto – L.R. n. 28/76 Formazione della Carta Tecnica Regionale) used in the Winterstellung case study

Source	Year	Type of imagery	Resolution	Dimension in pixels
Reven Montagna Veneta	1982	Orthophoto	1.20 × 1.20 m	6078 × 6248
Reven Montagna Veneta	1991	Orthophoto	1 × 1 m	6223 × 5887
Reven Vicenza	2001	Orthophoto	1 × 1 m	6060 × 5769
Reven Asiago	2010	Orthophoto	0.17 × 0.17 m	6325 × 10742

The systematic analysis of time series digital aerial imagery captured between 1982 and 2010 (Table 6.1), highlighted some possible traces related to the Austro-Hungarian defense system. Analysis of the study area along the southern edge of the Bostel plateau identified part of the trench that unsettled the protohistoric stratigraphy (De Guio and Betto 2011a; Magnini et al. 2017b). On one hand, continuity with a structure previously excavated confirmed the interpretation and, on the other, served as a certain starting point for analysis of additional war-related features. On the west, there is another large area free of vegetation where there are numerous traces related to linear, meandering structures that follow the contours of the land and the limit of forest vegetation. Both the 1982 and 1991 (Fig. 6.5a) imagery confirm the presence of traces related to the passage of the trench for a total length of almost 400 m (Fig. 6.5b, red line); the 2010 imagery (Fig. 6.6a) shows in detail a section of just under 100 m where, thanks to the higher image resolution, it is possible to see the classic pattern of a trench (Fig. 6.6b, red line). A further stretch of the trench partially covered by vegetation, directly continuous with these latter traces, can be seen on the 1991 (Fig. 6.5b, red line) and 2010 (Fig. 6.6b, red line) imagery. In this case, the edge of the forest is interrupted close to a thin strip about 4–5 m wide without vegetation compatible with the morphological characteristics of a trench.

6.5.2 Field Survey and GPS Mapping

The field survey was carried out to identify the remaining traces of the Winterstellung structures and to track their conservation status. Ground truthing was also useful to verify the reliability of the remote sensing analysis. This noninvasive survey was combined with the use of a differential GPS Leica CS10 to acquire an accurate position of the trench line and to mark the positions of the main war features. The ground survey also led to the identification of five observation emplacements and 14 galleries (some with various internal branches) connected to the path of the trench line (Fig. 6.7).

The ground survey began at the site of Bostel di Rotzo (elevation 860 m) and extended to Longalaita, where the Gibraltar stronghold was built (elevation 720 m) (Fig. 6.7). This area is characterized by dense vegetation, soil cover, woods, and cliffs. The GPS equipment provided excellent accuracy in most of the area but was both inaccurate and of restricted use in wooded and rocky areas.

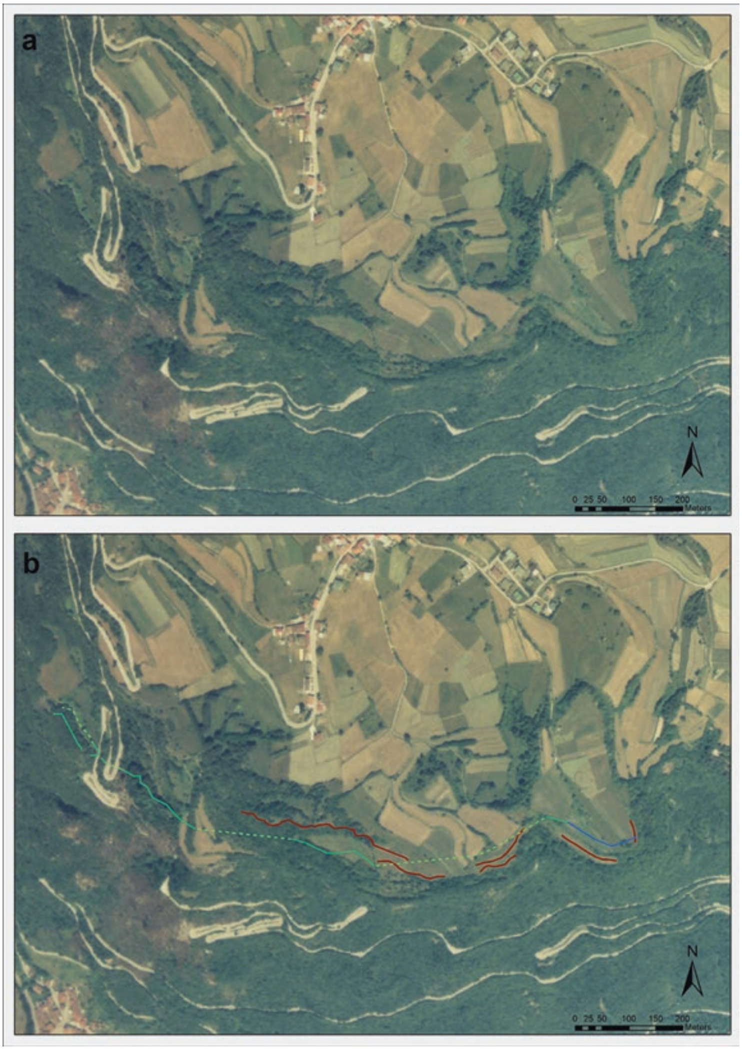

Fig. 6.5 (**a**) Orthophoto Reven flown in 1991. (**b**) The same air photo as (**a**) with trench traces identified by air photo interpretation (red). The dashed green line represents areas where no trench traces were identified during the ground survey and the dark green line, areas where trench traces were still visible during the ground survey. The blue line represents areas where trench traces were only partially visible during the ground survey

The survey revealed a wide range in the conservation status of the entrenched system shown in Fig. 6.7. Three general cases were identified: (1) Only in a few locations was it possible to positively identify the trench on the ground where it was only slightly obliterated and rather well preserved (Fig. 6.7, red line). (2) In other cases, it was still possible to follow the path of the Winterstellung line even though it was partially obliterated but still visible on the ground (Fig. 6.7, yellow line). (3)

Fig. 6.6 (**a**) Orthophoto Reven flown in 2010. (**b**) The same air photo as (**a**) with trench traces identified by air photo interpretation (red). The dashed green line represents areas where no trench traces were identified during the ground survey, and the dark green line, areas where trench traces were still visible during the ground survey

Lastly, in some places evidence of the entrenched line was completely lost and no longer visible on the ground (Fig. 6.7, dashed green line).

The heterogenous degrees of conservation and obliteration of the Winterstellung trenching system were ascribed to the different postdepositional processes that took place in the hundred years since the end of the war. In Case 1, the good state of conservation of the Winterstellung line is due to the particularly inaccessible positions of the trench (Fig. 6.8a). At one location, the trench was dug directly into the bedrock (Fig. 6.8b). In Case 2, the trench is only partially concealed, mostly due to natural factors such as small landslides or rock falls, which are typical of slopes in mountainous terrain (Fig. 6.8c and d). In Case 3, we were unable to identify the trench on the ground because it was completely buried by a combination of human actions and natural events: the processes of total obliteration of parts of the Winterstellung are in large part due to restoration of the pre-war landscape and fields by local communities, mainly for use as pasture.

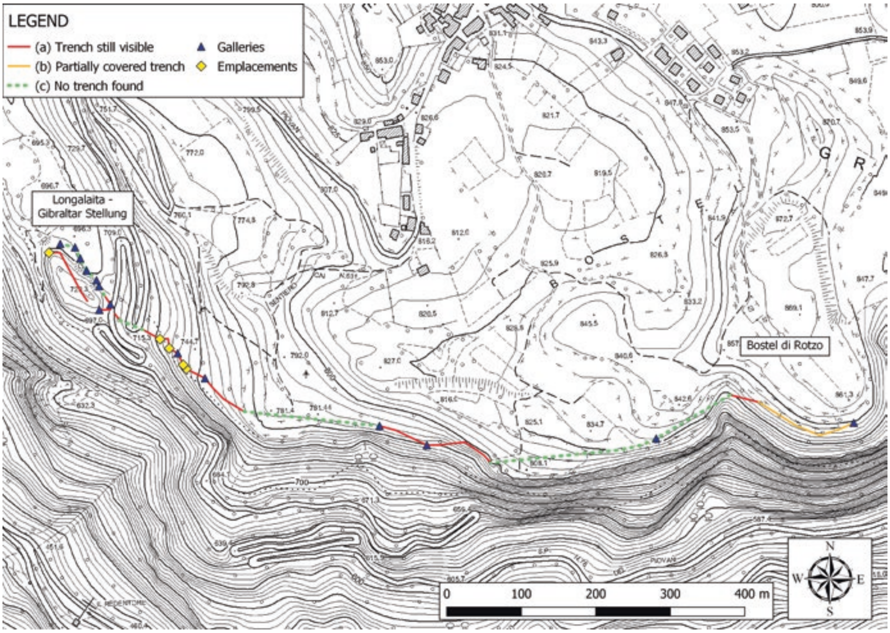

Fig. 6.7 GPS survey of the Winterstellung trench line. (Base map: Regione del Veneto – L.R. n. 28/76 Formazione della Carta Tecnica Regionale)

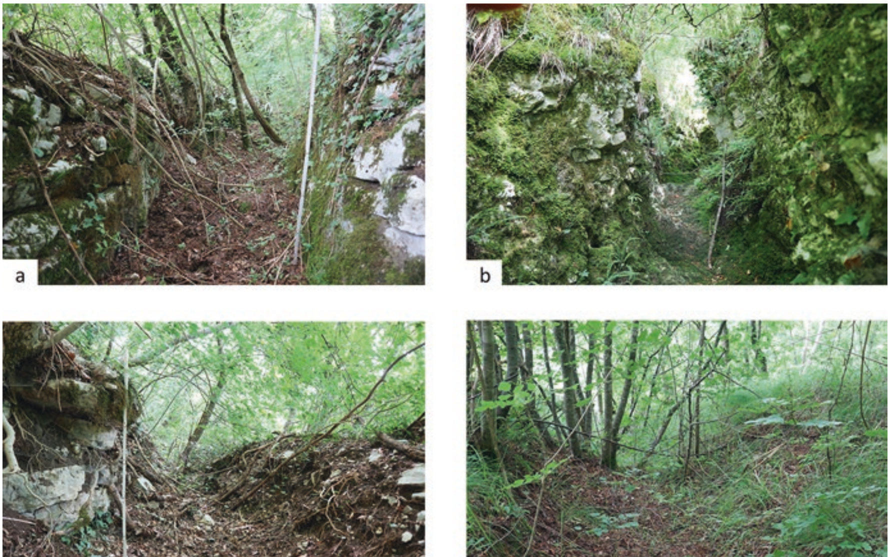

Fig. 6.8 Examples of trench remains along the Winterstellung line photographed during the ground survey. (**a**) Well-preserved trench, only slightly obliterated (case 1). (**b**) Trench dug directly into the bedrock showing a good state of conservation (case 1). (**c** and **d**) Trenches partially filled but still visible on the ground (case 2)

6.5.3 Archaeological Excavations

The analysis of the Winterstellung trench system also involved microinvasive archaeological excavation. This approach was used to examine the different post-abandonment dynamics that took place in two war infrastructures.

In the first instance, the archaeological dig, a stratigraphic excavation of a completely obliterated part of the entrenched line, only concerned a small segment of the trench line inside the Bostel di Rotzo Archaeological Site. This trench part had been identified by previous investigations in the area (De Guio et al. 2011). The excavation was carried out by digging a 4 × 4 m square in which the profile of the trench line and all the stages of filling that led to total obliteration and its leveling to the ground surface were identified (Fig. 6.9a). The results of the excavation were decidedly interesting, and led to the identification of several layers, some of which can be explained as the result of natural events (Fig. 6.9b, layer 909), whereas others appear due to anthropic actions aimed at obliterating the trench line (Fig. 6.9b, layers 902, 904, 905, 906, 907). The deeper layers (such as 906) were interpreted as the first phase of obliteration. They most likely consisted of the stone from the parapets that stood on both sides of the entrenched line. The operation of filling the entrenched line in the Bostel di Rotzo area was carried out with high accuracy, an indication of the will of the local community to get rid of the ground war traces. This was likely dictated by the economic needs of the post-war period that probably saw a return of agricultural activities to the area.

The second excavation adopted the half-section technique on an observation emplacement at the Austro-Hungarian Gibraltar stronghold (Fig. 6.7). This is a small hill overlooking all of the Astico Valley that was adapted as a stronghold through the construction of trenches, observation and machine-gun emplacements, galleries, and ammunition depots. It was readily identified during the ground survey because it was only partially obliterated. During WWI, this site became a fundamental Austro-Hungarian position from a strategic point of view thanks to its morphology: it controlled the confluence of the Assa and the Astico Valleys. Trenches on different levels were found in the Gibraltar stronghold, as were observation emplacements and many galleries with a complex system of internal junctions. The archaeological excavation only concerned the southern half of an emplacement and allowed the post-abandonment dynamics that led to a partial cover-up of the military infrastructure to be identified (Fig. 6.10a–c). The investigation revealed the almost total absence of archaeological stratigraphy and highlighted the boulder that closed the emplacement on the south in its entirety, revealing an embrasure in the lower part (Figs. 6.10b, d, 601). Another element detected, thanks to the excavation approach, was the bottom layer: this military feature was, in fact, excavated directly into the bedrock.

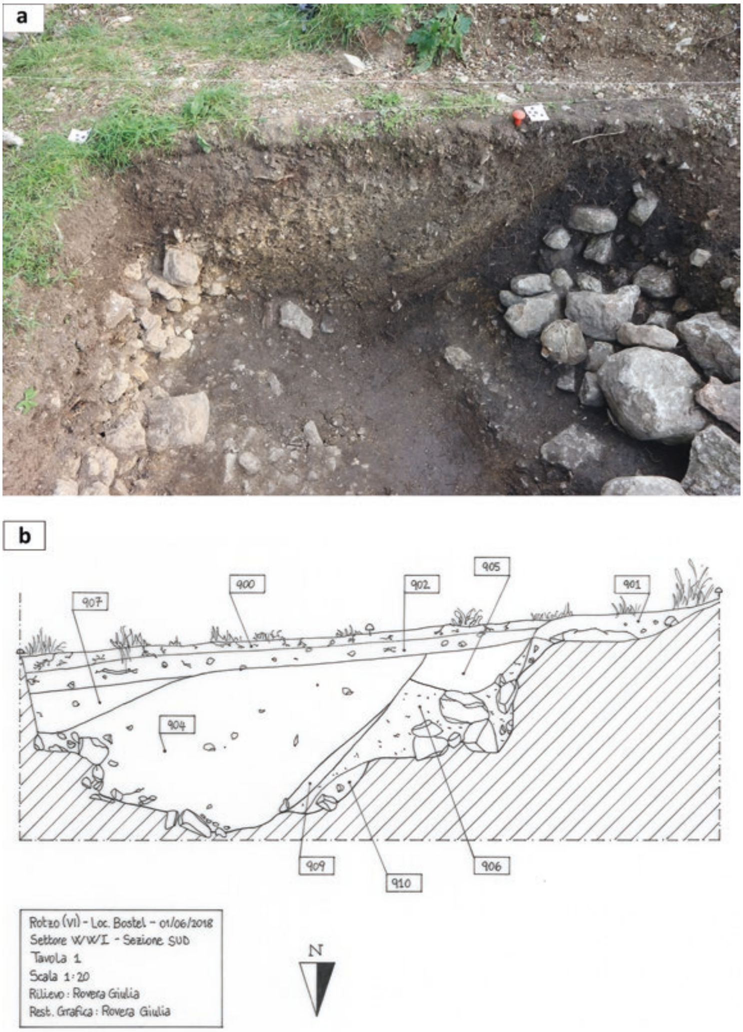

Fig. 6.9 (**a**) South section of the archaeological excavation that involved a completely obliterated Winterstellung trench section in the Bostel di Rotzo Archaeological Site. (**b**) The excavation has allowed the various phases of obliteration (due to natural events: 909; due to anthropic actions: 902, 904, 905, 906, 907) that led to a total cover-up of the trench in the post-war period to be highlighted

6.6 Conclusions

The two case studies confirmed that remote sensing analysis is the most effective small-scale investigation method for the study of the warscape even in partially wooded areas. In the Millegrobbe case study, it was possible to successfully map (semi)automatically more than 3 km of the trench using a combination of LIDAR-derived DTM visualization techniques and Object-based Image Analysis. This

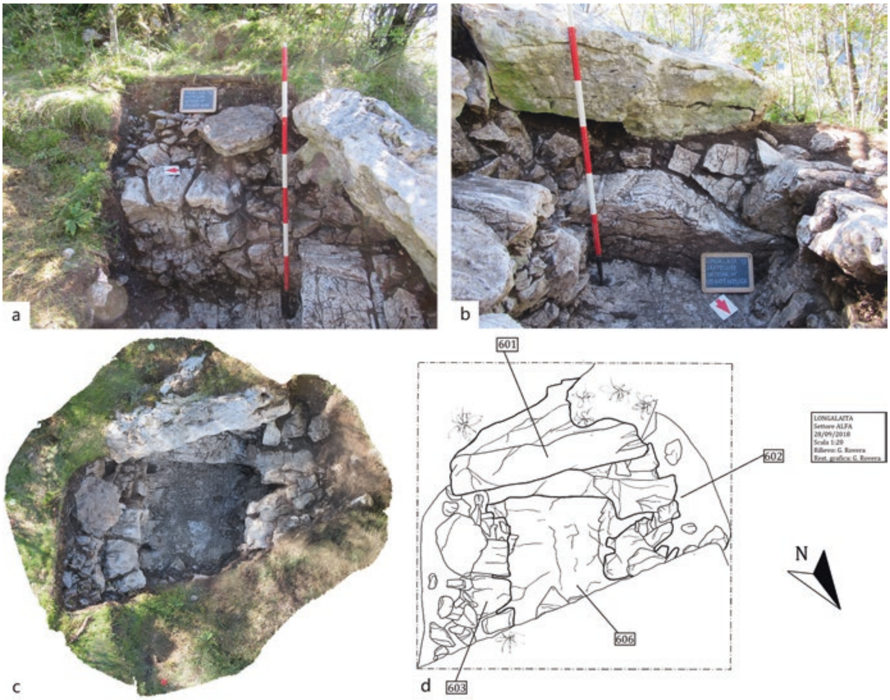

Fig. 6.10 Half-section of the emplacement in the Gibraltar stronghold. The trench was dug directly into the rocky surface, and the archaeological excavation revealed the post-abandonment natural dynamics that led to a partial coverup of the emplacement. (**a**) This image reveals the rampart of the military emplacement. (**b**) This image shows the boulder that closed the emplacement on the south section. (**c**) Orthophoto of the half-section. (**d**) Plan drawing of (**c**) at 1:20 scale indicating the archaeological layers

approach allowed us also to discern three different postdepositional outcomes of the original trench. This has been possible only by differentiating and adapting the semantic model of the trench to the different environmental and anthropic influences in context. The anthropic decision-making processes have also played a key role in the evolution of the trench formation and postdepositional processes. This is due to the different exploitation choices of the area in cognitive and functional perspectives, which are reflected in the recovery (Fig. 6.3, yellow), obliteration (Fig. 6.3, blue), and abandonment (Fig. 6.3, green) of the trench.

The subsequent ground survey confirmed the reliability of the rule set and of the interpretation. This application further demonstrates the potential of machine-learning techniques for the analysis of ancient landscapes if duly guided by a theoretical framework on the formation processes. In fact, without a diachronic semantic model derived from solid know-how of archaeological problems, the application of (semi)automatic recognition techniques would be strongly limited and decontextualized. In addition, these case studies further confirm that the assessment of the

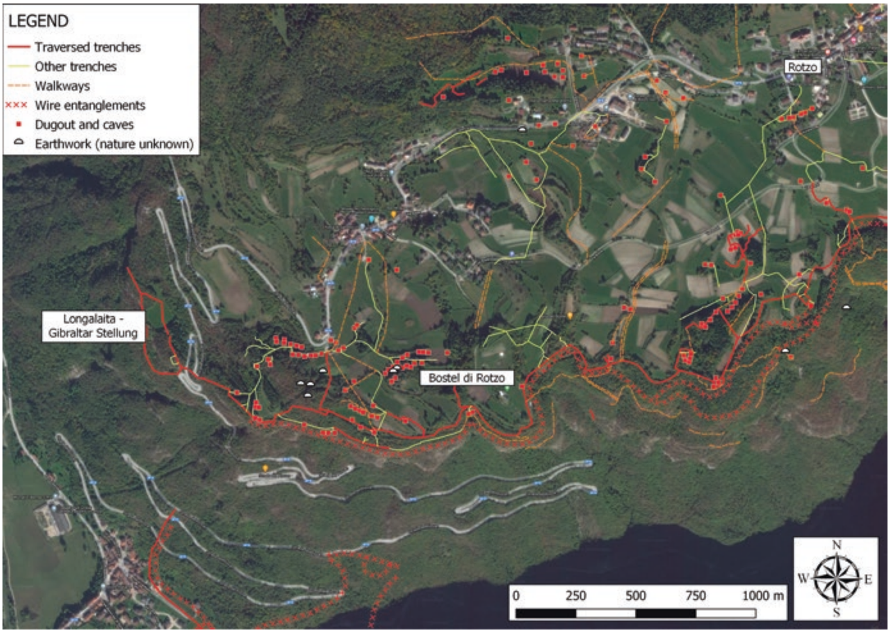

Fig. 6.11 Vectorization of the Winterstellung trenching system in the study area of Rotzo based on a British military map dated 28/08/1918 (Bondesan and Scroccaro 2017), overlain on a Google Hybrid satellite image. Details of the Austro-Hungarian trenching system found on the historical map are shown (see legend)

results of the (semi)automatic recognition is a key point in the workflow. In fact, automatic recognition procedures can only be improved through an accurate, ground-based analysis of the different outcomes of the formation processes that will provide new expert knowledge for future applications.

Almost 1 km of the trench was mapped with a differential GPS along the Winterstellung, and its reliability was verified through the combined use of remote sensing and historical maps (Fig. 6.11). The comparison between the results of our ground survey, the photo interpretation, and the British map confirms the high degree of accuracy of the topographic surveys during wartime. In fact, the traces identified and mapped by both GPS survey and remote sensing do not deviate significantly from the historical maps. Furthermore, through a systematic comparison of the trench on the British map with the traces left on the ground, it can be seen that much of the structural complexity of the defensive line is currently no longer visible or is in a precarious state of conservation. Although this allows archaeologists to study in detail the formation processes of structures in marginal and sparsely populated areas, it also leads to a significant impoverishment of the cultural heritage of one of the most important events of the twentieth century.

If LIDAR data had been available, however, the extent of the study area could have been enlarged: a LIDAR-derived high-resolution DTM would have allowed us to investigate those areas covered by trees (Crutchley and Crow 2010). The next step in the remote sensing analysis of the Millegrobbe trench system and the Winterstellung will be to acquire a new data set using an unmanned aerial vehicle (drone) with a thermal camera and a LIDAR sensor (Colombatti et al. 2017). Analysis of this data will allow the application of rule sets for the automatic identification of war-related features that have already been successfully tested at the Millegrobbe area (Magnini et al. 2017a; Magnini and Bettineschi 2019).

Thanks to stratigraphic excavations in different sectors along the trench in the Bostel di Rotzo area, we can confirm that the Austro-Hungarian trench has interfered with the layers resulting from the anthropic activities of the protohistoric village. The analysis of the stratigraphy also allowed the identification of various filling phases of the trench: nine different anthropic filling phases to obliterate and level up the war structure were identified. The applied methodology has also demonstrated the usefulness of the archaeological approach to study the heritage of the First World War: in fact, only through excavation and interpretation of the archaeological record, is it possible to clarify the phases of use of the site and the modalities of post-abandonment and obliteration. In this sense, the limited chronological gap that divides us from the use phases of the structure allows a greater understanding of the dynamics of abandonment and obliteration from an anthropic cognitive and decision-making perspective. In this case study (and more in general in contemporary archaeology), the cognitive approach allows us the possibility of understanding, not only the actions of the formation process but also why this process was done. For more ancient archaeological contexts, it is more difficult (but in some cases still possible) to understand the cognitive point of view of the human communities of the time.

The results obtained from the remote sensing analysis, the field survey, and the excavation of the Winterstellung trench line demonstrate the complexity and the importance of this defensive line for the Austro-Hungarian Army. The trench sections identified (and not excavated) during the survey comprise a massive structure: the construction of this entrenched system certainly required considerable Austro-Hungarian genius and effort, especially in inaccessible places like the slopes of the Astico Valley. Considering the above, the Winterstellung turns out to be a truly considerable work of military engineering which was to play a fundamental role in the Astro-Hungarian war strategy, especially considering the limited time for its construction.

In general terms, combining excavation, field survey, and the analysis of the remote sensing data, it was possible to outline a rather exhaustive picture of the obliteration dynamics (anthropic and natural) of the trenches in the investigated areas. These are largely attributed to natural processes in the case of partial or minimal filling of the structures located, in most cases, in wooded areas. On the contrary, the total obliterative processes are mainly assigned to human intervention and the need to return the land to agriculture and pasture.

The results of these scientific investigations will allow us to map the parts of the entrenched system that are still recognizable on the ground; this is fundamental to our goal of providing public access and guided tours of the local warscape in the future led by specialists in the field of conflict archaeology. The presence of experts will significantly improve the overall understanding of the "remaining warscape" and will stimulate reflections on the active role of every citizen in the protection of the WWI heritage.

References

Acerbi E (1992) Strafexpedition. Rossato, Valdagno

Balbi M (2015) La Grande Guerra e le montagne: soldati, alpinisti e alpinismo. In: Balbi M, Salvadori S, Giacomel P (eds) Il primo inverno in guerra. Kellermann jtane, Vittorio Veneto, p 18–33

Bondesan A, Scroccaro M (2017) Cartografia militare della Prima Guerra Mondiale. Cadore, Altopiani e Piave nelle carte topografiche austro-ungariche e italiane dell'Archivio di Stato di Firenze. Antiga Edizioni, Padova

Burigana L, Magnini L (2018) Image processing and analysis of radar and LIDAR data: new discoveries in Verona southern lowland (Italy). STAR Science and Technology of Archaeological Research 3:490–509

Colombatti G, Aboudan A, Bettanini C et al. (2017) Horus - a drone project for visual and IR imaging. 2017 IEEE International Workshop on Metrology for AeroSpace (MetroAeroSpace), Padova, p 589–592

Crutchley S, Crow P (2010) The light fantastic: using airborne laser scanning in archaeological survey. Historic England, Swindon

Davis DS (2018) Object-based image analysis: a review of developments and future directions of automated feature detection in landscape archaeology. Archaeological Prospection 26(2):155–163

De Guio A (2018) "Archeologia della Guerra": caro nonno ti scrivo… Aquileia Nostra LXXXVII (2016):11–42

De Guio A, Betto A (2005) Archaeology of the War, archaeology through the War: an analytical frontier in archaeological landscapes through digital technologies. In: Forte M (ed) Atti del II Workshop Italia-Stati Uniti. Roma, Italy, November 2003. Bar Publishing, Oxford, p 153–170

De Guio A, Betto A (2008) Archeologia della Guerra: nuove linee di ricerca. Archeologia della Grande Guerra 1:11–28

De Guio A, Betto A (2011a) Archeologia ed Etnoarcheologia della Guerra. Atti del 4° Convegno Nazionale di Etnoarcheologia, p 321–330

De Guio A, Betto A (2011b) Archaeology of the Great War: molto di nuovo dal Fronte Occidentale. In: Nicolis F, Ciurletti G, De Guio A (eds) Archeologia della Grande Guerra – Archaeology of the Great War. Atti del convegno internazionale di Archeologia della Guerra, Luserna, June 2006, Trento, p 143–176

De Guio A, Magnini L, Bettineschi C (2015) GeOBIA approaches to remote sensing of fossil landscapes: two case studies from Northern Italy. In: Traviglia A (ed) Across Space and Time. Papers from the 41st Conference on Computer Applications and Quantitative Methods in Archaeology, Perth, 25–28 March 2013. Amsterdam University Press, Amsterdam, p 45–53

De Guio A, Bressan C, Ferrari G et al. (2011) Bostel di Rotzo (VI) – stato di avanzamento delle ricerche. Quaderni di Archeologia del Veneto XXVII:168–183

de Matos-Machado R, Toumazet JP, Bergès JC et al. (2019) War landform mapping and classification on the Verdun battlefield (France) using airborne LIDAR and multivariate analysis. Earth Surface Processes and Landforms 44(7):1430–1448. https://doi.org/10.1002/esp.4586

Desfossés Y, Jaques A, Prilaux G (2009) Great War archaeology. Ouest-France, Rennes

Dolejš M, Samek V, Veselý M et al. (2020) Detecting World War II bombing relics in markedly transformed landscapes (city of Most, Czechia). Applied Geography 119. https://doi.org/10.1016/j.apgeog.2020.102225

Doneus M (2013) Openness as a visualization technique for interpretative mapping of airborne LIDAR derived digital terrain models. Remote Sensing 5:6427–6442

Doyle P (1998) Geology of the Western Front, 1914-1918. Geologist's Association Guides Issue 61. Geologist's Association, London

Eliseo S (2013) Le trincee quali fortificazioni campali durante la Grande Guerra. Rassegna dell'Esercito on-line 2, p 74–83. https://www.esercito.difesa.it/comunicazione/jtania/Rassegna-Esercito/Tutti-i-numeri/2013/Documents/n-2/rassEI_2_13_art_3.pdf

Fraser AH, Brown M (2007) Mud, blood and missing men: excavations at Serre, Somme, France. Journal of Conflict Archaeology 3(1):147–171

Gaudio D, Betto A, Vanin S et al. (2013) Excavation and study of skeletal remains from a World War I mass grave. International Journal of Osteoarchaeology 25(5):585–592

Gheyle W, Saey T, Van Hollebeeke Y et al. (2016) Historical aerial photography and multi-receiver EMI soil sensing, complementing techniques for the study of a Great War conflict landscape. Archaeological Prospection 23(3):149–164

Gheyle W, Stichelbaut B, Saey T et al. (2018) Scratching the surface of war. Airborne laser scans of the Great War conflict landscape in Flanders (Belgium). Applied Geography 90:55–68

Halliday S (2013) I walked, I saw, I surveyed, but what did I see? … and what did I survey? In: Opitz R, Cowley DC (eds) Interpreting archaeological topography: airborne laser scanning, 3D data and ground observation. Oxbow Books, Oxford, p 63–75

Hesse R (2010) LIDAR-derived Local Relief Models - a new tool for archaeological prospection. Archaeological Prospection 17(2):67–72

Hunter J, Cox M (2005) Forensic archaeology. Advances in theory and practice. Routledge, London

Hupy JP, Schaetzl RJ (2006) Introducing "bombturbation" a singular type of soil disturbance and mixing. Soil Science 171(11):823–836

Hupy JP, Schaetzl RJ (2008) Soil development on the WWI battlefield of Verdun, France. Geoderma 145(1):37–49

Keegan J (1998) The First World War. Hutchinson, London

Kokalj Z, Hesse R (2017) Airborne laser scanning raster data visualization: a guide to good practice. Založba ZRC, Ljubljana

Lang S (2008) Object-based image analysis for remote sensing applications: modeling reality - dealing with complexity. In: Blaschke T, Lang S, Hay GJ (eds) Object-based image analysis. Spatial concepts for knowledge-driven remote sensing applications. Springer, Berlin, p 3–28

Le Bailly M, Landolt M, Bouchet F (2012) First World War German soldier intestinal worms: An original study of a trench latrine in France. The Journal of Parasitology 98(6):1273–1275

Liber T, Leitempergher U, Kozlovic A (1988) 1914-18. La grande guerra sugli altipiani. Folgaria, Lavarone, Luserna, Vezzena, Sette Comuni, M. Pasubio, M. Cimone e sugli altri fronti di guerra. Rosato, Valdagno

Magnini L, Bettineschi C (2019) Theory and practice for an object-based approach in archaeological remote sensing. Journal of Archaeological Science 107:10–22

Magnini L, Bettineschi C (2021) Object-Based predictive modeling (OBPM) for archaeology: Finding control places in mountainous environments. Remote Sensing 13:1197

Magnini L, Bettineschi C, De Guio A (2017a) Object-based shell craters classification from LIDAR-derived sky-view factor. Archaeological Prospection 24:211–223

Magnini L, Bettineschi C, De Guio A (2017b) Il sito protostorico del Bostel di Rotzo: note di aggiornamento sugli scavi in corso. In: Deotto G, Bettineschi C, Magnini L et al. (eds) Progetto Horus: visioni dall'alto dello spazio archeologico. Padova University Press, Padova, p 13–19

Magnini L, Bettineschi C, De Guio A et al. (2019) Multisensor-multiscale approach in studying the proto-historic settlement of Bostel in northern Italy. Archeologia e Calcolatori 30:347–365

Masters P, Stichelbaut B (2009) From the air to beneath the soil – revealing and mapping Great War trenches at Ploegsteert (Comines-Warneton), Belgium. Archaeological Prospection 16(4):279–285

Mlekuž D, Košir U, Črešnar M (2016) Landscapes of death and suffering: archaeology of conflict landscapes of the upper Soča Valley, Slovenia. In: Stichelbaut B, Cowley D (eds) Conflict landscapes and archaeology from above. Ashgate, Farnham, p 127–146

Offelli S (2006) 1916 La spedizione punitiva. Rossato, Novale

Robertshaw A, Kenyon D (2008) Digging the trenches: the archaeology of the Western Front. Pen and Sword Military, Barnsley

Saunders NJ (2003) Trench art: materialities and memories of war. Berg, Oxford

Saunders NJ (ed) (2012) Beyond the dead horizon: studies in modern conflict archaeology. Oxbow Books, Oxford

Saunders NJ, Cornish P (eds) (2014) Contested objects: material memories of the Great War. Routledge, London

Schiffer MB (1972) Archaeological context and systemic context. American Antiquity 37:156–165

Schofield J (2005) Combat archaeology: material culture and modern conflict. Duckworth, London

Stal C, Bourgeois J, De Maeyer P, et al. (2010) Kemmelberg (Belgium) case study: comparison of DTM analysis methods for the detection of relicts from the First World War. Remote Sensing for Science, Education, and Natural and Cultural Heritage, Proceedings of the 30th EARSeL Symposium 2010, Paris, p 65–72

Stenghele D (2010) Storia fotografica: la Grande Guerra nella Valle dell'Astico, terra di Confine. Li, Velo d'Astico

Stichelbaut B, Gheyle W, Saey T et al. (2016) The First World War from above and below. Historical aerial photographs and mine craters in the Ypres Salient. Applied Geography 66:64–72

Thompson M (2008) The White War: life and death on the Italian Front 1915-1919. Basic Books, London

Traviglia, A, Torsello A (2017) Landscape pattern detection in archaeological remote sensing. Geosciences 7(4):128. https://doi.org/10.3390/geosciences7040128

Van den Berghe H, Gheyle W, Note N et al. (2019) Revealing the preservation of First World War shell hole landscapes based on a landscape change study and LIDAR. Geografisk Tidsskrift - Danish Journal of Geography 119(1):38–51

Vergara MN, Bondesan A (2020) The Cadore Offensive: theoretical military geography considerations. In: Guth PL (ed) Military geoscience. Bridging history to current operations. Springer Nature, Cham, Switzerland, p 67–83

Vergara MN, Bondesan A, Ferrarese F (2019) GIS analysis of the trafficability determined by slope in the eastern Tyrol front (WWI, Eastern Alps): a military history reading. Cartography and Geographic Information Science, 45(6):477–494

Yokoyama R, Sirasawa M, Pike RJ (2002) Visualizing topography by openness: A new application of image processing to digital elevation models. Photogrammetric Engineering and Remote Sensing 68:257–265

Zakšek K, Oštir K, Kokalj Z (2011) Sky-View Factor as a relief visualisation technique. Remote Sensing 3:398–415

Chapter 7
The Italian Corps of Engineers in World War I: Innovations in Mining and Tunnel Warfare

Paolo Macini and Paolo Sammuri

Contents

Abstract During World War I, miners and sappers of the Italian Corps of Engineers were engaged in challenging tunnel warfare to undermine Austro-Hungarian fortifications located in difficult high-mountain environments. On the Italian Front, the area most affected by tunnel warfare was the Dolomite sector of the Alps; more than 30 large mines blasts took place here between 1916 to 1918. The aftermath of some of these mines modified the local landscape, reshaping cliffs and peaks.

The efforts and technical challenges of the Corps are examined in this paper based on documents stored in the ISCAG Archive, the Historical and Cultural Institute of the Italian Corps of Engineers in Rome. These documents allowed the reconstruction of methods, engineering concepts, technical innovations, and strategies of the Corps itself. A large number of documents concern "listening" methods and instruments, as well as descriptions of mechanical drilling equipment. As for listening, the application of geophysical methods, still in their infancy at the time, involved the technological development and construction of geophones, recording "microseismophones," and several other devices.

Keywords World War I · Tunnel warfare · Corps of Engineers · Military mining

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7.1 The Italian Corps of Engineers and Its Organization During WWI

The Italian Corps of Engineers was established on 11 June 1775, in the service of the King of Savoy. In 1848, the Corps was constituted the 1st Regiment of Engineers, composed of two battalions with one miner and four sapper companies. During the Crimean War (1855–1956), a bridge engineers unit was added to the sapper companies, as was a telegraphist unit in 1859. The railway regiment was created in 1860–1861 and the 3rd Regiment Telegraphists in 1883.

The reorganization of the Italian Army in 1910 reshaped the Corps into six regiments: 1st and 2nd Regiments Sappers, 3rd Regiment Telegraphists, 4th Regiment Bridges, 5th Regiment Miners, 6th Regiment Railways, and one Specialists battalion. This latter dealt with specialties not yet fully developed inside the Corps: aerostatics, photoelectricity, military photography, telephotography, and radiotelegraphy. An aerostats plant and workshop, which developed into the Aeronautic Service of the Corps in 1912, was also established in Rome, in 1884.

A few years later, World War I (WWI) trench warfare and the spread of new weapons and military strategies were reflected in the organization and importance of the Corps. Its development during WWI was remarkable. The 80 companies of the pre-war period rose to 486 and new specialties, such as radio communications, cableways, machinists, lagoon troops, searchlight units, flamethrowers, and electricians, were developed and widely used during the war (Borgatti 1928; Baldini 1991).

The 5th Regiment Miners' experience in dealing with explosives, together with its knowledge of mining techniques, was very useful for the Corps, for both defensive and offensive purposes. At the outbreak of WWI, many soldiers and officers were professional miners or railway engineers. However, their number was not sufficient to guarantee and address the needs of the entire theater of war. Therefore, in January 1917, a specialization course to train infantry troops, the "Applied Course for Mine Works," was launched (ISCAG 1917b, c). Six schools were set up to instruct a total of 2700 personnel. Each school planned three month-long courses with 150 trainees in each. Participants were selected from masons, stonemasons, carpenters, blacksmiths, and miners. The course was structured into applied and theoretical activities, covering the basics of mining, tunneling, and explosives.

7.2 Italian Mining and Tunneling Technology in the Late Nineteenth Century

The Alpine tunnels were amongst the technical masterpieces of the nineteenth century, a real test for the engineering skills of the time. Construction of the Frèjus tunnel in Italy, together with cutting the Suez Canal, were symbols of the technical progress in the field of transportation engineering. At the time, the Italian concept of building tunnels more than 10 km long prevailed over the Austrian one, which favored long, winding open-air railways, such as the Brenner (1867) and Pontebba (1872) railways. Three great Alpine tunnels, Frèjus (1871, Italy-France, 13.6 km), St. Gotthard (1882, Switzerland, along the line Italy-Germany, 15 km), and Simplon (1906, Italy-Switzerland, 19.8 km) were constructed.

Italian tunnel warfare in WWI largely drew upon mechanical drilling technologies developed for the Alpine tunnels, when the industrial revolution resulted in the mechanization of large parts of the production activities. Mechanization also changed traditional underground mining and open-pit quarrying technologies by applying steam power, compressed air, and electricity to replace manual drilling to prepare blast holes, in which one man turned the drill while the second swung the hammer. It was a hard, difficult, and slow operation, the real bottleneck of the entire mining sector.

The construction of Frèjus and Hoosac (USA) railway tunnels, driven during the 1850s and 1860s, produced a large number of innovations in rock-drilling equipment, notably the introduction of compressed-air drills (Drinker 1878). It is worth recalling that before 1860, compressed-air technology had no industrial application; the Frèjus tunnel was the main driver for its development at a large scale in Europe (Lesca 1998).

Very little is known about hard-rock drilling before 1850, although the technique was in use in several parts of the world (Brighenti and Macini 2008). In Europe, Rudolphe Leschot invented a system for hard-rock drilling with diamond tools as early as 1862. Leschot was a French railway engineer, born in Switzerland of a long-established watch-making family and educated at the École Centrale in Paris (Blake 1871). He was working on the Frèjus tunnel when he realized that drilling mechanization was required to complete the project in a reasonable period of time (Burt 2014). Unfortunately, his concept was never fully developed commercially, but a decade later, the system was industrialized as a coring tool for mining exploration. Leschot patented his device in the United States in 1863; the patent was reissued in 1869 (Brantly 1971).

Mechanical drilling saw large improvements in the second half of the nineteenth century. In 1844, Robert Beart filed an application for a patent in England concerning a device for rotary drilling, possibly drawing on an idea of the French engineer Pierre Pascal Fauvelle (Fauvelle 1845, 1846). Both systems were conceived for water-well drilling in soft rocks. In the field of hard-rock mining, Jonathan J. Couch of Philadelphia devised a steam-driven cylinder-piston system in 1849 and patented the world's first mechanical percussion rock drill (Drinker 1878). In 1871, Simon Ingersoll invented a steam-driven drill mounted on a tripod that kept the drill steady and enabled it to operate at virtually any angle (Lynch and Rowland 2005). In 1897, John George Leyner developed a hammer drill as an alternative to the piston drill. He perfected the rotating "rifle bar" pneumatic drill in 1897 and shortly afterward, introduced several innovations; his "rock drilling engine" was patented in 1900 (Leyner 1900). These drills required two men for operation, but in the following decade, hammer drills were made light enough for a single person to use. Moreover, this new drill featured a hollow drill rod to flush out the cuttings from the borehole by means of compressed air and, later, water. Leyner's drills not only performed better than earlier tools but also dramatically reduced one of the most dreaded miners' occupational diseases, silicosis. Although there are hundreds of patents for jackhammers and pneumatic tools, the earliest appears to have been filed by Charles Brady King on 19 May 1892 and granted on 30 January 1894 (US Patent 513,941). It was for the riveting of steel structures and caulking (King 1894).

Early steam-driven drills proved impractical in tunneling due to ventilation problems: steam was not an ideal power fluid due to condensation and the resultant difficulty in breathing in the tunnel. The Frèjus tunnel (1857-1871), the manual excavation of which proceeded slowly (about 0.20 m/day up to 1861), experienced a technological breakthrough with the introduction of the drilling machine invented by Germano Sommeiller, Sebastiano Grandis, and Severino Grattoni. The concept was drawn from an idea of Giovanni Battista Piatti, who unfortunately did not correctly patent it (Lesca 1998). In 1853, Piatti proposed a percussion drill driven by compressed air generated by hydraulic rams, thereby, also obtaining aeration in the tunnel. The basic concept of Piatti was applied to the design of a specific drilling machine used to drive the Frèjus drift tunnel from 1861 to 1871.

The Sommeiller-Piatti machine, which used waterpower to drive a number of air compressors located outside the tunnel (both volumetric and hydraulic-ram types), was an automatic drilling wagon. Compressed air was transported to the drills by dedicated pipelines for more than 7 km, a record for the time. The drilling wagon (12 tons) featured six to 12 drills acting simultaneously on the excavation front. The drills, fed with 0.3–0.6 MPa air pressure, were capable of 250 strokes per minute and completed a single blast hole about 1 m long and 25–38 mm in diameter in 1 hour. The 55–80 holes on the excavation front were then charged with black powder and fired with a slow-burning fuse. Mechanical drilling of blast holes allowed completion of the project in 13 years; it would have required 40 years if done by manual operations only. Thanks to mechanical drilling, the tunnel penetration rate in 1861 increased up to 0.46 m/day, ending at up to 2.27 m/day in 1870. The Sommeiller-Piatti machine made many inprovements in tunneling of the years to come (Pontecorvo 1935).

The difficulties and hazards of placing steam engines in confined spaces or transmitting mechanical power had previously prevented the mechanization of underground mining. Moreover, the cost, complexity, and technical difficulties to produce and transport compressed air for long distances soon shifted interest towards electric power. In 1877, the German Werner Siemens Company started an extensive program to explore the use of electricity in mining (Dorion 1893). Siemens proved the efficiency of a solenoid-operated rock drill, both percussion and rotary types, and designed an electric locomotive for underground mining. In 1882, an electric railway was installed in a coal mine in Saxony, and the necessary systems to prevent the risk of underground gas deflagration were soon developed (Nebeker 2009).

In Italy, the electrification of the Montevecchio Sardinian mines started in the early 1900s using alternators driven by coal gas engines: this was the first power plant in Sardinia (1903; 128 HP, 550 V, 50 Hz). Soon, Siemens-Halske electric (0.9 kW) and compressed-air drills were adopted in underground mining: the first underground electric compressor was an Ingersoll, which allowed the use of two fixed drills and three hammer drills. The pneumatic system was successful and allowed a large increase in production. Electric drills included both percussion (Van Depoele, Marwin, Jenkins, Morgan) and rotary (Siemens-Halske) types (Dorion 1893; Rolandi 1949).

The Italian mining industry had wide experience and kept pace with European mining technology due to the many foreign companies operating in the country. At the outbreak of WWI, the Italian government nationalized mining activities managed by English and French companies; later, German companies were also obliged to leave Italy. The military authorities confiscated and strictly controlled national mining production and managed production sites according to the military needs. In addition, the miners were militarized and subjected to military discipline and chain of command (Pistolesi 2011; Sammuri 2015).

7.3 Overview of Tunnel Warfare in Italy, 1916–1918

The Alpine Front, including the high peaks of the Dolomites, was an area of hard-fought mountain warfare, where Austro-Hungarian and Italian engineers worked with extreme skill. After the first rudimentary Austro-Hungarian mine blast at Lagazuoi in 1916, the Italian supreme command decided to rely on this new tactic: underground mining warfare. Results, however, were much less than expected.

WWI was a huge "continental siege" in which strong defensive systems, such as barbed wire, trenches, tunnels, and bunkers, were used in conjunction with machine guns to stop open-air assaults. The war of movement soon became a war of attrition and, as in ancient sieges, tunnel warfare became a realistic tactical option. The strategic plan of the Italian supreme command envisaged that the military forces located in the Alpine sector would adopt a defensive line, with only local offensive activity used to reinforce the Front. In fact, the Italian Army concentrated its main efforts on the Isonzo River Front (11 battles from June 1915 to November 1917), trying to reach Trieste and Ljubljana. Figure 7.1 shows the locations of most of the places cited hereinafter.

The Alpine Front was a difficult battlefield, located in a region of sheer peaks, steep rock faces, and cliffs, with extreme winter temperatures and deadly avalanches. Austria-Hungary always had a defensive strategy along this Front, except in 1916, during the *Strafexpedition*, or Battle of Asiago, that was fought in the nearby High Plains. The Alpine positions were, in fact, easily defensible with limited deployment of troops. The Austro-Hungarians controlled countless Italian assaults and, except for limited setbacks, the defensive line remained almost unchanged until the end of the conflict (Vianelli and Cenacchi 2006).

The Dolomite Alpine Front was an area of hard-fought mountain warfare, and Austro-Hungarian and Italian engineers worked with extreme skill at these high altitudes. Beyond building underground shelters, both armies attempted to break the stalemate of trench warfare by tunneling under no man's land and placing massive explosive charges beneath enemy positions. Central to this was the risk of being

Fig. 7.1 Map of the Italian border in 1917 and geography of tunnel warfare in northeastern Italy. In the early stage of WWI (1915), this strategy was carried out inside Area A (Carso-Isonzo). In 1916, the tunnel warfare moved to Northern Dolomites (Area B, Lagazuoi-Col di Lana, which includes Mt. Sief and Castelletto mines described in the text). Finally, in 1917-1918 underground mining and tunnel warfare ended at Asiago-Pasubio (area C). (Modified from map data ©2020 Google)

spotted during tunnel construction, before firing the mine, or the hazard of neutralization by counter-mines. Overall, not less than 34 mines were fired on the Alpine Front between 1916 and 1918 (Table 7.1 and Fig. 7.1), the first one on 1 January 1916 at Lagazuoi Piccolo (300 kg), and the last one on 14 March 1918 in the Mt. Pasubio area (50 tons).

Tunneling and mine warfare were not exclusive to the Alpine Front. This strategy was first attempted at Mt. S. Michele (Italian Eastern Front, Carso-Isonzo area, Fig. 7.1), where the first Italian mine was prepared in 15 days, loaded with 200 kg of blasting gelatin, and fired on 2 October 1915, but with no remarkable results, probably due to its small size (Ministero 1929). A few days later, on 8 October 1915, the general commanding the Italian Corps of Engineers ordered a detailed study of several technical issues with mechanical drilling as applied to tunnel warfare. He emphasized, among other issues, the size of drilling units, the efficiency of water circulation to remove rock cuttings, maximum borehole length, possible instability issues due to interbedded soft rock, and noise generation. A safe testing site was identified and developed close to the Italian Eastern Front, on a hill in the village of Medea (Fig. 7.1), which features the same geological configuration as the nearby Carso-Isonzo area (ISCAG 1917d).

Two years later, a similar strategy was tried at Mt. Pohouc (Monte Rosso, close to today's Batognica, Slovenia), very close to the Mt. Krn (Monte Nero) battlefield (Fig. 7.1, area A). After a series of tunnel and counter-tunnel battles, the Italian

Table 7.1 WWI tunnel warfare on the Alpine Front in chronological order. Italian and Austrian documents report 34 underground mine blasts, 20 Italian (I), and 14 Austro-Hungarian (A). Tunneling refers to underground works, not only mine warfare, where no blasts are recorded. Rearranged and updated after Striffler (1993), Schramm (2011) and ISCAG Archives

N.	Army	Date	Location	Explosive (tons) or only tunneling
1	A	1915	Tonale Pass, Punta Albiolo	Tunneling
2	A	01 Jan. 1916	Lagazuoi, Cengia Martini	0.3
3	A	06 Apr. 1916	Col di Lana	0.11
4	I	17 Apr. 1916	Col di Lana	5.02
5	A+I	1916	Pasubio East area, Monte Maio	Tunneling
6	A+I	1916	Riva del Garda, Monte Sperone-Rocchetta	Tunneling
7	A+I	1916–1917	Vallarsa area, Zugna, Monte Coni Zugna	Tunneling
8	A+I	1916	Sesto Dolomites, Croda Rossa	Tunneling
9	I	11 Jul. 1916	Falzarego Pass, Castelletto della Tofana	35
10	I	17 Sept. 1916	Arsiero area, Monte Cimone di Tonezza	Unknown
11	A	23 Sept. 1916	Arsiero area, Monte Cimone di Tonezza	14.2
12	I	17 Nov. 1916	Cortina d'Ampezzo, Zuoghe-Croda de r'Ancona	Unknown
13	A+I	1916-1917	Sesto Dolomites, Torre Toblin, Sasso di Sesto	Tunneling
14	A+I	1917	Sesto Dolomites, Monte Piana – Val Popena	Tunneling
15	A	14 Jan. 1917	Lagazuoi, Cengia Martini	16
16	I	03 Mar. 1917	Col di Lana, Monte Sief	Unknown
17	A+I	1917	Ortles, Monte Cristallo	Tunneling
18	I	12 Apr. 1917	Rolle Pass, Monte Colbricon	0.8
19	A	22 May 1917	Lagazuoi Piccolo	30.4
20	I	08 June 1917	Asiago, Monte Zebio, Mina di Scalambron	2–4
21	I	10 June 1917	Asiago, Monte Rotondo – Monte Zebio	Unknown
22	I	20 June 1917	Lagazuoi Piccolo, Anticima	33
23	I	16 Jul. 1917	Rolle Pass, Monte Colbricon	4
24	A	16 Sept. 1917	Lagazuoi Piccolo	5
25	I	19 Sept. 1917	Rolle Pass, Monte Colbricon	Unknown
26	A	26 Sept. 1917	Marmolada, Forcella a "V"	0.8–1.25
27	I	27 Sept. 1917	Col di Lana, Monte Sief	Unknown
28	A	29 Sept. 1917	Pasubio	0.5
29	I	02 Oct. 1917	Pasubio	13
30	I	10 Oct. 1917	Rolle Pass, North Colbricon, Buse del Oro	0.4

(continued)

Table 7.1 (continued)

N.	Army	Date	Location	Explosive (tons) or only tunneling
31	A	21 Oct. 1917	Col di Lana, Monte Sief	45
32	I	22 Oct. 1917	Pasubio	1
33	I	24 Oct. 1917	Marmolada glacier	0.5
34	I	29 Oct. 1917	Marmolada glacier	1
35	A	03 Nov. 1917	Marmolada glacier	Unknown
36	A+I	1917–1918	Pasubio North-West, Monte Corno di Vallarsa	Tunneling
37	A	24 Dec. 1917	Pasubio, Dente Italiano	6.4 (A) + 1.7 (I)
38	I	21 Jan. 1918	Pasubio	0.6
39	A	02 Feb. 1918	Pasubio, Dente Italiano	3.8
40	I	13 Feb. 1918	Pasubio	Unknown
41	A	24 Feb. 1918	Pasubio	Unknown
42	I	05 Mar. 1918	Pasubio	Unknown
43	A	13 Mar. 1918	Pasubio, Dente Italiano	50 (A) + 1.5 (I)

Army constructed a network of tunnels loaded with 2 tons of nitroglycerine, but the site was spotted (15 August 1917) and the action failed since the Italian blast was only partial. Later, at the beginning of the Kobarid offensive (Caporetto, the Italian defeat, 24 October 1917) the Austro-Hungarians detonated a charge of 400 kg, again with no significant results (Ministero 1954).

In the heart of the Dolomites, which today are a UNESCO World Heritage site, 11 mine blasts are recorded (Fig. 7.1, area B); five Austro-Hungarian and six Italian. Italian mine warfare in the Dolomites area, conceived to contain a possible invasion of northeastern Italy, took place from December 1915 to December 1917 (Striffler 1993; Di Martino 2012).

After the first Austro-Hungarian blast of 1 January 1916 at Lagazuoi Piccolo, Italy decided to rely on a new tactic: mine warfare. On 14 January 1916, the well-trained Italian mining engineer Lt. Gelasio Caetani (1877–1934), based along the Col di Lana Front, not far from Lagazuoi, suggested to his commanding officer, Lt. Col. Perelli, “to dig a tunnel under the Austrian ass and blow them up” (Caetani 1919, p. 101; original text: *Piuttosto Le scavo una galleria sotto il sedere degli austriaci e li facciamo saltare per aria*). This was the birth of the Col di Lana mine concept, which was soon approved by the supreme command. On 13 January 1916, the excavation began with the goal of blowing up the top of Col di Lana. The Italian network of tunnels, over 200 m in length including a 55-m-long mine tunnel with an inclined shaft and two blasting rooms, was completed without mechanical drilling to reduce noise. Explosives and forced ventilation were used only during the last days to speed up final operations. The network was completed on 9 April 1916. Crews formed of eight miners each were employed in eight-hour shifts, allowing a tunneling rate of 4 m per day. On 17 April 1916, 5500 kg of blasting gelatin was fired around midnight, creating a crater 50 m in diameter and 15 m deep, which allowed the conquest of the peak (Caetani 1919). This was the first Italian mine blast on the Alpine Front. After the blast, the Austro-Hungarians retreated for only a few hundred meters and continued the exhausting war of position from the top of Mt. Sief (see below).

A few months later, the Italian Alpini (mountain infantry) completed a 500 m upward-slanting tunnel at Castelletto della Tofana, near Lagazuoi, without the help of the Corps of Engineers. Lt. Eugenio Tissi, Royal Corps of Mines, and Lt. Luigi Malvezzi, a railway engineer, both from the 7th Alpini Regiment, were in charge of tunnel construction, which started on 3 January 1916. They purchased two drilling units (one Ingersoll, 13 kW, and one Sullivan, 30 kW), each with its own 7-bar compressed-air tank. Two underground rooms were constructed beside the main tunnel to accommodate these units. The drilling crew consisted of 30 men working six-hour shifts. These crews constructed a tunnel with a cross-section of 1.8 by 2 m, working nonstop and with a tunneling rate of 5–6 m per day. A light, narrow-gauge track (decauville type) was used to haul the debris with mine carts; more than 3500 m^3 of debris were dumped in a ravine out of sight. Lt. Tissi also ordered the construction of a spiral tunnel that branched off the main tunnel. In response, the Austro-Hungarians started to hand-dig a counter-mine, but did not reach the Italian tunnel in time, because they received a drilling unit too late. Lt. Col. Tatoli of the Corps of Engineers supervised the loading and priming of the mine (35 tons), which was completed at 15:00 on 9 July. The provision of explosives, which amounted to half the total Italian monthly production of blasting gelatin, was also challenging. A four-day battle followed the blast, fired on 11 July 1916, and the Alpini conquered the Castelletto also using the spiral tunnel.

Concerning Mt. Sief, a report dated 29 March 1917 (ISCAG 1917a) describes the preparation of an Italian underground counter-mine using accurate drawings. The 8th and 62nd Sappers Companies, together with a platoon from 12th Miners Company of the Corps of Engineers supported by infantry sapper squads, carried out the tunneling. The engineers accurately designed an explosive charge of 4 tons, placed in a room at a depth of 25 m that had a calculated blasting radius of 22 m. This radius would have covered the whole ridge to a depth of 47 m, and so would have ensured the complete destruction of enemy tunnels. The blasting gelatin priming was prepared with 20 gun-cotton primers, 20 electric primers, and one torpedo. At 06:45 on 6 March 1917, the chief commander ordered the blasting of the mine. The explosion destroyed the advanced Austro-Hungarian position and opened a cut in the ridge, 25 m deep by 50 m long, and induced a plume of smoke at the mouth of the enemy tunnel as evidence of destruction.

After 1917, mine warfare shifted south to Asiago-Pasubio (Fig. 7.1, area C), where 10 mines were exploded between October 1917 and March 1918 (Traniello 1928). Mine warfare ended with a big Austro-Hungarian mine: 50 tons of explosive loaded into two mine chambers caused the collapse of the rocky spur known as Dente Italiano (Italian Tooth), which buried more than 40 men under the debris. The mine exploded only a few hours before an Italian counter-mine, and both sides then put an end to this inconclusive strategy (ISCAG 1919-1920).

7.4 Tunneling and Listening in the War of Mines: Methods and Instruments

WWI mine warfare along the Alpine Front involved the construction of complex tunnel networks in hard rocks and glaciers, utilizing manual methods, mechanical drilling, and explosives. The high mountains put the logistics of supply to the test, and mining and tunneling experience marked the strategies of both armies. The archive documents testify to intense research activity on both new drilling methods and the development of dedicated listening tools.

7.4.1 Tunneling and Underground Construction in Alpine Mine Warfare

Since 1914, the European armies involved in WWI had dug into the soft soils of France and Russia to blow up opposing positions. Two years later, mine warfare between the Italian and Austro-Hungarian Armies along the Alpine Front would take over the character of a superhuman technical enterprise. The Alpine Front no longer attracted only soldiers, but also miners, blacksmiths, motorists, and photographers, an army of professional roles not strictly connected with traditional combat. The high altitude put the logistics of supply to the test, as well as bearers, mules, dogs, and cableways. Austrian machine-gun fire and snipers continually disturbed operations, which were mainly performed at night or when poor visibility due to bad weather prevailed.

The Italians were well-equipped compared to the Austro-Hungarians. They transported generators, drills, and air compressors into the mountains, often in surprising ways, to drive tunnels from bottom to top, which made rock-debris haulage easier. In times of emergency, mechanical drilling allowed the construction of 10 m of tunnel 1 by 1.5 m across in one day. In some cases, workshops for drilling units' maintenance and repair were built inside the mountains, as were dedicated underground spaces for the compressors. As mentioned above, the preparation of the Castelletto mine involved the construction of two underground rooms to accommodate the compressors, with an area of 30 and 40 m^2, respectively, and a height of 2–2.2 m (Ministero 1936).

The Austro-Hungarians, on the other hand, usually dug tunnels from top to bottom, and during the early phases of mine warfare, constructed them by hand, generally with a cross section of about 0.8 by 1.3 m. Only later did they use mechanical drilling with the aid of well-trained Austrian and German miners.

Soon after the Lagazuoi mine (January 1916), the Italian Army rationalized its drilling services and personnel, by instituting the "Drilling Units Control Commission" (Commissione di Controllo per materiali perforatori), operating at the 5th Regiment of the Corps of Engineers. Among other functions, the Commission aimed to "eliminate some inconveniences that occurred due to direct purchases of materials by some units" (Supreme Chief of Staff Gen. Luigi Cadorna, letter dated 31 January 1916, p. 1, ISCAG 1916b).

Modification of mining technologies for use in the various theaters of war, to minimize the noise of underground activities, was paramount. Due to the reduced size of the tunnels, the large and efficient wagon drills utilized in railway tunneling could not be used in mine warfare. Only pneumatic portable hammer drills were used to prepare drill holes for blasting. Typically, 5–6 hours of drilling alternated with frequent stops for listening and was followed by the blast, aeration, and rock-debris haulage. Drilling operations alternating with periodic listening were preferred so that the progress of enemy work could be detected. Sometimes the noise of the drills was covered with mortar fire. For the same reason, close control of external dumps and smoke coming out of the tunnels was common practice on both sides.

In the search for new strategic drilling technologies, it is worth noting the contribution of Prof. Adolfo Viterbi (1873–1917). Professor of Geodesy at the School of Engineering at the University of Pavia, he was a volunteer Lieutenant in the 1st Regiment Sappers of the Corps of Engineers. Viterbi proposed testing drilling long holes in excess of 10 m and 10 cm in diameter to remedy the lack of underground topographic surveys to maintain tunnels direction and to detect any enemy counterattacks (report of 10 February 1917 written by Lt. Viterbi, 5th Regiment Miners of the Corps, ISCAG 1917e). According to Viterbi, these experiments were already in progress in the Carso-Isonzo area under the design and supervision of his friend, Prof. Augusto Stella (1863–1944), a mining engineer and high-level technical consultant to the Italian Army. Contrary to Viterbi, Stella was a mining technology expert: he was the first professor to hold the chair of Mining Engineering at the Universities of Turin and Rome. According to Viterbi, long-hole drilling would be a sufficiently silent operation. He proposed core drilling with diamond bits, confident that even cheaper steel-tooth bits could be used. He reports that 57.5 cm bits were used, although today, this seems technically impossible. Viterbi was a geodetic survey expert with strong military ability and was later promoted to Captain. To reduce the noise of drilling and blasting, he proposed using pure rotary instead of roto-percussion drilling (probably to be carried out with electric drills) to prepare a series of closely-spaced parallel boreholes, separated by thin diaphragms. The diaphragms were to be removed later by hand or chemical means. However, he noted the problem of power supply, which was estimated to be in excess of 100 HP. Evidence of experimental drilling tests with diamond bits, probably carried out by Stella at the experimental drilling site at Medea (Fig. 7.1), is correspondence between the Italian Army general command and some British suppliers (June to August 1917) concerning the possible purchase of industrial diamonds (ISCAG 1917e).

Together with the mechanical drilling units imported from the United States (e.g., high-class brands like Ingersoll and Sullivan) as early as 1916, the Italian industry started domestic production of drilling units. As stated by the supreme command, "since the drilling units sent by the USA were insufficient, our industry was able to supply them in large quantities" (Ministero 1936, p. 17). This was one of the results of the Industrial Mobilization Supreme Committee, a body entrusted with the task of organizing, regulating, and disciplining maximum production of war materials, to rethink the framework of the national economy and to use resources most effectively in support of the war effort. During WWI, it seems that electric drills were not used on the Italian Front, although Siemens-Halske electric drills were already in operation in Sardinian mines (Rolandi 1949). As for the design and production of domestic mechanical drilling units (mainly air compressors), the most commonly used in military operations were the following:

(a) Brusa-Marelli unit (named after the manufacturers' brand name), made up of three parts: (1) petrol engine and DC generator; (2) electric cable (200 m); and (3) DC electric motor, air compressor, flex hose (3.5 m), and air drill. The specifications for this equipment required the air compressor to be located very close to the excavation front, whereas the DC electric generator could be situated 200 m away in open-air for the safe exhaustion of combustion gases.
(b) Brusa-Svedese unit, as above, but without the DC generator: a petrol engine directly drove the air compressor. This was a skid-mounted, lightweight unit (130 kg) designed to reduce possible failures of a DC generator system. Unfortunately, it had no underground applications due to the limited possibility of extending the length of the exhaust pipe and muffler (max. 5 m), and so it was mainly used for road, trench, and bunker construction.
(c) Diatto unit, a skid-mounted, compact, and portable moto-compressor driven by a two-cylinder, water-cooled, petrol engine in line with a two-cylinder air compressor (ISCAG 1917d). It was 1.2 m long, 1.25 m high, 0.70 m wide, and weighed 350 kg. Introduced in November 1916, it was produced by the Diatto Company, a car and lorry manufacturer based in Turin.
(d) Romeo unit (also known as Small Italian), similar to the above (24 HP moto-compressor, two + two cylinders) but more easily transportable due to its modularization (ISCAG 1917g). In December 1915, Nicola Romeo, owner of a company that manufactured air compressors and other equipment for the mining industry (since 1907, he was the exclusive representative agent of Ingersoll Rand for Italy), supplied over 2000 Small Italian units to the Italian Army.

In general, air-drilling tools were the Ingersoll type, allowing a rate of penetration of 15–20 cm/min in the hard rocks of the Alpine Front. It is worth recalling that one of the major tasks of the abovementioned Military Commission for Mechanical Drilling was the management and rationalization of a regular supply of drilling materials to the operative units and, not least, the organization of efficient maintenance programs and the supply of spare parts. Documents report that in 1917, more than 10% of drilling units were under repair at the central workshops (ISCAG 1917f).

7.4.2 Underground Listening

The distinctive aspect of mine warfare is the detection and location of enemy tunneling in various types of rock. The sensitivity and number of detecting instruments and the training and skills of the "listeners" were the key to success. In 1915, a relatively limited number of listening instruments were available: in fact, geophysical sciences were still in their infancy.

Mine warfare in France and Belgium (the Western Front) was principally carried out in clay and chalk. More care is necessary for listening in soft and plastic clayey formations because excavation can be performed almost noiselessly. In fact, the Tunneling Companies of the Royal Engineers (UK) employed the peacetime technique of "clay kicking," a gouging-and-scraping excavation method that had been used to construct the London Underground system; it seems that this technique was unknown to the German engineers. Mining in chalk, on the other hand, is much noisier and more easily heard, since it is necessary to apply a chipping-and-crushing action to excavate this hard and elastic rock (Barrie 1988; Goodbody 2016).

For the French, the two most successful and easily portable instruments were the Géophone SP and the Rojet, which were very similar in construction. The French geophone was an acoustic stethoscope, made up of a pair of circular frames containing two mica discs, about 10 cm in diameter sealed by rubber rings, filled with mercury and a thin air volume. Rubber tubes connected both frames to the stethoscopic earpieces. Invented in 1915 by Prof. Jean Perrin (1870–1942) of the Sorbonne University, the Géophone SP magnified sound waves up to 2.5 times. The Germans used the Edelmann and Schmidtmann systems, with listening ranges of 20–40 m, and the Knieriem and Waetzmann systems, which in some cases, depending on the nature of soils and rocks, could extend the listening distance up to 80 m (Trounce 1938).

The Italian Army employed similar instruments beginning in late 1916. During listening, an activity that could last for many hours, the two discs were placed in contact with the floor or walls of a tunnel, and the listener knelt or sat in front of them with the stethoscopic earpieces adjusted and a compass ready for the survey; taking compass bearings was a vital part of any listening activity. The comparison of the records of different listeners allowed for triangulation, i.e., the application of geometrical calculations to locate the point of sound origin. Depending on the quality and accuracy of listeners' activity, in some cases, it was also possible to calculate tunneling direction and average penetration rate.

During the first stage of tunnel warfare on the Alpine Front, the strategic objectives were clearly identified and underground listening was not crucial; rock excavation alternating with periodic listening was preferred, to detect the progress of enemy work. For the same purpose, visual control of dumps was common practice for both sides. Hard limestone and dolomite are the prevailing rock types, and so, the only practical method to obtain an acceptable penetration rate was by drilling and blasting, a very noisy activity in itself. In Alpine mine warfare, sometimes, enemy tunnels were so close that the use of listening devices was useless.

However, a number of devices were developed and utilized on the Italian side. Apart from the geophone, many other names were used to identify the listening tools. The reports of the Italian Army use the terms microseismophones, telegeophones, seismomicrophones, and seismostethoscopes, for example, most of the time not clearly reporting the specifications (Ministero 1932). The Italian Army introduced the use of listening devices quite late: the Chief of Staff, in a letter dated 28 June 1916, anticipated the imminent arrival of "geophones" for use in underground warfare operations, after appropriate training and the preparation of instruction manuals. The Supreme Chief of Staff, Gen. Luigi Cadorna, solicited information about underground listening activities even later, in a letter dated 21 December 1916 (ISCAG 1916a).

Italy has a long tradition in the study and construction of seismological instruments. In 1856, Luigi Palmieri (1807–1896) invented an electromagnetic seismograph to monitor Mt. Vesuvius, conceived to measure direction, intensity, and duration of an earthquake, and capable of responding to both horizontal and vertical motions (Palmieri 1859, 1870). In 1898, Giuseppe Vicentini (1860–1944), professor of Physics and Seismology at the University of Padua, together with his assistant Giulio Pacher (1867–1900), constructed the Vicentini-Pacher Microsismofono Registratore, a mechanical recording microseismograph (Dewey and Byerly 1969). It was intensively used in the Mt. Pasubio area, during the last stage of Alpine mine warfare in response to the first Austro-Hungarian blast in the area on 29 September 1917 (Table 7.1). The morphology of the underground battlefield here was more complex, compared to that of the northern Dolomite Front, and a large network of tunnels was developed by both sides.

The Vicentini-Pacher microseismograph was a small and delicate instrument with both installation and maintenance problems. Its recordings were traced on smoked paper mounted on a cylinder and allowed for a rough estimation of the enemy's position by using only two instruments arranged inside small niches along the main tunnel. Prof. Vicentini supervised the field installations and preliminary tests at Mt. Pasubio in early September 1917, but the frantic warfare action in the area did not allow the planned testing activities to be fully carried out (ISCAG 1918). However, the Italian Chief of Staff deemed that underground listening activity was very important, and on 18 October 1917, ordered specific training courses for commissioned and noncommissioned officers to be held at the experimental drilling site at Medea, which at the time was also the general warehouse for Corps' drilling equipment (ISCAG 1918).

The reports of the Italian Army also describe the use of microphones and telephonic kits. These relied on the use of a particular Microfono Altisonante (high-resonant microphone), patented by Giovanni Battista Marzi (1857–1928) who, in 1886, built the first telephonic network for the State of Vatican City and Holy See. Specifically devised for listening in underground tunnels, these systems were not able to give exact indications about the direction of the sound and, according to instructions from the Italian Army Chief of Staff, they were to be utilized inside special "listening branches," excavated beside the main tunnel (Ministero 1932).

7.5 Conclusion: Post-war Evaluation of Tunnel Warfare in Italy

The Dolomites were an area of hard-fought mountain and tunnel warfare, where Austro-Hungarian and Italian engineers worked with extreme skill. Overall, on the Alpine Front, no fewer than 34 mines were fired between 1916 and 1918. The first blasts occurred in January 1916 (Lagazuoi-Col di Lana area, Fig. 7.1), although this strategy did not have the results expected in the planning phase. After this blast, there was a crescendo of frustration generated by the inability to understand that the key to the Alpine war was to bypass the peaks through the valleys, and not conquer or destroy them, immediately facing another peak to conquer. Mine warfare ended in March 1918, with the blast of 50 tons of explosives at Mt. Pasubio (Asiago-Pasubio area, Fig. 7.1).

WWI tunnel warfare used up-to-date mining engineering and explosives technologies with large use of recently developed compressed-air applications and listening activities. Most of the tunneling was carried out in hard rocks by means of explosives, with a few exceptions at the initial stage of mine warfare, or when the logistics of moving complex and heavy machinery would have slowed down the operations. In addition to the mechanical drilling units imported from the US, Italian industry started domestic production of drilling and compressor units beginning in early 1916. Original contributions included the development of large-diameter diamond coring, which, however, remained undeveloped, and the setup of a dedicated experimental drilling site at Medea.

Paramount was the rearrangement of mining technologies for use in the various theaters of war, with the need to minimize the noise of underground activities. As for tactical purposes, these activities also led to a remarkable technical development in listening tools and analog recording devices. WWI paved the way to applied geophysics in the field of micro-seismic methods for subsurface rock characterization and, last but not least, for modern oil and gas exploration, thanks to the seminal studies of Ludger Mintrop on seismic refraction.

In conclusion, mine warfare on the Alpine Front did not produce the desired effects and was not decisive for either of the opposing sides. As stated in a 1919 report by Col. Guido Bertani of the Italian Corps of Engineers, “except in very special cases, I believe that large mines are a waste of energy, explosives, and materials that is not compensated by the final results” (ISCAG 1919-1920, p. 12).

References

Baldini G (1991) L’Arma del Genio. Rivista Militare, Roma

Barrie A (1988) War underground – the tunnellers of the Great War. Tom Donovan Publ., London

Blake WP (1871) Recent improvements in diamond drills and in the machinery for their use. Trans. AIME 1:395–400

Borgatti M (1928–1931) Storia dell’Arma del Genio: dalle origini al 1914. Rivista di Artiglieria e Genio (4 volumes), Rome

Brantly JE (1971) History of oil well drilling. Gulf Publishing Co., Houston

Brighenti, G, Macini, P (2008) History of the Upstream Industry. In: Encyclopedia of hydrocarbons, vol V. Istituto della Enciclopedia Italiana Treccani, Rome, p 525–548

Burt R (2014) Diamond core drills: their invention, early development and consequences for mining and quarrying. The Mining History Journal 21:23–39

Caetani G (1919) Lettere di guerra di un ufficiale del genio - dal 29 agosto 1915 al 17 agosto 1918. Unione Tipografica Cooperativa, Perugia

Dewey J, Byerly P (1969) The early history of seismometry (to 1900). Bull. Seism. Soc. Am. 59:189–227

Di Martino B (2012) La Guerra di mine sui fronti della grande Guerra. Rossato, Valdagno

Dorion CJ (1893) Exploitation des mines. Baudry, Paris

Drinker HS (1878) Tunneling, explosive compounds, and rock drills. Wiley & Sons, New York

Fauvelle PP (1845) Un noveau procédé pour le forage de puits artesiens. Perpignan. English edn: Fauvelle PP (1845) A new method of boring for artesians springs. Journal of the Franklin Institute 12(3):369–371

Fauvelle PP (1846) Sur un nouveau système de forage par M. Fauvelle, de Perpignan (communiqué par M. Arago). Comptes Rendus des Séances de l'Académie des Sciences 23:438–440

Goodbody A (2016) Tunneling in the deep. Mining Magazine. https://www.miningmagazine.com/mining-the-past/opinion/1263557/tunnelling-deep. Accessed 29 December 2019

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1916a) Bookcase 1, box 90, folder 2, Guerra di mina e contromina. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1916b) Bookcase 2, box 149, folder 2, Commissione di controllo per la perforazione meccanica. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1917a) Bookcase 1, box 95, folder 1, Brillamento di mine e relazioni varie. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1917b) Bookcase 1, box 95, folder 3, Corsi pratici per lavori di mina. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1917c) Bookcase 1, box 100, folder 7, Corsi sugli esplosivi e appunti su lavori di mina. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1917d) Bookcase 2, box 149, folder 1, Lavori di mina ed esperimenti di perforazioni lunghe in roccia, containing letters dated 1915. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1917e) Bookcase 2, box 149, folder 4, Servizio perforazione a distanza. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1917f) Bookcase 2, box 150, folder 2, Personale e materiali impiegati per i gruppi perforatori. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1917g) Bookcase 2, box 150, folder 3, Situazione gruppi e martelli perforatori. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1918) Bookcase 2, box 151, folder 3, Materiali e mezzi per l'ascoltazione sotterranea. Rome

Historical and Cultural Institute of the Italian Corps of Engineers Archives (ISCAG) (1919-1920) Bookcase 5, box 486, folder 1, Studi particolari sui minatori in guerra e Invenzioni varie. Rome

King CB (1894) Pneumatic tool. US Patent 513,941, 30 Jan 1894

Lesca C (1998) Tre ingegneri per un traforo: la storia della ferrovia del Frejus. Melli, Borgone di Susa

Leyner GJ (1900) Rock drilling engine. US Patent 651,487, 12 June 1900

Lynch AJ, Rowland CA (2005) History of grinding. Society for Mining, Metallurgy, and Exploration, Littleton, CO

Ministero della Guerra. (Ministero) (1929) L'esercito italiano nella grande guerra, vol II, Le operazioni del 1915. Poligrafico dello stato, Roma

Ministero della Guerra (Ministero) (1932) L'esercito italiano nella grande guerra, vol VI, parte I, Le istruzioni tattiche del Capo di Stato Maggiore dell'Esercito. Poligrafico dello stato, Roma

Ministero della Guerra (Ministero) (1936) L'esercito italiano nella grande guerra, vol III, Tomo I & II, Le operazioni del 1916. Poligrafico dello stato, Roma

Ministero della Guerra (Ministero) (1954) L'esercito italiano nella grande guerra, vol IV, Le operazioni del 1917. Poligrafico dello stato, Roma

Nebeker F (2009) Dawn of the electronic age: electrical technologies in the shaping of the modern world, 1914 to 1945. Institute of Electrical and Electronics Engineers, Hoboken, NJ

Palmieri L (1859) Il sismografo elettromagnetico. Annali del Regio Osservatorio meteorologico Vesuviano 1859:20–24

Palmieri L (1870) Seismographe electro-magnétique. Annali del Regio Osservatorio meteorologico Vesuviano 1870:225–245
Pistolesi C (2011) L'età delle miniere. L'industria mineraria italiana dall'Unità alla seconda Guerra mondiale. Archivinform, Venturina
Pontecorvo L (1935) Perforatrice. In: Enciclopedia Italiana Treccani. Istituto della Enciclopedia Italiana Treccani, Rome
Rolandi G (1949) Notizie sull'industria del piombo e dello zinco in Italia. Società Italiana del Piombo e dello Zinco, Montevecchio
Sammuri P (2015) Italian mines and miners in First World War. Rend. Online Soc. Geol. It. 36:110–114
Schramm J-M (2011) Geology and High Alpine Warfare during World War I. Häusler H, Mang R (eds) International Handbook Military Geography: Proceedings of the 8th International Conference on Military Geosciences, vol 2. Arbeitsgemeinschaft Truppendienst, Ministry of Defence and Sports, Vienna, p 443–456
Striffler R (1993) Le 34 mine fatte brillare sul fronte alpino tirolese 1916-1918. Aquile in guerra, Società Storica per la Guerra Bianca 1:43-46. German edn: Striffler, R (2000) Die 34 Minensprengungen an der Tiroler Gebirgsfront 1916-1918. Fortifikation 14:89–95
Traniello V (1928) Il Pasubio e la Guerra di mine. Rivista Militare Italiana 2(2):195–227
Trounce HD (1938) Military mining. The Military Engineer 30(169):58–61
Vianelli M, Cenacchi G (2006) Teatri di Guerra sulle Dolomiti. Mondadori, Milano

Chapter 8
The World War I Tactical Maps of the Italian Army: Proposals for a Typological Classification, an Interpretation of Symbols and a Digital Analysis of the Cartographies in the Historical Archive of the Third Army

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Contents

Abstract Innovations in military operations during the First World War have been widely documented by international historiography. The necessities of trench warfare and their consequences in the production of military maps, however, still require in-depth study. Accordingly, this paper addresses military maps preserved in the Historical Archives of the Italian Third Army in Padua, Italy. The Third Army had a

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crucial role in the conflict, as it settled along the Piave River after the Retreat of Caporetto and later led the final advance toward Istria. We focus on tactical maps, i.e., maps that were continuously updated during battle, to show the evolution of frontline positions and activities. The analysis of this map collection opens a new research path for interpreting map symbols and typological classification categories depicted on military maps. Major attention has been paid to the Italian Istituto Geografico Militare printed maps that were continuously updated by hand on the battlefield during military operations. First, the map corpus is described; second, a typological classification and semiotic decoding (based on interpretation of the map symbols) is carried out; and finally, a digital analysis using georeferencing and data vectorization of troop movements and battlefield dynamics is presented.

Keywords Military cartography · First World War · Historical geography · Historical GIS · Tactical maps · History of cartography

8.1 Introduction

The interpretation of the First World War (WWI) as a watershed, with reference to the history of military cartography, was raised in 2014 at the 5th International Symposium of the International Cartographic Association (Liebenberg et al. 2016). This discussion inaugurated a research path culminating in a special issue of the 2018 International Journal of Cartography. Essays dealt with map production in the British, American, Russian, German, and Austro-Hungarian armies, and included an in-depth study of the advances in photogrammetry and its role in the conflict (Chasseaud 2013; Collier 2015b; Schneider 2017; Demhardt 2018).

Since the dawn of their history, *ars bellica* (the art of war) and cartographic practices have been closely linked (Lacoste 1976). For a long time, the knowledge and representation of space have been directly subjected to political and military activities. Since the end of the nineteenth century, the evolution of military sciences and military operations, as well as the progressive professionalization of geographical studies and cartographic production, led to a remodeling – but certainly not to an attenuation – of this link (Francis 2014). The First World War represented a significant turning point because of the unprecedented mobilization that involved science and technology in the conflict and the advances developed during its course (Collier 2015a, b; Fox 2018). For these reasons, international studies agree in defining WWI as “indeed a terrible mother of invention” (Demhardt 2018, p. 241).

Until now, international literature has neglected the Italian situation. However, several Italian scholars from the field of historical geography have begun to address it (Bondesan and Scroccaro 2016; Dai Prà 2018; Masetti 2018; Chirico and Conti 2018). In this paper, we analyze a selection of the military maps produced and used by the Army of the Italian Kingdom during WWI. The cartographic corpus of the Historical Museum of the Third Army in Padua has been chosen for this case study because it consists of a unitary set of documents that have been preserved since the end of the conflict. Among the different types of maps and aerial photos produced during the war, our work focuses on tactical maps, those that were updated daily during battle to depict the evolution of front line positions and activities.

Our aim is to propose an initial approach to the analysis of Italian military maps produced during WWI to shed new light on both the role of cartography in the conflict's strategies and tactics, as well as the impact of the war on cartographic practices. First, the corpus of maps is described; second, a typological classification and semiological decoding based on the interpretation of the symbols used on the maps is presented; and finally, a digital analysis using georeferencing and vectorization of data is outlined. The latter includes a solution for the digital representation of troop movements and battlefield dynamics using the QGIS software (https://www.qgis.org/en/site/ accessed 27 July 2020).

8.2 The Documentary Corpus of the Italian Third Army

The Third Army played a crucial role during WWI. In May 1915, it was positioned in the Carso and Trieste areas of operations (SW of the border front between the Italian Kingdom and the Hapsburg Austro-Hungarian Empire) with the initial task of containing attacks carried out by the Austro-Hungarian Army (Fig. 8.1).

Fig. 8.1 Location map showing the border between the Austro-Hungarian Empire and the Italian Kingdom before and during WWI, with place names indicating the areas of the Third Army operations

Command of the Italian Army was entrusted to General Emanuele Filiberto of Savoy-Aosta; Cervignano del Friuli was designated as headquarters in the war zone. The Third Army gained a prominent role during the Isonzo battles, which lasted from June 1915 to the late summer of 1917. The battle of Caporetto (24 October to 19 November 1917) resulted in the collapse of the Italian Front and advance by the Austro-Hungarian Army of more than 100 km in the direction of Venice. The Third Army had retreated to the Piave River line without having been directly defeated and thus, rightfully earned the title of "The Unbeaten." From there, it was able to contain the Austro-Hungarian advance to participate in the battle of Vittorio Veneto (24 October to 3 November 1918) and to lead the final advance to Istria and Trieste (Jung 2000; Morselli 2001; Gibelli 2007).

After the end of the war in July 1919, the Third Italian Army was dissolved. Most of the documents related to its activities were divided between the Ufficio Storico dello Stato Maggiore (Historical Office of Italian Army High Command) in Rome and local archives in Padua. In 1956, General Alberto Aliberti, the head of the Italian Northern Interregional Defence Forces Command, established the Historical Museum of the Third Army (Museo Storico della Terza Armata) in Padua to safeguard local relics and documentation. The museum houses numerous historical sources – only partially inventoried – which were produced during WWI by the Central Command or by the offices and subordinate bodies of the Third Army. The archive contains about 13,000 text documents, 4,000 volumes, 5,000 aerial and ground photos, and 1,000 maps, focusing primarily on the Carso and the Basso Piave areas. This documentary corpus has a heterogeneous composition including photo albums, reports, trench newspapers, and manuscripts written by officers and their subordinates, in addition to war bulletins, telegrams, pigeon-post, and correspondence. Despite – or thanks to – this heterogeneity, this archival collection provides a basis for understanding the daily routine in the Third Army during the war years.

The map collection itself is a complex documentary *corpus*. The maps produced between 1914 and 1919 are heterogeneous, as they were prepared using different procedures to meet the varied needs of the troops during the military operations. Recently, these WWI maps have been organized into different categories based on their content and use (Dai Prà, Gabellieri 2020a). The five categories include base maps, tactical maps (representing the locations of troop units, artillery positions, and defensive lines, or those created for artillery calculation purposes), predictive maps (for the planning of offensives), engineering maps (for the identification or planning of bridges, transport, long-distance communication or defensive flooding), maps prepared specifically for Allied armies, and intelligence maps (copied from captured enemy maps or produced using information collected by spies or during aerial surveys).

8.3 The Tactical Maps

At the outset of the war, the Italian Army was equipped with the *Grande Carta topografica del Regno d'Italia*, a comprehensive map of the territory of the Kingdom developed by the Istituto Geografico Militare (IGM; Military Geographic Institute) at a scale of 1:100.000 (Cantile 2013). For the most important strategic areas (such as the NE regions close to the border with the Austro-Hungarian Empire), more detailed sheets at a scale of 1:25.000 (the IGM *tavolette*) were available. Starting from May 1915, the IGM focused its activities on the support of the Italian Army.

Throughout Europe, the rapid transformation from a war of movement to a war of position prompted an equally rapid change in the use and the very nature of military cartography (Chasseaud 2013). The dynamics of the clashes, with battles that often raged for days within a few square kilometers, made it necessary to use large-scale maps almost exclusively. For example, updated, accurate, and precise topographic maps were fundamental tools for the calculation and planning of artillery fire. Furthermore, troop positions changed daily, rendering maps rapidly obsolete, and requiring the maps to be replaced or updated quickly.

To gain better knowledge of the battlefield, and especially due to the new nature of the conflict as a trench war, it was necessary to prepare even more detailed maps at a new scale of 1:10.000 by photomechanical enlargement of the available 1:25.000 sheets. Geometrical elements such as geographic grids were added to some sheets, to facilitate artillery calculations (Collier 2015b; Cantile 2019). Around 20,000,000 maps of the battlefields were printed by the IGM during the conflict to supply Central Command and the frontline units (Mori 1922).

Despite these efforts, IGM maps were unable to meet the needs of headquarters and local commands, both of which required constantly updated maps showing day-by-day changes at the front. Therefore, daily maps were produced using the IGM sheets as a base and adding handwritten information on the location of troops, artillery identification, and the positions of trenches, as well as other data that could be of relevance to military operations. These continuously updated maps produced to represent the constant changes on the battlefields were used by all the armies involved in the war and are referred to as tactical maps (Chasseaud 2013; Schneider 2017; Espenhorst 2018).

Tactical and strategic information about the state of enemy positions was obtained from the reports of troops, interrogation of prisoners, enemy maps taken as spoils of war, and most importantly, from the interpretation of aerial photographs. Despite the limits of a technical field that was still developing, aerial photographs and their interpretation allowed information services to collect a large amount of both systematic and general data: "From being a tool of interest to a relatively narrow group of surveyors and instrument designers, photogrammetry moved into the mainstream" (Collier 2018, p. 286). As a matter of fact, the use of the Air Force for intelligence purposes was one of the most important advances in military operations during the war. Camera design and photographic technologies had undergone significant improvements in the 1910s (Espenhorst 2016; Carbone and Ciaschi 2018). The Air Force or the Centro di Raccolta Informazioni (Centre for Collecting Information) collected data over the front and then shared it with Army headquarters and its cartographic offices (Dai Prà and Gabellieri 2020b).

However, military reconnaissance flights were not the only innovation. During the conflict, armies experimented with new weapons, defensive and offensive strategies, and new technologies (Fox, 2018). For example, innovations such as machine gun positions and trenches required the creation of new symbols and taxonomies to be recorded on the maps. Each map was then provided with a special legend necessary at a time when the symbolic categories were not yet adequately codified and universally shared. Initially, the date (and sometimes even the time of creation) was recorded on each sheet, demonstrating the transitory nature of these maps.

8.4 The Maps Produced in the Last Years of the War

Because the tactical maps represented daily situations, they were continually destroyed and replaced with new and updated ones. For this reason, most of the preserved maps date from the last two years of the war. The maps prepared in the last few months of the war, between 1 June and 30 November of 1918, form a homogeneous collection: 203 maps comprise this series. They depict the final advances of the Third Army from the Piave River into the Istria region within the territory of the Austro-Hungarian Empire (Fig. 8.1).

The counteroffensive on the Piave River and the subsequent advance towards Istria began in October 1918. The maps, which were produced daily or even more frequently, show the gradual progression of the Third Army battalions and brigades through time towards the east. The last map, produced on 10 July 1919, after the end of the conflict, shows the position of the Italian occupation troops in Trieste and Istria.

As noted above, the maps in this collection were produced to record the daily positions of Italian troop units. They show, with a high level of detail, the changing front. Since they were produced when the Austro-Hungarian Army was retreating and the Italian Army was occupying new territory every day, their aim was to record the location of the advancing army, not the positions of enemy defenses. The maps display battalions, brigades, and changing artillery positions, as well as the locations of headquarters and supply units. Different symbols and colors are used to mark their position. On the bottom of each map, the cartographers have noted the production date. In contrast to other map series, the ones in this collection have no grid. This absence indicates that they would not have been used for artillery barrage purposes.

Figure 8.2 shows one of the first maps in the collection. It records the troop positions (both on the front line and in the rear), the names or the codes of the brigades and battalions present, the names of the division commanders, and precisely when it was produced (2 June 1918, morning). At the bottom of the sheet, the code

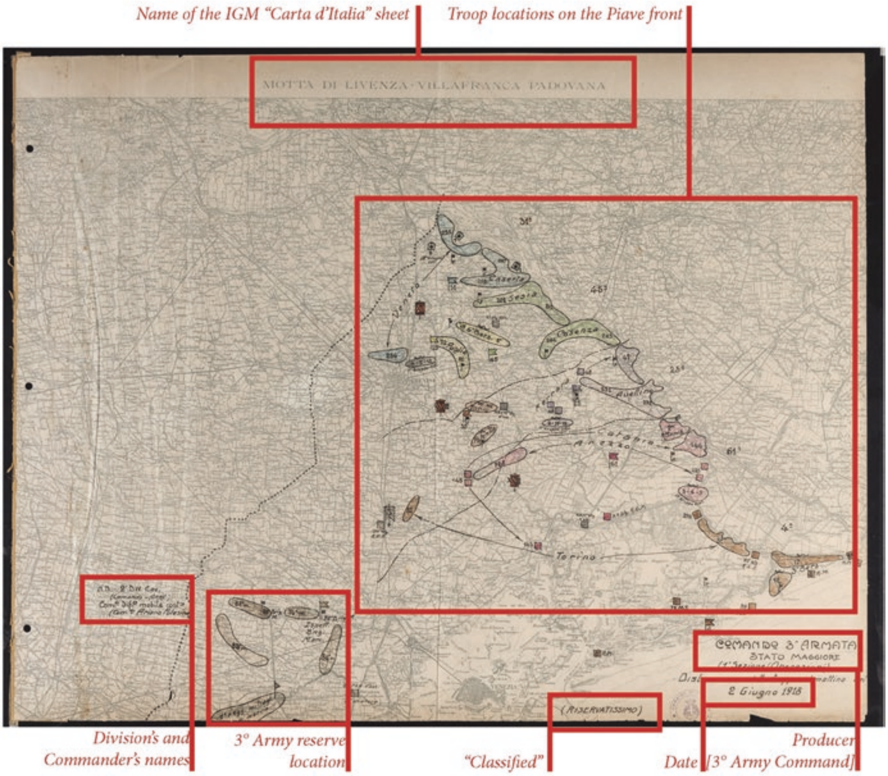

Fig. 8.2 Overview of a tactical map showing unit locations on 2 June 1918, with data and information highlighted. (Modified from HA 1918a; used with permission from Director of the Museum of the Third Army, Padua)

Riservatissimo (Top Secret) indicates that this map was intended to be used only at the command level, and not at the front, as it contains sensitive information, which should not fall into enemy hands. Only some of the analyzed maps have the code *Riservatissimo* written on them.

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Some of the data inscribed on the maps differ slightly among the documents, as shown on the map of Fig. 8.3, which highlights the division of the front into different sectors. In Fig. 8.4, a map created on 1 November 1918, after the beginning of

Fig. 8.3 Example of a tactical map showing unit locations on 17 June 1918 with the front line divided into sectors. (From HA 1918b; used with permission from Director of the Museum of the Third Army, Padua)

the offensive arrows, indicates the forward movement of the troops. Due to the new battalion positions, the division into sectors has completely changed.

Whereas all the maps produced prior to 2 November 1918 covered the same geographic area, beginning on 3 November, the base sheet was altered to map the changing unit positions during the offensive. Figure 8.5 shows a map composed of three different sheets, which represent the territory between Trieste, Udine, and Venice through which the troops were advancing.

8.5 A First Analysis of the Symbols Adopted on Military Maps

The cartographic corpus described in the previous section consists of a series of printed IGM maps enriched with handwritten information that has been added in pencil and pen. The purpose of these maps was to provide headquarters with timely available information about the state of the battlefield. These documents are a

Fig. 8.4 Example of a tactical map showing unit locations and movements on 1 November 1918. (From HA 1918c; used with permission from Director of the Museum of the Third Army, Padua)

Fig. 8.5 Example of a tactical map composed of three sheets showing unit locations during the advance toward Trieste in November 1918. The attribute *approssimativo* (approximate) in the map name demonstrates that the situation was rapidly changing. (From HA 1918d; used with permission from Director of the Museum of the Third Army, Padua)

particular case/set of thematic maps, which had to meet the daily needs of troops as well as solve the problems posed by accurate representation of mobile battle formations and inclusion of novel equipment. Machine guns, bunkers, and other war innovations required parallel innovations in map symbolism.

Analysis of these old maps and handwritten updates confirms the artistry and attention to detail by the technicians and military experts of the time, as well as their ability to interpret tactical aerial photographs. A careful analysis of the map symbols is necessary to gain a full understanding of the information contained in the thematic maps (Delano-Smith 2007; Dai Prà 2013). Such an assessment can be even more fruitful in a period of cartographic innovation like that of WWI.

As noted above, the tactical maps in this period were produced using daily reports by field unit commanders and the interpretation of aerial photographs from aerial reconnaissance operations. The information obtained from aerial photography had to be processed before being transcribed onto the maps. The transcription, called the reporting process, consisted of subjective interpretation involving at least three steps/individuals of the person who collected the data, the person who transmitted it to the cartographic offices, and the mapmaker himself. During the last year of the war, cartographers already had a settled inventory of usable symbols at their disposal, which had been previously developed and tested and which was probably known to everyone at the time. This is suggested by the absence of a legend on most of the later maps. The symbol taxonomy remained unchanged in the entire map corpus. However, despite this homogeneity, differences in style among the tactical handwritten maps should also be noted. For example, on some maps, the Piave Front during the defensive phase is divided by dotted lines into different areas of operation defined by Roman numerals (Figs. 8.2 and 8.3). These are further divided into sectors; others are divided into subareas that are identified with a letter plus numbers in succession. This methodology for classifying different sectors was abandoned during the offensive.

A focus on the use of semiology suggests that some symbols were useful for the Army: flags, squares, banners, standards, or ensigns were, therefore, directly related to the respective military symbols. The symbols used on the maps to represent units on the battlefield include squares, circles, flags, and rectangles, which indicated the different levels of the command structure in the Army. For example, a square corresponds to a battalion (or to part of one), which at that time was the basic field unit; a square with a dot, to a battalion equipped with artillery; and a colored polygon, to the area in which the battalion was quartered. Due to the limited availability of colored pencils, the chromatic range was limited, and, in many cases, colors were repeated for different brigades.

A square with a small anchor inside indicated Royal Navy battalions, revealing the presence of naval units on the Piave Front located next to the coast. A square containing two colors indicated a cavalry battalion or squadron. The names of the brigades (named after cities or geographical areas, e.g., Foggia or Veneto) and the numeric codes (in Arabic numerals) of the battalions are written in pencil next to the symbols, in order to easily identify them. The names of the brigades are written in full.

The different colors indicated the different brigades composing the battalions. Commands are represented by flags: a banner with Roman numerals indicates the Commands of the Army Corp, a colored flag corresponds to brigade command, and a small black flag is a battalion command. Specifying the hierarchy of the units can provide a comprehensive view, offering a full understanding of the key or legend. The order is, from largest to smallest: armies, corps, divisions, brigades, regiments, battalions, companies, platoons, and squads.

By comparing these symbols with existing legends from other contemporary maps, plus using guidelines written by the Ministry of War before the conflict (Ministero della Guerra, 1912) and the cartographic standards of the following years, an interpretation of the different symbols has been developed and is shown in Fig. 8.6.

Even artillery and machine guns had different symbols, depending on the type. The basic symbol defining an artillery unit during the war was a circle so that it would be immediately differentiated from infantry units: in this case, the standardization used during the war completely diverges from the cartographic symbols

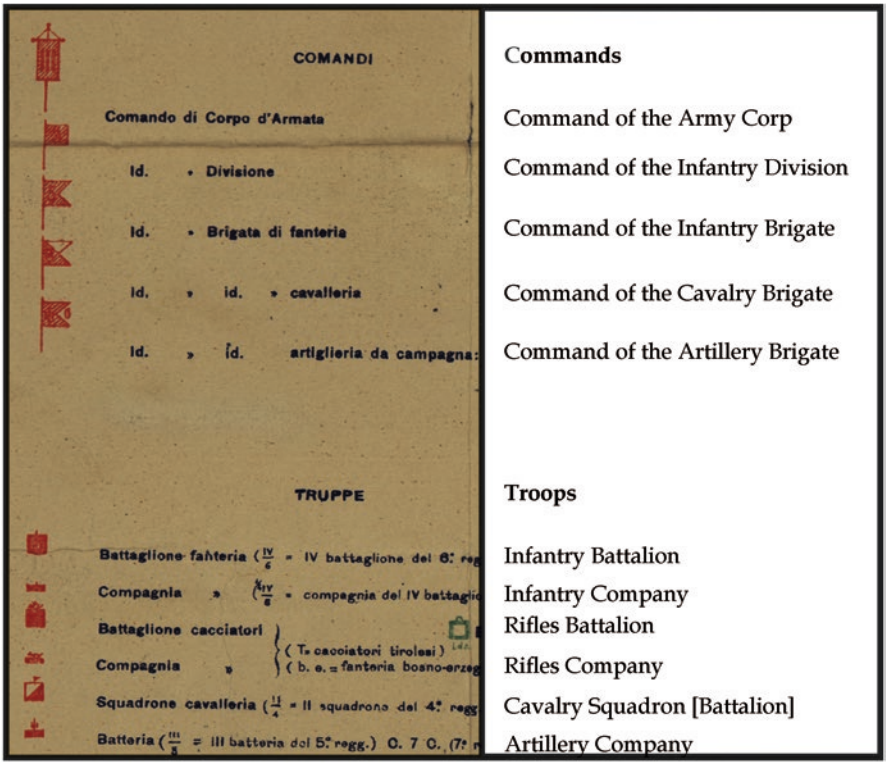

Fig. 8.6 One of the legends from the Third Army military maps that has been used for deciphering the symbols used on the maps produced late in the war. (Modified from HA 1915a; used with permission from Director of the Museum of the Third Army, Padua)

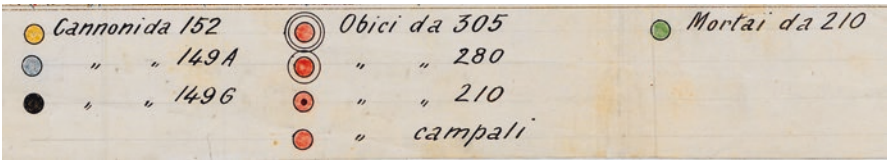

Fig. 8.7 Example of a legend with different symbols for each type of artillery piece. Different colors refer to different guns (cannon, yellow; howitzer red; and mortar, green). The taxonomy specifies the caliber of the gun (from heavy to light, such as the *campali*). The letter specifies the material from which the cannon is made, with "A" indicating steel (*acciaio*), and "G," cast iron (*ghisa*). (From HA 1915b; used with permission from Director of the Museum of the Third Army, Padua)

developed by the Ministry of War before the conflict when an artillery unit was shown with a circle with many lines inscribed and overwritten according to a different type of guns (as in Ministero della Guerra 1912), in favor of simpler and more easily understood symbols. Different colors represented the type and nature of artillery pieces (e.g., cannon, howitzers, mortars, and bombards). As shown by the legend in Fig. 8.7, the different sizes and colors of the circles were related to the size of the guns. The number is related to the caliber of the piece, and the letter specified the material. In this case, the map legend shows the presence of older cannons made of cast iron (letter G, *ghisa*), together with modern cannons made of steel (letter A, *acciaio*). Although steel and cast iron cannon were the most common during the war, some maps also indicated that bronze cannon (B) from the nineteenth century were still being used by the Italian Army.

According to Chasseaud (2018), at the end of the war, the armies of three of the allied countries (United Kingdom, France, and Italy) had developed a shared and common symbology for most war elements to be depicted on maps. These symbols, which differed from those used by other countries such as Germany, the United States, and Russia (the USSR after 1922), remained mostly unchanged until the Second World War when other innovations in military operations and mapping technologies resulted in changes in map evolution (Hershey 2012). In 1949, with the establishment of the North Atlantic Treaty Organization (NATO), the use of a new coherent and standardized taxonomy, largely inspired by that developed in the United States, became mandatory. Even though it has been slightly modified, it is still in use and has been incorporated into the APP-6A NATO Standard (US War Department 1941; Traversi 1968; Stato Maggiore dell'Esercito 2000).

8.6 A Digital Analysis and Visualization: From Georeferencing to the Time Manager Plugin

According to Burrough (1986, p. 6), a Geographical Information System (GIS) is "a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes," or the software environment that allows the data to be organized in a database management system.

GIS software is nowadays applied to the production of geographical information to understand spatial dynamics in many different disciplines. Among them, Historical GIS (HGIS) has been defined as an interdisciplinary research tool that can integrate the most advanced techniques and tools from geographical information sciences with the sources and the methodologies of historical and geohistorical research. By these means, researchers can reach a better understanding of past spatial dynamics and collect data for historical interpretations (Gregory 2002; Knowles 2002; Grava et al. 2020).

For example, HGIS has been successfully applied to the study of the First World War to identify the physical heritage of the war such as trenches and bunkers. The digitization, georeferencing, and vectorization of battlefield aerial photos, by which trenches can be identified in the current landscape, is one of the main methods of battlefield archaeology (Stichelbaut 2005, 2006). GIS software can also be used to process WWI tactical maps to create a comprehensive geodatabase. For instance, HGIS was developed in the fields of military history and military geohistory utilizing historical maps as the main source to identify routes followed by armies (Piovan et al. 2017), assess planimetric accuracy of historical military maps (Giordano and Nolan 2007), or reconstruct battlefields and the strategies used in some of the most important battles in history (Maio et al. 2013).

Maps provide different information from aerial photos. First, they can represent features of the battlefield not visible in photos (for instance, names of military units or headquarters and supply locations); moreover, the integration of multiple maps can allow reconstruction of day-by-day events along a front. Secondly, maps contain extracted and symbolized data that are more easily understood than aerial photos, particularly for identifying hidden positions or for recognizing various types of artifacts (e.g., the military road, path). On the other hand, maps, as selected reproductions of real spaces, have inherent limitations: they often only record some of the elements or can have imprecision in location.

The maps produced during the final offensive have been digitized and georeferenced using IGM maps as bases; the information contained in them has been vectorized whenever possible (Fig. 8.8). Twelve maps were digitized and information, including the positions and the name of units on each map, were vectorized in the form of point elements. In order to focus on the advance to Trieste in the last months of the war, one map for each month from 17 June 1918 to 17 October 1918, plus four maps representing changes from 17 October to 17 November 1918 when the military situation changed faster, were digitized. The last digitized map was produced on 10 July 1919 and shows the brigade quarters in occupied Istria; it is the last one produced before the dissolution of the Third Army. In this way, it has been possible to develop a geodatabase with registered positions of the different brigades for each day.

The areas controlled by each Italian or Austro-Hungarian Army on the eve of the outbreak of the conflict, as well as those of the Third Army units on the Piave Front, and the changes over time have been pinpointed. The digitized corpus will be increased in the future: for example, the daily nature of the data on the various maps will allow the identification of the topographic position of each brigade and battalion as well as the reconstruction of its advance.

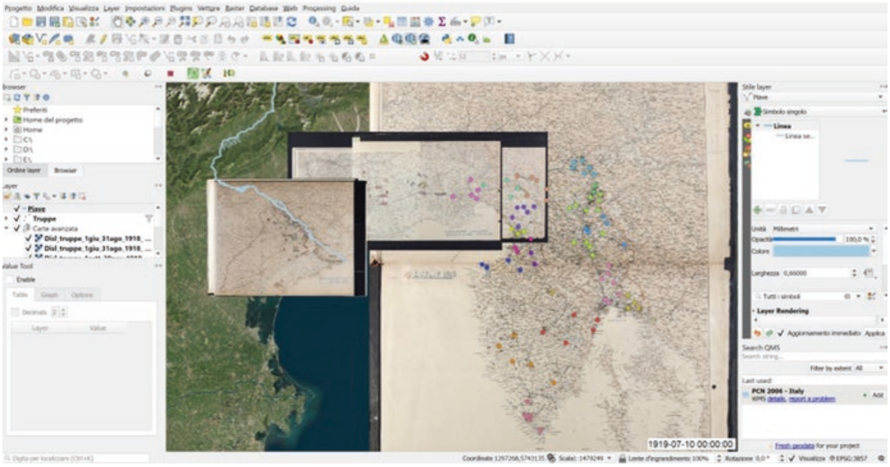

Fig. 8.8 Screen caption of the HGIS with georeferenced maps and vectorized data, such as the locations of battalions

Using the new QGIS Time Manager Plugin (see https://plugins.qgis.org/plugins/timemanager/ accessed 31 July 2020), it has also been possible to make a video showing progress during the final stages of the war. Time Manager is a plugin of the QGIS software that allows spatial data to be animated and visualized. The attribute table of a vector layer needs to have a time data parameter, in the form of a date and the time of day. The Time Manager plugin has great potential as it allows integration of the time data parameter in software developed essentially to focus on synchronic analysis (Stuckey 2017). It has been successfully applied to map social and environmental changes that have occurred over time (Zehele 2015; Lovejoy 2019).

Time Manager is a simple and effective tool for visualizing tracking data such as troop movements. Our dataset contains 669 positions for 88 battalions in 36 brigades collected from 12 tactical maps produced between 16 June 1918 and 7 July 1919. The plugin automatically filters the point elements related to a particular date, showing their different positions each day. The points appear and disappear on the map according to the configured time lapse. It is possible to use different images in the background, such as the original topographic maps, or contemporary aerial photos from the Bing website that are integrated into the Plugin.

Individual images from each time frame can be exported and then converted to a video using a movie maker application. In this way, an animation that shows the different positions of brigades and battalions through time has been developed (Fig. 8.9). The Third Army appears to be settled on the Piave River Front until October 1918, with only limited battalion movements. The advance began in November 1918, and the troops moved quickly into the current Veneto and Friuli territories. By July 1919, the Army controlled the whole Istria peninsula. In addition to carrying a high information value, especially during the offensive, the final video is based on the topographical location of each battalion.

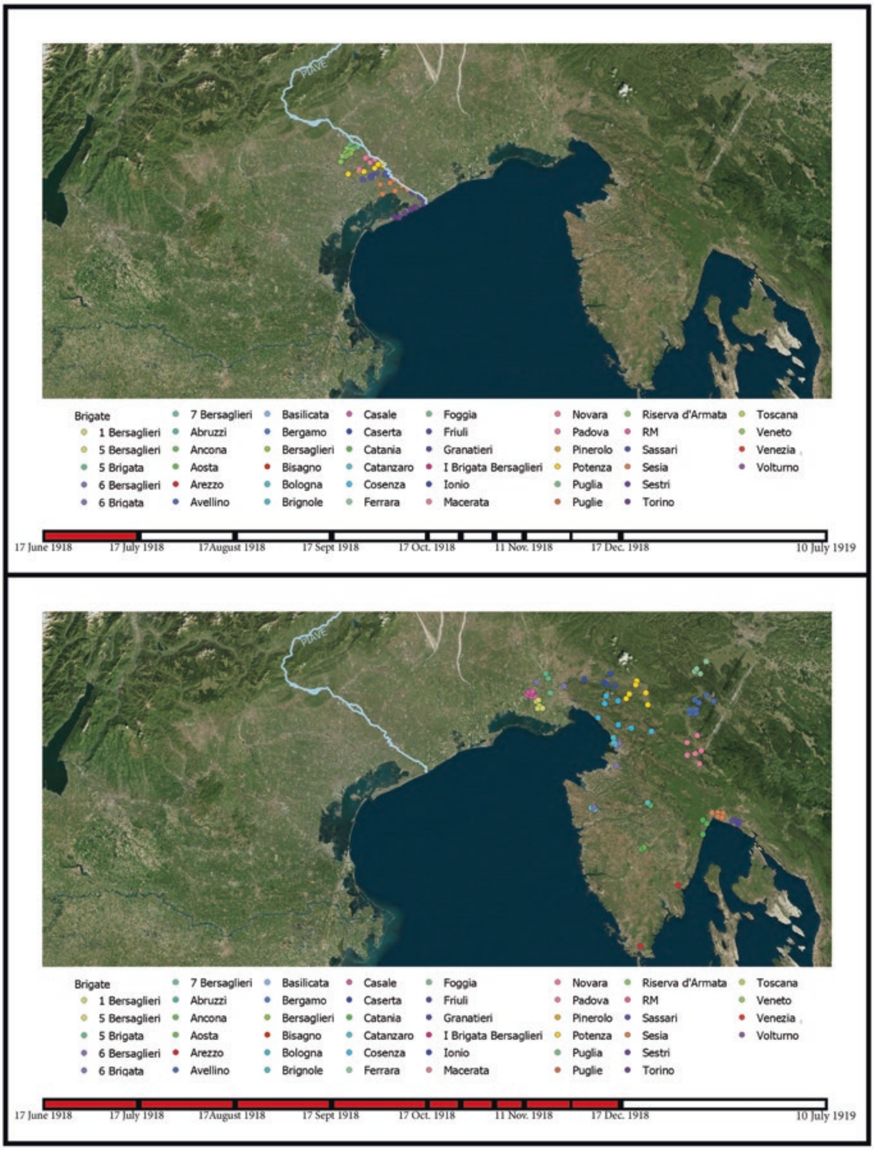

Fig. 8.9 Frames from the video showing the advance of the Third Army towards Istria from June 1918 to July 1919, developed by analysis of digitized historical tactical maps using the QGIS plugin, Time Manager

8.7 Conclusion: Military Maps as Both a Source of Information and a Cultural Heritage

Military geohistorical sources, such as maps and aerial photographs, are a heuristic device with multiple values. They are relevant both for the rediscovery of military events and their spatial analysis (Knowles 2013) and for gaining a better understanding of spatial dynamics and their application to territorial management and planning (Fuchs et al. 2015).

Large-scale tactical maps, as well as smaller-scale operational maps, had great importance in tactical operations and the planning of military operations during the First World War. Research using the archival collections of the Museum of the Third Army in Padua allowed access to documents related to cartographic production during the war. Additional textual and cartographic documents are housed in other archives located in different barracks; these need to be identified and inventoried.

In particular, it appears urgent not only to safeguard the cartographic documents from oblivion and dispersion but also to refine, with an appropriately critical approach, the tools and categories of analysis and taxonomic classification required for the study of symbols and for a critical interpretation of this documentation. Such intervention is necessary to allow scholars and members of the armed forces to fully understand and easily gain access to such data. This ambitious path can open a new and unique opportunity for bilateral knowledge exchange and common effort between the Italian Army and civilian academic institutions, in order to approach and assess such a complex field of research.

In order to enhance these sources and to make them accessible to the larger public, digital procedures should be developed. According to Azzari (2010), digitizing historical maps makes it possible to increase the range of analysis methods, to preserve them, and to share them via the web or other user-friendly interfaces (Azzari 2010; see also Jobst 2011). The construction of an HGIS for First World War battlefields could be useful for gaining a better understanding of war dynamics, as well as for developing media tools that can be used in various ways for public dissemination and education. In this case, the Time Manager video of the final advance in Italy at the end of the First World War will be screened at the Museum of the Third Army in Padua.

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References

Azzari M (2010) Prospettive e problematiche d'impiego della cartografia del passato in formato digitale. Bollettino AIC 138:217-224

Bondesan A, Scroccaro M (eds) (2016) Cartografia militare della I Guerra Mondiale. Cadore, Altopiani e Piave nelle carte topografiche austro-ungariche e italiane dell'Archivio di Stato di Firenze. Edizioni Antiga, Treviso

Burrough PA (1986) Principles of Geographic Information Systems for land resource assessment. Clarendon Press, Oxford

Cantile A (2013) Lineamenti di storia della cartografia italiana. Geoweb, Rome

Cantile A (2019) Il contributo dell'IGM alla Grande Guerra. In: Dai Prà E. (ed) Cesare Battisti, la Geografia e la Grande Guerra. CISGE, Rome, p 35-46

Carbone L, Ciaschi A (2018) La Grande Guerra vista dall'alto. In: Masetti C. (ed) Per un Atlante della Grande Guerra. Labgeo Caraci, Rome, p 167-174

Chasseaud P (2013) Mapping the First World War: the Great War through maps from 1914 to 1918. Collins, London

Chasseaud P (2018) British military mapping on the Western Front 1914–18. International Journal of Cartography 4(3):245-271. https://doi.org/10.1080/23729333.2018.1508400

Chirico M, Conti S (eds) (2018) La Grande Guerra. Luoghi, eventi, testimonianze, voci. Aracne, Rome

Collier P (2015a) Warfare and cartography. In: Monmonier M (ed) Cartography in the Twentieth Century. History of Cartography, vol VI. The University of Chicago Press, Chicago, p 1696-1700

Collier P (2015b) World War I. In: Monmonier M (ed) Cartography in the Twentieth Century. History of Cartography, vol VI. The University of Chicago Press, Chicago, p 1770-1775

Collier P (2018) The development of photogrammetry in World War 1. International Journal of Cartography, 4(3):285-295. https://doi.org/10.1080/23729333.2018.1497439

Dai Prà E (2013) La carta, processo interpretativo plurimo: dall'analisi semiologica allo studio del territorio. In: Dai Prà E (ed) APSAT 9. Cartografia storica e paesaggi in Trentino: approcci geostorici. SAP, Mantua, p 133-156

Dai Prà E (ed) (2018) Cesare Battisti geografo e cartografo di frontiera. CISGE, Rome

Dai Prà E, Gabellieri N (2020a) *Imago proeli*. La cartografia storica della Prima Guerra Mondiale del Museo Storico della 3° Armata: spigolature per una analisi tipologica e semiologica. Bollettino della Società Geografica Italiana, 14(3):59–79

Dai Prà E, Gabellieri N (2020b) Cartografia, aerofotogrammetria e intelligence dell'Esercito Italiano durante la Grande Guerra. Gnosis, 16(1):70-81

Delano-Smith C (2007) Signs on printed topographical maps, ca. 1470 – ca. 1640 In: Woodward D (ed) Cartography in the European Renaissance, vol III, Part I, The History of Cartography. The University of Chicago Press, Chicago, p 258-280

Demhardt IJ (2018) A terrible mother of invention: cartographic progress during World War I. International Journal of Cartography 4(3):241-244. https://doi.org/10.1080/23729333.2018.1522741

Espenhorst J (2016) The eye of the Army. German aircraft and the aero cartography in World War I. In: Liebenberg E, Demhardt IJ, Vervust S (eds) History of Military Cartography. Springer International, Heidelberg, p 61-82

Espenhorst J (2018) Germany and Austro-Hungary: the cartography of the defeated. International Journal of Cartography 4(3):308-335. https://doi.org/10.1080/23729333.2018.1496629

Fox A (2018) Learning to fight. Military innovation and change in the British Army, 1914-1918. Cambridge University Press, Cambridge

Francis RA (2014) On war (and geography): engaging with an environmental frontier. Progress in Physical Geography 38(3):265-270. https://doi.org/10.1177/0309133314534597

Fuchs R, Verburg PH, Clevers J et al. (2015) The potential of old maps and encyclopaedias for reconstructing historic European land cover/use change. Applied Geography 59:43-55. https://doi.org/10.1016/j.apgeog.2015.02.013

Gibelli A (2007) La grande guerra degli italiani. Bur, Milan

Giordano A, Nolan T (2007) Civil War maps of the Battle of Stones River: history and the modern landscape. The Cartographic Journal 44(1):55-70. https://doi.org/10.1179/000870407X173850

Grava M, Berti C, Gabellieri N et al. (2020) Historical GIS. Strumenti digitali per la geografia storica in Italia. Associazione Italiana di Cartografia, Edizioni Università di Trieste, Trieste

Gregory I (2002) A place in history: a guide to using GIS in historical research. Oxbow, Oxford

Hershey A (2012) Not just lines on a map: a history of military mapping. Strategy & Tactics 274(23):22-27

Historical Archive of the Third Army (HA) (1915a) Carte tattiche 3° Armata: Comando 3° Armata, Stato Maggiore, *Dislocazione delle truppe dell'Esercito Austro-Ungarico.* Padua

Historical Archive of the Third Army (HA) (1915b) Carte tattiche 3° Armata: Comando 3° Armata, Stato Maggiore, *Foglio Primo, Gradisca*, *situazione al 15 di agosto*. Padua

Historical Archive of Third Army (HA) (1918a) 1:100.000 scale Carte dell'ultimo semestre di guerra: Comando 3° Armata, Stato Maggiore, *Dislocazione delle truppe al mattino del 2 giugno*. Padua

Historical Archive of Third Army (HA) (1918b) 1:100.000 scale Carte dell'ultimo semestre di guerra: Comando 3° Armata, Stato Maggiore, *Dislocazione alle ore 8 del 17 giugno.* Padua

Historical Archive of Third Army (HA) (1918c) 1:100,000 scale Carte dell'ultimo semestre di guerra: Comando 3° Armata, Stato Maggiore, *Dislocazione alle ore 6 del Novembre*. Padua

Historical Archive of Third Army (HA) (1918d) 1:100,000 scale Carte dell'ultimo semestre di guerra: Comando 3° Armata, Stato Maggiore, *Dislocazione approssimativa dell'armata al mattino del 11 nov.* Padua

Jobst M (ed) (2011) Preservation in digital cartography. archiving aspects. Springer, New York

Jung P (2000) L'ultima guerra degli Asburgo. Basso Isonzo, Carso, Trieste. 1915–1918. LEG, Gorizia

Knowles AK (ed) (2002) Past time, past place: GIS for historians. ESRI, Redlands

Knowles AK. (2013). A cutting-edge second look at the Battle of Gettysburg. https://www.smithsonianmag.com/history/A-Cutting-Edge-Second-Look-at-the-Battle-of-Gettysburg-1-180947921. Accessed 29 Sept 2019

Lacoste Y (1976) La geographie ca sert d'abord à faire la guerre. Francois Maspero, Paris

Liebenberg E, Demhardt IJ, Vervust S (eds) (2016) History of Military Cartography. Springer International, Heidelberg

Lovejoy HB (2019) Mapping uncertainty: the collapse of Oyo and the trans-Atlantic slave trade, 1816–1836. Journal of Global Slavery 4(2):127-161

Maio CV, Tenenbaum DE, Brown CJ et al. (2013) Application of geographic information technologies to historical landscape reconstruction and military terrain analysis of an American Revolution Battlefield: preservation potential of historic lands in urbanized settings, Boston, Massachusetts, USA. Journal of Cultural Heritage 14(4):317-331. https://doi.org/10.1016/j.culher.2012.08.002

Masetti C (ed) (2018) Per un Atlante della Grande Guerra. LabGeo Caraci, Rome

Ministero della Guerra, Comando del Corpo di Stato Maggiore, Ufficio istruzioni e manovre (1912) Servizio in guerra, vol I. Servizio delle truppe. Voghera Enrico Tipografo, Rome

Mori A (1922) La cartografia ufficiale in Italia e l'Istituto Geografico Militare. Stabilimento tipografico per l'Amministrazione della guerra editore, Rome

Morselli M (2001) Caporetto 1917: Victory or defeat? Military history and policy. Frank Cass, London

Piovan SE, Maugeri E, Hodgson ME et al. (2017) I percorsi delle armate del generale Sherman attraverso le aree umide del South Carolina (1865). Bollettino dell'Associazione Italiana di Cartografia 159:93-107

Schneider U (2017) Maps, geography and the representation of space. In: Daniel U, Gatrell P, Janz O et al. (eds) 1914-1918-online. International Encyclopedia of the First World War. Freie Universität Berlin, Berlin. https://encyclopedia.1914-1918-online.net/article/maps_geography_and_the_representation_of_space. Accessed 31 July 2020

Stato Maggiore dell'Esercito Italiano (2000) Manuale sulla simbologia terrestre. Ministero della Difesa, Stato Maggiore dell'Esercito Italiano, Rome

Stichelbaut B (2005) The application of Great War aerial photography in battlefield archaeology: the example of Flanders. Journal of Conflict Archaeology 1:235-243

Stichelbaut B (2006) The application of First World War aerial photography to archaeology: the Belgian images. Antiquity, 80:161-172. https://doi.org/10.1017/S0003598X00093339

Stuckey O (2017) A Comparison of ArcGIS and QGIS for animation. Cartographic Perspectives 85:23-32. https://doi.org/10.14714/CP85.1405

Traversi C (1968) Tecnica cartografica. Istituto Geografico Militare, Florence

US War Department (1941) Basic field manual. Conventional signs, military symbols, and abbreviations. US Government Printing Office, Washington, DC

Zehele S (2015) Documenting depletion: of algorithmic machines, experience streams, and plastic people. In: Maxwell R, Raundalen J, Vestberg NL (eds) Media and the Ecological Crisis. Routledge, New York, p 53-68

Chapter 9
Geographical Representation of the Royal Italian Army War Sectors and Sites during the First World War

Paolo Plini, Sabina Di Franco, and Rosamaria Salvatori

Contents

Abstract The commonly agreed representation of the Italian front during the First World War places it along the border between the Austro-Hungarian Empire and the Kingdom of Italy. However, Italy also sent troops to many other fronts throughout Europe, the Middle East, and northern Africa (Cotillo, Italy during the World War. The Christopher Publishing House, Boston 1922). The geographical knowledge related to troop deployments along these war fronts often lacks detail about the actual locations of those places.

After 5 years of research, places involved during the war and their locations are now represented using geographical tools. The research is based on a geographical information system (GIS) technology and is aimed at identifying, cataloguing and georeferencing the so-called places of war.

Dissemination of this information relies on two different, but complementary, tools: a gazetteer and an online GIS. The gazetteer facilitates searching with the online GIS and provides unambiguous results for sites related to the deployment of military units, airfields, harbours, war cemeteries, prisoners of war camps and military logistics infrastructure. Both the gazetteer and online GIS provide geographical

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support not only for historical studies but also for the preservation of local history and the memory of men and events.

Keywords WWI · Italian front · Military geography · Geographic information system · Gazetteer

9.1 Places and Memory

The link between memory and place is a dynamic and two-way relationship; our memories are closely linked to spatial landmarks that help us to anchor and clarify the memories. The connection between places and memories is so close that the disappearance or alteration of the name of a place can lead to a substantial change in the memory of that place and of the events that took place there, up to the point where the collective memory of the event itself is cancelled. Nevertheless, the community can structure the space around a certain event and, according to shared collective memories, create a place of memory (Till 2003; Truc 2012).

In the case of the First World War (WWI), the memory of places suffered an understandable and inevitable contraction. At the national level, there are only a few dozen places that represent the collective memory. At the local level, the places become more numerous, but they are different from area to area, as are the memories associated with them. However, it remains true that over the course of a hundred years, the connection between many places and their associated war events has been lost.

In 1965, the writer and journalist Paolo Monelli, formerly an officer of the Val Cismon Alpine Battalion, commented that

> …the names of those damned places became the personification of insatiable monsters: Doberdò and its plateau, which we and the Austrians used to call 'hell'; San Michele, a funereal mountain carved by dry valleys with dark holes and rugged crevasses consisting of four peaks, one of which was called by the Magyars 'the mountain of corpses' because so many had been piled up that they altered the profile; and the Vallone, a sad hollow around the dead swamp of Doberdò, where cemeteries grew like mushrooms after each battle. How many are the survivors now, survivors by miracle, who still remember these names that once had so much evocative strength… (Manzutto and Bianchi 1965, p 12)

Places have always been given names, but how can a place be uniquely identified? It is commonly recognized, geographically, that the location of a place, even if corresponding to an area, is generally indicated by a point and that points are defined by geographical coordinates (Melo and Martins 2016). Although this is true in most cases, there are situations in which the correspondence between the name and geographical coordinates is not unambiguous, as in the case of toponymic homonyms, where the same name may be used to indicate different places having the same name (e.g. there are two occurrences of Monte Cristallo and four of Ronchi in Italy and four of Veliki vrh in Slovenia).

In an ideal world, a geographical entity would have a single and unique name; in reality, geographical names vary according to language, people's habits, history and socio-political situations (Hoelscher and Alderman 2004). These differing names are known as variants. Misunderstandings and uncertainty may, therefore, occur if the name of an entity is written in different ways, when different names are used for the same geographic entity or when a name is attributed to a place in a different way than the generally shared one (DeLozier et al. 2016). In 1928, Paolo Monelli wrote:

> For the spelling of certain geographical names I returned to the true and traditional, and I repudiated that one although sanctioned by some war bulletin, but due to the incorrect transcription of the Austrian papers… (Monelli 1928, p XI)

In any case, dealing with geographical names implies the need to take into account the toponymy, which is the study of the place names (IGMI 2004a; Löfström and Pansini 2012). Toponyms, from the Greek words tópos (place) and ónoma (name) and meaning the name of the place, are represented in natural language, and most of the time they are the result of a subjective interpretation and a creative process guided by the local population (Conedera and Krebs 2007). Moreover, the naming process is strongly dependent on the social and historical contexts (Borin et al. 2014).

Geographical names have a labelling function in order to exactly identify different places. Geotagging, the attribution of geographic coordinates to objects (Lieberman et al. 2010), and naming processes are influenced by elements such as the characteristics of the place (e.g. Busa del ghiaccio – Ice Hole, Bosco triangolare – Triangular Wood), the type of use (e.g. Piani delle Bombarde – Plain of Bombs) and reference to particular people (e.g. Forcella Dal Col – Dal Col Pass, Monte Corno Battisti – Mount Corno Battisti) and often have the purpose of remembering the fallen or commemorating events (e.g. Isola dei Morti – Island of the Dead, der Blutige Kote – Bloody Hill).

At the time of their creation, toponyms have a clear and shared meaning. Their meaning is 'transparent' for the people then, but with the passage of time, the meaning can disappear completely or lose its original clarity so as not to be more explicit and immediately intelligible (Jordan 2009).

9.2 From the Name to the Place

Geographic names are usually collected in dictionaries called gazetteers, which include the geographical names as well as their location and information about the type of feature. The names may occur at different scales, both global and local. Nowadays, gazetteers can be consulted online and represent a precious resource for the automatic search for toponyms (Goodchild and Hill 2008; Zhu et al. 2016).

On the other hand, historical-geographical studies are still largely conducted by consulting text documents and maps prepared without the use of computer technology and written by different authors in diverse languages. In addition, some of the texts may have been written under problematic conditions, i.e. during military actions. It is not an easy task, therefore, having multiple types of documents as sources, to identify and precisely locate places, mainly because many of these places are no longer shown on official modern maps.

A validation of the geographical content is necessary to identify a specific place, i.e. to determine its actual name and position on an official modern map. Most of the time, the enormous quantity of potential historical-geographical information, which can be downloaded from the web, cannot be directly used to know and compare the data with the current geographical position. In addition, inconsistencies and redundancies of names found in different sources can make the identification of places on the maps contradictory and confusing. The same can occur when trying to locate a place via the web with a search. One can get no results, obtain the name on which you are working as the only result or obtain names that are numerous, inaccurate or misleading, resulting in a search that is practically useless.

The automatic resolution of a toponym is, therefore, difficult because geographic databases are sometimes insufficient and because one can run into errors connected to the high degree of ambiguity in the name of a place due, for example, to terminological variations (terminology is defined as the study of words and their use) or, in some cases, to real errors (Leidner 2008). Bringing the name of a place back to a single pair of coordinates, latitude and longitude, that unequivocally identify a point is not an easy task. Different types of errors and variations in the names of the sites and the lexical variants (different forms of a word that concern the morphological or phonological characteristics or are limited to spelling variants) make the task of identifying and georeferencing places particularly challenging.

9.3 The Great War of the Italian Royal Army: In Search of Places

In the early twentieth century, even during WWI, geographical knowledge of the war zones was lacking and incomplete in most of the population. At best, the knowledge was limited to combat units, confined to the local level or available in military and academic environments (Porro 1898). This situation is clearly recognizable in the historical texts that we have analyzed.

There are places whose names help to anchor collective memories; those where WWI was fought from May 1915 until November 1918 are no exception. Some toponyms like Monte Cengio, Pal Piccolo, Grave di Papadopoli, Montello and Caporetto have a highly symbolic value because they were the sites of important events, sometimes decisive for the fate of the war. Furthermore, some places that did not have names before the war or whose names were changed during or immediately after the conflict became an element for the preservation of memory.

The association of place names with events allows us to better remember the event itself. Using tools that manage the names of these places in a computerized system allows the events of the past to be brought closer to today's reality. The use of geographical information systems (GISs) to collect and organize the names of WWI has, therefore, had a dual purpose: to correctly place the most or lesser-known places on current maps and, above all, to make them accessible to the public, thus passing on their memory.

Defining an a priori strategy aimed at finding places is a challenging and complex task. If there is no adequate pre-existing digital corpus or a local geographic dictionary, it is necessary to consider the chronological distance from the facts and the heterogeneity of the available textual and cartographic sources.

The search for places, whose names were extracted directly from texts and old maps and which are identified on official modern maps, was one of the major problems encountered during this study. The difficult cases were numerous also due to the extension of the area under examination, which includes, in addition to Italy, parts of the current Republic of Slovenia (Primorska), the Republic of Austria (Carinthia), France (Lorraine, Champagne-Ardennes and Picardy) and Albania, Macedonia, and Greece.

In the data organization phase, homogeneous geographical macro-sectors were defined a priori. These are (Fig. 9.1) Ortles-Cevedale-Adamello, Giudicarie-Garda-Altipiani, Dolomites-Carnic Alps, Julian Alps-Isonzo-Friuli lowland, middle-low Piave, Linea Cadorna, Western Front (Second Battle of the Marne) and Eastern Front (Albania-Macedonia-Greece). We decided not to create a sector dealing with the activities of the Italian Navy since the places are widely scattered along the coasts of the Mediterranean. These choices, in addition to having a scientific and operational motivation, also took into account the chronology and type of war events.

Fig. 9.1 The war sectors involving the Italian Army. (1) Western Front, (2) Linea Cadorna, (3) Ortles-Cevedale-Adamello, (4) Giudicarie-Garda-Altipiani, (5) Dolomites-Carnic Alps, (6) middle-low Piave, (7) Julian Alps-Isonzo-Friuli lowland, (8) Eastern Front. (Data from the National Research Council of Italy (CNR), map from the Database of Global Administrative Areas (GADM))

9.4 The Sources

The collection of geographical data on WWI was performed by manually extracting the information from over 400 documents attributable in terms of publication date to two periods. The first refers to documentary material published from 1915 until the end of the 1940s. This material includes the 'War Bulletins' issued daily by the General Staff (Anon. 1923); the 'Historical Corps and Commands Summary in the 1915–1918 War' (Ministero della Guerra 1924-1929); the official report 'Österreich-Ungarns Letzter Krieg 1914–1918' in seven volumes, issued by the Austro-Hungarians and published in the 1930s (Glaise-Horstenau 1931-1938); and many other reports on the early years of the war. Official and unofficial monographs predominantly describe the character of events and the actions of specific combat units. This group includes battlefield guides prepared by the Italian Touring Club (Anon. 1929-1940) and Michelin (Anon. 1919a; Anon. 1919b). All these documents have a very heterogeneous content and very often lack geographical precision, both in terms of textual information and in the availability of cartography.

The second category of documents includes volumes published from the 1950s through to the present. On the occasion of the 50th anniversary of the war (1965–1968), several volumes with a predominantly celebratory and reminiscent character were published, whereas in subsequent years, texts dedicated to specific topics such as battles, fortifications and coastal defences, photographic collections and historical-hiking itineraries began to appear. A detailed list of the sources used is listed in an ad hoc web page (Bibliotecalpina 2006).

The analysis of the texts and the extraction of the sites from the documents were carried out without the support of information technology tools. This low technology and time-consuming procedure allowed the search for sites to be extended to cartographic sources and contemporary texts only available in paper form. The approach also guaranteed the identification of a large number of sites with remarkable exactitude from the point of view of their location.

The main purpose of the project was to create an inventory of places as complete and detailed as possible. To populate the inventory of places, we chose the following methodology: the researcher reading the document (in printed or digital form) identified a geographical name then searched the existing raw geodatabase. If already present in the database, the record was marked, ready to be filtered to create the WWI geodatabase and become a WWI place name. If there was no result from the raw geodatabase, the GeoNames online database (GeoNames n.d.) was consulted in parallel with a web search to find the name and insert it, duly marked, in the raw database. If the name was still not found, a modern map was consulted to find the place, using the information about its position obtained both from text and/or maps. Again, if nothing occurred, the last step in the process was to search for the geographical name on an historical map. This last step provided fruitful results, especially when the place name had changed after the war. Finally, in the case where no result was obtained, the last possibility was that the candidate WWI place name contained an error (a typo, for example) or was an unregistered kind of variant of the proper name. In this case, a sort of 'trial and error' procedure was used to find the correct form of the name by substituting one letter or inverting part of the term. At the end of this process, the correct name (toponym) and its variants were inserted into the geodatabase.

We adopted an approach that analyzed official Italian and Austro-Hungarian source texts with additional documentary material. Some of the official summary documents have not proved particularly exhaustive: this is the case for the collection of the Bulletins of the War, in which less than 9% of the total census sites are mentioned. On the contrary, documents, such as summaries or historical diaries of battalions, regiments, and brigades, contain detailed references to places that should be considered. Although of secondary importance in the general framework, these places deserve to be remembered. They represent second- or third-line locations, troops' transit hubs, airfields, ports, headquarters or military medical facilities. At present, more than 400 volumes have been read and the geographic information contained extracted. Although the material contains an enormous amount of geographical information, the lack of associated maps must be noted: the information contained in the texts tends to take readers for granted by assuming a thorough knowledge of the places.

9.4.1 Basic Cartography

The official Italian Military Geographical Institute (IGMI) maps at a scale of 1:25,000 were used to position the places extracted from the source documents. In the area not covered by Italian cartography, different resources were used depending on the area. For Slovenia, the cartographic portal of the Republic of Slovenia, (eZKN n.d.), was used. For France, Albania, Macedonia and Greece, mainly historical maps were used.

Recent cartography related to Italy (IGMI 1:25,000 and 1:100,000 scale maps and orthophotos) was accessed using the national Geoportal through Web Map Services (WMS) (Geoportale Nazionale 2017). In the same way, it was possible to consult maps of the Trentino-Alto Adige, Veneto, and Friuli-Venezia Giulia regions.

For the identification of the sites, we made extensive use of period and modern maps, both in digital and printed format. The most useful resources among the historical maps of Italy were the 24 1:100,000-scale sheets of the 'Great Map of the Italian War' published in 1917 by the Italian Touring Club and the Military Geographic Institute (TCI 1917). In 1965, those maps were described in the following manner:

> Who has not unfolded and used the two hundred and fifty thousand and then the most detailed one hundred thousand scale [maps] created on purpose for the War, staying at his own table at home or, even along the lines of combat and movement, finding places never heard before... (Manzutto and Bianchi 1965, p 5)

As for the Austro-Hungarian sources, we used the online version of the 'Spezialkarte der Österreichisch-Ungarischen Monarchie' produced by k.u.k. Militärgeographisches Institut at a scale of 1:75,000, completed in 1890 and integrated in 1894 (NYPL 2020). It includes the part of the Austro-Hungarian Empire currently in Italian territory. The online version of the 1910 'General Atlas of Central Europe' (Generalkarte von Mitteleuropa), at a scale of 1:200,000 was also used (Landkartenarchiv 2003-2019; katonai felmeres n.d.).

From this description of cartographic sources, the heterogeneity of the representation scales is evident. The maps thus required projections and coordinate systems to be harmonized to make them compatible with the WGS84 geodetic geographic coordinate system adopted within the GIS.

In addition to the official maps, around four hundred papers, maps, sketches, drawings and photos containing information referring to the territory were analyzed, following the procedure above described. All this allows the extraction of the greatest possible amount of information, such as the evolution of the front line or the locations of sites no longer found on modern maps.

9.4.2 Digital Sources

During the first phase of the project, the largest amount of material already available in digital format (gazetteers) was collected. The Database of Global Administrative Areas (GADM 2018) was used, as well as the OpenStreetMap database (OpenStreetMap n.d.; Haklay and Weber 2008). Other sources consulted were the GeoNames database (GeoNames n.d.) and the online place search engine provided by the Italian Geographic Military Institute (IGMI n.d.). The Italian Official Toponyms database is not available since it has been developed only for the internal use of the IGMI.

The data were mainly organized in layers of points, although objects, such as lines and polygons, have also been taken into consideration. These were necessary to highlight changes in the front line during the war. Representation of the drainage network and national, regional and municipal boundaries was also necessary.

9.5 The Analysis of Toponyms

As easily predicted, the toponyms collected by an analysis of the texts do not always present themselves in an unambiguous form. About a quarter of the sites have one or more different forms. All the forms encountered in the texts were duly collected, archived and brought back to the form considered preferred, which is, for the Italian territory, the one represented on the official IGMI 1:25,000 scale maps. When the name of the location was no longer available on current maps, the name was found in other sources. If the place was located abroad and had a name in Italian, the latter was used; otherwise, the name in the local language was used. Using the same criteria, the linguistic equivalents in French, Slovenian and German, as well as forms in the local languages (mainly Friulian and Ladin), were also collected.

Identification of the terminological variants was fundamental to guarantee exactitude and precision, both of which were key factors in obtaining completely acceptable geographical names accessible using a search engine. Harmonizing toponyms from different sources along with their geographic coordinates led to the creation of a table specifically dedicated to the management of toponyms themselves, i.e. a gazetteer or geographical dictionary (IGMI 2004b). This allowed terminological issues related to the different forms of geographical names, such as use, language, translation and meaning, to be highlighted.

When carefully analyzing the numerous terminological variants of geographical names for their locations, we noted that many of these variations were connected at different levels with the memory of places as true commemorations of events and people or as traces of the passage of time. The abundance of these variants suggested a careful analysis of their nature and how the variations may retain a meaning linked to events and can, therefore, be read as memories of events.

The toponyms showing variant forms were collected and marked by distinct terminological classes, in the following lexical variants:

- Spelling variants (spacing and punctuation, spelling, omitted components, misspellings)
- Dialectal variants
- Translations, and
- Other names (civil and military)

Lexical variants differ from synonyms in that the latter are different terms for the same concept, whereas lexical variants are different forms of words for the same expression (Adesam et al. 2012). These forms can derive from variations in spelling or grammatical variations or even appear as abbreviations.

Spelling variants give us little information regarding the memory related to a certain place but are important for the unambiguous attribution of coordinates for a certain toponym. Therefore, in our analysis, we have taken the most significant spelling variants used in place names into consideration.

Dialectal variants include those cases in which one of the names is represented by the Italian form, where a variant with the same meaning in the local dialect occurs in other texts (e.g. Valle dell'Acqua, Fiumicello and San Pelagio in Italian vs. Valle de l'Aga, Flumisel and San Polai in local dialect). Due to the complex geomorphology and cultural history of the places located in mountainous areas, it is important to emphasize that the dialectal form could sometimes vary even between two adjacent valleys; therefore, the generic form 'local dialect' was used without going further into detail. In the case of toponyms located in Friuli-Venezia Giulia, all the equivalents available in the Friulian language have been recorded in a separate field. In the case of the exonym equivalents of translation, i.e. the national form of a foreign name, and translation from other languages, most of them represent toponyms in Slovenian (e.g. Monte Lupo – Volkovnjak Croda Rossa – Rudeci rob, Dresenza – Drešnica; the first name is Italian and the second Slovenian).

Finally, the last class is dedicated to names that have undergone changes in both civil and military origin, connected or not to war events. For example, Il Triangolo became Croda Rossa, altitude 213 became Monte Sambuco, Rifugio Longeres became Rifugio Auronzo, Bocchetta del Gendarme became Passo di Casamadre and Pizzo Tresero became Cima Tresero. Once the classes of toponyms were finalized, the terminological variants were compared to show possible correlations, trends and evolutions. More than 4600 toponyms have at least one and up to seven variants (lexical, formal, linguistic, synonyms), for a total of more than 6500 alternative names.

At present, over 11,700 sites have been identified and located on the so-called Italian front in Italy, Slovenia and Austria and away from this front in France, Albania, Macedonia, Greece, Croatia and Montenegro (Fig. 9.2). The places have been clustered into two main geographical macro-categories respectively dealing with physical and human geography. They were then classified successively into 55 sub-categories (Table 9.1). Four hundred and sixty-one sites have at present been

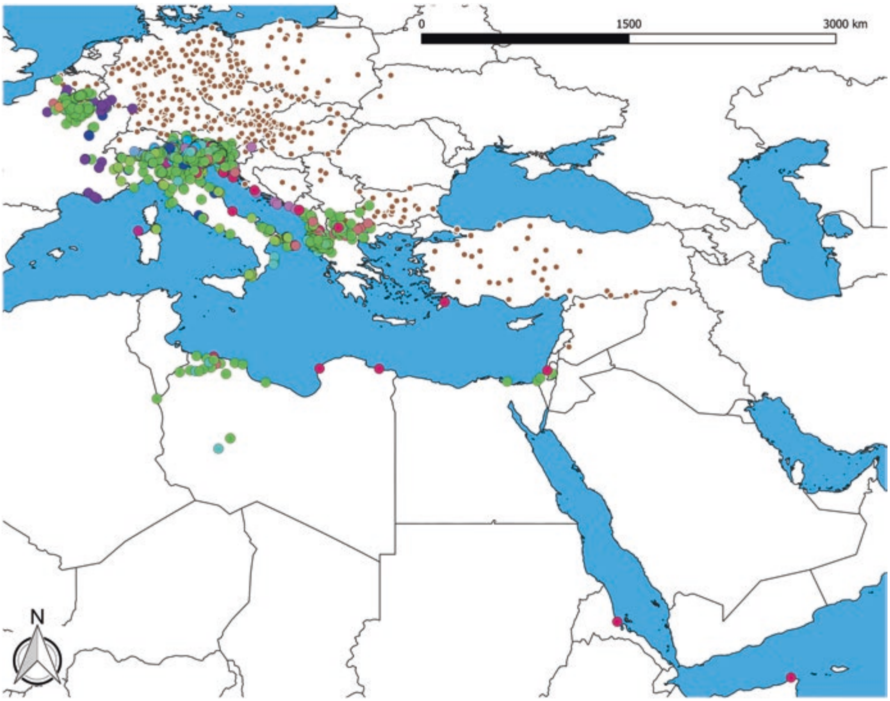

Fig. 9.2 The places identified so far. Larger dots in different colours represent the war places classified according to different sub-categories. The colours (e.g. green for inhabited places, violet for cemeteries, light blue for areas, magenta for naval bases) are used within the GIS to identify the different types listed in Table 9.1. In the online GIS, they are replaced by symbols. The small brown dots identify the POW camps where Italian soldiers were detained. (Data from CNR, map from GADM)

Table 9.1 List of typology of places so far identified

Air field	Fountain	Pass	Sea
Area	Gallery	Pathway	Spot elevation
Artillery battery	Glacier	Peak	Spring
Bridge	Inhabited place	Port	Stronghold
Building	Island	Quarry	Telemetry tower
Bunker	Lake	Railway barrier	Armoured train
Cableway	Lighthouse	Railway gallery	Trench
Canal	Memorial	Railway junction	Trenched line
Cave	Monument	Railway station	Valley
Cemetery	Mountain chain	Railway viaduct	War village
Crossing keeper's booth	Mountain group	River	Water pump
Dolina	Mountain ridge	River bank	Waterfall
Emplacement	Naval base	Road	Woodland
Fort	Observatory	Road barrier	

identified as prison camps (POW camps) where captured Italian soldiers were detained. These were located mainly in the Austro-Hungarian Empire but also in Germany, Ukraine, Turkey, Syria and Iraq and some other European states.

According to the terminological variant categories, more than half of WWI toponyms belong to the class of spelling variants. More than one third are names that have undergone changes following historical, civil and military events; 9% can be attributed to translation variants and only 5% to dialect variants.

The situation of spelling variants appeared problematic from the beginning. The most relevant situations were represented by formal variants in which both forms of the names could be considered correct (e.g. Tre Ponti or Treponti, Zuc dal Bôr or Zuc dal Bor, Governolo or Govérnolo, Malè or Malé). Furthermore, partial inversions, the replacement of one or more letters, and partial transliterations often occurred.

When the variants are linked to different languages, it is important to relate them to changes in the national borders before and after the war. These changes led to the need to manage names in three languages (Fig. 9.3). The places located along the border between the Kingdom of Italy and the Austro-Hungarian Empire now mainly belong to Italy and Slovenia; only a line of about 50 km still follows the historical border along the Carnic Alps. Therefore, the places now located in Italy had German names (e.g. Malborgeth became Malborghetto), whereas those in Slovenia had both Italian and Slovenian names (e.g. Cosarsa and Kozaršče). In some cases, places have names in up to three languages (e.g. Sv Duh na Banjščici in Slovenian, Bainsitza S. Spirito in German, Santo Spirito della Bainsizza in Italian).

It is interesting to note that during the war, the use of names such as Toblacco resulted from an adaptation of the original German name Toblach, whereas the actual Italian name is Dobbiaco. Some names have been converted into Italian based on the original foreign name, which was derived from their geographical position before the war (e.g. Crna Griža became Cerna Grisa), whereas others (Valle

Fig. 9.3 An example of places along the Carnic Alps border showing the names in Italian, Slovenian, German and local dialect. (Data from CNR, base map from Google Earth™)

Seebach) are the result of the merging of part of the German name (Seebachtal) with another part of the Italian one (Val Rio del Lago).

Within the large number of accessible documents, some places are named in different ways. Some of them can be classified not as actual terminological variants but as places that have changed their names for historical reasons to remember and commemorate specific relevant events or fallen soldiers (Kadmon 2000). Some toponyms officially known as spot elevations were renamed during the war, such as the so-called quota 85, which became Quota E. Toti, taking its name from Enrico Toti, a civilian aggregated to the Third Regiment of the Bersaglieri Cyclist Battalion, who fell on 6 August 1916 during the Sixth Battle of the Isonzo. He was awarded the Gold Medal for Military Valour. Other toponyms that already had a name were renamed during the war. These are mainly dedicated to soldiers who fell there (e.g. Volnik became Quota Gen. Papa).

Another case is that of places that did not have a name before the war but were named during the war for a specific reason. For example, the fighting during the Isonzo battles caused the Italian Army to assign names, even if not officially, to uniquely identify relevant places, such as the Vallone del Sangue (Bloody Valley). Another interesting case is that of a peak previously, and only unofficially, known as quota 2556, which is located in the mountainous group of the Piccolo Lagazuoi. It was renamed Punta Berrino by the Italians and Öllacher Stellung (Öllacher emplacement) by the Austro-Hungarians in memory, respectively, of two soldiers who fell five days apart in October 1915. In other cases, the names of the places have been modified after the victory to remember battles or symbolic places. For example, Nervesa became Nervesa della Battaglia and Paderno d'Asolo became Paderno del Grappa. Finally, some cities or municipalities changed their names many years after the war without any connection with WWI. Among others, Cavazuccherina became Jesolo, Grisolera became Eraclea, Ronchi di Monfalcone became Ronchi dei Legionari and Moglena (Μογλενά, Greek Macedonia) became Almopia (Αλμωπία).

Numerous toponymic homonyms have also been found, e.g. Monte Cristallo in the Central Alps (3434 m) and Monte Cristallo in the Dolomites (3221 m). Since, in many areas, the places may have the same physical and/or historical characteristics, very often the names come from the geographical characteristics that make them distinguishable and unique in a given area. A specific analysis was necessary to disambiguate these cases. For example, in the historical summary of the Pinerolo Brigade (Ministero della Guerra 1924-1929 vol 10: 18), the troops were described as having left the Tagliamento river, heading towards a place called Pielungo by crossing the Forcola Pass. The pass in question certainly cannot correspond to the Passo della Forcola, which is near the border between Italy and Switzerland in the Lombardy region more than 200 km away. It is instead the Cuel di Forchia, the official (and Friulian dialectal) form of the toponym, which when translated into Italian would correspond to Passo della Forcola. This is a case where the evaluation of the context as described in the source avoided significant errors.

In some cases, even the variant found in a document must be considered as a variation of another variant of the official name. Cima Valbruna, for example, is a variant of Cima Val Bruna. whereas the official name is Monte Foppe.

A further case study concerns those sites where the name has remained but today corresponds to a place different from that of wartime. The Osteria di Monfenera shown on the Italian Touring Club maps (TCI 1917) is today called Malga il Doc, whereas Osteria di Monfenera is located 3 km to the east.

Special mention should be given to transcription errors. These are cases in which the form found in a document is not acceptable as it cannot be traced back to any of the above cases, such as the changes from Collibron instead of Colbricon, Callari instead of Calgari and Conegliano (which exists but in this case was wrongly reported) instead of Conoglano.

While analyzing the toponyms, we found that the most frequent and numerous dialectal and linguistic variants are related to the names of peaks and mountain groups. This could be related to the geographical position of the war events since the events of WWI took place mostly in mountainous areas on the Italian border. In ancient times, only places relevant to agriculture and husbandry were given a name by local communities, and many peaks were only given names when they became interesting to climbers and tourists. The same mountain could have different names when its slopes were inhabited by people with different cultures and languages or communities with poor mutual interaction. Only in 1879, with the first edition of the Grand Map of Italy (Mori 1922), have official names been given to the mountains.

Lexical variations were rare for the drainage network in general and for rivers in particular (Costanzo Garancini 1975). In fact, the names of the rivers are traditionally very stable and are little influenced by dialectal variants, perhaps because a river maintains a long, recognizable identity throughout its journey. The only variations are due to linguistic changes related to rivers that flow through different countries.

The naming process of cemeteries and war monuments mainly deals with places that have been given a name only during or after the war. Examples include Cimitero di guerra ‘Col. Cisterni’ and Cippo Brigata Sassari, respectively.

9.6 The Places-of-War Gazetteer

The analysis of name variations resulted in a specific Places-of-WWI Gazetteer, in which the names are listed. This list of terminological forms of toponyms represents an improvement leading to a better, easier and more effective geographical search. Whereas variants usually produce a noise level incompatible with common search tools, in this case they provide extra value and an additional element, leading to positive search results. They also provide a contribution in terms of the lexical richness of geographical names that are strictly connected with both geographical features and the history of places.

The Places-of-WWI Gazetteer along the Italian fronts contains all the necessary information to ease the search for toponyms within the online GIS (see below). All the occurrences are listed, and the non-preferred ones are linked to the preferred forms, which contain the additional information coming from the geodatabase. The preferred place names in this gazetteer can be used in any activity where it is important to mention the preferred toponymic form.

All the forms contained in the gazetteer are pivotal elements connected to the search function in such a way that each name now corresponds to one and only one place and the name itself can be used while performing queries to provide unambiguous results. Only in the case of synonyms is the user’s skill required to make the right choice that takes the historical and geographical context into account.

Two gazetteers, namely ‘Places-of-WWI Gazetteer Along the Italian Fronts’ and ‘List of Prisoner-of-War Camps Where Italian POWs Were Detained’ were published on 15 May 2020 and are now available online (http://luoghigrandeguerra.cnr.it/risultati/il-geodatabase/) as PDF files. New versions of the gazetteers are expected to be published every six months.

9.7 GIS and Online GIS

A specially structured GIS was created to manage the geographical data collected and to guarantee the precise positioning of each site. A GIS is an integrated system that allows the acquisition, management, visualization and return of geographic information. Two characteristics make a GIS suitable for the activities involved in this study: being able to create information layers from data associated with geographical coordinates and to allow the stratification of these layers. For example, in a historical GIS (Gregory and Healey 2007), it is possible to overlay one or more layers of information corresponding to locations no longer shown on the map, such as landscape elements, front lines, and deployments, onto a current cartographic base. This system of geographic data management can also be used profitably for the analysis of historical events linked to the territory, as in the case of the places where combat occurred during WWI (Plini et al. 2017).

The GIS used to manage the identified places was then set up to be used as an online GIS (http://webgis.isp.cnr.it/GGGIS) to guarantee remote access for all users interested in the locations linked to the events of WWI. The online GIS was organized to allow places to be searched using any of the forms found in the texts, in addition to forms in the other languages used in the geodatabase. By selecting the name of the place, it is possible to view its location in the territory, with the possibility of configuring the display parameters and the representation scale.

The views are generated by the server in real time. The user has at his disposal a set of navigation tools. Depending on the area to be represented, it is possible to enlarge or reduce the view, set the transparency of layers, position the selected level in the centre of the display window or search on some vector layers.

Using the internal search engine, it is possible to enter all or only the initial part of the name to be searched. The system automatically searches for the selected field and positions itself to include the identified locations on a single screen showing the following information in a pop-up window: preferred name, place type, height, province, region, state, other names, French name, other French names, German name, other German names, Slovenian name, other Slovenian names, local name (dialect or other languages), other local names, war sector and the Touring Club of Italy (TCI 1917) map reference. In the case of search by site name, the system draws on the fields related to Italian, Slovenian, German, French or other names.

There are three types of data available in the online GIS:

- Vector data from the gazetteer related to locations, drainage, airfields, exhumation zones of the 11 Italian Unknown Soldiers, places mentioned in songs and poems about WWI, the tracing of front lines in different periods and the location of the so-called Case del Soldato (Soldiers' Houses, small buildings containing books, 78 rpm discs, playing cards, built by the Italian Army along the front line to provide momentary relief to the combatants)
- Cartographic data, such as historical georeferenced maps and a digital terrain model derived from the Shuttle Radar Topography Mission imagery (SRTM 2020); and
- Cartographic data accessible via WMS

9.8 Final Considerations

The creation of a combined WWI GIS and a Places-of-WWI Gazetteer dealing with the operations of the Italian Army is quite unique in the international scene, in that this is the first effort with such wide geographical coverage and that it takes its cue not solely from official documents available in digital format but also from an analysis of a heterogeneous set of texts available only in printed form. We were initially faced with a situation of a relatively small number of points scattered over a wide area, but these did not provide a complete view of the extent of the territory involved and/or the complexity of the war actions. At present, however, the large number of points reveals the complexity of the events on the Italian war fronts and correlates the toponyms in an area with a detailed memory of the events.

The possible associations of toponyms and their location with respect to current maps can be summarized as follows:

- One name, one place
- One name, no place (the place no longer exists)
- No name, one place (this is the case of numerous anonymous spot elevations)
- One name, several places (in the case of homonyms)
- Multiple names, one place (toponymic variants)

These situations have been addressed and resolved using a manual terminological approach because the absence of a similar geographic dictionary and a true digital corpus made it difficult to use automatic or semi-automatic tools. Such tools were not fully suitable for this specific project, and in fact the use of semi-automatic and automatic text analysis tools (Boschetti et al. 2014) was limited to the analysis of the digital corpus, which included only a low number of volumes. It highlighted important shortcomings when it came to effectively identifying all the places potentially identifiable and to distinguishing differences in the geographical domain where misinterpretations and multiple terminological occurrences (homonyms) can be very frequent. A couple of examples, both taken from the War Bulletins, help to clarify this. The phrase ‘a valle di Seebach’, meaning ‘downstream of Seebach’, was interpreted as ‘valley of Seebach’ and consequently misplaced. In the phrase ‘sulla zona tra Isonzo e Vippacco’, meaning ‘between Isonzo and Vippacco’, where both Isonzo and Vippacco are rivers, Vippacco was associated with the wrong homonym, the Slovenian town on Vipava instead of the Vipava river (both translated into Italian as Vipacco or Vippacco).

The analysis of the collected data allowed us to identify 21,856 toponyms linked to 11,700 preferred forms. This high level of exactitude is mainly due to an approach that made it possible to harmonize historical, linguistic and geographical knowledge by combining it with the experience gained during the research work. This procedure, apparently of low technology and very expensive in terms of time, has guaranteed very high coverage in terms of identified places and very good coverage with regard to their location in the territory (26 states covered). Only slightly more than 2% of toponyms are still devoid of location. The geographic/terminological component has enriched the system with valuable information that is difficult to find elsewhere, as it is generally disaggregated into a myriad of different cartographic texts and sources.

The high level of detail exhibited within the data (granularity) reached, combined with a dual geographical and terminological point of view, resulted in the creation and maintenance of a specific Places-of-WWI Gazetteer. In this gazetteer, the aforementioned terms are listed, unambiguously geolocalized and made available on the web through an online GIS where the available search keys are represented by preferred forms, variants and equivalents in other languages and the result is represented by the preferred form and its location in the territory.

The analysis of terminological forms of toponyms represents a huge step forward that leads to better, easier and more effective research. The names of the places in this gazetteer are linked in such a way that each name now corresponds to only one place and the name itself can be used when executing queries that provide unique and unambiguous results.

Until a few years ago, anyone who wanted to carry out place name research dealing with the Italian Army operational fronts would have had to rely on generic search engines. However powerful they might be, the result would be generally heterogeneous, sometimes conflicting and frequently lacking geographical context. For example, in the historical summary of the Livorno Brigade, we read '... operations that led to the occupation of Prezzo and Baite' (Ministero della Guerra 1924-1929 vol 2: 166). In Italian, Prezzo means 'price' and Baite means 'huts'. A combined search for 'Prezzo', 'Baite' and 'war' produces no meaningful results. Searching for 'Prezzo' and 'Italy' on Google™ leads to a meaningful result located in the Trento Province. This is not the same for 'Baite'. In this case, a different place called 'Baite' can be found in the Sondrio Province (Lombardy region). Only the use of the online GIS makes it possible to identify the locations of the two toponyms.

Compared to the pre-existing situation, the search and dissemination of results online represent a turning point, bringing together all the information acquired in a single system, normalizing its content and allowing controlled but flexible access. The high number of sites identified, which is destined to grow larger, gives a measure of how much Italy suffered from the impact of WWI, although in many cases there is nothing left but a name to remember.

References

Anon. (1919a) Guida dei Campi di Battaglia. 4. Agenzia Italiana Pneumatici Michelin, Milano

Anon. (1919b) La deuxième bataille de la Marne. Michelin & Cie, Clermont-Ferrand

Anon. (1923) Bollettini della Guerra MCMXV-MCMXVIII. Alpes, Milano

Anon. (1929-1940) Sui Campi di Battaglia. 7. Touring Club Italiano, Milano

Adesam Y, Ahlberg M, Bouma G. (2012) Bokstaffua, bokstaffwa, bokstafwa, bokstaua, bokstawa ... Towards Lexical Link-up for a Corpus of Old Swedish. LTHist, Konvens Workshop, Vienna, 2012. http://www.oegai.at/konvens2012/proceedings/54_adesam12w/54_adesam12w.pdf. Accessed 9 Dec 2019

Bibliotecalpina (2006) http://www.plini-alpini.net/bibliotecalpina/. Accessed 19 March 2020
Borin L, Dannells D, Olsson LJ (2014) Geographic visualization of place names in Swedish literary texts. Literary and Linguistic Computing 29:400-404. https://doi.org/10.1093/llc/fqu021
Boschetti F, Cimino A, Dell'Orletta F et al. (2014) Computational analysis of historical documents: an application to Italian war bulletins in World War I and II, LREC Workshop on language resources and technologies for processing and linking historical documents and archives - Deploying linked open data in cultural heritage, Reykjavík, p 70-75. http://bit.ly/1kE9cpf. Accessed 9 Dec 2019
Conedera M, Krebs P (2007) Using toponymy to reconstruct past land use: a case study of 'Brusada' (Burn) in Southern Switzerland, Journal of Historical Geography 33:729-748
Costanzo Garancini A (1975) La romanizzazione del bacino idrografico padano attraverso l'odierna idronimia. La Nuova Italia, Firenze
Cotillo SA (1922) Italy during the World War. The Christopher Publishing House, Boston
Database of Global Administrative Areas (GADM) (2018) https://gadm.org/download_country_v3.html. Accessed 19 March 2020
DeLozier G, Wing B, Baldridge J et al. (2016) Creating a novel geolocation corpus from historical texts, LAW X - The 10th Linguistic Annotation Workshop, Berlin, p 188–198
GeoNames (n.d.) http://www.geonames.org/. Accessed 19 March 2020
Glaise-Horstenau E (ed) (1931-1938) Österreich-Ungarns Letzter Krieg 1914-1918. 7 vol. Verlag der Militärwissenschaftlichen Mitteilungen, Vienna
Goodchild MF, Hill LL (2008) Introduction to digital gazetteer research. International Journal of Geographical Information Science 22(10):1039-1044
Gregory IN, Healey RG (2007) Historical GIS: structuring, mapping and analysing geographies of the past. Progress in Human Geography 31(5):638-653
Haklay M, Weber P (2008) Open street map: user generated street maps. IEEE Pervasive Computing 7(4):12-8
Hoelscher S, Alderman DH (2004) Memory and place: geographies of a critical relationship. Social and Cultural Geography 5(3):347-355. https://doi.org/10.1080/1464936042000252769
Istituto Geografico Militare (IGMI) (2004a) Atlante dei Tipi Geografici, Istituto Geografico Militare, Firenze. https://www.igmi.org/italia-atlante-dei-tipi-geografici. Accessed 9 December 2019
Istituto Geografico Militare (IGMI) (2004b) Linee guida per la normalizzazione dei nomi geografici ad uso degli editori di cartografia ed altri editori. 22nd Session of the United Nations Group of Experts on Geographical Names, New York, Supplement to L'Universo 6/2004, Firenze
Istituto Geografico Militare (IGMI) (n.d.) https://www.igmi.org/it/geoprodotti#b_start=0. Accessed 19 March 2020
Geoportale Nazionale (2017) http://www.pcn.minambiente.it/mattm/. Accessed 19 March 2020
Jordan P (2009) Some considerations on the function of place names on maps. ICC proceedings. https://icaci.org/files/documents/ICC_proceedings/ICC2009/html/nonref/12_2.pdf. Accessed 9 Dec 2019
Kadmon N (2000) Toponymy: The lore, laws and language of geographical names. Vantage Press, New York
katonai felmeres (n.d.) http://lazarus.elte.hu/hun/digkonyv/topo/3felmeres.htm. Accessed 19 March 2020
Landkartenarchiv (2003-2019) https://www.landkartenarchiv.de/oesterreich_gkm.php. Accessed 19 March 2020
Leidner JK (2008) Toponym resolution, text, annotation, evaluation and applications of spatial grounding of place names. ACM SIGIR Forum 41(2):124-126 http://delivery.acm.org/10.1145/1330000/1328989/p124-leidner.pdf. Accessed 9 December 2019
Lieberman MD, Samet H, Sankaranarayanan J (2010) Geotagging with local lexicons to build indexes for textually-specified spatial data. IEEE 26th International Conference on Data Engingeering, p 201-212

Löfström J, Pansini V (2012) Toponymes et cartographie: perspective historique et enjeux linguistiques. Cartes & Géomatique, Revue du comité français de cartographie 211:127-139

Manzutto G, Bianchi E (eds.) (1965) La nostra guerra 1915-18 nel cinquantenario. Touring Club Italiano, Milano

Melo F, Martins B (2016) Automated geocoding of textual documents: a survey of current approaches. Transactions in GIS 21(1):3-38

Ministero della Guerra (1924-1929) Riassunti storici dei corpi e comandi nella Guerra 1915 – 1918. Libreria dello Stato, Roma (10 vol.)

Monelli P (1928) Sette battaglie. Treves, Milano

Mori A (1922) La cartografia ufficiale in Italia e l'Istituto Geografico Militare. Stabilimento poligrafico per l'Amministrazione della guerra, Roma

New York Public Library (NYPL) (2020) Spezialkarte der Österreich-Ungarischen Monarchie https://digitalcollections.nypl.org/collections/spezialkarte-der-osterreichisch-ungarischen-monarchie#/?tab=about. Accessed 19 March 2020

OpenStreetMap (n.d.) https://www.openstreetmap.org/. Accessed 19 March 2020

Plini P, Di Franco S, Salvatori R (2017) Geography of WWI sites along the Italian front by means of GIS tools. In: Cefalo R, Zieliński JB, Barbarella M (eds) New advanced GNSS and 3D spatial techniques. Lecture notes in geoinformation and cartography. Springer Nature, Switzerland, p 229-235. https://link.springer.com/chapter/10.1007/978-3-319-56218-6_18

Porro C (1898) Guida allo studio della geografia militare. Unione Tipografico Editrice, Torino

Shuttle Radar Topography Mission (SRTM) (2020) https://www2.jpl.nasa.gov/srtm/. Accessed 19 March 2020

Till K (2003) Places of memory. In: Agnew J, Mitchell K, Toal G (eds) A companion to political geography, p 289-301

Touring Club Italiano and Istituto Geografico Militare (TCI) (1917) Grande Carta della Guerra italiana. 24 sheets

Truc G (2012) Memory of places and places of memory: for a Halbwachsian socio-ethnography of collective memory. ISSJ 203-204:147-159. Blackwell, Oxford

Zemljiško Katastrskih Načrtov (eZKN) (n.d.) https://gis.gov.si/ezkn/. Accessed 19 March 2020

Zhu R, Hu Y, Janowicz K, McKenzie G (2016) Spatial signatures for geographic feature types: examining gazetteer ontologies using spatial statistics. Trans. in GIS 20:333–355. Wiley Online Library

Chapter 10
Italian Prisoners of War in South Africa During the Second World War: Circumstances and Contributions

H. A. P. Smit

Contents

Abstract On the featureless plains of the South African Highveld, a sign, in Italian, reads *Cimitero Militare Italiano*. The signpost seems strangely out of place in the predominantly Afrikaans cultural landscape. The cemetery honours the 312 Italian prisoners of war (POWs) who remained behind in South Africa when their compatriots left at the end of World War II. Theirs was not a choice; they died waiting for the end of their plight. After the war, some POWs chose to stay in South Africa and adopt the country as their new homeland. Many more returned to South Africa over the next few years. These new South Africans contributed much to their adopted country, but even those that departed and never returned, left an indelible signature on the landscape of South Africa.

Today, more than 73 years after the last Italian POWs were repatriated, their imprint is fading. However, even a cursory investigation reveals their contributions and their importance in shaping modern South Africa. A review of available literature sources and archival material, fieldwork and personal interviews were used as basis for the investigation of this underexplored piece of South African and Italian history. This chapter reports on the circumstances surrounding the incarceration of the Italian POWs, as well as the geographical extent and significance of their contributions to South Africa.

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10.1 Prisoner-of-War Experiences

Life as a prisoner of war (POW) is rarely a pleasant experience. To be robbed of your freedom of movement, put in captivity and, to a varying degree, be deprived of rights you had always taken for granted constitute a serious challenge to most POWs (Pautch 2003). Hickman (2008) alleges that both legitimate and illegitimate purposes for continuing the custody of POWs are adopted by captor states because the captives are not seen as part of the moral community. The moral community, Hickman explains, comprises those people to whom moral obligations are owed because of shared moral values. During war, members of the captor state oftentimes exclude POWs from the moral community. Prisoner-of-war experiences are sometimes described by words such as 'mental and physical hardship', 'great suffering' and 'extreme hardship' (Horn 2011, p. 101) or even 'physical and psychological abuse' and 'horrendous brutality and persistent atrocities' (Sutker et al. 1993, p. 240). It seems as if this was not the case for the Italian POWs in South Africa. Although by no means an enjoyable experience, it seems that the Italian POWs, after a bad start, were generally treated fairly, and many of them used the opportunities available to contribute meaningfully to a number of projects in the country of their captivity. In doing so, they left a geographical footprint over vast areas of South Africa. Although the footprint is fading, both in a physical and psychological sense, it is still obvious for anyone interested in the influences their labour had on contemporary South Africa.

10.2 Italian Prisoners of War in South Africa

On 4 and 5 April 1941, the first Italian POWs arrived from North Africa. According to Moore (1997, p. 123), the early campaigns in 1941 against the Italians were unexpected military successes that generated a 'superabundance' of prisoners. The Italian POWs who were captured early in 1941 were dispatched to the Union of South Africa. They disembarked in Durban, and most of them ended up in Zonderwater,[1] a camp hastily established near Cullinan, east of Pretoria (Delport 2013).

Geography was the driving force behind the location of the camp (Fig. 10.1). Ample space was available at the chosen location. Furthermore, it was close to the capital, Pretoria, but some 6000 km separated Zonderwater from the battlefields of

[1] The meaning of the name 'Zonderwater' is rather ominous. Literarily translated it means 'without water.'

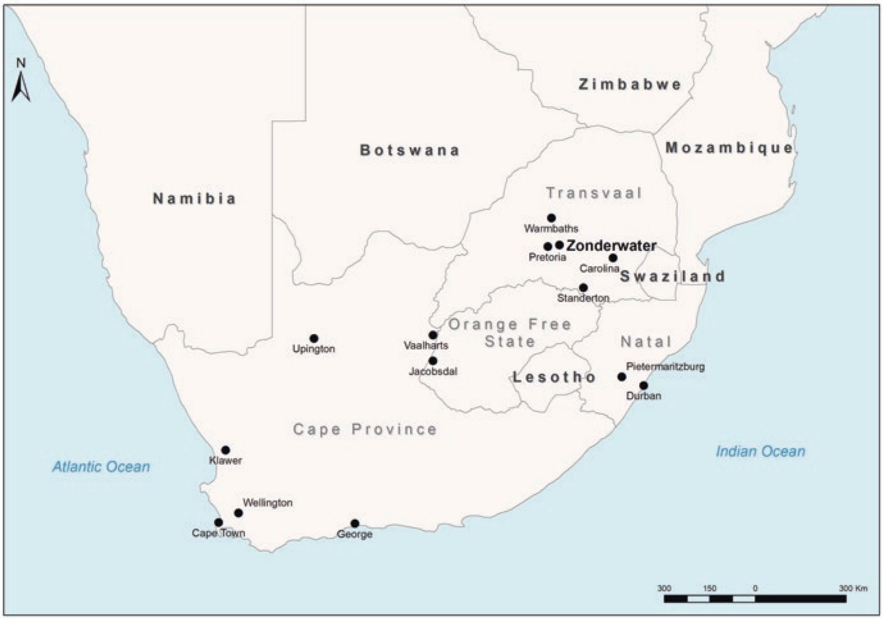

Fig. 10.1 Provinces, major cities and towns relevant to the prisoners of war in South Africa during the Second World War. For clarity, neighbouring countries are indicated by their current names

North Africa. This made successful escape extremely unlikely. A good railway and road network from Durban to Zonderwater made the transport of large numbers of prisoners easy and aided in the provision of supplies. The location also made escape to a sympathetic country unlikely. The nearest friendly country, Mozambique, was nearly 400 km away (Fig. 10.1; Sani, 1992).

Five base camps housed the Italian POWs. Of these, the Zonderwater camp was by far the largest and thus receives the most attention in this paper. The ones at Pietermaritzburg, Standerton, George and Worcester were much smaller. Four transit camps were used to move prisoners from the main disembarkation point at Durban to the various camps or areas of work. A detention centre near George housed cases of misconduct, whereas a convalescence camp near Carolina was used to house POWs recuperating from serious illness, from wounds sustained during battle or from accidents at their place of employment.

A brief note on the peculiar situation of Italian POWs during the Second World War is needed here. At the start of the war and up to 1943, the Italian POWs were treated in accordance with the stipulations of the Geneva Convention (Fedorowich and Moore 1996). Between January and September 1943, with Italy on the verge of surrender, the Allies used prisoners for labour in labour-starved Britain and the Dominions (including South Africa). When Italy surrendered in September 1943 and switched sides, Italian POWs became known as 'co-belligerents' and not Allies. This semantic manoeuvre allowed the Allies to bend the international rules governing the treatment of POWs, allowing them to become 'co-operators', rather than prisoners, engaged in a wide variety of work in exchange for more freedom and payment for their labour (Moore 1997). The reason the Allies did not release the Italian POW immediately, was because they became too valuable in the war effort by providing cheap labour in a labour-scarce environment to simply release them.

10.3 Conditions in South Africa

10.3.1 Initial Conditions and Political Dilemma

South Africa was not ready for the influx of such a large number of POWs.[2] The political situation at the time was also not conducive to the incarceration of POWs. On 4 September 1939, a motion of neutrality brought before Parliament by the Prime Minister, General JBM Hertzog, was defeated by a narrow margin of 13 votes, and General Jan Smuts, the deputy Prime Minister, was asked to form a government. He declared war against Germany on 6 September (Van der Waag 2015). During the early stages of the war, the division in the population between the pro-war group and the anti-war group remained a political dilemma for Smuts. Katz (2012, p. 281) alleged that 'Smuts had to maintain a delicate, political, high-wire act for the remainder of the war, keeping in balance relations with the United Kingdom and harmony back home ….' To exacerbate this situation, the Anglo Boer war concentration camps[3] remained a source of resentment towards Britain for a large part of the South African population. To now house huge numbers of Italians in POW camps was politically fraught with danger – something Smuts realised only too well. To illustrate this point, Fiasconaro (1982, pp. 20–21) related how he marched to Clairwood on his arrival to Durban:

A most extraordinary thing happened to us on the short march. Many people sidled up to us and, glancing furtively round, hurriedly shook hands or patted our shoulders and congratulated us before melting away. Only much later did we understand that these were Afrikaners and other South Africans, who had been totally opposed to the Union's entering the war on the side of the Allies.

Zonderwater was originally a tented camp, named *Tendopoli* or Tent City by the POWs (Somma 2010). The camp commandant was Colonel De Wet (Sani 1992). Conditions were bad, and many POWs were killed by lightning. Considering the flat terrain, almost totally devoid of trees, as well as the long metal centre tent poles, the danger of lightning strikes was obvious.

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[2] At the end of the war, more than 100,000 Italians had spent time in South Africa as prisoners of war.

[3] During the Anglo Boer War (1899–1902) large groups of women and children were rounded up and held in so-called 'concentration camps'. Due to the high mortality rate and dismal condition in the camps, it sparked resentment against Britain that lingered long after the end of the war itself.

Fig. 10.2 Colonel Hendrik Federik Prinsloo, Camp Commandant of Zonderwater from 1943 to 1947 (© Italian Prisoner of War Museum, Zonderwater. Used with the kind permission of Emilio Coccia)

Smuts realised that something had to be done, and in December 1942 he appointed Colonel Hendrik Frederik Prinsloo (Fig. 10.2) as new camp commandant. Prinsloo took office in January 1943. As a young boy of 12, Prinsloo experienced life as a POW when he was caught fighting against the British with his father during the Anglo Boer War. The young Prinsloo was thrown into a concentration camp at Barberton, together with his mother (MHJ 1967).

Prinsloo was strict and a good administrator, and his own experiences of being a POW left him with much empathy for the Italians in his care. During his administration, conditions improved dramatically, something he was given credit for by former POWs. In this regard, Somma (2010, p. 71) states:

Opinion on the character, ethos and humanity of the Zonderwater camp is surprisingly uniform. Most of the Ex-prisoners of war interviewed by the author, as well as those cited in secondary sources, agree that once the camp established itself under the command of Colonel Hendrik Frederick Prinsloo the material needs and, as far as possible, emotional states of the Prisoners were met and taken into account.

10.3.2 Life in Zonderwater

Zonderwater was divided into 14 blocks. Each block was designed to accommodate up to 8000 men. Blocks were further divided into four camps per block, each able to house 2000 men. Hardline Fascists were separated from the prisoners with more moderate political views to avoid conflict. Zonderwater accommodated a maximum of 60,000 to 80,000 POWs at any one time. According to Sani (1992, p. 298), 'The tent town grew into a sort of a city whose population grew to match that of an average Italian town'.

Il Comitato Superiore (the Senior Committee) ran the camp. The Senior Committee consisted of the Camp Commandant (Prinsloo), two assistant Camp Commandants, a Welfare officer, the Italian director of the POW hospital, a member of the Senior Italian Office, the Chief Chaplain (Italian) and two members of the prisoner-of-war senior committee (Senior Italian Committee 1944).

A hospital with a capacity of 3200 beds – at that time one of the largest hospitals in South Africa – catered to all medical needs. As boredom was a constant threat to the inhabitants, 25 football fields and ten athletics tracks catered to the sporting needs of the POWs. Other sports, such as boxing and fencing, were also popular. At one stage, the camp boasted 28 football teams (Kruger 1996)!

Several schools were built, and between 9000 and 11,000 POWs were taught basic literacy by 150 Italian teachers – all fellow POWs (Ball 1967). Two types of schools were built. The Duca d'Aosta schools provided basic literacy education, roughly the equivalent of Grades 1 to 5. The HF Prinsloo schools, on the other hand, offered vocational training for a diversity of occupations, from carpentry to electrical and mechanical engineering (Fig. 10.3). Some of the schools also offered courses in woodwork, art, etc. (Emilio Coccia, pers. comm. 2019a, b; DNMMH, File 1).

In addition, 16 theatres were built. Twenty-two orchestras regularly performed in them, and a number of musicals and operas were staged. According to Somma (2010, p. 83), music was 'a link to home, a way of re-creating community, a way of poking fun at their captors, of processing their experiences and even a way of integration into South Africa for those who stayed'. It also created solidarity between the different blocks in Zonderwater and kept the memories of civilian life alive.

Art and crafts produced by the POWs were sold in the surrounding area, with exhibitions held on certain days. This enabled the POWs to earn cash to buy items not supplied by the camp authorities.

One item made by a POW at Zonderwater has an extraordinary history. A violin crafted by Luigi Galiussi was sold during one of the craft days. The violin ended up in an antique shop in South Africa and was bought by EA Steyn many years later. Steyn noticed inscriptions on the violin and decided to return it to the South African military. After negotiations between the Italian and South African militaries, Mr. Galiussi was traced and the violin returned to him almost 40 years after he made it in Zonderwater. In the final act of the story, Luigi Galiussi travelled to South Africa in 1984 to personally return the violin. He believes that because the violin was made in South Africa, it belongs in South Africa. The violin can now be seen at the Italian Prisoner of War Museum at Zonderwater (Younghusband 1984; DNMMH File 2).

A large, multi-purpose exhibition hall, built by POWs, housed theatres and music and sports administration, as well as art and craft exhibition space (Fig. 10.4). In addition, a newspaper, *Tra I Reticolati* (Behind Barbed Wire), was regularly produced in the camp. It continued to be produced by the Zonderwater Block Association after 1963 (Buranello 2009; Somma 2010).

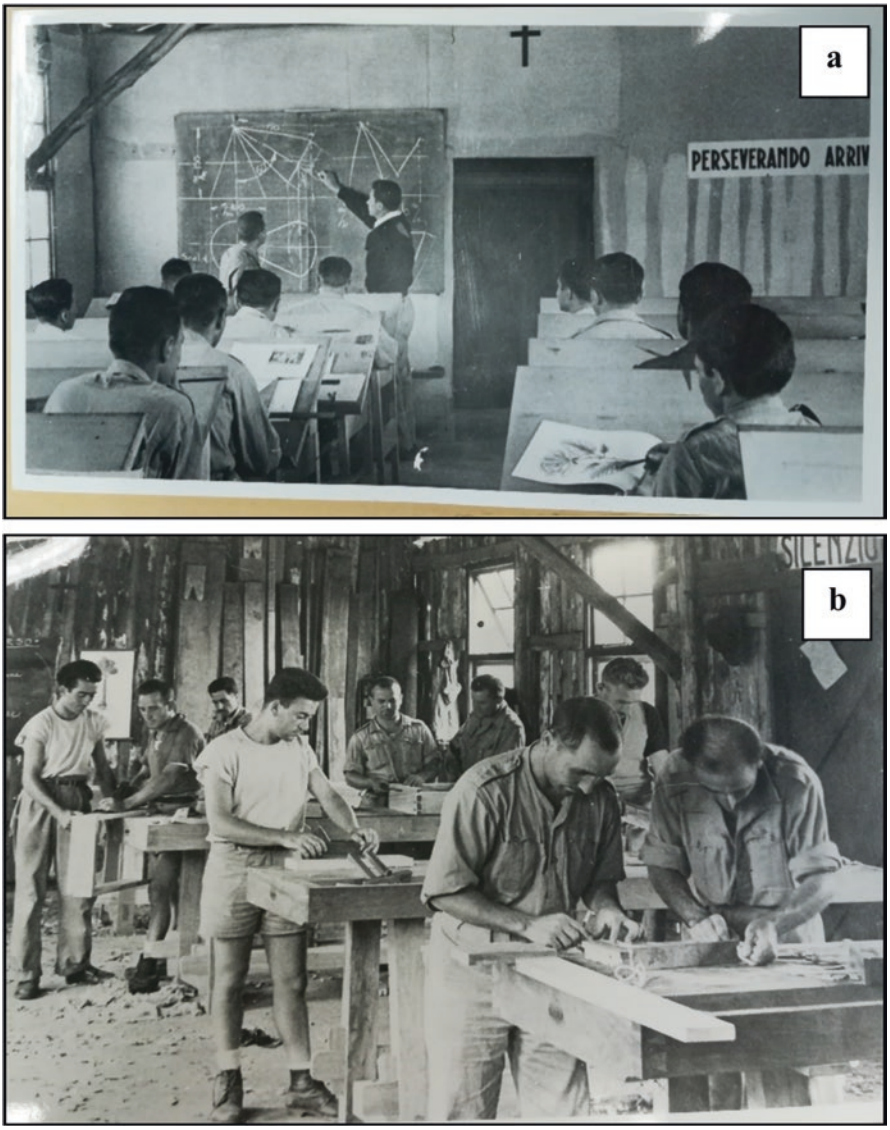

Fig. 10.3 (**a**) Education in subjects such as mathematics, technical drawing, science, physics, etc. and (**b**) training in carpentry, metalwork, etc., provided in Zonderwater (© Italian Prisoner of War Museum, Zonderwater. Used with the kind permission of Emilio Coccia)

10.4 Contributions to the South African Society

From June 1942 onwards, about 25,000 Italian POWs were employed all over South Africa in various roles. Figure 10.5 indicates the geographical spread of the contributions of the Italians. It is clear that virtually no place in South Africa escaped the presence and influence of the POWs.

Fig. 10.4 The Exhibition Hall designed and built by the Italian POWs. Public exhibitions of the works have been held annually (© Italian Prisoner of War Museum, Zonderwater. Used with the kind permission of Emilio Coccia)

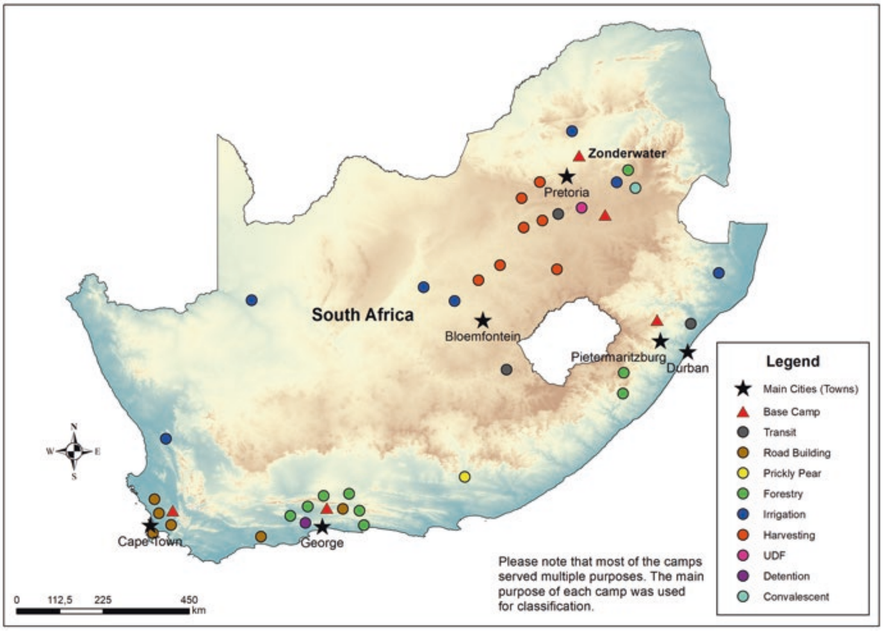

Fig. 10.5 The geographic spread of the impact of the Italian POWs on South Africa (the map was compiled using information supplied by Emilio Coccia, current President of the Zonderwater Block Ex-Prisoner of War Association; pers. comm. 2019a, b)

As noted above, although the Geneva Convention prohibited the use of POWs in military activities, this stipulation was circumvented by the status of co-belligerents the Italians enjoyed after the Italian surrender and Italy joined the Allies. After the surrender, the Italians were technically not POWs anymore, and could thus be utilised in military activities. POWs were employed at the Union Defence Force

Quartermaster General in Lyttelton and at various other Air Force and Union Defence Force bases (Emilio Coccia, pers. comm. 2019a, b).

A large number of POWs worked on farms. They performed all kinds of farm labour all over South Africa, from harvesting grapes and building wine cellars on wine farms in the southwestern part of South Africa to maize harvesting in the northeast. To aid communication, a special Afrikaans, Italian and English practical dictionary for use 'by farmers and others who make use of Italian POWs' was compiled and printed (DNMMH File 3).

POWs also worked in the forestry industry. Here, they helped to begin many forestry projects and assisted in planting, pruning and harvesting trees in the plantations. The Italians supported the forestry industry, especially in the George area of the Southern Cape and also in present-day KwaZulu-Natal and Mpumalanga in the east of South Africa (Emilio Coccia, pers. comm. 2019a, b).

Prickly pear (*Opuntia ficus-indica*) is an invasive member of the cactus family introduced from Central America in the mid-1700s. It became widespread throughout the Eastern Cape region of South Africa (Van Sittert 2002). Prickly pear spread over 800,000 hectares of the Eastern Cape as large impenetrable thickets that rendered the invested areas unusable for farming or other land uses (Zimmerman 1980; Shackleton et al. 2007). Initially, it was removed manually and burnt. The Italian POWs helped with the tedious and labour-intensive eradication programmes, supporting the reclamation of large areas for use in agriculture. Today, the reclaimed land houses some of the most productive agricultural areas of South Africa.

Many large-scale irrigation schemes commenced in the period 1941–1947. The POWs played a pivotal role in laying the foundations of these schemes, most notably the Olifants river irrigation scheme at Klawer, north of Cape Town, and one on the Orange River near Upington. Other irrigation schemes where they contributed their expertise and labour are those at Jacobsdal, Vaalharts and Warmbaths (see Fig. 10.1). All of these schemes are still in use today and form vital components of the regional economies (Emilio Coccia, pers. comm. 2019a, b).

Probably the most well-known contributions of the POWs were in construction and road building. Many fine buildings were built by Italians. The most notable surviving example is the *Madonna delle Grazie* church in Pietermaritzburg. The Camp Chaplain of the POW camp near Pietermaritzburg, Padre Giacomo Conte, asked for the church to be built as a place of worship and to combat boredom among the POWs. The construction of the church started in 1943, and it took 13 months to complete. Built with shale from a quarry some 2-km distance from the camp, this impressive building was used by the POWs until their repatriation. The church was declared a national monument in 1977 (Fig. 10.6; Rhys Jones 2016).

Roads through mountain passes such as the Du Toitskloof, Bainskloof and Chapmans Peak passes near Cape Town and the Tradouw and Outeniqua passes in the Southern Cape, benefitted from Italian know-how and labour (Delport 2013). In many of these passes, the excellent stonework in retaining walls and tunnels can still be seen. The Italians played a pivotal role, especially in the building of the Du Toitskloof Pass, by supplying labour and expertise. The pass was skilfully constructed through the extremely difficult terrain (Fig. 10.7). A small monument along

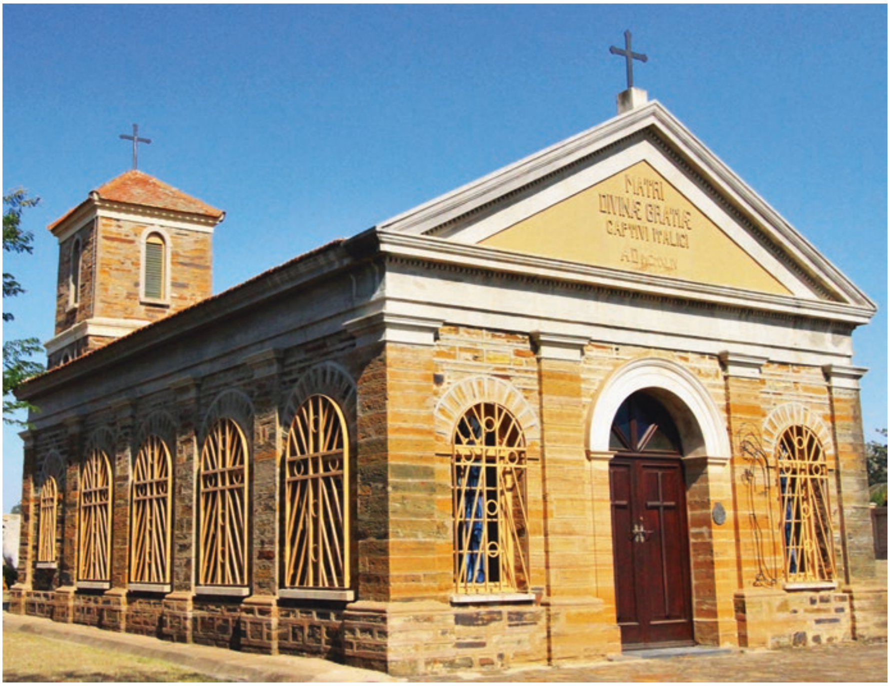

Fig. 10.6 The *Madonna delle Grazie* church in Pietermaritzburg. (Used with the kind permission of Hugh Bland)

Fig. 10.7 (**a**) Tunnel and (**b**) retaining wall built by Italian POWs in Du Toitskloof Pass, South Africa. Note the difficult terrain in (**a**) through which the road was built

the road and a steel cross on top of one of the highest mountain peaks overlooking the pass acknowledge the contribution made by these foreigners to the road infrastructure of modern South Africa (Sani 1992).

It is clear that the Italian POWs, who spent up to six years in South Africa, contributed significantly to the cultural and physical landscape of the country. This important legacy should not be forgotten.

10.5 Selected Contributions

To further demonstrate the impact of the Italian POWs on contemporary South Africa, the contributions of two prisoners of war who chose to stay behind in South Africa, Eduardo Villa and Gregorio Fiasconaro, are briefly set out below. Many more prominent Italians contributed to the development of various sectors of South African society, but only these two examples are highlighted.

10.5.1 Eduardo Daniele Villa (1915–2011)

Born in the village of Redona, on the outskirts of Bergamo, Italy, Eduardo Daniele Villa (1915–2011) became the foremost abstract sculptor in South Africa. Villa was captured in Egypt and sent to South Africa. He spent four years in Zonderwater, where he developed his artistic talents further (Van Bart 2015). To this day, his public sculptures mark the metropolitan landscape of Johannesburg – his sculptures are better represented in that city than the work of any other artist (Fig. 10.8). His numerous works – he produced more than 1000 sculptures – have also transformed the urban landscape of many other South African cities (Kruger, 1996).

In 1995, on his 80th birthday, the Eduardo Villa Museum at the University of Pretoria was opened in honour of his contribution to South African art. Villa also received the Chancellor's Medal of the University of Pretoria in recognition of his work. In addition, a second Villa Museum was established in Treviglio, Italy, by Giovanni Cervi, a Villa admirer and prolific collector of his sculptures (Read 2010).

10.5.2 Gregorio Fiasconaro (1915–1994)

The story of Gregorio Fiasconaro reads as something dreamed up for a war novel. As a young pilot, he was shot down and captured in Abyssinia (Ethiopia) and sent to South Africa as a prisoner of war. Incarcerated in the POW camp near Pietermaritzburg, Gregorio managed to meet his future wife while on an errand under guard, persuaded a prison guard to help him see her again and eventually convinced her to marry him. He accomplished this while he was barely able to speak

Fig. 10.8 'Conversation I' by Eduardo Daniele Villa (© UP Space Institutional Repository, Department of Library Services. Used with kind permission from University of Pretoria Archive)

any English, and May (short for Mabel) Brabant, his future wife, could not understand any Italian at all! Gregorio managed to escape from the camp a number of times to spend time with her and returned in time for roll call each morning, breaking back into the camp.

The fact that he was a gifted opera singer and that the Camp Commandant was an ardent opera fan saved him from severe punishment and enabled him to start a career in singing while still a POW. This talent also made it possible for him to see May from time to time and to visit her after obtaining special permission. After the war, his request to remain in South Africa was denied, but he fell seriously ill and missed the last boat transporting POWs back to Italy. This allowed him to apply again, this time successfully (Fiasconaro 1982).

Gregorio married May in August 1947, moved to Cape Town and became the first director of the School of Opera at the University of Cape Town. During his distinguished career in the music industry in South Africa, he produced more than 50 operas and sang roles in 34 of them. Gregorio is hailed as the 'Father of Opera' in South Africa and played a major role as a mentor to many South African opera stars. Ironically, some of those mentored by him became well known in his country of birth, Italy (Sani 1992).

The contribution of the Fiasconaro family to South Africa does not stop with Gregorio. On 19 July 1949, the only child of Gregorio and May Fiasconaro, Marcello Luigi Fiasconaro, was born. He became an accomplished middle-distance runner at a time when South Africa produced a couple of extraordinary athletes. Because of the sports ban against South Africa due to the racial policy of Apartheid, South African athletes could not compete internationally. However, because Marcello's father was of Italian birth, he qualified to run for Italy, and thus the sports ban did not apply to him. He moved to Italy, and on 27 June 1973, he broke the Italian and world records in the 800 m in Milan (Fiasconaro 1982). His time of 1:43.7 is still (2020) the national Italian hand-timed record, with an electronic record at 1:43.74. With that achievement, Marcello inspired a new generation of middle-distance athletes. He returned to South Africa and currently lives in Johannesburg.

10.6 Keeping the Memories Alive

In South Africa, the memories of the POWs are fading. However, in 1954, an association that promoted the interests of former Italian POWs in Italy was established in Milan. After a decade of contact between the Italian association and ex-POWs in South Africa, the Zonderwater Block Ex-Prisoners of War Association was founded in Orange Grove, Johannesburg, on 23 October 1965. The then South African Minister of Justice and future Prime Minister BJ Vorster attended the occasion in Orange Grove as an honorary guest. The aim of the Zonderwater Block was to facilitate contact between ex-POWs, both in South Africa and in Italy, and to keep the memories of the Italians who spent a long time in South Africa, and their impact, alive. The first President of the Association was Vittorio Giacchetti; the executive committee consisted of Enrico Mottalini, Ernesto Colombo and Duilio de Franceschi (Kruger 1996).

The current President of the Zonderwater Block is Emilio Coccia (Fig. 10.9), and the membership is mostly the children and grandchildren of ex-POWs (Elisa Longarato, pers. comm. 2019). A notable entry on the membership list is that of Paolo Ricci, the last known surviving inmate of Zonderwater, who turned 100 in 2019 (Fig. 10.10).

At the site of the Zonderwater camp, a cemetery with the remains of the 312 Italian POWs who died during their incarceration, together with former prisoners who chose to be buried at Zonderwater, bears silent testimony to the Italian presence in South Africa during the Second World War (Fig. 10.11). A small museum (Fig. 10.12) was opened in the Zonderwater cemetery on 4 November 1990 and houses articles made by the POWs, artwork and documents relating to Zonderwater and its inhabitants (Kruger 1996).

Every year since 1956, former POWs and members of the Italian community in South Africa, as well as representatives of the Italian and South African governments, gather at Zonderwater to honour the POWs held captive there so many years

Fig. 10.9 Emilio Coccia (right), current President of the Zonderwater Block Association, with the author, holding a violin made by Mr. Luigi Galiussi, one of the POWs at Zonderwater. The logo of the Zonderwater Block Association is in the background

ago (Kruger 1996). This is a fitting tribute to the people who shared the South African space for a relatively brief period in time but made a lasting impact on the South African landscape.

10.7 Conclusion

After the initial problems were resolved, the Italian POWs in South Africa were generally treated fairly and housed in acceptable conditions. One fact supporting this is that the mortality rate amongst POWs in South Africa. Between February 1941 to 1947, it was 312/109,000 or 0.3%. Compared to the mortality rates of 24.8% for British and 41.6% for American POWs in Japan during the early part of the Second World War (MacKenzie 1994), the favourable conditions under which the Italian POWs were kept becomes obvious

Fig. 10.10 The only known surviving prisoner of war held in Zonderwater still living in South Africa, Paolo Ricci (left), who turned 100 in 2019. The person on the right is an unknown retired lieutenant-general of the Italian Alpine Troops. (Photo used with the kind permission of Emilio Coccia)

Fig. 10.11 The cemetery at Zonderwater

Fig. 10.12 The entrance to the museum at the Zonderwater Cemetery

After the war, Colonel Prinsloo received the *Ordine della stella della solidarietá italiana* (Order of the Star of Italian Solidarity) from the post-war Italian Government. This award was established in 1947 to 'reward those who have especially contributed to the reconstruction of Italy' (Carlesso 2009). In addition to this, His Holiness the Pope conferred upon him the *Attestato di benemerenza* (the Papal certificate of Good Merit[4]; Ball, 1967). Hamish Paterson, education co-ordinator at Ditsong National Museum of Military History, maintains, 'Prinsloo is one of the only Camp Commandants of prisoner of war camps I know of that were honoured in this way' (Hamish Paterson, pers. comm. 2019). Many former POWs also applied to remain behind in South African after the war, and more returned later

Gabrielle Sani (1992) coined the term 'the Spirit of Zonderwater' to explain the special bond between ex-POWs held captive at Zonderwater. The concept also encompasses the good relations that generally existed between the Italian POWs and the South African population, as well as the prisoner of war camp personnel.

[4] This certificate, dated 5 June 1946 and signed by Monsignor Giovanni Battista Montini, then the substitute of the Secretary of State, was donated by the Prinsloo family to the Zonderwater Block Ex-POW Association and is exhibited in the Museum at the Cemetery, together with Prinsloo's uniform and commander's sword (Carlesso 2008).

Sani emphasises the sometimes-lasting friendships forged between POWs and farmers and other employers of the Italians. He even alleges that the former POWs who stayed behind in South Africa had more influence in the South African government than the officials sent to Pretoria from Rome after the war (Sani 1992)

The Italians made an immense and lasting contribution to South African society by assisting in laying the foundations of modern South Africa. The effects of their labour and skill can even now be seen in the many mountain passes, roads and buildings constructed by them. Many of the projects the Italians assisted in are still in use today and form vital components of the South African infrastructure. The irrigation schemes they helped develop supplied work to soldiers returning after the war and still form the backbone of the regional economies of the areas where they were established.

In conclusion, it is evident that the Italians who were held captive in South Africa during the Second World War and those who settled in South Africa, both before and after the war, played an immensely important role in South African society. They left a lasting impression on the South African landscape, sometimes to a greater extent than what their numbers suggest.

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References

Ball JA (1967) Italian prisoners of war in South Africa 1941-1947. Military History Journal 1(1):1-6

Buranello R (2009) Between fact and fiction: Italian immigration to South Africa. Centro Altreitalie, Globus et Locus, p 23-44

Carlesso L (2008) L'emigrazione italiana in Sud Africa. Rapporto italiani nel mondo 2009. Idos Edizioni, Roma, p 330-340

Carlesso L (2009) Centomila prigionieri italiani in Sud Africa. Longo Editore e Regione del Veneto, Ravenna, p 230

Coccia E (noh2o@gam.co.za) 2019a. RE: Italian POWs camps in South Africa. Email to HAP Smit (hennies@ma2.sun.ac.za) (10 May)

Coccia E (noh2o@gam.co.za) 2019b. RE: Schools at Zonderwater. Email to HAP Smit (hennies@ma2.sun.ac.za) (11 August)

Delport A (2013) Changing attitudes of South Africans towards Italy and its people during the Second World War, 1939 to 1945. Historia 58(1):167-190

Ditsong National Museum of Military History (DNMMH) (n.d.), Official collection, Zonderwater file B472 (68), files 1 to 3

Fedorowich K, Moore B (1996) Co-Belligerency and prisoners of war: Britain and Italy, 1943-1945. The International History Review 18(1):28-47

Fiasconaro G (1982) I'd do it again. Cape and Transvaal Printers, Cape Town

Hickman J (2008) What is a prisoner of war for? Scientia Militaria, South African Journal of Military Studies 36(2):19-35

Horn K (2011) Narratives from North Africa: South African prisoner of war experience following the fall of Tobruk, June 1942. Historia 56(2):94-112

Katz D (2012) A case of arrested development: The Historiography relating to South Africa's participation in the Second World War. Scientia Militaria, South African Journal of Military Studies, The South African armed forces 1912-2012 (Special Centenary Issue) 40(3):280-317

Kruger C (1996) The Zonderwater Italian prisoners of war 1941-1947: Fifty years down the line. South African Journal of Cultural History 10(2):88-104

Longarato E (info@zonderwater.com) 2019. RE: General information regarding the Italian POWs in South Africa. Email to HAP Smit (hennies@ma2.sun.ac.za) (28 February)

MacKenzie SP (1994) The treatment of prisoners of war in World War II. The Journal of Modern History 66(3):487-520

Military History Journal (MHJ) (1967) Forty-seven years after 'Spion Kop'. The South African Military History Society. http://samilitaryhistory.org/vol011mr.html. Accessed 14 November 2019.

Moore B (1997) Turning liabilities into assets: British Government policy towards German and Italian prisoners of war during the Second World War. Journal of Contemporary History 32(1):117-136

Paterson H 2019. RE: Italian prisoners of war and their treatment. Personal communication to HAP Smit (hennies@ma2.sun.ac.za) (29 April)

Pautch ID (2003) Prisoners of War and Internees in the Second World War – a Survey of Some Recent Publications. Contemporary European History 12(2):225-238

Read E (2010) Eduardo Villa, a biography. https://www.everard-read.co.za/artist/EDOARDO_VILLA/biography/. Accessed: 11 November 2019

Rhys Jones R (2016) The little church with a big history. The Sunday Tribune, 23 October

Sani G (1992) History of the Italians in South Africa, 1489-1989. Zonderwater Block, Edenvale

Senior Italian Committee (1944) Italian prisoners of war in the Union of South Africa. Reprinted in 1998. Tiger Press, Johannesburg

Shackleton CM, McGarry D, Fourie S et al. (2007) Assessing the effects of invasive alien species on rural livelihoods: Case examples and a framework from South Africa. Human Ecology 35(1):113-127. https://doi.org/10.1007/s10745-006-9095-0

Somma D (2010) Music as discipline, solidarity and nostalgia in the Zonderwater prisoner of war camp of South Africa. SAMUS: South African Music Studies 30/31(1):71–85

Sutker PB, Allain AN, Winstead MS et al. (1993) Psychopathology and Psychiatric Diagnoses of World War II Pacific Theater Prisoner of War Survivors and Combat Veterans. American Journal of Psychiatry 150(2):240-245

Van Bart, M (2015) Bronsfiguur van Edoardo Villa haal R120 000: Italiaanse krygsgevangene is steeds 'n gerekende beeldhouer. Beeld, 12 June

Van der Waag I (2015) A Military History of modern South Africa. Jonathan Ball, Johannesburg

Van Sittert L (2002) Our Irrepressible Fellow-colonist: The Biological Invasion of Prickly Pear (*Opuntia ficus-indica*) in the Eastern Cape c. 1890–c1910. Journal of Historical Geography 23*:*397-419

Younghusband T (1984) Precious violin comes back 'home.' Pretoria News, 5 March

Zimmerman HG (1980) Doringturksvy/Prickly pear. In: Stirton CH (ed) Indringerplante, mooi, maar gevaarlik. Credo Press, Kaapstad, pp. 112-115

Chapter 11
The 10th Mountain Division at Camp Hale, Colorado: The Origin of Mountain Alpine Warfare Testing and Training in the US

William W. Doe III and Michael R. Czaja

Contents

Abstract This paper examines the history, geography, and legacy of how and where the US Army established its first military installation for the testing and training of soldiers in alpine and mountain warfare in anticipation of fighting in the European Theater during World War II. The establishment of Camp Hale, located in the Colorado Rocky Mountains, from 1942 to 1944 was an important episode in the Army's efforts to develop a unique fighting force designated as the tenth Light Division (Alpine), later the 10th Mountain Division. The construction, completed in eight months, was an engineering feat with a massive, federally funded effort requiring over 8000 construction workers. At Camp Hale, the Army conducted rigorous training, including military skiing, mountaineering, altitude training, and the use of pack mules and sled cargos. More than 16,000 soldiers and their animal companions trained there. The legacy of Camp Hale and its veterans remains an important component of Colorado's geomilitary cultural heritage, including the development of Colorado's major ski areas. Razed in 1986, leaving behind only a few structures, the

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Camp's site and its relationship to the tenth Mountain Division have been aptly memorialized, including proposed designation by the US Congress as the first National Historic Landscape.

Keywords Camp Hale · 10th Mountain Division · Mountain alpine warfare · Military construction

11.1 Introduction

The establishment and construction of Camp Hale, Colorado, in 1942 and 1943 (Fig. 11.1), and the subsequent establishment of the US Army's first formal unit, the 10th Mountain Division, to be designated and trained for fighting in mountain and alpine environments, represent a unique military story in the annals of the US Army. In 2019, the nation and the State of Colorado celebrated the 77th anniversary of the construction of Camp Hale by proposing the designation of about 11,625 hectares surrounding Camp Hale as the first-ever National Historic Landscape for the purpose of ensuring historic preservation, providing recreational opportunities, and protecting the natural resources of the area (Neguse 2019). Furthermore, in 2019, the European Allies of World War II (WWII) celebrated the 75th anniversary of a number of important battles and events that preceded the end of the war in 1945. These celebrations presaged the 75th anniversary in 2020 of the January–February

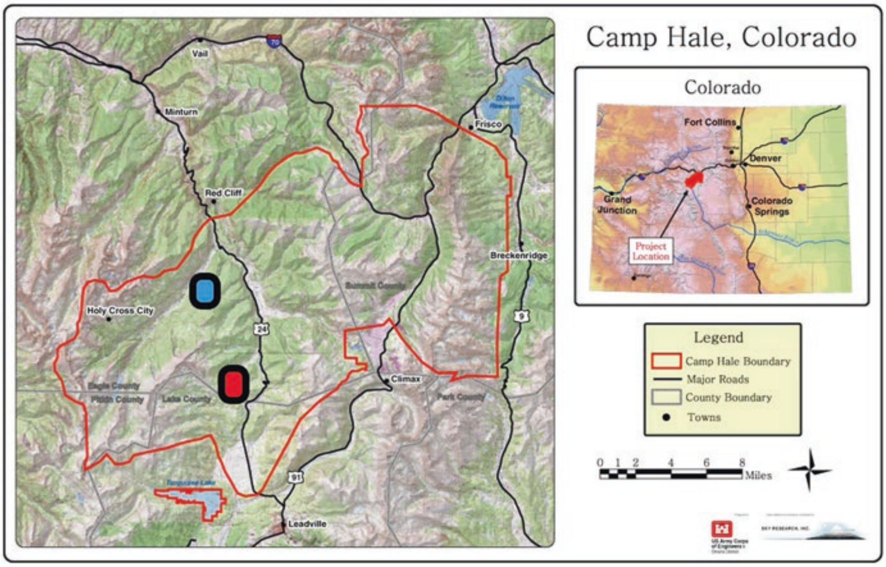

Fig. 11.1 Map of Camp Hale training area boundary showing locations of the cantonment (blue rectangle) and Cooper Hill ski training hill (red rectangle). (Modified from USACE n.d.)

1945 battles fought on Riva Ridge and Monte Belvedere in the Apennine Mountains in the Italian Theater by the 10th Mountain Division. These battles validated the mountain training of the Division, with important victories that helped to turn the tide of the war in favor of the Allies. These recent historical and memorial celebratory events provide an opportunity to reexamine the establishment of Camp Hale and the origins and training of the 10th Mountain Division from new perspectives.

Specialized training of units for alpine and mountain warfare was not seriously undertaken by the US Army until the approach of US entry into World War II (WWII) in the early 1940s. In anticipation of operations in the European Theater, training for extended operations in cold and mountainous areas was initiated in November 1941 with the activation of the 87th Mountain Infantry and the Mountain and Winter Warfare Board at Fort Lewis, Washington. Training and testing were conducted by these organizations throughout the winter of 1941–1942 at Mount Rainier, Washington—one of the US national parks, characterized by a rugged strato-volcano at the elevation of 4393 m in the Cascade Range. These units, under the command of Lieutenant Colonel Onslow S. Rolfe,[1] were later to become the nucleus of the 10th Mountain Division and the purpose for the training that took place at Camp Hale.

The need for mountain and alpine training was prompted by several consequential battles in the subarctic region of the Aleutian Islands of Alaska against the Japanese in 1942, one of the US Army's first major campaigns. The Aleutian Islands are a volcanic island chain off the coast of Alaska—a landscape complicated by subarctic climatic conditions and a volcanic terrain characterized by significant mountains and high relief. This campaign, the only campaign of WWII fought on US soil, and the Battle of Attu have been studied in depth by numerous historians and geographers (e.g., Palka 2005). Unfortunately, many of the lessons learned relate to an unprepared Army that did not understand the consequences of operating in this type of environment, both operationally and in terms of soldier survival and cold weather training. The 7th Infantry Division, chosen to conduct these operations, had received most of its training in the Mojave Desert of southern California rather than in the subarctic environments of Alaska or other colder and more mountainous regions (Doe 2011).

More broadly, the Army was concerned with "low mountain" terrain—where no timberline or summer snow existed (Marzoli 2019). The Army was preparing for an anticipated invasion of Sicily, off the southern coast of Italy, an island characterized by rugged and craggy terrain. Since many of the standard Army divisions designated for this deployment were based on the East Coast, the Army initiated a low-mountain training program in the National Forests of Virginia and West Virginia (Marzoli 2019). From mid-1943 until mid-1944, Regimental Combat Teams from five Army Divisions trained in these national forests to familiarize them with operations in mountainous terrain (Marzoli 2019). Additional detachments of troops

[1] Colonel Rolfe, a native of New Hampshire and only an amateur skier, was a 1917 graduate of the US Military Academy at West Point, New York, and a highly decorated veteran of WWI (Isserman 2019).

were sent to locations such as Camp McCoy, Wisconsin, and Pine Camp, New York, for similar training.

11.2 Finding and Building Camp Hale

During the period in which the 87th Mountain Infantry was undergoing training at Mount Rainier, plans were being made to find a more permanent location for mountain training and a site was selected for a center at which an entire division could be trained in the tactics and techniques of alpine and mountain warfare. In September 1942, the Army Ground Forces Command activated a Mountain Training Center at Camp Carson, Colorado, near the city of Colorado Springs (Witte 2015). Subsequently, a cadre of officers from the Training Center selected a permanent training area and cantonment site in the nearby Rocky Mountains. In November 1942, The Mountain Training Center, with members of the 87th Mountain Infantry as a cadre, commenced operations at the newly constructed Camp Hale.[2]

In selecting a location for its mountain/alpine training, Army planners identified several critical criteria for the site based on the inadequacy of other sites upon which it had trained. As noted in the Army Ground Forces study (Govan 1946):

> Fort Lewis, in the lowlands of western Washington, did not have sufficient snow for skis, nor was it high enough for mountain work. The nearest suitable location was Mount Rainier, sixty two miles away over paved and sloughed highways and owned by the National Park Service.

Site selection was based primarily on five major criteria: (1) high elevation with sufficient snowfall; (2) potable water availability for 20,000 soldiers; (3) remote location but with accessibility by paved road and rail; (4) availability of nearby coal supplies for electricity; and (5) access to nearby federal land. The selection of the Camp Hale training area consisting of more than 171,000 hectares met all of these criteria (Fig. 11.1). The site was accessible by Highway 24 and the Denver-Rio Grande railroad, adjacent to large tracts of national forest, and relatively near the established mining town of Leadville, which could provide living facilities for the construction workers (Govan 1946).

Located in what was called Eagle Valley, the site was on the edge of the Sawatch Range of the Colorado Rockies. The Sawatch Range is known as the “backbone of the continent” and forms the continental divide from Tennessee Pass in the north to Marshall Pass in the south. The range contains 15 peaks over 4300 m in elevation (Isserman 2019). The geology and irregular topography of the site had evolved during the Pleistocene glacial period when a large terminal moraine had been deposited, damming the original Eagle River and forming a lake basin. When the lake overflowed, the Eagle River was forced to cut a new channel forming the deep

[2] Camp Hale was named after Brigadier General Irving Hale, a Denver, Colorado native, valedictorian of the West Point Class of 1884, and a hero of the Spanish American War.

narrow canyon occupied by the river and the railroad. Over time, the lake drained but the meandering river formed a broad, flat-floored valley representing the floor of the old glacial lake (Witte 2015). Dominant vegetation communities in the region consist of spruce and subalpine fir forests, tundra meadows, aspen and lodgepole pine forests, and mountain wetlands and riparian areas.

Officially located in Pando, Colorado, the construction of Camp Hale required the Army to work closely with town officials from Leadville, where all of the housing and infrastructure existed for the construction workers (Fig. 11.1; Coquoz 2003). Formal agreements were made with the city to construct trailer parks and increase infrastructure for water and sanitation. One of the more interesting aspects of the Army's move to the area was the closing of Leadville's "Red Light District," which had existed since the inception of Leadville as a mining town in the 1880s (Coquoz 2003).

Once the appropriate cantonment site within the training area boundary was identified, a massive, federally funded construction effort began in April 1942. Over 8000 construction workers descended upon this mountain valley to construct a military camp. This large-scale project was completed in eight months. Unfortunately, in the haste to build the cantonment and get training started, little consideration was given to the fragile alpine environment. The valley swamp was drained, and the Eagle River, which flows through the valley, was channelized to flow directly through the cantonment in a ditch (Fig. 11.2). Hectares of native willows, spruce, and sagebrush were cleared, and the valley was filled with more than 134,500 m^3 of natural material from the surrounding mountainsides to make a level surface area for the cantonment (Isserman 2019). A full military city was constructed complete with all of the facilities typical of a permanent encampment, including barracks, mess halls, warehouses, training facilities and firing ranges, office buildings, stables, theaters, chapels, a field house, hospitals, and stalls for the mules. Overall, more than a thousand buildings were constructed. They were painted a uniform white with sharply pitched roofs to shed snow and aligned along a grid of four avenues, intersected by 21 numbered streets. Each barracks was designed to house 63 men, along with their equipment and skis (Isserman 2019). The accommodations were rustic, but they were more than adequate for the purpose at hand. Unfortunately, the coal-fired heating plant produced terrible air pollution in the Pando Valley such that many soldiers became ill with what was known as the "Pando hack" (Saunders 2005). In addition to the construction of the main cantonment, a number of ski slopes were constructed approximately 11 km from the cantonment at the summit of Cooper Hill (Fig. 11.1). Intermediate and advanced ski slopes were serviced by several 300-m long T-bar lifts.

Fig. 11.2 Channelized Eagle River

11.3 Training and Preparations for War at Camp Hale

The completion of construction at Camp Hale coincided with the end of the US Army's unit designation of a special fighting force for mountain and alpine environments. In July 1943, the 10th Light Division – Alpine, consisting of three regiments and supporting units, was designated at Camp Hale. This designation replaced the first Battalion, 87th Infantry Mountain Regiment, which was established by General George Marshall shortly after the Japanese attack on Pearl Harbor, Hawaii, in December 1941 and only a year after the Battle of Attu in the Aleutian Islands in May 1942. Lieutenant Colonel Rolfe, the original commander of the 87th Regiment and newly promoted to Brigadier General as Commander of the Mountain Training Center, became the Commanding General of Camp Hale and moved his staff there to commence training.

Officials of the National Ski Association and the American Alpine Club recruited a number of civilians skilled in ski and mountaineering techniques to join the ranks of the 10th Mountain Division at Camp Hale. Among these were the acclaimed Norwegian ski jumper Torger Tokle; Dartmouth College, New Hampshire, ski coach Walter Prager; miscellaneous Olympians; and scores of fiercely anti-Nazi former ski instructors from Austria. Noted mountaineers Paul Petzoldt and David Brower signed on, as did Mount Rainier mountaineers Dee and Kay Molenaar (Jenkins 2003; Saunders 2005). Skiing as a hobby was then largely confined to regions of the country where snow and winter sports were part of the social fabric. At the collegiate level, skiing was a common sport among the rich, so a strong component of graduates from elite universities, such as Yale, Harvard, and Princeton, joined the Division as well (Jenkins 2003; Saunders 2005). Rounding out the Division's ranks was an array of lumberjacks, ranch hands, and others familiar with mountain life.

Rigorous training, including military skiing, mountaineering, altitude training, and the use of pack mules and weasels (sled cargos), was conducted at Camp Hale. The story of the camp revolves primarily around the 16,000 soldiers and their animal companions, which included 5000 mules and 200 K9 dogs, who trained at Camp Hale between 1942 and 1943 (Isserman 2019). Extensive individual training and unit-level training maneuvers were held in all conditions. The sounds of live artillery and other weapons firing punctuated the valley. Soldiers learned to survive in the cold and altitude on extended overnight exercises.

Aside from the continuous training, life at Camp Hale consisted of recreational and educational activities, even including dances with members of the local population. Writing letters and postcards and hosting occasional visitors, even families, helped the soldiers fight off the inevitable boredom of being stationed in a remote location with little to do outside the encampment. Occasionally, groups of soldiers would escape to Leadville, where they had to be retrieved by military police (Isserman 2019). There were many other interesting aspects to life at Camp Hale, including the arrival in the summer of 1943 of several hundred women from the US Women's Army Corps and several hundred German prisoners of war who were reportedly captured from German General Rommel's famous Afrika Korps (Isserman 2019).

11.4 Post Camp Hale Deployment and Fighting in Italy

In June 1944, only a year after its arrival at Camp Hale, the 10th Mountain Division was moved to Camp Swift, Texas, for flatland training as part of the so-called Louisiana Maneuvers in anticipation of combat in the European Theater. This had a tremendous negative impact on morale. Only six months later, the Division was converted to a standard US infantry division and shipped to the Italian Theater, where it fought gallantly in the assault up the Italian peninsula, to include difficult fighting in the Apennine Mountains at Riva Ridge and Monte Belvedere. Thus, in some ways, the mountain training provided to them at Camp Hale produced some dividends, although certainly not to the full scope of their alpine and cold weather capabilities (Jenkins 2003). The heroic exploits and successes of the 10th Mountain Division in Italy and their direct contributions to the Allied victories in 1945 are well documented (e.g., Jenkins 2003; Isserman 2019).

11.5 The Postwar Period at Camp Hale

In March 1946, the Army moved its remaining elements out of Camp Hale and established the Mountain and Winter Warfare School at Camp Carson, now Fort Carson, near Colorado Springs (Fig. 11.1). However, Camp Hale's legacy as the Army's original training site for winter and mountain warfare continues to this day. From 1959 to 1965, the Central Intelligence Agency secretly trained Tibetan soldiers there. Camp Hale was used for other military purposes until it was deactivated in 1965 and returned to the US Forest Service as part of the White River National Forest. In 1986, the US Army Corps of Engineers razed the entire Camp Hale cantonment area. At the time, the costs of retaining the nonpermanent structures were not consistent with the Forest Service's plans for the recreational use of the area. Remaining today are only a few foundations and remnants of the field house and rifle ranges standing like gravestones (Fig. 11.3). The site was designated as a National Historic Site by the US National Park Service in September 1992 (Anon. n.d.-a) and subsequently proposed as a National Historic Landscape in 2019 (Neguse 2019).

Despite these federal designations, significant environmental cleanup was required due to remnant munitions and other environmental impacts identified after the area was transferred in 1965 to the US Forest Service and opened to the public for recreational uses. There are two environmental legacies—first, the hazard resulting from the military ordnance and munitions used on firing ranges in the East Fork

Fig. 11.3 Remaining structures (field house) at Camp Hale (Doe 2011)

Valley of Camp Hale, including antitank rounds, grenades, mortars, artillery, and small arms rounds and, second, the channelization of the Eagle River (Fig. 11.2).

In the late 1990s and continuing through 2007, several hazardous site investigations were conducted. Ordnance items were encountered and disposed of by Fort Carson Explosive Ordnance Disposal personnel. This work consisted of a surface clearance of approximately 200 hectares in the valley. Munitions or munition-related scrap materials were found in 214 grids, and 24 live items were destroyed. To date, hikers, hunters, firefighters, and the US Army Corps of Engineers have found military munitions in the Camp Hale project area. For example, since September 1999, 17 potentially hazardous munitions have been found within the site boundaries (USACE n.d.).

The second environmental impact resulted from filling the valley floor of the Eagle River with gravel and other materials from the surrounding mountainsides, channelizing a formerly sinuous mountain stream (Fig. 11.2). Recent efforts to return the Eagle River to its original channel configuration were strongly opposed by military veterans of Camp Hale, testifying to the tensions between various realities and views of military spaces and places and environmental restoration. However, recently, a plan for the restoration of the river has been devised with cooperation between the US Forest Service and numerous public and private entities (Anon. n.d.-b).

11.6 Legacy and Memorialization of the 10th Mountain Division in Colorado

The Camp Hale site and its close relationship to the 10th Mountain Division have been aptly memorialized at the original location. The land is open to the public, and there are numerous plaques detailing the history of the site and the training conducted there. About 11 km south of the Camp Hale site, at Tennessee Pass (elevation 3177 m; Fig. 11.4), a memorial has been established in honor of the 992 fallen soldiers and more than 4000 wounded veterans of the 10th Mountain Division and its sister units (Fig. 11.5). The memorial was dedicated on Memorial Day[3] of 1959. Each Memorial Day, a service attended by many veterans of the 10th Mountain Division, other veterans, and their families is held there.

After the war, many 10th Mountain Division veterans distinguished themselves in civilian and environmental ventures to a degree unrivaled by veterans from other divisions. Some of them returned to the vicinity of Camp Hale in the Colorado Rockies and created and designed Colorado’s major ski areas, including Vail and Aspen, thus bringing full circle the association of the Army with the mountain landscapes it had first chosen for its training sites for mountain and winter warfare.

[3] Memorial Day has been a US federal holiday since 1868 honoring Americans killed in wartime. Since 1971 it has been celebrated on the last Monday in May

Fig. 11.4 Memorial sign at Tennessee Pass, Colorado Rockies

Fig. 11.5 The tenth Mountain Division Memorial at Tennessee Pass

Fig. 11.6 The 10th Mountain Division Ski Memorial at the Vail, Colorado Ski Area

A typical story was that of Peter Seibert, a native of Sharon, Massachusetts, and high school athlete, who competed on the ski team. Seibert enlisted at age 18 after hearing about the Division at Camp Hale and reported there from Boston in June of 1943 as a private. After his training at Camp Hale, he was deployed to Italy with the tenth Mountain Division, where he was severely wounded. Returning to the US after recovering from his wounds, he again took up skiing and became a member of the 1950 US Olympic Ski Team. In the early 1960s, Seibert was one of the original Camp Hale veterans who returned to Colorado to open the first commercial ski areas in Vail. His full story from ski athlete to mountain soldier to ski entrepreneur is fully described in his biography (Borden 2017). The close relationship between the Division and Colorado's famous ski areas is further illustrated by the monument to the "Ski Troops" in Vail, within view of the ski lifts (Fig. 11.6; Jenkins 2003; Saunders 2005), and by a historical display of 10th Mountain Division artifacts at the Colorado Snowsports Museum, also in Vail.

11.7 Conclusion

The story of the construction of Camp Hale and the example of specialized alpine and mountain training conducted there by the 10th Mountain Division in preparation for World War II are remarkable. At the time, the scale and magnitude of the efforts to build an entire military installation in only eight months were unprecedented.

These efforts required a total commitment of resources and support from local governments and communities and the mobilization of over 8000 construction workers to a remote site to build the Camp. The recruitment of thousands of elite athletes, professional skiers, and outdoorsmen from across the country to volunteer and fill the ranks of the 10th Mountain Division and to be housed and trained at Camp Hale remains a singular example of recruitment and patriotism that is unfamiliar to our current society and its smaller volunteer Army. The postwar contributions of veterans from the 10th Mountain Division, returning to the mountains of Colorado after leaving military service and establishing the first commercial ski areas of what is today a major economic driver of Colorado's economy, provide a legacy that allows this important story to live on.

References

Anon. (n.d.-a). US National Park Service Register of Historic Places http://www.nps.gov/history/nr/feature/va/2001/hale.htm. Accessed 4 August 2020

Anon. (n.d.-b). US National Forests Camp Hale – Eagle River Headwaters Restoration Project: collaborative recommendations for restoration and management http://www.Nationalforests.org/assets/blog/Camp-Hale-Master-Plan.pdf. Accessed 4 August 2020

Borden L (2017) Ski soldier: A World War II biography. Calkins Creek Press, Honesdale, PA

Coquoz R (2003) The invisible men on skis: the story of the construction of Camp Hale and the occupation of the 10th Mountain Division, 1942-1945. Johnson Publishing Company, Boulder, CO

Doe W. (2011). Cold regions and mountain testing and training areas in the United States. In: Häusler H, Mang R (eds) International Handbook Military Geography: Proceedings of the 8th International Conference on Military Geosciences, vol 2. Arbeitsgemeinschaft Truppendienst, Ministry of Defence and Sports, Vienna, p 132-143

Govan TP. (1946). Training for Mountain and Winter Warfare, US Army Ground Forces Study No. 23. http://www.history.army.mil/books/agf/agf23.htm. Accessed 4 August 2020

Isserman M (2019) The winter army: The World War II odyssey of the 10th Mountain Division, America's elite alpine warriors. Houghton Mifflin Harcourt, New York

Jenkins, M. (2003). The last ridge: the epic story of the U.S. Army's 10th Mountain Division and the assault on Hitler's Europe. Random House, New York

Marzoli N (2019) The best substitute: U.S. Army low-mountain training in the Blue Ridge and Allegheny Mountains, 1943-44. Army History, the Professional Bulletin of Army History 113: 6-24

Neguse J. (2019). The Colorado outdoor recreation and economy act. House (Committee) Report 823, 116th US Congress, Washington, DC. https://www.congress.gov/bill/116th-congress/house-bill/823. Accessed 4 August 2020

Palka E (2005) World War II in the Aleutian Islands: Physical Geographic Challenges in the Battle for Attu. In: Palka E, Galgano F (eds) Military geography from peace to war, McGraw Hill Custom Publishing, Boston, MA, p 67-90

Saunders C. (2005). The boys of winter: life and death in the U.S. ski troops during the second World War. University Press of Colorado, Boulder, CO

US Army Corps of Engineers. (n.d.). Camp Hale Colorado Military Munitions Project. http://www.camphale.org. Last accessed 30 December 2019

Witte D (2015) World War II at Camp Hale: Blazing a New Trail in the Rockies. The History Press, Charleston, SC

Chapter 12
German Military Geography and Geology at the Eastern Front 1941–1945

Hermann Häusler

Contents

Abstract In 1940, prior to the invasion of the Soviet Union, MilGeo, Branch Nine of the German Army General Staff, prepared a series of booklets, including maps depicting the terrain, population and infrastructure of European Russia. At the same time, military geology teams (MGTs) provided trafficability maps for the area west of Moscow at a scale of 1:300,000. During the Second World War, at least 139 German and Austrian military geologists in 34 MGTs were deployed to the Eastern Front. From 1940 onwards, 15 MGTs were assigned to fortress engineers, the Inspectorate of Fortifications, and territorial military commanders and 19 MGTs to Higher Commands of Army Groups, Armies and Panzer Armies. Approximately 3500 military geologic reports and written opinions, which provided insight into terrain characteristics for the attacking and retreating German Armies, were prepared. Military geology teams dealt with a wide range of geotechnical problems, including water supply, earthworks, provision of construction materials for roads and railways and assessment of off-road trafficability for both tracked and wheeled vehicles. Russian engineer instructions on traversing moors and frozen rivers in

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addition to statistical data on thawing and flood periods of rivers allowed for a detailed prognosis of the going conditions for armoured brigades.

Keywords Second World War · Military geography · Military geology · Military geology team · Trafficability · Forschungsstaffel z.b.V. · Operation Barbarossa

12.1 Introduction

After the declaration of military sovereignty in 1935, it was imperative for the *Wehrmacht* (German Armed Forces) to have control of the mapping and survey services in the interest of defence (Klinckowstroem 1945). In order to create a military agency that would look after the interests of the Wehrmacht, the Geodetic Section, up to that time affiliated to Branch One (Operations) of the Army General Staff, was made a regular branch of the General Staff and was designated as Branch Nine: Mapping and Survey Branch. In 1937, Branch Nine of the General Staff proposed centralising the mapping and survey services of the Army, Navy and Air Force into the Armed Forces Cartographic Office. However, it was argued that a hydrographic map had nothing in common with a terrain map and that a pilot chart for aerial navigation served other purposes than did the General Staff map. As a result, the Luftwaffe and Army independently developed their own 1:500,000 scale map series of (greater) Germany (Klinckowstroem 1945).

At the same time as the occupation of Poland in September 1939, the General Staff of the German Army prepared for invasions of Denmark and Norway; the Netherlands, Belgium and France; and the Soviet Union. This paper deals with geographic and geologic information on the Eastern Theatre, which was provided by six different branches of the Wehrmacht:

1. MilGeo, the geographic service of the German Army
2. Technical Military Geology, the leading applied geologic service of the Army High Command deployed to the Inspectorate of Fortifications
3. Technical Military Geology, subordinate to the Army Ordnance Office
4. Technical Military Geology of the *Waffen-SS* deployed to the Operational Headquarters of the SS
5. *SS-Wehrgeologenkorps* (Geological Corps) of the Waffen-SS; and
6. *Forschungsstaffel z.b.V.*, the research staff for special terrain evaluation duties of the Supreme Command of the Armed Forces High Command

Interestingly, despite organisational problems until 1940, in 1941, and independently from each other, these applied military geoscientific branches involved with military geography and geology were organized by different offices of the Armed Forces High Command, the Army High Command and the Waffen-SS. Figure 12.1 does not show command channels as of any given period but rather represents major

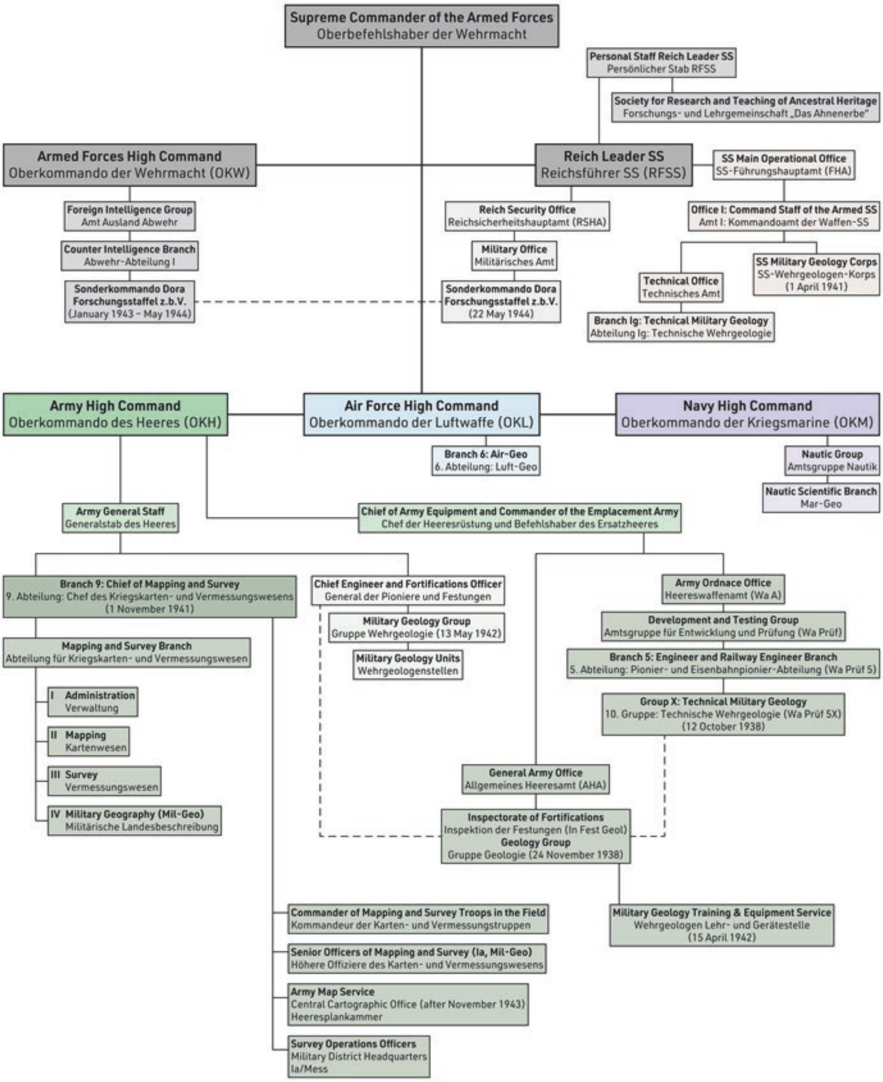

Fig. 12.1 The major functional relationships of mapping and survey services in the Wehrmacht during the Second World War. (Compiled from Klinckowstroem 1945; War Department 1945; CIA 1951; Häusler 1995a; Häusler and Willig 2000; Müller and Hubrich 2009)

functional relationships between offices of the German Army during the Second World War dealing with military geography and geology. The Army General Staff was a functional part of the Army High Command and must not be confused with the General Staff Corps, members of which filled almost all the important command and staff positions throughout the Army. In time of war, the Army General Staff was stationed at field headquarters, leaving only a small rear echelon in Berlin. The following description gives the nomenclature and function of the most important subdivisions of the Armed Forces High Command related to military geography and geology.[1]

According to the US Handbooks on German Military Forces (War Department 1943, 1945), the Army High Command in peacetime consisted of 12 branches within five sections of the *Oberquartiermeister* (Senior General Staff Officer), including Branch Nine: Topography. At the beginning of the war, several sections of the *Generalquartiermeister* (Chief Supply and Administration Officer) took care of the whole supply and administrative structure of the Field Army. Most of these branches of the Senior General Staff Officer and the Chief Supply and Administration Officer are not depicted in Fig. 12.1, except for Branch Nine of the First Senior General Staff Officer. This branch had been handled by the Chief of Mapping and Survey in the General Staff since 1 November 1941. According to the chart of Klinckowstroem (1945), the Mapping and Survey Branch was at that time affiliated with the Army General Staff as Branch Nine. For the duration of the war, this branch of the Army General Staff, the Mapping and Survey Branch, was headed by a chief of branch called Chief of Mapping and Survey, who was part of the rear echelon of the General Staff and, prior to the start of the Russian campaign, was represented by the Commander of Mapping and Survey Troops at field headquarters (Fig. 12.1). Organisational diagrams of the Chief of Mapping and Survey dating from 1 August 1941, May 1942 and January 1943 were published by Müller and Hubrich (2009). In November 1943, in order to standardise the permanent military mapping and survey establishments, the Army Map Service was reorganised as the Central Cartographic Office, a designation that characterised it as the main centre for all military mapping and survey offices (Klinckowstroem 1945).

The Chief Engineer and Fortifications Office headed both the Group Geology, affiliated to the Inspectorate of Fortifications, which was subordinate to the General Army Office of the Chief of Army Equipment and Commander of the Emplacement Army, and the Military Geology Group of the Army General Staff beginning on 13 May 1942. In addition, the development of geologic and geophysical methods was performed at a desk of the Army Ordnance Office, which, comparable to the Inspectorate of Fortifications (concerned with the training of fortress engineers), was also subordinate to the Chief of Army Equipment and Commander of the Emplacement Army. The Development and Testing Group was responsible for the development and testing of ordnance equipment for all arms and services. The Technical Military Geology Group was the tenth desk of the fifth section of the Engineer and Railway Branch subordinate to the Development and Testing Group (Häusler and Willig 2000).

Since real concentration of mapping and surveying within the Wehrmacht was not accomplished until February 1945, joint tasks had to be solved by co-operation between the top-level agencies responsible for mapping and survey in the Army, Air

[1] See Appendix 12A for German terms not defined in the text or in Fig. 12.1.

Force and Navy. On questions at the Wehrmacht level, Branch Nine of the Army General Staff was invested with Wehrmacht authority (Klinckowstroem 1945) and co-operation was especially close with Branch Six of the Luftwaffe General Staff, which was responsible for photographic survey flights and photogrammetry (Häusler 2007). In addition, Branch Seven, later Division Seven of the Reich Air Ministry, was charged with the production and procurement of maps and produced fluorescent maps for night flights in Russia. The map sections of the regional commands, which had been advanced into Russia, functioned as map supply centres (Drechsel 1947).

12.2 Military Geographical Studies of Eastern Europe

During the war, the military geographic service of the Army General Staff published more than 100 geographical handbooks on about 40 countries, as well as more than 300 map sheets, more than 500 city plans and more than 1300 *Stadtdurchfahrtpläne* (maps showing the best ways to get through cities; CIA 1951). *Generalstab des Heeres, Abteilung für Kriegskarten- und Vermessungswesen, IV Mil.-Geo.* (Fig. 12.1), herein abbreviated as MilGeo (fourth section of the Mapping and Survey Branch), issued more publications on the USSR than on any other country. Military geographical studies on European Russia were classified *Nur für den Dienstgebrauch* (for official use only) and were prepared from August 1940 to August 1942, most of them prior to the beginning of Operation Barbarossa (the German invasion of Russia) in June 1941. In 1942, another series was printed on military geographical studies of Asian Russia as well as booklets on high mountain passes in the Caucasus and, in 1943, secret studies on Russian rivers (CIA 1951).

The handbooks of the Army General Staff on western Russia comprised the following 13 volumes of cardboard folders consisting of handbooks and maps (*Mappe A-N*) (Fig. 12.2):

- *Mappe A*: General Overview (1 March 1941; earlier edition: 10 August 1940)
- *Mappe B*: Baltic Countries (March 1941)
- *Mappe C*: Leningrad Region (10 June 1941)
- *Mappe D*: Karelia and Kola Peninsula (15 June 1941)
- *Mappe E*: White Russia (27 March 1941; second edition: 22 April 1941)
- *Mappe F*: Ukraine (15 May 1941; third edition: 5 September 1941)
- *Mappe G*: Central Russia (without Moscow; 15 May 1941)
- *Mappe H*: Moscow (20 June 1941)
- *Mappe J*: Caucasus (10 August 1941; second edition: 17 August 1942)
- *Mappe K*: Volga River Region (10 July 1941; supplement 1 December 1941)
- *Mappe L*: Ural Mountains Region (30 September 1941)
- *Mappe M*: Vologda-Arkhangelsk Region (5 August 1941)
- *Mappe N*: Northeast Russia (Draft, 1 June 1942)

Fig. 12.2 German handbooks on European Russia printed by the Chief of Mapping and Survey in 1941, many of them provided before 22 June 1941, the beginning of the German invasion of the USSR. (Used with permission from the archive of the Salzburger Wehrgeschichtliches Museum)

The typical MilGeo handbook was a pocket-sized paper folder containing an assortment of booklets and folded maps, each 15 × 22 cm in size (Fig. 12.2). The folder generally contained a comprehensive *Textheft* (text volume) of 100–200 pages with a section in which the entire country was discussed by topics; a section describing the geographic regions of the country; an inventory of roads, railroads, waterways, water resources, health facilities, industrial plants, principle towns, airfields, population and administrative districts; and five to 20 black-and-white maps on a variety of subjects (CIA 1951). Descriptions that were useful for military interpretations, such as economic conditions, administrative boundaries, population, transportation, telecommunications, drainage, vegetation and soil cover, were also included. The folder also usually contained a *Bildheft*, a 100–200-page booklet of photographs with captions. Depending on the region, map types included an *Operationskarte* (Operations map), which showed terrain types, relief and trafficabilities, as well as drainage patterns. A booklet of Stadtdurchfahrtpläne showed the best route for traffic through a city. In general, the Textheft did not provide a military analysis of the data presented, but it did call the user's attention to items of military significance by printing a bold black line in the margin opposite selected passages. For a few areas, however, the text contained a concise military section entitled *Militärische Beurteilung* (military evaluation) or *Gesamtbeurteilung* (overall evaluation) (CIA 1951).

As can be seen on the cover page of Textheft Mappe G (Fig. 12.3), these booklets were produced by MilGeo. They provided excellent descriptions of geomorphology, drainage, vegetation, soils, construction materials and aggregates, and industrial raw minerals. However, except for the personal knowledge of the authors, information was derived predominantly from older literature and maps, and information on military geologic conditions was rare. An exception was a military geologic map of European Russia printed in March 1941 at a scale of 1:2,500,000 with a legend of 17 different terrain units and general conclusions on mobility and

Fig. 12.3 (**a**) Cover of Mappe G: Textheft on Central Russia printed in May 1941, an example from a series of military geographic fact sheets on European Russia. (**b**) Figure depicting this region within the surrounding regions B to K. (Used with permission from the archive of Salzburger Wehrgeschichtliches Museum)

groundwater. Furthermore, the legend included the latitude of arctic permafrost, mean frost duration in months (the period when rivers could easily be crossed), regions with outcrops of hard rock (for surveys of aggregates and construction materials), the occurrence of black soil (chernozem; with comments on camouflage problems) and steep slopes of former marine coasts (Fig. 12.4). This map was provided by the Geology Group of the Inspectorate of Fortifications and very instructively described surface and sub-surface features that were not obvious on topographic maps of the same scale.

Another military geology map at 1:500,000 scale of the Pripyat-Polesie region (Fig. 12.5) was printed in March 1941 as a military geographic Operations map and was attached to MilGeo Mappe E on White Russia. The Pripyat River flows eastward through Belarus through the cities of Brest, Pinsk and Mazyr. The flat to undulating terrain was rich in dry woodland, wet to marshy woodland, marshes, peat and smaller lakes. The legend (Fig. 12.5b) differentiated between nine terrain classes, and the explanations characterised each according to geomorphology, soil type, vegetation and the depth to groundwater. Furthermore, in a second column of the legend, assessments of *Durchgängigkeit* (passability) and *Befahrbarkeit* (trafficability; during non-frost conditions) were made for each terrain. A third column assessed the function of these terrain types as natural obstacles, a fourth

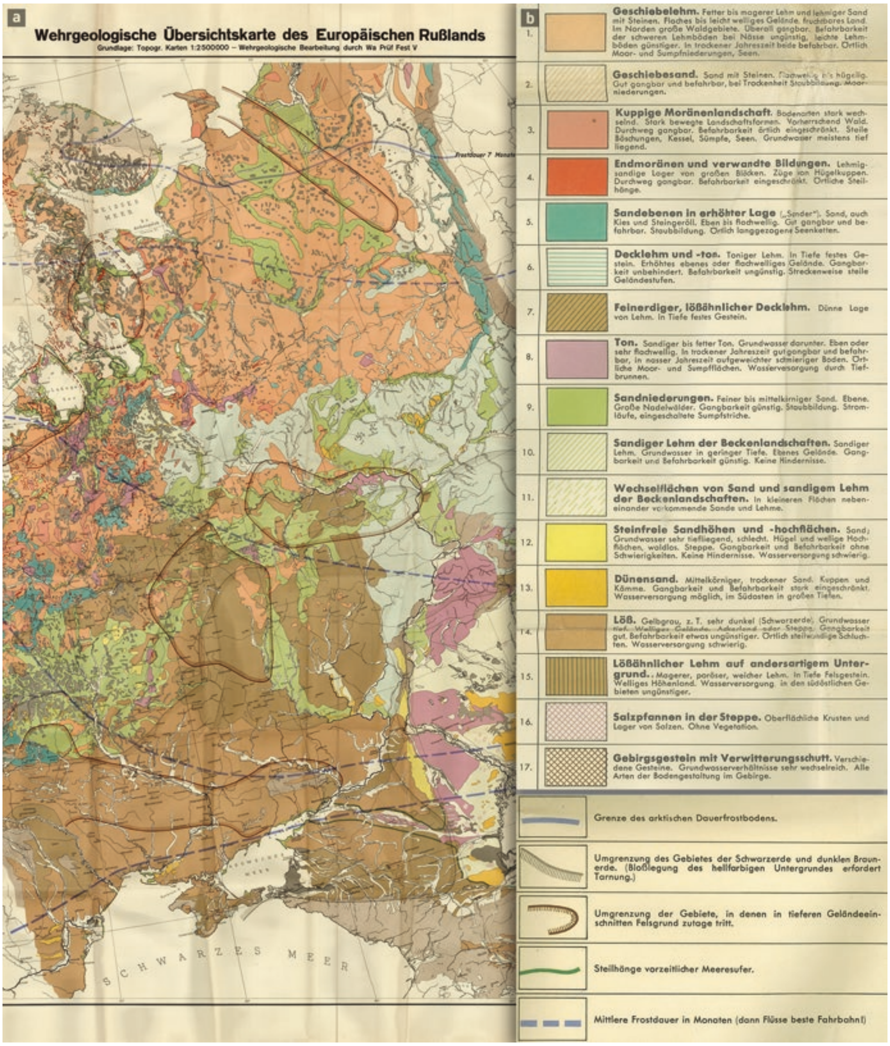

Fig. 12.4 (**a**) Section of the Military Geologic Overview Map of European Russia at a scale of 1:2,500,000. (**b**) A section of the legend from MilGeo Mappe A on European Russia, printed in March 1941. (Used with permission from the archive of Salzburger Wehrgeschichtliches Museum)

addressed the construction of entrenchments and the drinking water supply (according to the depth of the water table) and a fifth provided general recommendations on the trafficability of marshes, visibility and camouflage. Columns 4 and 5 are not shown in Figs. 12.4 and 12.5. Despite missing detailed information on the geologic agent (usually inserted in such maps), it can be concluded that, compared to the style of the military geologic map of Fig. 12.4 (and others), the 1:500,000 scale Military Geographic Operations Map of the Pripyat

Fig. 12.5 (**a**) Section of a 1:500,000 scale Military Geographic Operations Map of Pripyat-Polesie from Mappe E: White Russia provided by MilGeo in March 1941. (**b**) Section of the legend including a total of nine terrain units with descriptions of soil, vegetation and groundwater and containing general conclusions on trafficability and defence positions. (Used with permission from the archive of Salzburger Wehrgeschichtliches Museum)

region (Fig. 12.5) was also provided by the Geology Group of the Inspectorate of Fortifications.

The stock of the booklet series is unknown, and presumably they were distributed only to higher commands. Colonel Karl-Heinrich Graf von Klinckowstroem, who served as deputy chief of the Mapping and Survey Branch of the Army General Staff from August 1944 to early 1945, stated that 'Opinions in Wehrmacht circles concerning these studies in military geography were contradictory. While some thought them too bulky and too extensive, others found fault with them for not containing enough details' (Klinckowstroem 1945, p. 11). These booklets, printed by the German Army Map Service, are not at all well represented in European archives. The best sources for procuring loan copies of such German MilGeo materials from the Second World War are the German Military Documents Section, the Office of the Adjutant General, the Department of the Army and the US Central Intelligence Agency Map Library (CIA 1951). In recent times, German documents from the Russian Theatre, including the MilGeo booklet series, were scanned within a German-Russian project for digitising German documents that were stored in archives of the Russian Federation (Deutsch-Russisches Projekt 2020).

12.3 Deployment of German Military Geology Teams to the Eastern Front

Although the organisation and map production of the German Army Map Service during the Second World War is well documented (Müller and Hubrich 2009), only a few papers report on the military geology of the Eastern Front (Häusler 1995a, 2000, 2018c; Häusler and Willig 2000). This section briefly introduces the course of events from the beginning of the Polish campaign in 1939 to the planning of the Axis invasion of the Soviet Union in 1940. From that time on, *Geologenstellen* (geologic teams (GTs)) were deployed. In 1941, the GTs were renamed *Wehrgeologenstellen* (military geologic teams (MGTs)) and supported German troops until the end of the war.

Each military geologic team consisted of nine persons. The team leader and his deputy were military geologists holding university degrees, termed *Wehrgeologen*, in particular geologists but also palaeontologists, petrologists and geophysicists. Three non-commissioned officers acted as technicians, and four other ranks served as typists, drilling assistants and drivers for the two vehicles assigned to the team (a car and a 3-tonne truck for bulky equipment; Häusler and Willig 2000). During the four full years of hostilities lasting from the invasion of the western Soviet Union to the retreat of the German Armies, about 139 military geologists were deployed to 15 stationary and 19 mobile MGTs in the Eastern Theatre (Appendix 12B).

The invasion of Poland, which marked the beginning of the Second World War, was a joint effort carried out by Germany, the Soviet Union, the Free City of Danzig and a small Slovak contingent. The invasion began one week after the signing of the Molotov-Ribbentrop Pact[2] on 1 September 1939 and ended on 6 October the same year with Germany and the Soviet Union dividing the whole of Poland under the terms of the German-Soviet Frontier Treaty (Invasion of Poland 2020). In the two years leading up to the invasion of the Soviet Union (Operation Barbarossa), Germany and the Soviet Union signed political and economic pacts for strategic purposes. Nevertheless, the Wehrmacht High Command began planning an invasion of the Soviet Union in July 1940, which Adolf Hitler authorised on 18 December 1940 (Operation Barbarossa 2020). Over the course of the operation, about four million Axis power personnel, the largest invasion force in the history of warfare,

[2] The non-aggression pact agreed upon between Germany and Russia.

Fig. 12.6 Invasion of the western Soviet Union by Axis troops during Operation Barbarossa beginning on 22 June 1941. (Redrawn based on the figure of Kinder and Hilgemann 2000, p. 484)

invaded the western Soviet Union along a 2900-km front. Figure 12.6 shows the operational approach of the Axis troops from the staging area west of the demarcation line on 22 June 1941 until the Battle of Moscow in December 1941, the counter-attack of Soviet troops from January to March 1942 and the German offensive in summer 1942. The Axis troops were organised in *Heeresgruppen* (Army Groups), such as the three Army Groups (North, Centre and South), the Rumanian Army Group Antonescu and a Hungarian Army. As far as is known, MGTs were only attached to German Army Groups, Armies, and Panzer Armies.

At least since the preparation of the MilGeo booklets described above, the Army General Staff was aware of major problems for military operations in a region of about ten million square kilometres. Although the general distribution of climate, vegetation, geomorphology, rivers, geology, soils, outcrops of hard rocks, etc. was well known (see Figs. 12.4 and 12.5), information on the actual conditions of infrastructure and the influence of seasonal changes on trafficability could hardly be assessed in advance (Fig. 12.6). Tasks for the MGTs deployed to Higher Engineer Officers of the Armies and Panzer Armies were manifold. They included, among others, reconnaissance of valleys and rivers for tactical decisions to be made by armoured divisions, special hydrogeological investigations for drinking water supply where water-drilling companies failed, reconnaissance of aggregates for the construction of roads and railways, and reconnaissance of mineral raw materials for the Armed Forces Economic Office. Therefore, knowledge of Russian geologic and paleontological literature, either original or in translation, as well as geologic maps, hydrologic maps, soil maps and special maps on aggregates and construction materials was of vital importance. To this end, reports and statistical climate and hydrological data from the Climate Institute of Minsk were gathered for a regional prognosis of flooding events in the Central Soviet Union. In addition, listings from the Institute of Geology of Minsk archive were used for the assessment of the thickness of geologic formations, and reports of the former Moor Archive of White Russia at Minsk were used for information on the depth of peat and marshes.

In addition, the military geologists used aerial photography for evaluating the composition and density of forests, in particular in the Pripyat-Polesie region. This also gave an insight into the existence of simple log roads that crossed large peaty areas. Knowledge of Russian engineer instructions, e.g. both on crossing rivers during winter and hindering the crossing of frozen rivers by simple technical means, was very important for recommendations to the Higher Engineer Officers of German Armies.

Retrospectively, from 1940 to 1945, three subsequent operational phases of Wehrmacht operations can be deduced, for which MGTs were deployed along the Eastern Front as follows (Table 12.1):

- *Phase 1*: Soon after the invasion of Poland in September 1939, from February 1940 to April 1941, five GTs were deployed to the Inspectorate of Fortifications East.
- *Phase 2*: In terms of the assignment of MGTs during Operation Barbarossa, two major military phases can be distinguished. According to a secret order of the General Army Office dated 15 April 1941, nine MGTs were assigned to Armies and Panzer Armies of Army Groups North, Centre and South (phase 2a). At the same time as the Battle of Moscow (10 October to 10 December 1941), the General Army Office deployed four more teams to the 1st, 2nd and 4th Fortress Engineers and to the Inspectorate of Fortifications East (phase 2b).
- *Phase 3*: Beginning on 19 November 1943 (only a few months after the disastrous defeat of the German Armies in the battle of Kursk-Orel during Operation Zitadelle that lasted from July to August 1943 and rang in the Soviet summer offensive that resulted in the retreat of the German Armies), another group consisting of 11 MGTs was deployed to Army High Command, High Commands of Army Groups as well as other Higher Engineer Officers.

From 1940 to 1945, a total of 34 MGTs were deployed to Higher Engineer Officers of Armies and Panzer Armies; to the headquarters of Army Groups North, Centre and South; to Army Groups A and B; and to Army Group *Südukraine* (South Ukraine) (Table 12.1). It is unknown how many military geology teams of the

Table 12.1 Deployment of military geology teams to the Eastern Theatre during phases 1 to 3 (Häusler 1995a)

Inspector of Fortifications, Fortress Engineer & Territorial Military Commander	Army High Command and High Command of Army Group		
Phase 1 – 3 (1940 – 1943)	Phase 2a (1941)	Phase 2b (1941)	Phase 3 (1943)
Phase 1 (1940): GT1 – 5			
Phase 2a (1941): MGT19 (FestPiKdr I, Konigsberg)	MGT2: PzAOK 2 HGr Mitte		
	MGT6: PzAOK 1 HGr Süd		
Phase 2a (1941): MGT24 (FestPiKdr II)	MGT11: AOK 16 HGr Nord		
Phase 2a (1941): MGT26 (FestPiKdr IV)	MGT13: AOK 9 HGr Mitte		
	MGT14: AOK 17 HGr Süd		
	MGT20: AOK 4 HGr Mitte		
	MGT21: AOK 18 HGr Nord		
	MGT23: AOK 2 HGr Mitte		
	MGT25: AOK 17 HGr Süd HöPiFü 14; AOK 6		
Phase 2b (1941): MGT32 (InOst)		MGT16: AOK 11 HGr Süd	
Phase 2b (1942): MGT9 (WBefh Ostland)		MGT28: PzAOK 4 HGr Nord (?); PzAOK 3 HGr Mitte	
Phase 2b (1942): MGT7 (WBefh Ukraine)			MGT12: HGr A.; HGr Südukraine; HGr Süd
Phase 2b (1942): MGT8 (HöhWiPiFü/Wehrbezirk Südost; GenKdo z.b.V.; GenKdo 68 AK)			MGT20: HGr Mitte; AOK 4 HGr Mitte
Phase 3 (1943): MGT15 (HöPiFü 23)			MGT34: HGr B (?)
Phase 3 (1943): MGT32 (InOst)			MGT36: AOK 6, HGr B
			MGT37: HGr Mitte (?)
			MGT38: HGr Nord (?)
			MGT39: HGr Nord (?)
Phase 3 (1944): MGT35 (HöPiFü z.b.V. 109)			MGT9: HGr Mitte; HöhPiKdo 2

Abbreviations (in alphabetical order): *FestPiKdr* Festungspionier-Kommandeur (Chief of Fortress Engineers I, II and IV), *GenKdo Generalkommando* (Corps Headquarters), *HGr* Heeresgruppe (Army Group – North, Centre, South, A and B, South Ukraine), *HöhWiPiFü/Wehrbezirk* Höherer Wirtschafts-Pionierführer/Wehrbezirk (Higher Economic and Engineer Leader/sub-area headquarters), *HöPiFü Höherer Pionierführer* (Higher Engineer Officer), *InOst Inspektion der Ostbefestigungen* (Inspectorate of Fortifications East), *WBefh Wehrmachtbefehlshaber* (Territorial Military Commander), *MGT* Wehrgeologenstelle, *z.b.V. zur besonderen Verwendung* (for special duty),? = established due to order of Army General Office but not supported by archive documents

Waffen-SS supported SS Infantry brigades and divisions during the same time (see Sect. 12.4 below).

12.3.1 *Phase 1: German Military Geology in East Prussia and in the General Gouvernement (1940)*

Geology teams (GTs) had been deployed to the Commander-in-Chief East for supporting fortress construction along the new eastern border of the German Reich since February 1940. Seidlitz (1941) reported that a total of six GTs was established in the General Gouvernement of former Poland and another four in East Prussia.

Military geology reports were provided on aggregates and drinking water; these became the basis for military geology maps at scales of 1:100,000 and 1:300,000.

An archive document of the Army High Command dated 20 August 1940 indicated that there was one group of geologists deployed with the 1st Fortress Engineers at Konigsberg in East Prussia and another, with the general of engineers of the German Military Commander of the General Gouvernement (later termed 2nd Fortress Engineers) at Tomaszów. During that time, geologist Professor Dr. Wilfried von Seidlitz headed these GTs as Inspector of Fortifications/Geology Branch at Bromberg in Poland (today Bydgoszcz). The following five GTs were deployed to the Military Commander of the General Gouvernement (Häusler 1995a):

- GT1: (Fortress Engineer Staff 6): Warsaw
- GT2: (Fortress Engineer Staff 6): Puławy
- GT3: Annopol (Gościeradów)
- GT4: Jarosław
- GT5: Dynów

The proceedings of the sixth military geology course,[3] held in Heidelberg from 14 to 20 December 1940, provided details of these military geology works (Beurlen 1941; Schröder 1941). At the same time, MGT13 provided trafficability maps at a scale of 1:300,000 for the region west of Moscow (Fig. 12.7). These maps were desk studies based on available Russian maps on geomorphology, soils, and the evaluation of moors, and conclusions were drawn on trafficability. Among others, these preparations of the Army High Command suggest that the planning for an invasion of European Russia was in full swing at the end of 1940.

12.3.2 Phase 2: German Military Geology during Operation Barbarossa (June 1941–November 1943)

This section presents the deployment of MGTs in 1941 and early 1942 as well as during the German summer offensive in 1942. It is based on several thousand archive documents from the Heringen Collection stored at the Federal Archive/Military Archive at Freiburg im Breisgau since the 1960s (Holdings RH 32; Häusler 1995a, b; Willig 2009).

At the beginning of Operation Barbarossa, there were three Army Groups: North, Centre and South (Fig. 12.8). Army Group North included two MGTs: MGT11 (AOK 16) and MGT21 (AOK 18); Army Group Centre included four: MGT2 (PzAOK 2), MGT13 (AOK9), MGT20 (AOK 4) and MGT23 (AOK 2); and Army Group South also had four: MGT6 (PzAOK 1), MGT 14 (AOK 17), MGT16 (AOK

[3] Education of military geologists of the Army was organised within special courses. The first military geology course took place in Aachen from 15–20 January 1940. In the same year, five other military geology courses were held in Aachen, Gießen, Tübingen, and Heidelberg. The sixth course in military geology was held in Heidelberg (Häusler 1995a).

Fig. 12.7 Section of the 1:300,000 scale trafficability map, sheet Y56 Gshatsk (west of Moscow), provided by MGT13 of the Army High Command 9 in December 1940. *Steilhang* = steep slope, *schwerer Lehm* = heavy loam, *ungangbar* = impassable, *Trocken: gut befahrbar* = good going when dry. The map was printed as a special edition by the *Reichsamt für Landesaufnahme* (Reich Survey Office) in Berlin. (Used with permission from the Bundesarchiv/Militärarchiv in Freiburg im Breisgau, Document RH32/3098)

11) and MGT25, first assigned to AOK 17 and then assigned to AOK 6 in November 1942. In March 1942, MGT28 was first assigned to Army Group North but in November 1942 was reassigned to Army Group Centre. In order to indicate MGTs that were deployed to different armies, their number is marked with a superscript digit.

At the beginning of the German summer offensive on 9 July 1942, when priority was given to the southern sector of the Front, Army Group South was reorganised into northern Army Group B and southern Army Group A. At that time, the MGTs were also reorganised and deployed to these newly established Army Groups. In October 1943, four additional MGTs were assigned to Army Groups North and Centre and to Army Group B. In November 1943, MGT37 was assigned to the High Command of Army Group North (Table 12.1).

Figure 12.9 highlights trafficability problems caused by the so-called *rasputitsa*, the semi-annual mud season in Eastern Europe (literally ‘roadlessness’ due to heavy rains and muddy earth roads). On the other hand, due to post-glacial erosive processes, steep valley-side slopes were dissected by gullies (*ovrag*) and broader valleys (*balkas*) were incised, which allowed for localised staging areas of armoured brigades.

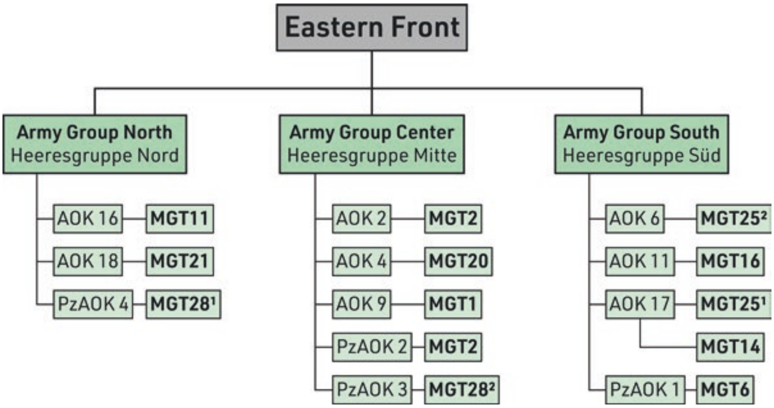

Fig. 12.8 Deployment of 11 MGTs to Army Groups North, Centre and South from the invasion of the Soviet Union until 1942 (AOK *Armee-Oberkommando*, Army High Command, PzAOK *Panzerarmee-Oberkommando*, Panzer Army High Command). For comments on the changing of the affiliation of MGTs to Armies, such as of MGT25 (MGT25[1, 2]), see text

Fig. 12.9 MGT14 during the advance of the High Command of the 14th Army on earth roads in Ukraine towards the Donbas region from July/August 41 to winter 1941/42. (Used with permission from Dr. Helmut Stremme; author's collection)

Figure 12.10 displays the major topics in reports written by MGT14 deployed to the Higher Engineer Officer of Army High Command 17. In 1941 and 1942, the 17th Army proceeded from its staging area east of Krakow towards the southeast, to the Sea of Azov and the northern Caucasus (see Fig. 12.6), and retreated in 1943–1944 from the Kuban Peninsula and the Crimea to the Vistula River. About

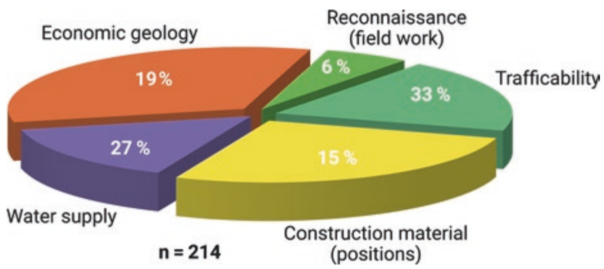

Fig. 12.10 Classification of 214 written reports provided by MGT14 for the Army High Command 17 in European Russia from 1941–1944. The majority of tasks concerned trafficability (33%) and water supply (27%)

one third of the orders of the Higher Army Engineer concerned trafficability and approximately another third, the investigation of drinking water. Field reconnaissance was necessary for investigating proper aggregates and construction materials and for underground investigations on defensive positions. Reports prepared by this MGT also referred to investigations on mineral raw materials such as salt and gypsum at Artemivsk, manganese at Nikopol, coal in the Donetsk area and at Kirovgrad as well as iron ore at Krivoy Rog (today Kryvyi Rih; Fig. 12.10).

12.3.3 Phase 3: Military Geology During the Retreat of the German Armies (November 1943–March 1945)

After the decisive defeat of German troops at Kursk and Orel on 19 November 1943 and the following Soviet summer offensive, German MGTs supported the retreat of the German Armies. Due to rapidly changing positions during the retreat in 1944 and to scarce records of military geology expertise, it is very difficult to draw an organisation chart for MGTs at this time. However, in an order dated 19 November 1943, another group consisting of five MGTs was deployed to Army Group B, Army Group Centre and Army Group North (Häusler 1995a; see Table 12.1). As the German war effort became increasingly directed towards defensive warfare, the need increased for data that were more detailed and more suitable for tactical use (CIA 1951). During the one and a half years of the German retreat, MGTs investigated areas for defensive positions and anti-tank trenches and provided large-scale maps ranging from 1:25,000 to 1:126,000.

In July 1944, the engineer general of Army Group *Nordukraine* (North Ukraine) ordered a military geology report on experiments with blowing up Panzer trenches in various soils. For this purpose, 3.5-m-deep boreholes were drilled 5 m apart along a line, and each was filled with 50 kg of explosives. The result of this test, shown in Fig. 12.11, was so important that 20 copies of this report were distributed.

Furthermore, documents describe field studies on blowing up trenches in Poland in October 1944, directly in front of attacking Soviet divisions. Trafficability

Fig. 12.11 Photo from the report on Panzer trenches blown up at Lvov (Poland) provided by MGT16 for Army Group North Ukraine on 13 July 1944. (Used with permission from the Bundesarchiv/Militärarchiv, Freiburg im Breisgau, Document RH32/2305)

experiments for both Soviet and German standard tanks, such as the Soviet T34 and the German Panther, were also carried out with respect to crossing anti-tank trenches (Table 12.2).

To this end, an evaluation of archive documents in the Heringen Collection revealed that ~1000 military geology *Gutachten* (written reports) were provided by the military geology teams during the first two years of the Eastern campaign (from 1940 to 1941). Another set consisting of 1000 military geology reports was provided during the next year (1942), and ~1500 more reports were provided for German troops from 1943 to 1944. Up to now, a total of 3466 of these reports have been counted, and, adding the monthly mean of late 1944, it can be estimated that a total of about 3500 military geology reports for German troops were provided for Engineer Commanders-in-Chief of Armies and Army Groups in the east until the end of hostilities in May 1945.

12.4 Military Geology of the Waffen-SS

Only a few comments of Klietmann (1965), Kater (1974), Tessin (1980), Häusler (1995a, b), Häusler and Willig (2000) and Kaienburg (2015) refer to the military geology work of the Waffen-SS. With an order of Reich Leader SS, Heinrich Himmler, dated 18 April 1941, the SS Military Geology Corps was installed in the

Table 12.2 Examples of military geologic reports prepared during the retreat of the German armies

Military geology team	Date	Report for superordinate command
MGT36	11 February 1944	Trafficability in Ukraine in the Bug-Dnieper region at a 1:300,000 scale for Army High Command 6
MGT14	27 March 1944	Trafficability and positions in White Russia south of Minsk at 1:126,000 scale for Army High Command 17
MGT16	13 July 1944	Blown-up Panzer trenches in various soils in Poland for Army Group North Ukraine (see Fig. 12.11)
MGT2	15 September 1944	Reconnaissance of a valley depression for tank trafficability near Jedlina, Poland, at 1:25,000 scale for Higher Construction Engineer 8
MGT16	30 October 1944	Experiments with crossing a Panzer trench using Soviet T34 and German Panther tanks east of Bochnia, Poland, for Army Group A

SS Main Operational Office at Berlin (Fig. 12.1). *Chefgeologe-SS* (chief of the military geologists of the Waffen-SS) assigned to the Command Staff of the SS Main Operational Office was the geologist and archaeologist Rolf Höhne, who headed the SS military geologists until the end of the war. In April 1941, Höhne was styled both *Kommandogeologe* (commanding geologist) of the Command Staff Reich Leader SS and chief geologist of the Waffen-SS and also headed the *SS-Wehrgeologen-Bataillon 500* (SS Military Geology Battalion 500). It is very likely that in June 1942, a unit of Höhne's military geology battalion was deployed to the SS Division *Prinz Eugen* in the Eastern Theatre, where a *Bakteriologisches Feldlaboratorium* (hydrologic field laboratory) was used for investigations on groundwater for the medical company of this SS division (Kaienburg 2015).

Military geology companies of the SS Military Geology Corps were assigned either to Army High Commands or to divisions or brigades of the Waffen-SS for duties analogous to those of the Army geology units (Klietmann 1965). In 1943, the SS-Military Geology Battalion 500, based in Berlin, consisted of four companies, each consisted of up to 400 men. The technical companies were ordered independently to battlefields in the east and to France and Italy. They were well-equipped engineer units but were also trained for combat. Their officers were mostly graduate geologists, mineralogists and other earth scientists. Due to losses during the war, only a few documents exist that define the duties of military geologists in the SS Military Geology Corps on the Eastern Front. A listing of 388 references in the library catalogue of the SS Military Geology Corps in Berlin indicates the existence of textbooks as well as geologic, hydrologic and pedologic literature, in particular on Poland and the USSR.

Kaienburg (2015) refers to a military geology company that in the second half of 1941 was ordered from Berlin via Zhytomyr, Ukraine, to Orel, Russia. Presumably in 1941, a military geologic map of the Jwanowo-Jaroslawl area northeast of Moscow at a scale of 1:1000,000 was designed by the SS Branch for Technical Military Geology. Another map prepared by this branch was a general map at a scale of 1:1500,000 that portrayed the construction industry and mineral deposits in the Moscow area (*Baustoffindustrie- und Lagerstätten-Karte des Moskauer Gebietes*). It depicted quarries, aggregate sources and occurrences of mineral raw materials. In December 1942, it was planned that each SS MGT should be supported by its own dowser, and it is reported that by the end of 1942, three dowsers were already stationed with a division of the Waffen-SS in Belgrade (Kater 1974).

In 1942, when Himmler controlled the German colonisation of Ukraine at Hegewald, his field headquarters in Zhytomyr District, some 12.5 km west/southwest of Kiev (Field Headquarters Hegewald n.d.), an SS Military Geology Battalion called *Einsatzkommando Shitomir* was active in that region. At least two written reports prepared by this battalion, dated 30 December 1942 and February 1943, were provided directly to the Personal Staff of Reich Leader SS. They dealt with well drilling and the reactivation of Russian wells down to depths of 127 m. The yield of 500 m^3 per day was calculated for supporting at least 5000 persons, and three more wells were planned, more than enough for the 100 SS officers and around 1000 soldiers defending the headquarters. This so-called Mission Command Zhytomyr of the Military Geology Battalion, which consisted of 61 personnel, was also used for guarding the Command Staff of Reich Leader SS at Hegewald. A friendly letter from Himmler to the dowser Dr. Walther Wüst, who had visited him in Zhytomyr, indicated that dowsing played a big role in sub-surface investigations there (Prokop and Wimmer 1985). In addition, a military geology report written by the 3rd SS Military Geology Company dated 22 April 1943 refers to geological profiles from the city of Kharkov that were provided to the Corps Headquarters of the SS Panzer Corps, which was attached to Army Group South in Ukraine that participated in the Third Battle of Kharkov (SS Panzer Corps 2020). In 1944, the 4th SS Military Geology Company of the SS Military Geology Battalion 500 also was deployed to the Eastern Theatre and supported retreating SS troops in White Russia. Written reports prepared by MGT21, deployed to the headquarters of the 18th Army of Army Group North, were sent to the SS chief geologist Dr. Rolf Höhne of the SS Main Operational Office.

12.5 Terrain Evaluation by the OKW-Forschungsstaffel in the Eastern Theatre

In January 1941, the Counter-Intelligence Branch of the Armed Forces High Command (OKW) launched Operation Dora to update terrain information for North Africa and reconnoitre the frontier between Libya and Chad. *Sonderkommando Dora* (Special Command Dora) consisted of about 100 personnel and a scientific unit of about ten military geoscientists, such as geographers, cartographers, geologists, astronomers, meteorologists and road specialists. The military scientific teams were fully motorised and supported by reconnaissance flights (Häusler 2007, 2011, 2018a, b). When Sonderkommando Dora's mission in Libya ended and the teams returned to Germany in January 1943, the Command was not closed down but continued to function as an administrative headquarters with battalion status. From April 1943 to the end of the war, this research group was termed the *Forschungsstaffel z.b.V.* (research unit for special terrain evaluation). According to Roscoe (1953, p. 75), this OKW research unit

> … was outstanding in its photo-reconnaissance and photo-interpretation work applied to special military needs, its mobility from one theatre to another the celerity with which it produced the required information and its famous "combination mapping method" by which the scientists from the different earth sciences worked in teams in performing the air reconnaissance, the photogrammetry, and especially the photo interpretation necessary to produce military maps…

Documents of the Reich Marshal of the Greater German Reich, Hermann Göring, dated 22 May 1943, refer to future tasks of the Forschungsstaffel for Eastern Europe. Among others, they included (for reasons unknown to the author) a special order for the construction agency, *Organisation Todt*, on the mapping of the catchment of the Pripyat River. An office of the Forschungsstaffel was established at Riga, Latvia, early in the summer of 1943, and work began on a plant association map of Lithuania (1:1000,000 scale) and a vegetation and groundwater survey of the oil-shale area in the Narva region, southwest of Leningrad. A group based in Kiev worked on drainage problems along the Pripyat River and on irrigation possibilities in southern Ukraine (Smith and Black 1946). Paralleling the deployment of MGTs in the east, the Forschungsstaffel developed new methods for integrated terrain analysis. Based on a combination of the interpretation of plant associations on aerial photography, reconnaissance flights and local expeditions, maps of, e.g., the Konka depression south of Zaporizhia (Zaporozhye east of Nikopol) at a scale of 1:50,000 and of the Pripyat region at a scale of 1:300,000, were prepared and provided.

A very interesting example of terrain evaluation refers to the wetland and swamp area of the Pripyat region in Eastern Europe, which was assessed as impassable by the Wehrmacht High Command prior to the attack of the German Armies in 1941 (Häusler 2006). Figure 12.12 depicts a section of the 1:300,000 scale passability map of the Pripyat marshes south of Minsk provided by the Forschungsstaffel in March 1944. Its key included three terrain classes: swampland, mossy peat and moist sandy soils, each with typical vegetation and military interpretation focussing on passability and trafficability. With the exception of winter periods, swampland and mossy peat were assessed as impassable (no-go areas), whereas non-flooded, soil-covered areas were assessed as good for all vehicles, particularly during winter. Where meadows were covered by bushes or deciduous forest prevailed, soil type was printed in big characters across the area (Fig. 12.12). This map was designed based on Russian and Polish sources that were enhanced by field reconnaissance, including details on vegetation, size and composition of road bridges (with an index of numbered bridges) and calculations of bearing capacities, the width of valleys and the depth of lakes. Additional MilGeo support for mapping the region in 1944 was provided by High Commands of the Army Groups Centre and South as well as by the Senior Officer of Mapping and Survey (East and Northeast; see Fig. 12.1). The most important difference between the 1:300,000 scale Pripyat map (Fig. 12.12) dated March 1944 and the 1:500,000 scale overview map of the Pripyat-Polesie

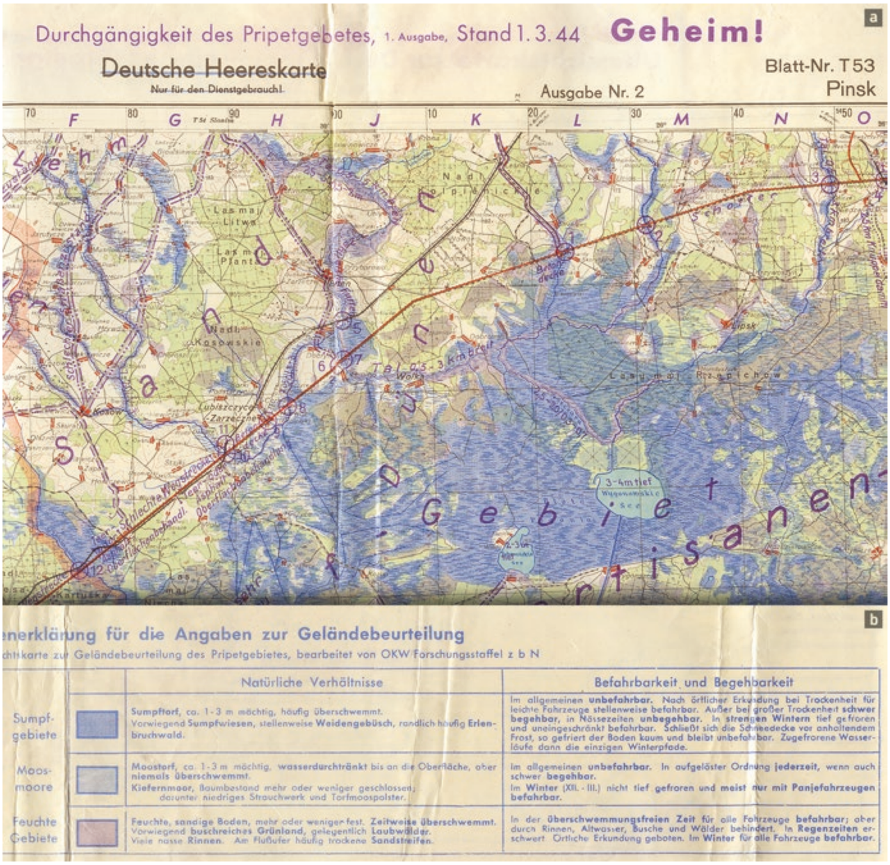

Fig. 12.12 (**a**) Section of map *Durchgängigkeit des Pripjet-Gebietes* (Passability of the Pripyat Region), Sheet T 53, Pinsk, White Russia, at the original scale of 1:300,000 dated 1 March 1944. *Trockene Böden* = dry soil, *Sand* = sand and *Lehm* = loam. (**b**) A section of the legend. The map is classified *Geheim* (secret). (Modified from Häusler (2006, 2007, 2011, 2018b) and reproduced with permission from Stiftung Preußischer Kulturbesitz, Berlin)

region, shown in Fig. 12.5, printed in March 1941 was the higher topicality and accuracy of the wetlands, vegetation and road net on the 1944 map that resulted from aerial photo interpretation and field reconnaissance. Another very important aspect that was relevant for tactical purposes was the simple but instructive choice of three terrain types (swampland, mossy peat and moist sandy soils) compared to the more detailed legend of the older 1:500,000 scale Pripyat-Polesie map (Fig. 12.5) with its nine terrain units. It can be concluded that all this updated information on the region was very useful for decision-making by the military commanders and, thus, the trafficability 1:300,000 scale map of the Pripyat area prepared by the Forschungsstaffel was of tactical use for the German Panzer Armies.

The Forschungsstaffel of Sonderkommando Dora was subordinated to the Military Office of the Reich Security Office until the end of the war by a secret order from the Chief of the Armed Forces High Command (WFSt/Ic Nr. 005639/44 g.K.) dated 22 May 1944. By order of Reich Marshal Hermann Göring dated 2 May 1943, it was responsible for reporting to the Reich Research Council (Häusler 2007) with regard to technical matters. Interestingly, despite this new assignment, the priority of orders did not change, and therefore the tasks of the Forschungsstaffel for German troops remained the same as during its deployment to the Armed Forces High Command.

Another so-called one-package affair of the Forschungsstaffel produced during the retreat of the German Armies was an evaluation of the region northeast and northwest of Warsaw in late 1944. Figure 12.13 is one example of several Panzer maps at 1:100,000 scale that were designed based on German maps of (former) Poland overlain with the German Army grid, scientific interpretation of aerial photos and field reconnaissance in test areas of typical terrain. The Panzer maps were printed as special editions of the terrain evaluation maps for Army troops at a 1:100,000 scale. The map key comprised six thematic layers originally listed under A-F. Terrain trafficability for tanks (A) was divided into four classes; crossings of terrain such as steep slopes, dams and rivers (B) were assessed for five classes; woodland (C) was separated into four classes; and three types of roads (D) included details on the bearing capacities of bridges and important viewpoints. Special aspects for wheeled vehicles (E) were marked for areas containing loose sand, and map key F accentuated dammed areas that could potentially be flooded. For the latter purpose, tables on water levels measured at gauging stations in the region and months with ice load for the Vistula River were added.

Figure 12.13 depicts sections of the 1:100.000 scale Panzer map near Włocławek (west of Warsaw). Most important for the assessment of terrain for tank trafficability, comparable to the classifications of MGTs of the Army High Command, was the classification of soil type and vegetation. The going of sandy to loamy but dry soils

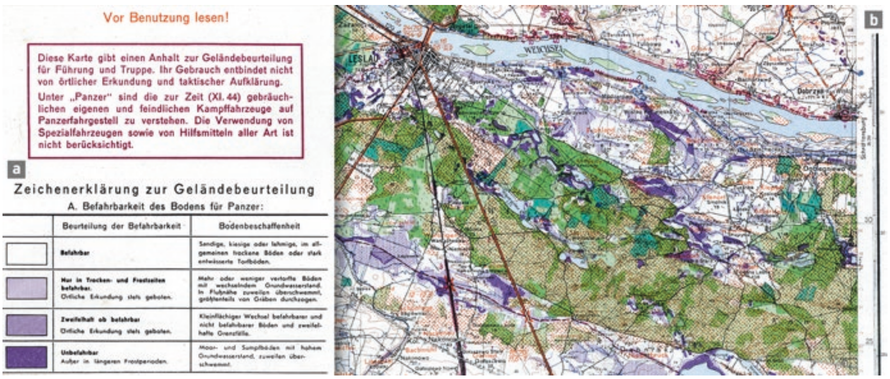

Fig. 12.13 Section of the legend (**a**) and map (**b**) of *Panzerkarte: Sonderausgabe der Truppenkarte zur Geländebeurteilung* (Panzer map: special issue of troop map for terrain evaluation) at the original scale of 1:100,000, sheet Piotrkow-Leslau-Sompolno-Klodawa, west of Warsaw, provided by the Forschungsstaffel in December 1944 (author's collection)

was assessed as good. Relatively large areas of peaty soils with changing groundwater levels were assessed as good during dry and frost seasons. Moors and peaty soils with high groundwater levels were classified as no-go except after longer periods of frost. Trafficability of smaller areas with rapidly changing soil conditions was described as questionable, and therefore local reconnaissance was recommended. An insert was printed on each of these terrain evaluation maps in magenta, which had to be read before using the map (*Vor Benützung lesen*; Fig. 12.13, upper left). It was clearly stated that the tank map only gave general information on trafficability and required local reconnaissance by the Military Commander. In addition, tanks were defined as armoured-tracked vehicles, as they were known in late 1944. Interestingly, this series of tank maps prepared in late 1944 was printed neither by the Forschungsstaffel itself nor by a motorised Mapping and Survey Unit of the Commander of Mapping and Survey Troops (Fig. 12.1) but by the Reich Survey Office in Berlin.

12.6 Russian Military Geology in the Second World War

Although Russian military geology had a long tradition, the first textbooks on military geology were published in 1924 and 1930. Czech officer and military geologist Dr. Karel Hlávka reported that any information on the organisation of Russian military geology during the Second World War was missing (Hlávka 1933). His paper on the military geology of the Russian Army in the 1930s gave an impression of the use of Russian hydro-technicians and geologists in the Soviet Armed Forces at that time. Military geologic education in the Russian Army during peacetime was jointly organised by the Office of Military Topographic Service and the Organisation of Geologic and Geographic Surveillance, together with members of scientific institutions and government offices. During peace, hydro-technical departments were deployed to 21 Army Corps that dealt with drilling, water supply, drainage and the use of flooding for tactical purposes, in particular as anti-tank obstacles. These departments also supported the medical service. Special departments of railway engineers dealt with the construction and maintenance of roads. During the mobilisation of divisions, corps and armies, technicians with geologic knowledge were deployed to military construction departments. In preparing for mobile warfare, the concept of military geologic and hydrologic maps at scale 1:200,000 was developed, and topographic maps at that scale became the basis for military geology specialist maps; in some regions, maps with larger scales were used. In order to highlight the geomorphologic relief, 10-m contour lines were drawn in brown, hydrology was printed in blue and objects such as roads, railways and houses were in black. Details on the thickness of geologic formations and the military use of soft and hard rocks were added. Detailed information on rivers and lakes was of particular interest. As a consequence, different types of Russian military geologic maps were provided, such as hydrogeologic maps, maps on the occurrence of construction materials and – according to Hlávka (1933) – also passability maps. The ultimate goal of these maps, including applied scientific and military explanations, was to avoid too much detailed information for Army staff, the Air force and the Sanitary Service. Unfortunately, the military geologic organisation of the Russian Army during peacetime was not known to Hlávka.

About half a century later, on 19 June 1986, Csapovski published a short comment on Russian military geology in the Journal of the Armed Forces of the Russian Federation (Red Star 2020). As a former head of the First Military Geology Department, he provided general information on the use of special Soviet military geology teams during the Second World War for the supply of engineer staff during attack and defence. Attempts by the author to contact Soviet authorities on the organisation of Russian military geology during the Second World War via the Austrian Military Attaché in Moscow failed in both November 1989 and August 1996.

Only a few archive documents of the Bundesarchiv – Abteilung Militärarchiv in Freiburg im Breisgau obtained as spoils of war refer to Russian military geology. A short document of the Army High Command (OKH; Anon. 1941a) reports that German MGT11 seized important documents from a Russian Military Geology Unit. The OKH ordered that literature and maps in Russian libraries, institutes and collections, relevant for a further German advance during Operation Barbarossa, be carefully collected, particularly in archives in Moscow and Leningrad. A second short document of the Inspectorate of Fortresses East (Anon. 1941b) describes a Russian hydrologic map with explanations on the military geology preparations of the Soviet Army; unfortunately, the original documents are missing. Another document dated 17 February 1944 indicates that, in 1940, a Russian, but ethnic German, geologist and mining geologist was deployed as a military geologist to *Bauverwaltung* 71 (Construction Administration 71), which was active in Minsk in 1942.

12.7 Final Remarks

During nearly four years of the Russian campaign, about 140 military geologists deployed to 34 German MGTs served the High Commands of eight Armies and four Panzer Armies. Providing about 3500 written geologic reports for terrain evaluation, these MGTs played a substantial role in supporting the tactical requirements of Higher Engineer Officers of Armies of Army Groups North, Centre and South during both attack and retreat. In addition to preparing military geographic and military geologic information prior to Operation Barbarossa, the heads of the MGTs, geologists educated in applied geology, were trained in military geology during previous campaigns. Such efficiency of terrain evaluation in a barely known country with extreme climatic conditions would not have been possible without the use of official data from Russian offices and research institutions. Among others, the German military geologists used statistical data on freezing and thawing periods for crossing large rivers, drilling profiles for drinking water supply, the occurrence of hard rocks and soft rocks for the provision of construction materials for roads and railways, and detailed pedologic maps and reports for the assessment of trafficability during different seasons. All these data were commandeered from Russian institutes and provincial archives, translated into German and listed in explanations or drawn as diagrams on military geology specialist maps depicting, e.g., groundwater fluctuations and flooding periods. The advantage of this system of German military geology lay in the fact that only one or two military geologists provided all terrain information necessary for tactical decisions of the Higher Engineer Officer of a German Army or Panzer Army.

Despite the small amount of information on the organisation of Soviet military geology during the Second World War, it can be taken for granted that engineers of the Russian Army were either supported by technicians with geologic backgrounds or advised by military geology units. During Operation Barbarossa, the German MGTs made use of Russian topographic maps at scales 1:300,000 to 1:400.000 as well as of Russian literature on geology and palaeontology and Russian specialist military maps. In addition to spoils of war, German military geologists studied archives, e.g., at the Geological Institute at Minsk, at the Climate Institute of Minsk and at the Moor Archive of White Russia at Minsk. Field reconnaissance as well as aerial photo interpretation enabled them to make detailed analyses of Russian terrain conditions, information that was not available from the booklets of the German Military Geographic Service provided prior to the attack on the Soviet Union. In summing up, terrain evaluation was of the essence for attack and defence, and the German Army High Commands and its adversaries had similar military geology units taking the best advantage of the terrain during the war.

Appendix 12A: Glossary of English/German Military Terms

English terms for the organisation of the Wehrmacht used in this paper follow those preferred by the War Department (1943, 1945), Klinckowstroem (1945) and CIA (1951).

English	German
Fortress Engineer	Festungspionier-Kommandeur
Armed Forces Operations staff	Wehrmachtführungsstab (WFSt)
Branch	Abteilung
Commander-in-Chief	Oberbefehlshaber
For special duty	z.b.V. (= zur besonderen Verwendung)
General Army Office	Allgemeines Heeresamt (AHA)
General Staff Corps	Generalstab
Geodetic survey	Landesaufnahme
Higher Engineer Officer	Höherer Pionier-Offizier
Higher Construction Engineer	Höherer Landesbau-Pionierführer
Militray Commander	Militärbefehlshaber
Office	Amt
Regional Command (administrative area of an air fleet)	Luftgau

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English	German
Reich Marshal of the Greater German Reich	Reichsmarschall des Großdeutschen Reiches (Hermann Göring)
Reich Research Council	Reichsforschungsrat
Reich Security Office	Reichsicherheitshauptamt (RSHS)
Reich Survey Office	Reichsamt für Landesaufnahme
Section	Gruppe
Senior General Staff Officer	Oberquartiermeister

Appendix 12B German and Austrian military geoscientists assigned as military geologists to geology teams (GT) and military geology teams (MGT) in Eastern Europe during the Second World War

Family name	First name	Nationality	Service years	Assignment
Achilles		German	1943	MGT7
Ahrens	Wilhelm	German	1940	MGT3
Arnold	Hellmut	German	1942–43	MGT7, MGT28
Bantelmann		German	1944–45	MGT11
Becksmann	E.	German	1942–44	MGT25
Berger	F.	German	1942–44	MGT11, MGT20, MGT38
Beschoren	Bernhard	German	1940	GT2
Beurlen	Karl	German	1940–41	MGT19
Beyer	Kurt Albert	German	1941–42	MGT11, MGT19, MGT24
Biener		German	1943	MGT29
Bistritschan	Karl	Austrian	1944	MGT1
Blüher		German	1941–44	MGT13
Brand	Erich	German	1940–44	MGT2
Breddin	Hans	German	1941–42	MGT14
Brüning		German	1944	MGT21
Bubeck		German	1944–45	MGT11

Family name	First name	Nationality	Service years	Assignment
Bülow	Kurd von	German	1941	MGT25
Denckmann		German	1943	MGT20
Dietz	C. (?)	German	1943–44	MGT15
Dorn	P.	German	1940–44	GT1, GT2, MGT7, MGT23, MGT24
Eckardt	(G.)	German	1943	MGT2
Eder		German	1943	MGT15
Eichele		German	1944	MGT10
Eigenfeld	Rolf	German	1943–44	MGT15, MGT29
Erich		German	1942, 1944	MGT7, MGT23
Ernst	Otto	German	1944	MGT37
Evers		German	1941	MGT14
Exner	Christoph	Austrian	1942–44	MGT19, MGT25
Fischer	Gerhard	German	1943–44	MGT13
Fischer	Ulrich	German	1943	MGT2, MGT25
Flum		German	1944	MGT9
Freyberg	Bruno von	German	1942	MGT8
Gallwitz	Hans	German	1944	MGT20
Genieser	Kurt	German	1942–45	MGT2, MGT9
Gerloff	Joachim	German	1943	MGT2
Groß (Gross)	Walter	German	1944	MGT23
Güth		German	1940	GT2
Haberfelner	Erich	Austrian	1944	MGT6
Hahne	C.	German	1941–44	MGT9, MGT13, MGT29
Haller	Wolfgang	German	1941–42	MGT23
Häusler	Heinrich	Austrian	1943–45	MGT6, MGT8, MGT16, MGT25
Hegenbart		German	1941–44	MGT20, MGT21
Herbst	Georg	German	1941	MGT11
Hertlein		German	1941	MGT11
Hirsch		German	1943–44	MGT13
Hohl	Rudolf	German	1944	MGT20
Hohnfeldt		German	1941	MGT14
Hübl	Harald Hans	German	1944	MGT2, MGT8, MGT9
Hunger	Richard	German	1944	MGT29, MGT39
Jacobsen	Werner	German	1942–44	MGT14
Jährling		German	1944	MGT39
Jörg	Erwin	German	1942	MGT7, MGT14
Keilbach	von	German	1941–42	MGT19
Keunecke		German	1944	MGT26
Kienow	Sigismund	German	1944	MGT12
Klein	(S.)	German	1940, 1942	GT2, MGT24
Kleinschrott	J.	German	1942–44	MGT23, MGT28
Kliemstein	H.	German	1940	MGT19
Knetsch	Georg	German	1943	MGT16

Family name	First name	Nationality	Service years	Assignment
Kobold		German	1942	MGT14
Kölbel	Heinrich	German	1944	MGT6
Kralik	(Bruno)	German	1944	MGT7
Kuckelkorn	Leo Jakob Medard	German	1943–45	MGT28
Kühn	Othmar	Austrian	1940–42	GT5, MGT25
Kumm	A.	German	1941–44	MGT9, MGT21
Kutscher	Fritz	German	1943	MGT16
Lange		German	1943	MGT13
Läuter	H.	German	1943–44	MGT20
Lemcke	Kurt	German	1941–44	MGT12, MGT13, MGT20
Lemke	Erich	German	1942–44	MGT7, MGT23
Leopold		German	1942	MGT26
Leschik	(Th.)	German	1943, 1945	MGT21, MGT23
Mägdefrau	Karl	German	1944	MGT36
Marschall		German	1944–45	MGT11
Martin		German	1942–44	MGT16, MGT36
Mempel		German	1944	MGT16
Mixius	Friedrich	German	1941	MGT2
Müller-Deile		German	1942–44	MGT7
Mutschlechner	Georg	Austrian	1942–44	MGT28
Neppel	(Arthur)	Austrian	1944	MGT21, MGT23
Niedermayer	Josef	German	1943–44	MGT8
Nöring	Friedrich	German	1944	MGT6
Oesterle		German	1944	MGT24
Ortmann	Karl	German	1941–42	MGT2
Papp	Adolf	Austrian	1941–42	MGT24
Peters		German	1941	MGT14
Petrascheck	Walther E.	Austrian	1944	MGT28
Pickel	Wilhelm	German	1942–44	MGT26
Pinkow	H.	German	1943	MGT23
Prey	Siegmund	Austrian	1940–44	GT2, MGT2, MGT35
Prosch		German	1941	MGT19
Putzer	Hanfrit	German	1940–44	GT2, MGT16, MGT19, MGT36
Raupach	Friedrich, von	German	1943–44	MGT2, MGT16
Richter	Wolfgang	German	1942	MGT26
Rode	Karl	German	1941–44	MGT14, MHT16, MGT34
Rost		German	1943	MGT23
Rotter		German	1943–44	MGT7, MGT12
Rücklin		German	1942–45	MGT11
Schilly		German	1944–45	MGT21
Schmidt	Wilhelm	German	1942	MGT25
Schröbler	Fritz	German	1941–42	MGT14, MGT22

Family name	First name	Nationality	Service years	Assignment
Schröder	Fritz	German	1940–43	GT1, MGT13, MGT14, MGT20
Schuh	Franz	German	1941–43	MGT7, MGT14
Schulte	Heinrich	German	1942–43	MGT9, MGT20, MGT35
Schulz	Günter	German	1943–44	MGT6, MGT20
Schulz	L.	German	1943–44	MGT6, MGT19, MGT8, MGT32
Schwan	Werner	German	1941–42	MGT20, MGT24
Schwarzbach	Martin	German	1942–43	MGT25
Schwegler	Erich	German	1940	GT1
Seidlitz	Wilfried, von	German	1940–41	GT1, MGT19
Seifert	Alfred	German	1940–44	GT1, MGT2, MGT28
Senarclens-Grancy	Walter, von	Austrian	1942–43	MGT8
Siegfried	Paul	German	1942–44	MGT12, MGT14
Simon	Wilhelm	German	1942–44	MGT9, MGT16, MGT28
Sindowsky	Karl Heinz	German	1941	MGT6, MGT24
Spielberger		German	1944	MGT29
Spoerel		German	1944–45	MGT23
Steffan		German	1944	MGT9
Steinhäuser	Walther	German	1943	MGT6
Stremme	Helmut E.	German	1941–45	MGT2, MGT14, MGT25
Taschenmacher	Willy	German	1940, 1944	GT1, MGT9
Thamm		German	1943–44	MGT7, MGT15
Thiele	H.	German	1944	MGT20
Thomas	E.	German	1943	MGT21
Thust		German	1943–45	MGT7, MGT9
Tröger	Walter	German	1942	MGT19
Tropp	Wilhelm	German	1944	MGT6, MGT29
Trusheim	Ferdinand	German	1941–42	MGT11
Voigt	Erhard	German	1941–44	MGT2, MGT21
Vollrath		German	1944	MGT39
Waldmann	Leo	Austrian	1940–41	GT4, GT5, MGT24
Walter		German	1940, 1944	GT5, MGT23
Watznauer	Adolf	German	1944–45	MGT2
Weber	(Alfred)	German	1943–44	MGT15
Wegerich		German	1941	MGT14
Wepfer	Peter	German	1941–44	MGT14, MGT15, MGT16, MGT21
Wieseneder	Hans	Austrian	1944	MGT37
Wunschik	Alfons	German	1940–41	GT3, GT4, MGT24
Zöbelein		German	1944	MGT38

References

Anon. (1941a) Oberkommando des Heeres vom 4 Juli 1941. Bundesarchiv – Abteilung Militärarchiv, Document RH12-20/64

Anon. (1941b) Inspekteur der Ostbefestigungen: Wehrgeologische Beutekarten der Sowjet-Armee vom 17 September1941. Bundesarchiv – Abteilung Militärarchiv, Document RH32/4050

Beurlen K (1941) Wehrgeologische Erfahrungen in Südostpreußen. 6th Wehrgeologischer Lehrgang in Heidelberg. Reichsdruckerei, Berlin, p 75-76

Deutsch-Russisches Projekt (2020) https://wwii.germandocsinrussia.org/de/nodes. Acceessed 7 July 2020

Drechsel E (1947) Maps and area studies of Russia for flying personnel. Headquarters European Command, Office of the Chief Historian, MS D-059 (Draft translation, US National Archives and Records Administration 1976)

Field headquarters Hegewald (n.d.) https://www.battlefieldsww2.com/field-hq-hegewald.html. Accessed 7 July 2020

Hlávka K (1933) Vojenská geologie a Ruská Armáda (Military Geology of the Russian Army). Vojenských Rozhledu (Military Review) XIV(10):1030-1035

Häusler H (1995a) Die Wehrgeologie im Rahmen der Deutschen Wehrmacht und Kriegswirtschaft. Teil 1: Entwicklung und Organisation. Informationen des Militärischen Geo-Dienstes 47. Bundesministerium für Landesverteidigung, Wien

Häusler H (1995b) Die Wehrgeologie im Rahmen der Deutschen Wehrmacht und Kriegswirtschaft. Teil 2: Verzeichnis der Wehrgeologen. Informationen des Militärischen Geo-Dienstes 48. Bundesministerium für Landesverteidigung, Wien

Häusler H (2000) Deployment and role of military geology teams in the German army 1941-45. In: Rose EPF, Nathanail CP (eds) Geology and warfare: examples of the influence of terrain and geologists on military operations. Geological Society of London, London, p 159-175

Häusler H (2006) Historic maps of terrain evaluation. In: Mang R, Häusler H (eds) International Handbook Military Geography. Bundesministerium für Landesverteidigung, Wien, p 257-271

Häusler H (2007) Forschungsstaffel z.b.V. – Eine Sondereinheit zur militärgeografischen Beurteilung des Geländes im 2. Weltkrieg. MILGEO 21. Bundesministerium für Landesverteidigung, Wien

Häusler H (2011) The "Forschungsstaffel z.b.V.", a special geoscientific unit of the German Counter Military Intelligence Service during the Second World War. In: Mang R, Häusler H (eds) International Handbook Military Geography, vol 2. Bundesministerium für Landesverteidigung, Wien, p 276-286

Häusler H (2018a) Sonderkommando Dora – Special military geoscientific unit of the German counter-intelligence service in North Africa 1942. Scientia Militaria, South African Journal of Military Studies 46(1):37-57. https://doi.org/10.5787/46-1-1224

Häusler H (2018b) Geographen im Zweiten Weltkrieg: Die „Forschungsstaffel z.b.V.": Nutzung der Potenziale des Georaumes für Militärische Zwecke. Mitteilungen der Österreichischen Geographischen Gesellschaft 160:9-56. https://doi.org/10.1553/moeg160s9

Häusler H (2018c). Dr. Helmut E. Stremme (1916 – 2009): Wehrgeologe im 2. Weltkrieg. Berichte der Geologischen Bundesanstalt 130:20-48 (https://www.zobodat.at/stable/pdf/BerichteGeolBundesanstalt_130_0020-0048.pdf). Accessed 7 July 2020.

Häusler H, Willig D (2000) Development of military geology in the German Wehrmacht 1939-45. In: Rose EPF, Nathanail CP (eds) Geology and warfare: examples of the influence of terrain and geologists on military operations. Geological Society of London, London, p 141-158

Invasion of Poland (2020) https://en.wikipedia.org/wiki/Invasion_of_Poland. Accessed 7 July 2020

Kaienburg H (2015) Der Militär- und Wirtschaftskomplex der SS im KZ-Standort Sachsenhausen-Oranienburg: Schnittpunkt von KZ-System, Waffen-SS und Judenmord, 2nd edn. Schriftenreihe der Stiftung Brandenburgische Gedenkstätten, vol 16. Metropol, Berlin

Kater MH (1974) Das "Ahnenerbe" der SS 1935-1945: ein Beitrag zur Kulturpolitik des Dritten Reiches. Deutsche Verlagsanstalt, Stuttgart

Kinder H, Hilgemann W (2000) dtv-Atlas Weltgeschichte. Deutscher Taschenbuch Verlag, München
Klietmann K-G (1965) Die Waffen-SS, eine Dokumentation. Verlag Der Freiwillige GMBH, Osnabrück
von Klinckowstroem K-H, (1945) Mapping and Survey Services in the German Army (1920-45). Office of the Chief of Military History Department of the Army. National Archives microfiche publication M1035 (fiche 0144)
Müller T, Hubrich D (2009) Teil 1: Überblick über das Karten- und Vermessungswesen des deutschen Heeres von 1919 bis 1945 (Ergänzter Nachdruck der von Oberst a.D. Dipl.-Ing. Theo Müller in der Schriftenreihe Militärgeographischer Dienst 1972 erschienen Arbeit mit Anhang "Synoptische Listen der Bestandszeiten der Fach-Dienststellen und -Einheiten des Heeres 1939-1945". Schriftenreihe Geoinformationsdienst der Bundeswehr, Heft 5/2009. Amt für Geoinformationswesen der Bundeswehr, Euskirchen, p 3-78
Operation Barbarossa (2020) https://en.wikipedia.org/wiki/Operation_Barbarossa. Accessed 7 July 2020.
Prokop O, Wimmer W (1985) Wünschelrute, Erdstrahlen, Radiästhesie. Die okkulten Strahlenfühlungslehren im Lichte der Wissenschaft, 3rd edn. Ferdinand Enke, Stuttgart
Red Star (2020) https://en.wikipedia.org/wiki/Krasnaya_Zvezda. Accessed 19 August 2020
Roscoe JH (1953) Photogrammetry. The Committee on Geophysics and Geography Research and Development Board (ed) Selected papers on photogeology and photo interpretation. US Air Force Directorate of Intelligence, Washington, DC
Schröder F (1941) Das Quartär im Gebiet des Brückenkopfes von Warschau in wehrgeologischer Hinsicht. 6th Wehrgeologischer Lehrgang in Heidelberg. Reichsdruckerei, Berlin, p 77-83
von Seidlitz W, (1941) Wehrgeologische Aufgaben im Generalgouvernement Polen und an der Ostgrenze. 6th Wehrgeologischer Lehrgang in Heidelberg. Reichsdruckerei, Berlin, p 71-74
Smith TR, Black LD (1946) German geography: war work and present status. Geographical Review 36(3):398-408
SS Panzer Corps (2020) https://en.wikipedia.org/wiki/II_SS_Panzer_Corps. Accessed 7 July 2020
Tessin G (1980) Verbände und Truppen der deutschen Wehrmacht und Waffen-SS im Zweiten Weltkrieg 1939-1945, 14th Band. Osnabrück: Biblio Verlag, Osnabrück
US Central Intelligence Agency (CIA) (1951). Mil-Geo: the geographic service of the German Army M12. Appendix A: inventory and analysis of Mil-Geo publications (arranged by area), Appendix B: Glossary, 2 maps, Central Intelligence Office, CIA-RDP79-00976A000100120001-5
US War Department (War Department) (1943). Handbook on German Military Forces. Technical Manual TM-E 30-451. Military Intelligence Division, Washington, DC
US War Department (War Department) (1945). Handbook on German Military Forces. Technical Manual TM-E 30-451. US Government Printing Office, Washington DC
Willig D (2009) Die Odyssee des Wehrgeologenarchivs als Teil der Heringen Collection. Versuch einer Rekonstruktion der Vorgänge von März 1945 bis heute. Geoinformationsdienst der Bundeswehr, Heft 4/2009. Amt für Geoinformationswesen der Bundeswehr, Euskirchen

Chapter 13
The Use of German Military Geology in the Adriatic Theatre 1943–1945

Hermann Häusler

Contents

Abstract Towards the end of the Second World War, five agencies of the German Reich provided military geoscientific information on the Adriatic Theatre. First, military geology units of the Army High Command supported fortress engineers with written reports on sub-surface conditions, such as drinking water supply; raw materials and aggregates for fortification; and flood maps. Second, the *Forschungsstaffel z.b.V.*, the Research Staff for Special Duty, provided terrain evaluation and off-road trafficability maps at scales of 1:100,000 and 1:200,000. Third, after the collapse of Axis partner Italy in October 1943, the construction agency *Organisation Todt* (OT) established positions along defensive lines crossing the northern Italian Apennines, such as the Green Line north of Florence, the Po Line, the Adige Line and the Blue Line west of Trieste. At present, it is unknown whether or not military geologists supported the *Bauleitungen* (works management offices) of the OT. Fourth, a few German geologists and mining engineers supported the *Wehrgeologen-Bataillon 500*, which reinforced fortifications on the former Alpine Wall in northern Italy. Fifth, military geologists of the SS supported the *Karstwehr-Bataillon* (later the *24 Waffen-Gebirgs-(Karstjäger-) Division der SS)*, which fought in northern Italy and was later accused of war crimes against partisans.

Keywords Second World War · Adriatic Theatre · Military geologists · Forschungsstaffel z.b.V. · SS-Wehrgeologen-Korps · SS-Wehrgeologen-Bataillon 500 · SS-Karstwehr-Bataillon · Organisation Todt

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13.1 Introduction

This paper deals with military geoscientific support for retreating German Armies in the Mediterranean – and in particular the Adriatic – Theatre during the Second World War. An understanding of the military situation in southern Europe at the end of the war can be easily gained from online sources and Tschudi (1960), Hillgruber and Hümmelchen (1978), Kinder and Hilgemann (2000) and Swanston and Swanston (2007), among others. As a response to the Allied Armistice with Italy on 8 September 1943, the Operational Zone of the Alpine foothills was established on 10 September 1943 by the German Reich (Stuhlpfarrer 1969). The Allied campaign in Italy consisted of operations from the invasion of Sicily in July 1943 until the surrender of the German Armed Forces in Italy in May 1945 (Swanston and Swanston 2007). The map of the Italian battle zone in Fig. 13.1 depicts the northern advance of Allied troops to the Gothic Line, one of the German defence lines crossing the Apennines (later called the Green Line). The spring 1945 offensive in Italy was the final Allied attack during the Italian campaign. The attack into the Lombardy Plain, which began on 6 April, ended on 2 May 1945 with the formal surrender of the German forces in Italy (Swanston and Swanston 2007).

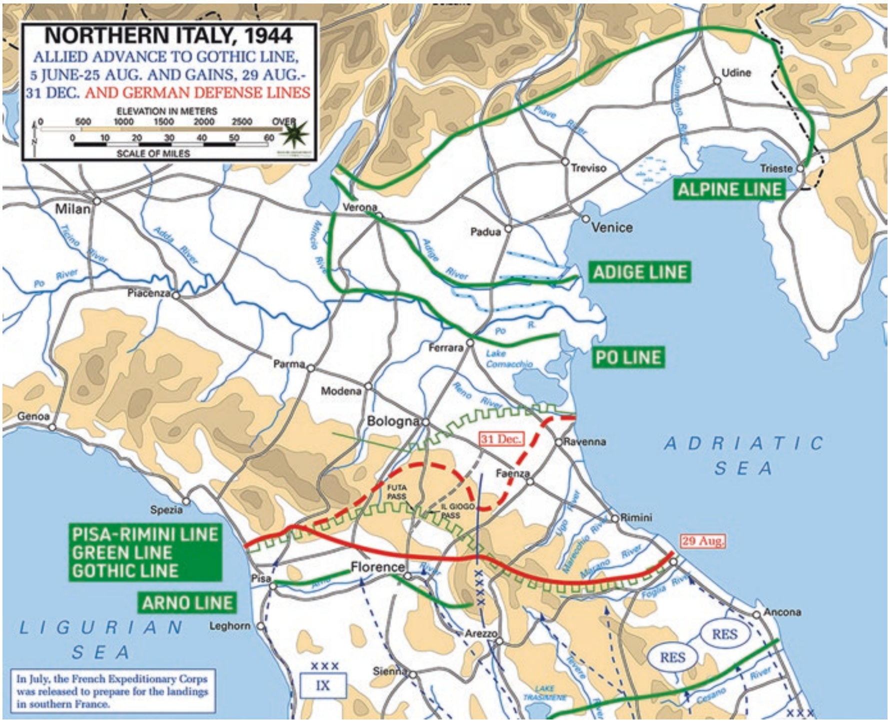

Fig. 13.1 Allied advance to the Gothic Line (centre) and gains to the north until 31 December 1944. (Modified from USMA 2020)

13.2 German Military Geologists Deployed to the Adriatic Theatre

This section deals with aspects of military geologic support for retreating German Armies in 1944 in the Balkans and on the Western Front in Italy until May 1945. In 1944, military geoscientific units of three different commands were active in the Adriatic Theatre: (1) military geology units of the Army High Command; (2) the *Forschungsstaffel z.b.V.*,[1] the research unit for special terrain evaluation that was deployed to the Counter-Intelligence Branch of the Armed Forces High Command in 1943 and assigned to the Military Office of the Reich Security Office in 1944; and (3) detachments of the SS Military Geology Corps affiliated to the Waffen-SS of the SS Main Operational Office.

13.2.1 Military Geology Teams of the Army High Command

From April 1941 to November 1943, the German Army High Command deployed a total of 40 *Wehrgeologenstellen* (military geology teams (MGT)) to Higher Engineer Officers of Armies, Army Groups and Fortification Engineers. During the course of the war, they served German Armies on the Western Front (in France, Holland and Belgium), in northern Europe (principally in Norway), at various times on the Eastern Front, in southeastern Europe (including Italy, Greece and Yugoslavia) and in North Africa. As explained in Häusler (2022), since November 1943, only a few months after the disastrous defeat of the German Armies in the battle of Kursk-Orel during Operation Zitadelle, eight new military geology teams were deployed to Army High Commands, High Commands of Army Groups, and Higher Engineer Officers of Fortress Inspectorates. Table 13.1 lists a few of the reports prepared by MGTs for the retreating German Armies in the battlefields of the Eastern Adriatic Sea, where five MGTs were deployed for service from 1943 to 1945.

13.2.2 Maps Prepared by the Forschungsstaffel

In 1941, the German Counter-Intelligence Service of the Armed Forces High Command founded a joint military-geoscientific reconnaissance team called *Sonderkommando Dora* (Special Command Dora) to update maps of the frontier between Libya and Chad in North Africa (Häusler 2018a, b). In 1943, this geoscientific research group of Special Command Dora was named Forschungsstaffel z.b.V. With a secret order issued by the Armed Forces Operations Staff (WFSt/1c

[1] '*z.b.V.*' is the abbreviation for '*zur besonderen Verwendung*', which means for special utilisation by high military commands.

Table 13.1 Deployment of military geology teams (MGT = Wehrgeologenstelle) to battlefields in the eastern Adriatic Sea from 1943 to 1945 and examples of reports prepared for the retreating German Armies (Häusler 1995a; Häusler 2000)

Number	Year	Deployment, region	Written reports
MGT 7	1944	High Command of 10th Army, Italy	Flooding of the Fucino Basin east of Rome, provision of raw materials for the construction of air-raid shelters, obstacles and fortifications (Verona, Feltre)
MGT 32	1944	Fortress Engineer, Croatia	Utilisation of caves for boat landings at Makarska near Dubrovnik, development of water supplies in the region of Istria (the islands of Mljet and Brac)
MGT 34	1943–44	Fortress Command within Army Group B in northern Italy	Provision of raw materials for construction sites at Ravenna and Trieste, flooding of eastern Venetia, preparation of 1:25,000 and 1:100,000 scale flood maps for the Po Valley, water supply in Istria for the Commander of Operational Zone of the Adriatic Littoral in 1944
MGT 35	1943–44	14th Fortress Engineers within Army Group F, Albania, southeast Italy, Yugoslavia and Austria	Provision of raw materials for construction sites, water supply, defensive positions
MGT 40	1944	Fortress Engineers west, Italian-Yugoslav border	Assessment of natural and man-made caverns (Trieste-Rijeka), water supply for troops in the Gorizia Basin (Isonzo River).

Nr. 005639/44 g-K. dated 22 May 1944; Häusler 2007), the Counter-Intelligence Branch of the Armed Forces High Command was reorganised, and the Forschungsstaffel (still subordinate to Special Command Dora) was deployed to the Military Office of the Reich Security Office until the end of the war. The Forschungsstaffel was headed by geographer Dr. Otto Schulz-Kampfhenkel and supported German troops in the European theatres with terrain evaluation maps. From 1943 on, the civilian-military Forschungsstaffel increased in size to a total of about 170 scientists, predominantly geographers, plant sociologists, geologists, cartographers and geodesists. The unique core competence of the Forschungsstaffel in military geosciences lay in the integration of all literature and maps available from different institutions and local field studies supplemented with reconnaissance flights (Roscoe 1953; Häusler 2006, 2007). The results of the integrated surveys were printed as special maps of the Forschungsstaffel at scales varying from 1:50,000 to 1:200,000. These maps were not classified as terrain evaluation maps but served to assess the terrain according to military needs (Häusler 2011, 2018a).

From 1944 to the end of the war, the Forschungsstaffel consisted of three research commands (Fig. 13.2): *Forschungskommando West* (Western Research Command) covering central Germany, *Forschungskommando Süd* (Southern Research Command) covering the Adriatic Theatre, and *Forschungskommando Ost* (Eastern Research Command) covering greater Germany to the east, in addition to a few *Einsatzgruppen* (area control staffs) in Ukraine, northern Russia and Lapland. In this regard, Einsatzgruppe must not be confused with SS-Einsatzgruppen, the

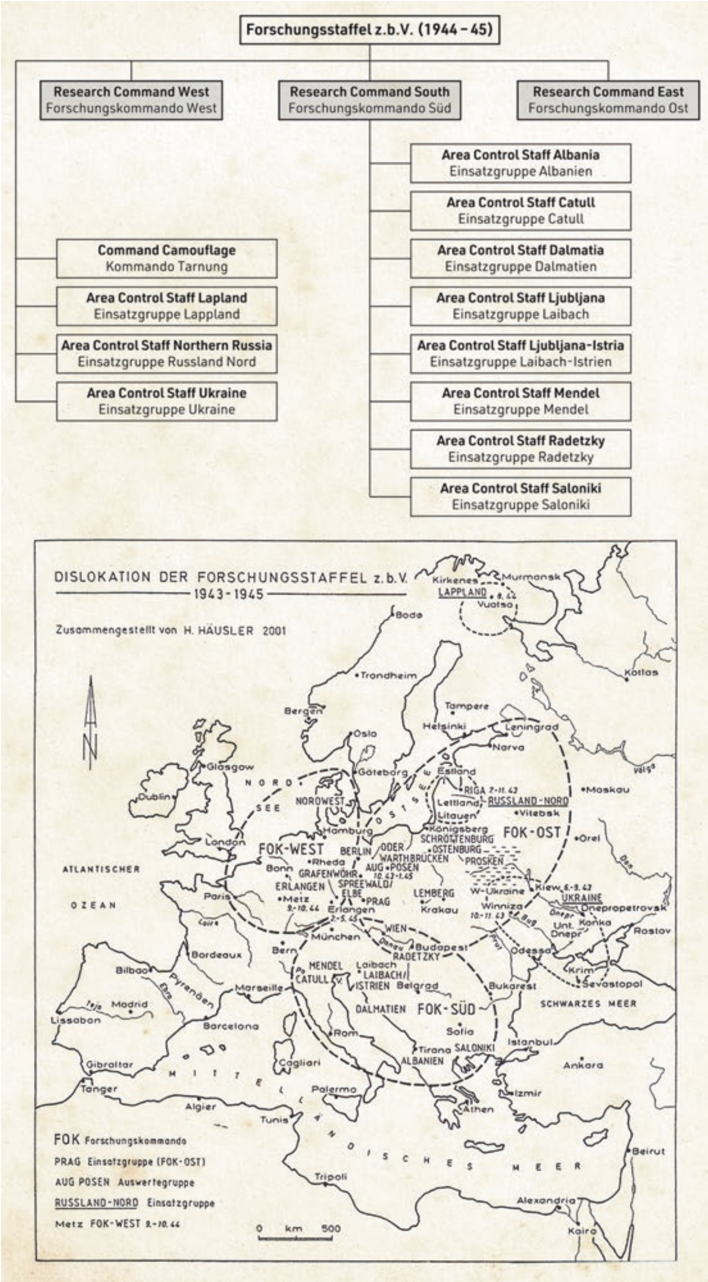

Fig. 13.2 (**a**) Organisation chart for the Forschungsstaffel in 1944–45 and (**b**) the areas in which its research commands were active. Southern Research Command of the Forschungsstaffel provided specialist maps for German Armies in the Adriatic Theatre. (Modified from Häusler 2007, 2018a)

mobile killing squads of the Waffen-SS. In addition, a camouflage command mostly dealt with fortification camouflage along the Mediterranean and Atlantic coasts.

Terrain evaluation maps prepared by the Southern Research Command comprise maps at scales varying from 1:100,000 to 1:500,000 of northern Greece, southeastern Europe and central Europe. They all were printed during the last phase of hostilities from August 1944 to March 1945 (Table 13.2).

In more detail, area control staff belonging to the Southern Research Command supported German actions in the Adriatic Theatre in Greece (Saloniki), in Albania and Yugoslavia (e.g., Laibach-Istria, Dalmatia) in autumn 1944, and in early 1945 in northern Italy (e.g., Catull, Mendel). Specialist maps along the Austro-Hungarian border (e.g. tank map Fürstenfeld-Varaždin) were also prepared. The geoscientific staff of the Southern Research Command consisted of 25 specialists, two plant sociologists, two (up to three) geologists, two interpreters of stereo aerial photography, one hydrologist, one geodesist, one specialist for mountain roads, one map specialist, one tank specialist, ten cartographers, two specialists for Slavic languages and one copyist. *Geländebeurteilung* (terrain evaluation maps) were designed at a scale of 1:100,000, e.g. sheets 50 Padova, 51 Venezia, 64 Rovigo and 65 Adria, all of which were printed in March 1945 (Häusler 2007, 2019b; see Fig. 13.3).

In addition, several maps of the northeast Adriatic coast, such as sheet 40 Palmanova (Fig. 13.4), 40A Goriza, 40B Postumia and 53A Trieste were printed as

Table 13.2 Examples of printed maps prepared by the Southern Research Command of the Forschungsstaffel from August 1944 to March 1945, listed by date of printing

Title	Scale	Month/Year
General map for *Geländebeurteilung* (terrain evaluation) of northern Greece and Thrace, region Larissa-Prewesa-Ohrid-Ditimotichon-Alexandrupolis	1:500,000	August 1944
Truppenkarte (troop map) for terrain evaluation, special edition *Panzerkarte* (tank map), region Zara-Knin-Sibenik	1:200,000	August 1944
Troop map for terrain evaluation, sheet 33/44 Zara/Zadar and sheet 34/44 Split/Spalato	1:200,000	September/ October 1944
Terrain evaluation map, Laibach-Cilly	1:200,000	October 1944
Troop map for terrain evaluation southeast Europe, sheet Laibach-Cilly-Pola-Senj	1:200,000	October 1944 (January 1945)
General map, Wien-Budapest	1:500,000	November 1944
Terrain evaluation map, Southern Alps	1:500,000	November 1944
Terrain evaluation map, Wien-Preßburg	1:200,000	February 1945
Troop map for terrain evaluation, special edition tank map Italy, sheets 40 Palmanova, 40A Goriza, 40B Postumia, 53A Triest, 53B Fiume	1:100,000	February 1945
Troop map for terrain evaluation Italy, sheets 50 Padua, 51 Venezia, 63 Legnano, 64 Rovigo, 65 Adria	1:100,000	March 1945
Water supply map, Adriatic karst	1:500,000	March 1945
Terrain evaluation map, Fürstenfeld-Varaždin	1:200,000	March 1945
Special edition tank map, Fürstenfeld-Varaždin	1:200,000	March 1945

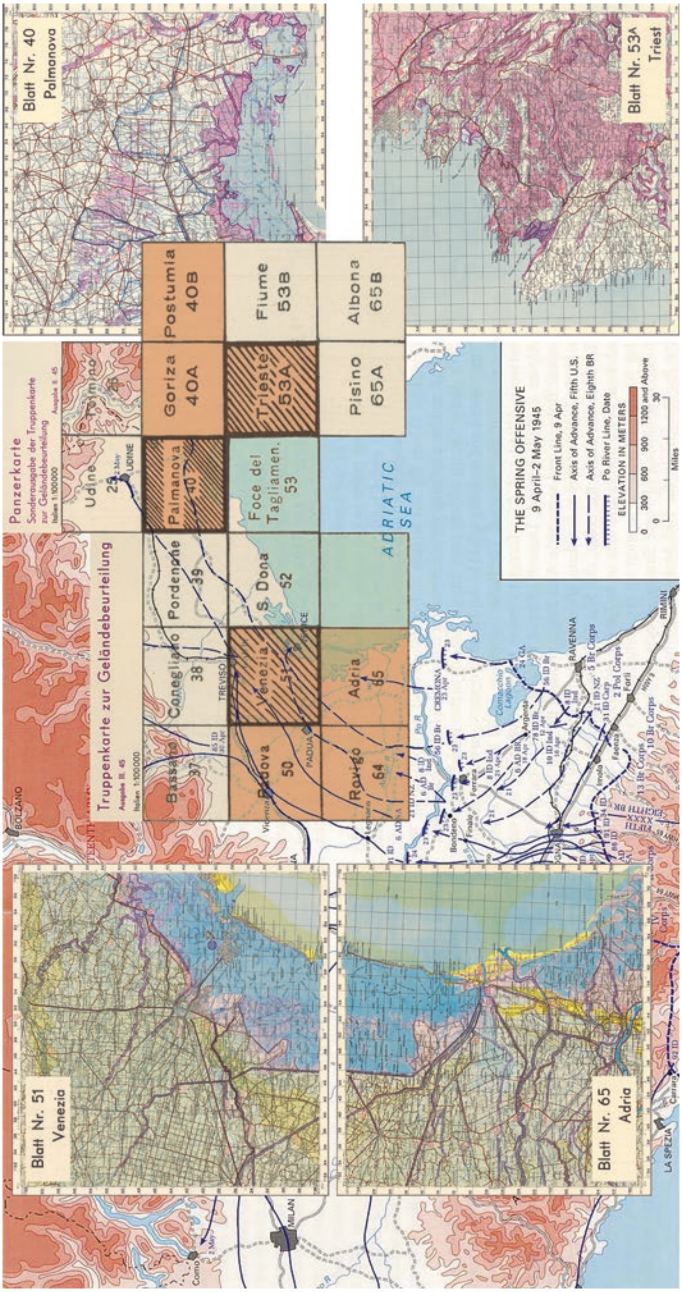

Fig. 13.3 Specialist maps of the North Italian and Yugoslavian Theatre at a scale of 1:100,000 dated February and March 1945, provided by the Forschungsstaffel prior to the Allied Spring Offensive, which started on 6 April 1945. (Adapted from Spring Offensive Italy 1945)

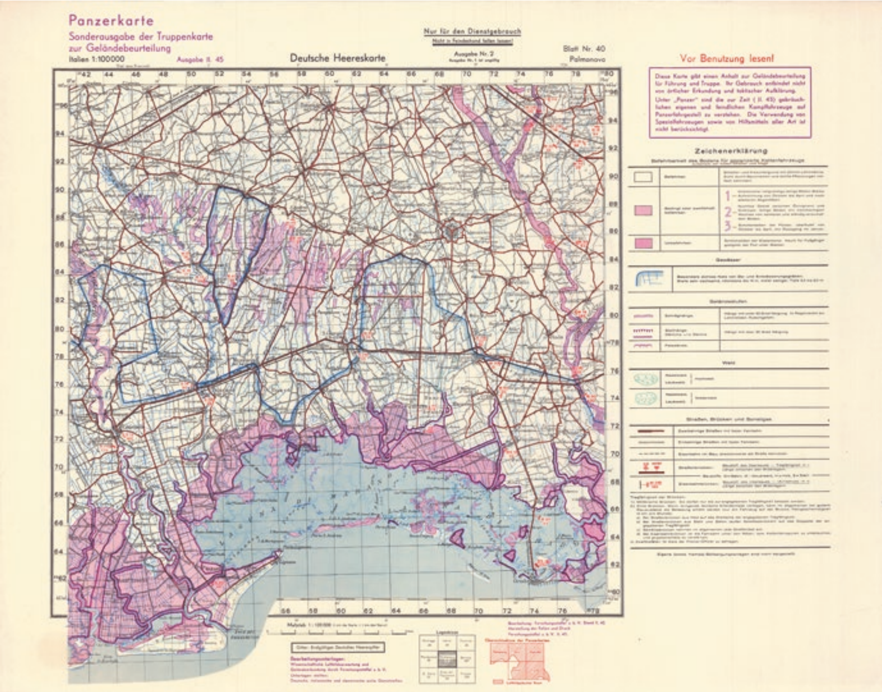

Fig. 13.4 *Panzerkarte Palmanova*, northwest of Trieste (Fig. 13.3), printed at a scale of 1:100,000 by the Forschungsstaffel in February 1945. For details of the legend, see Fig. 13.5. (Used with permission from Dr. Sven Fuchs, Vienna, Austria)

tank maps in February or March 1945. The newly developed method of terrain classification for the Palmanova tank map is described below.

The geographic information from German, Italian and Slovenian civilian offices was compiled for the Palmanova 1:100,000 scale tank map and then merged with the results from terrain reconnaissance and geoscientific information interpreted from stereo air photo pairs which covered the whole sheet. The legend included a table with areal and linear information and remarks for military use. Areal information comprised off-road trafficability, dense net of irrigation and drainage channels and forests.

Technical information on linear morphological features, such as slopes and dams and at certain points the material and bearing capacity of bridges, was noted. Off-road trafficability was described using three classes (Fig. 13.5). It was assessed as good where only a thin loam layer covered coarse fluvial deposits, as bad where wet coastal mud even caused problems for walking and as poor. Poor trafficability was further subdivided into three classes. Class 1 refers to coastal areas covered by thick layers of clay that caused trafficability problems during wet periods from October

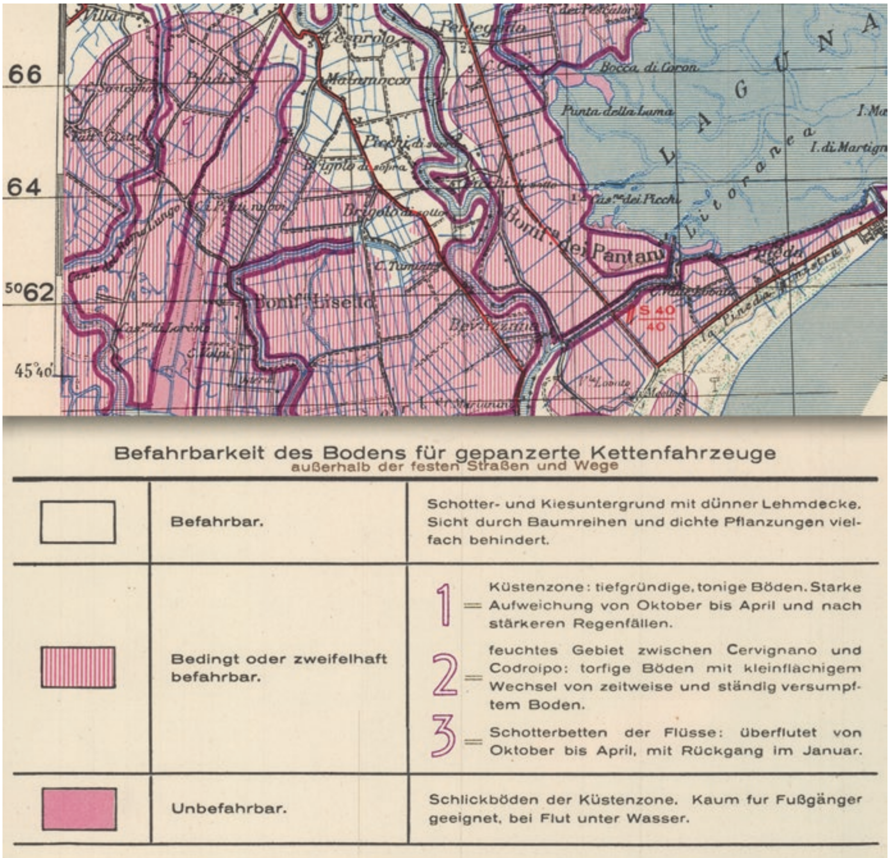

Fig. 13.5 Legend for the 1:100,000 scale Palmanova tank map (Fig. 13.4) printed by the Forschungsstaffel in February 1945. The three trafficability classes are *befahrbar*, good going, *bedingt oder zweifelhaft befahrbar*, poor going; and *unbefahrbar*, bad going. (Used with permission from Dr. Sven Fuchs, Vienna, Austria)

to April. Class 2 delineated the wet area between villages Cervignano and Codroipo, located in the centre and northwest of the sheet that was covered by boggy soil. Class 3 comprised coarse clastic fluvial beds that were intensively flooded from October to April but less so in January. In addition, the two-dimensional symbol for deciduous and coniferous forests was differentiated as brushwood or timber forest.

The terrain evaluation map also included a table with remarks for military use. Special symbols for airborne landing, for example, became visible when the map was held against the light. Summing up, these specialist maps were designed not as terrain evaluation maps for specific purposes but as integrated geoscientific maps that had to be evaluated by the military user.

13.2.3 Construction Agency Todt (OT)

Despite the general use of military geologists for the paramilitary construction agency *Organisation Todt* (OT; named after its founder, the German engineer Dr. Fritz Todt) as, e.g., recorded in Norway (Häusler 2019a), it is unknown if and how many military geologists supported the fortification work of the OT along the three German defensive lines, the Cassino Line between Rome and Naples, the Green Line south of Bologna and the Blue Line west of Trieste (also called Alpine Line; Lemmes 2010; see Fig. 13.1). The OT did not become active in Italy on a regional scale until September 1943. Later on, the newly established *Einsatzgruppe Italien* of the OT was designated front zone, and the collective area was designated Front-OT. Within this area of highest construction priority, the OT had the status of a military organisation and its personnel became members of the Wehrmacht (Supreme Headquarters Allied Expeditionary Force, Counter-Intelligence Sub-Division 1945). OT was engaged in fortifications in the Operational Zone of the Adriatic Littoral, among others, between Venice and Rijeka and between Ravenna and Ancona. In addition, OT was responsible for bauxite mining in the Veneto and the construction of underground installations for armament factories near Bozen and Meran (Seidler 1987; Lemmes 2010).

13.2.4 Military Geologists of the Waffen-SS

With the start of the Second World War, tactical control of the Waffen-SS was exercised by the *Oberkommando der Wehrmacht* (High Command of the Armed Forces or OKW) with some units subordinated to *Kommandostab Reichsführer-SS* (Command Staff Reich Leader SS) directly under Heinrich Himmler's control (Waffen-SS 2020). Some details on the organisation of MGTs in the Waffen-SS were published by Klietmann (1965), Tessin (1970, 1980), Kater (1974), Valente (2007), Schulte et al. (2014) and Kaienburg (2015). Archive documents and online sources tell of the various actions of two geologists in the Waffen-SS in the Adriatic Theatre: the German geologist Dr. Rolf Höhne (1908–1947) and the German geologist and mining engineer Dr. Ing. Hans Brand (1879–1959).[2]

The *SS-Wehrgeologen-Korps* (SS-Military Geology Corps) was established in the Reich Security Office on 1 April 1941 by order of Reichs Leader SS Heinrich Himmler. Dr. Rolf Höhne was chief of the military geologists of the Waffen-SS, assigned to the Command Staff of the SS Main Operational Office. He headed the SS military geologists until the end of the war (Höhne 2020). On 24 May 1941, a military geology company was established consisting of one gallery construction company, two technical platoons for water supply, one drilling platoon and a

[2] Dr. Ing. Hans Brand (1879–1959) must not be mistaken for the German military geologist Dr. Erich Brand (1914–2011), see Häusler (1995b).

geological equipment park (Kaienburg 2015). From 18 June 1941 onwards, this company was probably termed *1. Wehrgeologen-Kompanie* (first military geology company) and was based in the SS barracks in Oranienburg near Berlin. It was reorganised on 15 November 1941 into a battalion (Wehrgeologenbataillon 2020). There is evidence that in January 1942, the Military Geology Branch of the *Kommando-Stab RF-SS im SS-Führungshauptamt* (Command Staff of Reich Leader SS) at the SS Main Operational Office consisted of three *SS-Wehrgeologen-Kompanie*n (military geology companies) and four *SS-Wehrgeologie-Sondergruppen* (military geology groups) (Uwe Kleinert, personal communication, 2019). Due to the absence of documents, the structure of the entire SS military geology department during the war is unclear. In April 1941, presumably both the SS-Military Geology Corps (with its military geology companies) and the Technical Military Geology of the Technical Office were subordinate to Office I of the SS Main Operational Office.

According to Klietmann (1965), the military geology companies of the SS-Military Geology Corps were deployed to SS brigades and SS divisions at the front. There is documentary evidence indicating their involvement with several SS military geology battalions and companies: *SS-Wehrgeologen-Bataillon (mot)* (a motorised military geology battalion) in November 1941, *SS-Wehrgeologen-Bataillon 101* (SS-Military Geology Battalion 101) and *SS-Wehrgeologen-Kompanie 105* (SS-Military Geology Company 105), all active in 1943. From 15 September 1944 in northern Italy, the *Wehrgeologen-Abteilung 500* (SS-Military Geology Battalion 500) was installed in addition to the Motorized Military Geology Battalion (mot). The majority of privates in these military geology battalions were engineers; only company commanders were graduate geologists or mining engineers (Häusler 1995a).

About ten SS military geologists were deployed to military geology companies and battalions that were headed by Dr. Höhne, who had studied geology and graduated from Greifswald University in 1933. In 1939, at a time when Prof. Dr. Ernst Kraus headed the Technical Military Geology of the Army High Command, Höhne headed the subdivision “Referat Xc” of the tenth Group of Branch 5, the Engineer and Railway Engineer Branch of the Army Ordnance Office (Häusler and Willig 2000). He joined the SS and became a member of Himmler’s personal staff. For a short time, Höhne headed the Department for Geology and Mineralogy of the *Forschungs- und Lehrgemeinschaft: Das Ahnenerbe* (the Society for Research and Teaching of Ancestral Heritage) affiliated to the Personal Staff of the Reich Leader SS. In April 1941, Höhne was styled both *Kommandogeologe* (commanding geologist) of the Command Staff Reich Leader SS and *Chefgeologe* (chief geologist) of the Waffen-SS. It was presumably *Obersturmbannführer* (lieutenant colonel) Dr. Rudolf Höhne who commanded the Motorized Military Geology Battalion (mot) from May 1942 until 1945 (Kater 1974). Companies of the Motorized Military Geology Battalio (mot) were deployed to different theaters of war.

Among others, the fourth SS Company, headed by the Austrian mineralogist/geologist Dr. Johann Robitsch, was deployed to the east in 1943 and during the last months of the war to northern Italy (Häusler 1995b). Another company was presumably first deployed for construction work on the French coast in Normandy and then supported the reinforcement of defensive positions in northern Italy. It is very likely that in June 1942 a unit of Höhne's Military Geology Battalion was deployed to the SS Division *Prinz Eugen* in the Eastern Theatre, where a *Bakteriologisches Feldlaboratorium* (a hydrologic field laboratory) was used for investigations of groundwater for the medical company of this SS division. Furthermore, it cannot be ruled out that this SS Motorized Military Geology Battalion (mot) was in closer contact with the *Karstjäger-Bataillon* of the SS Division Prinz Eugen (see below).

The SS Military Geology Battalion 500 consisted of four companies that were deployed to different theatres of war. Each of these companies consisted of about 300 men and was headed by a graduate officer. Each company included one platoon each for *Brunnenbauzug* (well construction), *Bergbauzug* (mining) and *Pionierzug* (engineering) and was also trained for combat. In April 1944, the Motorized Military Geology Battalion (mot) had a strength of 12 officers, 50 non-commissioned officers and 580 men. Many of the officers were graduate specialists (Uwe Kleinert, personal communication, 2019). In September 1944, SS MGTs of the SS-Military Geology Battalion were deployed to *Kommandostab Voralpen*, the Operational Zone of the Alpine foothills in northern Italy, for the fortification of the Blue Line (Fig. 13.1), where they remained until the surrender on 2 May 1945. Their orders for work in the southern Alpine foothills between Lake Garda and the Etsch (Adige) Valley and from Rovereto to Trento, among other locations, comprised the investigation of anti-tank obstacles, the preparation of blasting road tunnels east and west of Lake Garda, the assessment of the load-bearing capacity of natural caverns (Häusler 1995a, b) and reinforcing fortifications along the former Alpine Wall (*Vallo Alpino).*

The Waffen-SS used special symbols from the military geology services in their tactical maps. Presumably, these tactical signs were planned in an early stage of establishing geology units of the SS before the military geology battalions were formed because the symbols refer to the deployment of geology groups to the staff of brigades, divisions, corps and armies, which is not documented. However, due to orders on the special geophysical investigations of SS military units (Klietmann 1965), the use of tactical symbols for special geologic cars, including geophysical and drilling equipment, is very likely.

Due to Himmler's interest in occultism, emphasis was laid on dowsing research, among other research areas, for groundwater investigations by SS military geologists. For this purpose, special training courses were organised by Das Ahnenerbe. The Department for Applied Geology of Das Ahnenerbe was headed by the Munich physician and grammar school teacher Dr. Josef Wimmer, who on 30 October 1940 provided a report on a position paper of the Reich Association for Dowsing dated 6 October 1938 (Wimmer 1940). In this report, Wimmer (1940, p. 4) argued: 'Today the situation has been reached, whereupon the physical side of the problem of dowsing can in general be seen as solved.'

In late 1942, it was planned that each SS MGT should be supported by its own dowser, and it is reported that three dowsers were stationed with a division of the Waffen-SS in Belgrade by the end of 1942 (Kater 1974). Prokop and Wimmer (1985, Fig. 9) published an example of a certificate from Das Ahnenerbe for *Rutengänger im Hauptberuf* (professional dowsing) for Mr. Samuel Otte, who passed a special training course for dowsing in December 1943. Häusler (1986) emphasised that the Inspector General for Water and Energy, as well as other German governmental offices, prohibited dowsing within their spheres of influence with an order dated 22 January 1943, and in 1944, the use of both the divining rod and dowsing certificates was prohibited by governmental offices of the German Reich as well as by the central office of the OT. Nevertheless, in September 1944, geologic dowsing was proposed by Wimmer (as head of the Department of Applied Geology of Das Ahnenerbe) for hydrocarbons in the Province of Venice.

13.3 The *SS-Karstwehr-Bataillon*

This section briefly introduces the beginnings of scientific research on karst and caves within Das Ahnenerbe. In 1944, investigations on caves became important for the storage of cultural property and the construction of underground installations for branches of the war industry, but these are not referred to here. Among other departments, the *Abteilung für Karst- und Höhlenkunde* (the Department for Research on Karst and Caves) was founded in October 1938. This department was first headed by Dr. Walther Steinhäuser and comprised, among others, branches for general karst research, karst geology and military geology (Kater 1974; see also Häusler 1995b). In 1939, Steinhäuser was replaced by Dr. Ing. Hans Brand (Klee 2014; Reitzenstein 2014). In August 1940, the name of this department was changed to *Forschungsstätte für Karst- und Höhlenkunde in der Forschungs- und Lehrgemeinschaft Das Ahnenerbe* (Research Institution on Karst and Speleology). From 1942 until 1944, Colonel Robert Ritter von Srbik from the Geologic Institute of Innsbruck University was contracted for the preparation of a survey of caves in Vorarlberg, western Austria, and the Tyrol. In February 1943, Brand also provided maps of caves in the Dinaric Alps, the mountain range in Southern and Southeastern Europe, at scales of 1:75,000 and 1:100,000.

The *Karstwehrversuchstruppe*, a special unit for fighting in karstified areas, was founded by an order dated 3 July 1942 and was renamed *Karstjägerbataillon* (Karst Hunter) in winter 1942/1943 (Tessin 1970). It was based in Pottenstein, Bavaria, and the facility was built with forced labourers from an outpost of the Flossenbürg concentration camp. On 10 July 1942, the SS Main Operational Office established a *Karstwehrbataillon*, which was renamed the *SS-Karstwehr-Bataillon* on 15 November 1942. On 2 June 1944, Himmler ordered the foundation of an Ahnenerbe research institution in the karstified area of Carniola (German: Krain; the historical region that comprised parts of present-day Slovenia) and the Operational Zone of the Adriatic Littoral (Knolle 2012). On 31 August 1944, Himmler, in his function as Commander of the Replacement Army and Chief of Army Equipment, ordered the installation of the *SS-Fortifikationsstelle zur Erkundung der italienischen Grenzwehranlagen* (fortification office) for the reconnaissance of fortification positions in the Operational Zone of the Alpine foothills along the Italian border. With the certification of Karl Wolff, General of the Waffen-SS and the highest-ranking SS and police leader in Italy, on 1 August 1944, *Standartenführer* (colonel)

Dr. Ing. Hans Brand was charged with the installation of this office and, in addition, with the installation of a research establishment on karst and caves. At that time, the former Karstjäger-Bataillon was reorganised (Tessin 1970) and in February 1945 was renamed as the *24. Waffen-Gebirgs-(Karstjäger-) Division der SS*. From November 1944 onwards, this Division fought partisans in western Slovenia and Julian Venetia, and war crimes are cited in Blood (2006) and Kaltenegger (2008).

13.4 Summary and Discussion

After the end of hostilities in North Africa (in May 1943), the major retreat of the German Armies in eastern Europe (in August 1943)and the armistice agreement between the Kingdom of Italy, the United States of America and Great Britain (on 8 September 1943), the war in Europe focussed more on the Adriatic Theatre and, in particular, on Italy. This paper has focussed on the geoscientific support for the German Armies and their fortress engineers provided by five different agencies: (1) military geology units of the Army High Command; (2) the Forschungsstaffel z.b.V. of the Armed Forces High Command, later on deployed to the Military Office of the Reich Security Office; (3) the Organisation Todt, (4) the Wehrgeologen-Korps of the Waffen-SS and (5) the SS-Karstjäger-Bataillon.

In contrast to thousands of written geologic reports that were provided by the military geology units of the Army High Command for the use of attacking German Armies in the east or occupied countries, only a few documents verify the geologic support provided by MGTs during the retreat of the German Armies during the last two years of hostilities in the Adriatic Theatre. These documents are housed in the Heringen Collection, stored in the Bundesarchiv/Militärarchiv in Freiburg im Breisgau.

After its establishment in early 1943, the Forschungsstaffel provided specialist maps for the terrain evaluation of potential northern Italian and Yugoslavian battlefields at scales 1:100,000 and 1:200,000. These maps were of very high quality. However, it cannot be ruled out that specialist maps that were printed in February and March 1945 were distributed too late for tactical use by the retreating German Army. It should be pointed out, however, that the written reports prepared by German military geology teams deployed to Armies and Fortress Engineers of the Army High Command were of immediate use for tactical decisions as well as for the supply of troops and the construction of defensive positions and fortifications. The military expertise and technical quality of printing of military-geoscientific maps prepared by the Forschungsstaffel some 75 years ago are still unique and are comparable to digital maps based on the North Atlantic Treaty Organization's (NATO's) software on the recognised environmental picture for the combination of geospatial, meteorological and oceanographic data, as developed by the Defence Geospatial Information Working Group (Kresse and Danko 2012).

At present, archive documents verifying that German military geologists supported the construction work of the OT along defensive lines in the northern

Apennines are missing. Regarding the efficiency of this German construction agency with respect to the construction of defensive works at the Westwall in Norway (Häusler 1995a, 2019a), it is very likely that the OT also employed geologists for sub-surface investigations on defensive positions and fortifications along the planned defensive lines across the Apennines (Seidler 1987; see Fig. 13.1, this paper). Additional efforts of the OT, and presumably of military geologists in Italy, were along the Ligurian coast, in particular at La Spezia and Genoa, as well as around Rome, Lazio, southern Tuscany and southwest Umbria (Supreme Headquarters Allied Expeditionary Force Counter-Intelligence Sub-Division 1945). Valente (2007) reported on the deployment of four military geology companies of the Waffen-SS for OT construction work in Trentino-Alto Adige between Rovereto and Riva. Due to known efforts of the OT on the southern flank of the Alps, public newspapers, magazine accounts and secret intelligence reports alike seriously explored a "national redoubt" concept for an area from southern Bavaria across the Austrian Alps to northern Italy as a "fortress that never was" (Starr 1965; Minott 1967; Seidler 1987).

In contrast to the military geology units of the Army High Command that provided written reports to the Higher Engineers of the Army High Commands as well as to the leading geologist of the Army High Command, the SS military geologists regularly reported on their duties to the SS Military Geology Corps in Berlin. In September 1944, companies of the SS Military Geology Battalion 500 supported the reinforcement of older fortifications along the Blue Line (Alpine Line in Fig. 13.1) in northern Italy, and Valente (2007) provided personal details on the SS military geologists in this battalion.

Founded as a research department on karst and caves in Europe in 1938 by the SS Society for Research and Teaching of Ancestral Heritage, Das Ahnenerbe, the SS-Karstjäger Bataillon, became a combat unit with a battalion status in 1942 and was involved in war crimes during the last months of the Second World War.

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References

Blood PW (2006) Hitler's bandit hunters: The SS and the Nazi occupation of Europe, 401. Potomac Books, Washington DC

Häusler H (1986) Die "historische" Rolle der Wünschelrute für Aufgaben der Angewandten Geologie. Mitteilungen der Gesellschaft der Geologie- und Bergbaustudenten 33:265-286

Häusler H. (1995a) Die Wehrgeologie im Rahmen der Deutschen Wehrmacht und Kriegswirtschaft. Teil 1: Entwicklung und Organisation. Informationen des Militärischen Geo-Dienstes vol 47. Bundesministerium für Landesverteidigung, Wien

Häusler H (1995b) Die Wehrgeologie im Rahmen der Deutschen Wehrmacht und Kriegswirtschaft. Teil 2: Verzeichnis der Wehrgeologen. Informationen des Militärischen Geo-Dienstes vol 48. Bundesministerium für Landesverteidigung, Wien

Häusler H (2000) Deployment and role of military geology teams in the German army 1941–45. In: Rose EPF, Nathanail CP (eds) Geology and warfare: examples of the influence of terrain and geologists on military operations. The Geological Society, London, p 159-175

Häusler H (2006) Historic maps of terrain evaluation. In: Mang R, Häusler H (eds) International Handbook Military Geography. Bundesministerium für Landesverteidigung, Wien, p 257-271

Häusler H (2007) Forschungsstaffel z.b.V. – Eine Sondereinheit zur militärgeografischen Beurteilung des Geländes im 2. Weltkrieg. MILGEO 21. Bundesministerium für Landesverteidigung, Wien

Häusler H (2011) The "Forschungsstaffel z.b.V.", a special geoscientific unit of the German counter military intelligence service during the Second World War. In: Häusler H, Mang R (eds) International Handbook Military Geography (Proceedings of the 8th International Conference on Military Geosciences, June 15–19, 2009), 2:276-286. Bundesministerium für Landesverteidigung und Sport, Wien

Häusler H (2018a) Geographen im Zweiten Weltkrieg: Die "Forschungsstaffel z.b.V.": Nutzung der Potenziale des Georaumes für Militärische Zwecke. Mitteilungen der Österreichischen Geographischen Gesellschaft 160:9-56. https://doi.org/10.1553/moegg160s9

Häusler H (2018b) Sonderkommando Dora – Special military geoscientific unit of the German counter-intelligence service in North Africa 1942. Scientia Militaria, South African Journal of Military Studies 46(1):37-57. https://doi.org/10.5787/46-1-1224

Häusler H (2019a) The northern Atlantic Wall: German engineering geology work in Norway during World War II. In: Rose EPF, Ehlen J, Lawrence UL (eds) Military aspects of geology: fortification, excavation and terrain evaluation. Special Publication 473. The Geological Society, London, p 83-108. https://doi.org/10.1144/SP473-16-061

Häusler H (2019b German military specialist maps of the north Italian theatre of war 1945. The 13th International Conference on Military Geosciences, Peace follows war: geosciences, territorial impacts and post-conflict reconstruction, Padova 24-28 June 2019, Abstract book. Societá Geologica Italiana, Roma, p 46. https://doi.org/10.3301/ABSGI.2019.03

Häusler H (2022) German Military Geography and Geology at the Eastern Front 1941-1945. In: Bondesan A, Ehlen J (eds) Military Geoscience: A multifaceted approach to the study of warfare, 978-3-030-79259-6, 490182_1

Häusler H, Willig D. (2000) Development of military geology in the German Wehrmacht 1939-45. In: Rose EPF, Nathanail CP (eds) Geology and Warfare: examples of the influence of terrain and geologists on military operations. The Geological Society, London, p 141-158

Hillgruber A, Hümmelchen G (1978) Chronik des Zweiten Weltkrieges – Kalendarium militärischer und politischer Ereignisse 1939–1945. Droste-Verlag, Düsseldorf

Höhne R (2020) https://de.wikipedia.org/wiki/Rolf_Höhne. Accessed 25 May 2020

Kaienburg H (2015) Der Militär- und Wirtschaftsstandort der SS im KZ-Standort Sachsenhausen-Oranienburg. Schnittpunkt von KZ-System, Waffen-SS und Judenmord. Schriftenreihe der Stiftung Brandenburgische Gedenkstätten, vol 16. Metropol Verlag, Berlin

Kaltenegger R (2008) Totenkopf & Edelweiß. General Artur Phleps und die südosteuropäischen Gebirgsverbände der Waffen-SS im Partisanenkampf auf dem Balkan 1942–1945. Ares Verlag, Graz

Kater MH (1974) Das "Ahnenerbe" der SS 1935-1945. Ein Beitrag zur Kulturpolitik des Dritten Reiches. Deutsche Verlags-Anstalt, Stuttgart

Kinder H, Hilgemann W (2000) dtv-Atlas Weltgeschichte. Deutscher Taschenbuch Verlag, München

Klietmann K-G (1965) Die Waffen-SS, eine Dokumentation. Verlag Der Freiwillige GMBH, Osnabrück

Klee E (2014) Das Personenlexikon zum Dritten Reich. Wer war was vor und nach 1945, 4. Auflage. Fischer Taschenbuch Verlag, Frankfurt am Main

Knolle F (2012) Materialien zur Geschichte der deutschen Höhlenkunde im Schatten des "Dritten Reiches". Abhandlungen der Arbeitsgemeinschaft für Karstkunde in Niedersachsen e.V., 5:1-66. Eigenverlag der Arbeitsgemeinschaft für Karstkunde in Niedersachsen e.V. (Digitale Neuauflage des Heftes aus dem Jahr 1987), Osterode https://www.karstwanderweg.de/publika/argekaha/5/1-66/index.htm. Accessed 25 May 2020

Kresse W, Danko D (2012) Springer handbook of geographic information. Springer, Berlin

Lemmes F (2010) Zwangsarbeit im besetzten Europa. Die Organisation Todt in Frankreich und Italien, 1940–1945. In: Heusler A, Spoerer M, Trischler H (eds) Rüstung und Kriegswirtschaft im "Dritten Reich". Schriftenreihe der BMW Group – Konzernarchiv 3. Oldenbourg Wissenschaftsverlag GmbH, München, p 219-252

Minott RG (1967) Top Secret. Hitlers Alpenfestung. Tatsachenbericht über einen Mythos. Rowohlt Taschenbuch Verlag, Reibek/Hamburg

Prokop O, Wimmer W (1985) Wünschelrute, Erdstrahlen, Radiästhesie. Die okkulten Strahlenfühlungslehren im Lichte der Wissenschaft. 3. völlig neu bearbeitete Auflage. Ferdinand Enke, Stuttgart

Reitzenstein J (2014) Himmlers Forscher. Wehrwissenschaft und Medizinverbrechen im »Ahnenerbe« der SS. Ferdinand Schöningh, Paderborn

Roscoe JH (1953) Photogrammetry. In: The Committee on Geophysics and Geography Research and Development Board (ed) Selected papers on photogeology and photo interpretation. Directorate of Intelligence, US Air Force, Washington DC

Schulte JE, Lieb P, Wegner B (2014) Die Waffen-SS. Neue Forschungen. Krieg in der Geschichte (KriG) vol 74. Ferdinand Schöningh, Paderborn

Seidler F (1987) Die Organisation Todt. Bauen für Staat und Wehrmacht 1938-1945. Bernard and Graefe, Koblenz

Spring Offensive Italy 1945. Wikimedia Commons. http://www.army.mil/cmh-pg/brochures/po/map2.JPG

Starr CG (1965) The Fortress that never was: The myth of Hitler's Bavarian stronghold. The Journal of American History, 52(2):411-412

Stuhlpfarrer K (1969) Die Operationszonen „Alpenvorland" und Adriatisches Küstenland" 1943-1945. Publikationen des Österreichischen Instituts für Zeitgeschichte und des Instituts für Zeitgeschichte der Universität Wien, vol 7. Brüder Hollinek, Wien

Supreme Headquarters Allied Expeditionary Force, Counter-Intelligenc Sub-Division. (1945) Handbook of the Organisation Todt (OT). MIRS/MR-OT/5/45, 36. Military Intelligence Research Section, London https://archive.org/stream/HandbookOfTheOrganisationTODTOTUK1945/Handbook-of-the-organisation-TODT-O-T-UK-1945_djvu.txt. Accessed 25 May 2020

Swanston O, Swanston M (2007) The historical atlas of World War II. Cartographica Press Ltd./Chartwell Books, Inc., London

Tessin G (1970). Verbände und Truppen der deutschen Wehrmacht und Waffen-SS im Zweiten Weltkrieg 1939-1945. 4. Band, Die Landstreitkräfte. Biblio Verlag, Osnabrück, p 15-30

Tessin G (1980) Verbände und Truppen der deutschen Wehrmacht und Waffen-SS im Zweiten Weltkrieg 1939-1945, 14 vols. Biblio Verlag, Osnabrück

Tschudi E (1960) Die militärischen Operationen in Europa 1939-1945. Karte 1:5,000,000. Kümmerly and Frey, Bern

US Military Academy (USMA) (2020) Maps of Allied Offensives: Allied Offensives in Northern Italy (June 5 - December 31, 1944). https://www.jewishvirtuallibrary.org/map-of-allied-offensives-in-northern-italy-june-december-1944. Accessed 20 May 2020

Valente L (2007) I geologi di Himmler. L'SS-Wehrgeologen-Bataillon 500 tra Veneto e Trentino: dalla rappesaglia della Laita (Tretto di Schio, 30 novembre 1944) all'ipotesi Pedescala. Nuova serie, vol. 63. Cierre-Istrevi, Verona

Waffen-SS (2020). https://en.wikipedia.org/wiki/Waffen-SS. Accessed 25 May 2020

Wehrgeologenbataillon (2020) https://www.forum-der-wehrmacht.de/index.php?thread/3203-ss-wehrgeologen-btl-mot-500/. Accessed 25 May 2020

Wimmer J (1940) Zur Denkschrift des Reichsverbandes für das Wünschelrutenwesen (vom 6.10.1938) und zum Bericht des S.D. (ohne Datum). Manuscript, 12 Seiten, nach „Ahnenerbe: Documents from Nazi Germany, 1936-1945" verfasst am 30. Oktober 1940. https://digitalcommons.ursinus.edu/dowsing/30. Accessed 25 May 2020

Part III
Twenty-First Century

Chapter 14
Sustainability of US Army Agribusiness Development Team Efforts: A Decade in Afghanistan

Alexander K. Stewart

Contents

Abstract The World Bank has said that the impact of foreign aid is unknown, with aid delivery in Afghanistan being the most challenging. Innovatively, the US Army developed Agribusiness Development Teams (ADTs) using hand-selected, solider-experts in 2008. These egalitarian, specialized counterinsurgency teams worked directly with and within local communities in Afghanistan to implement Afghan-first, sustainable, development projects. As a case study, the Texas ADT II implemented 50 projects in Ghazni Province during 2009 with 27 detectable projects using satellite imagery. Multitemporal image analysis was used to record project sustainability between 2009 and 2019. Nineteen percent of projects were considered positive; 60%, no change; and 21%, a loss or failed. Only the Ghazni Agriculture Complex and the Ghazni Minarets are positive for the entire decade. The Arbaba Environmental Park showed no progress after 2010 except adjacent construction. Failed projects included the Ghazni Demonstration Farm and the Ghazni Experimental Farm. Even well-thought-out development efforts provided by specialized soldier-expert teams working on Afghan-first projects were not enough to overcome the complex and difficult circumstances in Afghanistan. Nevertheless, exceeding best practices as described in the academic literature, ADTs were what development agencies dream of and should be included in future military-development efforts.

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14.1 Introduction

The World Bank, the international financial institution founded to support the governments of poorer countries with loans and grants for development, stated that they have yet to be able to quantify the impact of aid[1] efforts in a meaningful way (Baker 2000). A consensus among aid organizations at all levels—nongovernmental (NGO; e.g., Oxfam), governmental (e.g., United States Agency for International Development (USAID)), national (e.g., Islamic Republic of Afghanistan), and international (e.g., United Nations Environment Program (UNEP)) organizations—is that successful aid delivery as development, not as a handout, is problematic, especially in contested spaces such as Afghanistan. Aid delivery in insecure locations has been shown to run contrary to the intended purpose due to major gaps between donor-country policies and host-nation realities. This issue is one of primacy of output over outcomes and the militarization of aid, which make development efforts unlikely to achieve large and persistent effects (Oxfam 2014; Iyengar et al. 2017; SIGAR 2020). In Afghanistan, it has been shown that aid efforts developed and employed in contested districts, those under insurgent control, increase violence (Sexton 2016). This creates a paradox where the poorest nations with the most dangerous environments are those most in need of external support and the least likely to have it affect positive change. Providing this support and ensuring its effectiveness and sustainability, however, are key to helping beleaguered nations improve their development pathway to the benefit of their citizens.

The US military took on this challenge of aid delivery, in addition to its traditional warfare activities, as it has become increasingly focused on expeditionary efforts where forces are used. These efforts often simultaneously involve security and development (Shields 2011). They directly entered the development and reconstruction sector, which has historically been driven by other intergovernmental and governmental agencies and NGOs. Being able to transition from conducting traditional military operations, where the US military is well versed, well trained, well led and capable, to having an expeditionary mindset requires specialized and elevated levels of thinking in new operational environments. This, in turn, requires levels of compassion and understanding of the people in the battlespace to be developed in new and mostly untested ways (Shields 2011; Stewart 2015). The US

[1] Universally, aid is the general term for 'Official Development Assistance' with the United States considering all efforts to support foreign nations as Foreign Aid. No matter the delivery mechanism (e.g., military), it is an essential part of US foreign policy and covers national security, commercial interests and humanitarian concerns to provide a secure global environment for US products. In this paper, development falls under aid and was included in the Agribusiness Development Team name to recognize efforts to develop agricultural concerns in Afghanistan.

military has such a broad footprint, with forces in some 70% of the world's nations (Turse 2017), that it has acquired the ability to make developmental changes in these communities where security is a key issue. US soldiers are still being trained for traditional battle but are now also expected to think beyond military skills to provide for communities in ways not part of predeployment training. Although the US military was able to fund projects in Afghanistan (more than $137 billion has been spent thus far on reconstruction and aid; SIGAR 2020), it had yet to devise ways to implement aid and reconstruction once the initial phases of the war subsided. Funding, generally, was leveraged by schemes in which commanders were allowed to provide rapid and relevant development efforts through the Commander's Emergency Relief Program (CERP; Martin 2008). This program, widely used in both Iraq and Afghanistan, was primarily meant for property damage and/or accidental death payouts; funding of less than $25,000 was approved at the battalion level. As these CERP funds were increasingly being used, in 2006 upper echelon commanders began to recognize the need to formally introduce development efforts in support of the coalition forces' acceptance of the counterinsurgency doctrine (COIN) in Afghanistan (Marty 2016). To win "hearts and minds," President George W. Bush, along with US Army leaders, devised a unique tool to support these COIN efforts—Agribusiness Development Teams (ADTs; Stewart 2014). These teams, in addition to the international, civil-military Provincial Reconstruction Teams devised in 2002 to support public services (e.g., security, justice, and healthcare), were the tip of the military's reconstruction spear (Luehrs 2010; Stewart 2014).

These new soldier-expert hybrid teams were developed to provide the optimal combination of traditional military capabilities with individual expertise based on real-world, career-oriented experiences in agribusiness. Their mission was unique and was to work with and within local communities on long-term, sustainable (i.e., more than 5 years), community-devised and -accepted, Afghan-first projects with quality assurance and quality controls (QA/QC). The projects were funded by the US Army but owned fully by the community—all without fanfare, signage, or other conspicuous trappings.

14.1.1 US Army Agribusiness Development Teams

In early 2008, the US Army, in conjunction with various Army National Guard commands (state-based, reserve military forces), developed and deployed ADTs to Afghanistan. These specialized National Guard teams comprised 12 hand-selected soldier-experts within the agribusiness field who worked, when not deployed, as civilian professionals in (by team strength) geoscience, agronomy, veterinary science, engineering, agribusiness marketing, and pest management (Stone 2013). These National Guard soldier-experts were commanded by a National Guard colonel to increase unit maneuverability, support, and access in theater and were supported by a National Guard security force and headquarters elements. In sum, this provided a self-sustaining, unrestricted military unit of approximately 60 soldiers. All trained as a team for months before their deployment to generate the optimal combination of soldier-experts able to think and work on the ground as tacticians with an in-depth, strategic understanding of the insurgents and external, environmental elements contextualized within compassion and understanding of the host nation's culture. This host-nation culture in Ghazni Province in east-central Afghanistan (Fig. 14.1) is primarily Pashtuns in Ghazni City and surrounding areas and Hazaras in the mountainous west. US understanding of their customs, courtesies, and language was supported by interpreters who were either US citizens, US permanent residents, or vetted multilingual Afghans. The Afghan interpreters were from outside the Ghazni region to protect their identities and to minimize local and family connections to projects. Using an egalitarian team structure, these soldier-experts worked directly with both regional and local Afghan government officials and within the communities to support their agribusiness needs. ADTs provided agriculture-related education, training, and sustainable projects, which were US funded but locally operated, maintained, and sustained, with a staunchly held ethic that these projects not be charity. In all, nine states supported the ADT mission providing a total of about 50 teams that operated in 15 provinces. All told, they contributed nearly 700 agriculture-related projects, which generated over $42 million in economic benefits for the people of Afghanistan (NGB 2014).

The mission of the ADTs was to provide basic agribusiness education and services to support the legitimacy and effectiveness of the Afghan government.

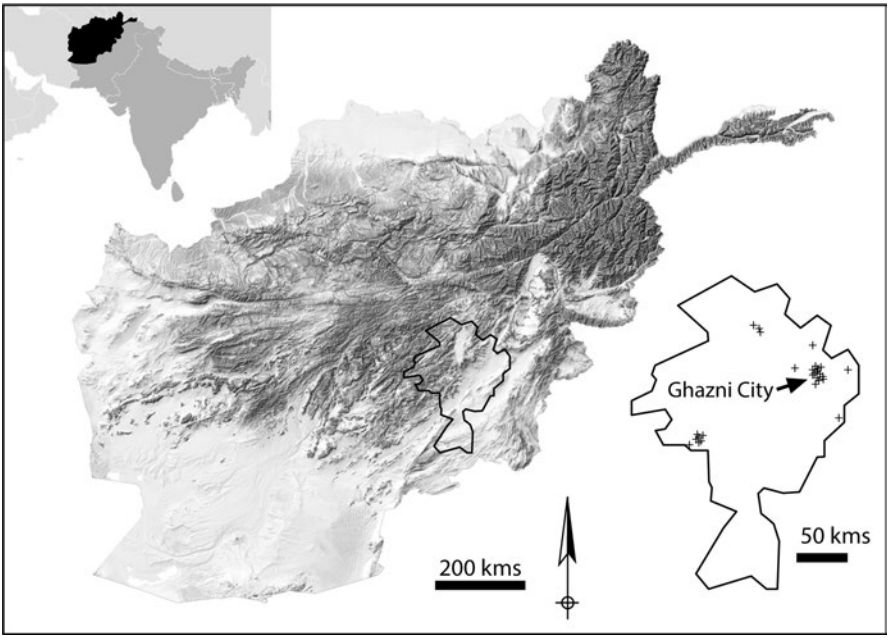

Fig. 14.1 Map of Afghanistan with South Asia (upper left) and Ghazni Province outlined with project locations (lower right). (The hillshade base map is modified from StackExchange (2020))

Working to support the Ministry of Agriculture, Irrigation, and Livestock, ADTs coordinated with the respective Provincial Directors of Agriculture, Irrigation, and Livestock (DAILs); district elders; and the public to develop and implement sustainable projects supporting the government of Afghanistan. Improving agriculture education and services was best achieved when soldier-experts worked in two- or three-member, flexible, problem-specific groups with direct support from the local community. Additional experts and ancillary support were provided by other team members and select academic institutions in the US. When not serving in the military, these professional soldier-experts from the Texas ADT II were a range management specialist with the Texas Parks and Wildlife Department, an aquaculturist with the Dallas World Aquarium, a professional farm manager with Afflerbach Farms, a project engineer with a road construction company, an environmental chemist working with Severn Trent Services, a renewable natural resource manager with Halff Associates, and a geology professor at Angelo State University (author).

14.2 Methods

In 2009, the Texas ADT II inherited, implemented, and planned a total of 52 development projects in Ghazni Province (Fig. 14.1) valued at approximately \$5.1 million. Ghazni Province, one of 34 in Afghanistan, covers approximately 23,000 km^2 with a population of approximately 1.3 million centered mostly in the urban areas of Ghazni City, Jaghori, and Malestan districts. Ghazni is a mountainous province with a relief of 2872 m (1933 m at the southern end and 4805 m in the Kharkush Mountain in the west) with a bioclimatic zone of a cool temperate desert scrub biome. Agriculture is centered along the generally flat valley fills of the transpressional plate boundary called the Chaman Fault between the Eurasian and Indian plates (following the Kabul-Kandahar road) and to the east where the terrain is flat to rolling. The mountainous parts of the province support small agricultural concerns located in valley bottoms.

Of the 52 projects, 27 (Table 14.1) could be monitored remotely using visible-spectrum, Earth Observing (EO) satellite data requiring no direct, in-country site visits. Site visits will likely be delayed many more years until hostilities in Afghanistan have subsided, enabling general scientific studies to continue or commence. To remotely evaluate these projects, EO data were thus key. Basic imagery from Google.com and Bing.com, for example, do not have adequate resolution or dense temporal coverage over Afghanistan. As a result, imagery from TerraServer (2020) was used exclusively for the remote-sensing analysis. It is a fee-based, image repository of the Earth's surface that was launched in 1998 and is owned by PrecisionHawk. Image quality and availability via TerraServer are the best available to the general public.

The suite of multitemporal imagery acquired over Ghazni Province extended from 2009 to 2019, although there was no imagery for 2011, 2012 and 2015. Nearly

Table 14.1 The 27 projects developed and implemented by the Texas ADT II, which are resolvable using satellite imagery with general location. Evaluation refers to the status of the project after analysis

Latitude	Longitude	Project	Evaluation
33.5	68.4	Arbaba Environmental Park	No change
33.8	68.4	Band-e Sultan dam	No change
33.6	68.2	Bochakhari dam	No change
33.6	68.4	Ghazni Agricultural Complex	Positive
33.5	68.4	Ghazni Agricultural Extension Training	No change
33.6	68.4	Ghazni Agricultural wind/solar	Loss
33.5	68.4	Ghazni bazaar	No change
33.6	68.4	Ghazni Demonstration Farm (gabions)	No change
33.6	68.4	Ghazni Demonstration Farm (general)	Loss
33.5	68.4	Ghazni Experimental Farm	Loss
33.6	68.4	Ghazni Minarets	Positive
33.6	68.4	Ghazni Wool Facility	No change
33.1	67.4	Jaghori Fish Farm (1)	No change
33.1	67.5	Jaghori Fish Farm (2)	Loss
33.1	67.4	Jaghori Slaughter Facility	No change
33.1	67.4	Jaghori/Sang-e Masha earthen dam	Positive
33.1	67.5	Jaghori Demonstration Farm	Loss
33.1	67.4	Jala village and earthen dam	No change
Assorted		Khwaja Omari River check dams	No change
33.9	67.9	Nawur Demonstration Farm (1)	No change
33.9	67.9	Nawur Demonstration Farm (2)	No change
33.1	67.5	Nawur Fish Farm	No change
33.9	67.9	Okaak earthen/masonry dam 1	Positive
33.9	67.9	Okaak/Nawur primary dam	Positive
33.6	68.4	Sanaee High School Agricultural Education Project	Loss
33.3	68.6	Sardeh Band Demonstration Farm	No change
33.6	68.7	Shetam dam	No change

1000 satellite images, however, were available to evaluate the 27 projects. There may be 10–20 different images in any 1 year at the selected spatial scale over one site. Images used in the analysis were clear and mostly cloud free, with resolutions sufficient to resolve meter-scale objects and were all acquired during summer and at midday to reduce shadows. In sum, 189 clear, midday summer satellite images at required resolutions were used to evaluate the 27 projects from their inception in 2009 until 2019, when the most recent imagery was obtained.

Site images were saved in jpg format and imported as individual “sheets” into Adobe Illustrator, where they were rectified, enabling each image to cleanly overlay the others. Images were then able to be toggled on-off and/or become partially transparent to better enhance changes from year to year (change detection). Structural changes (e.g., size), road and bridge emplacement or removal, and agribusiness activities, such as row planting and plant growth, were tracked for each image.

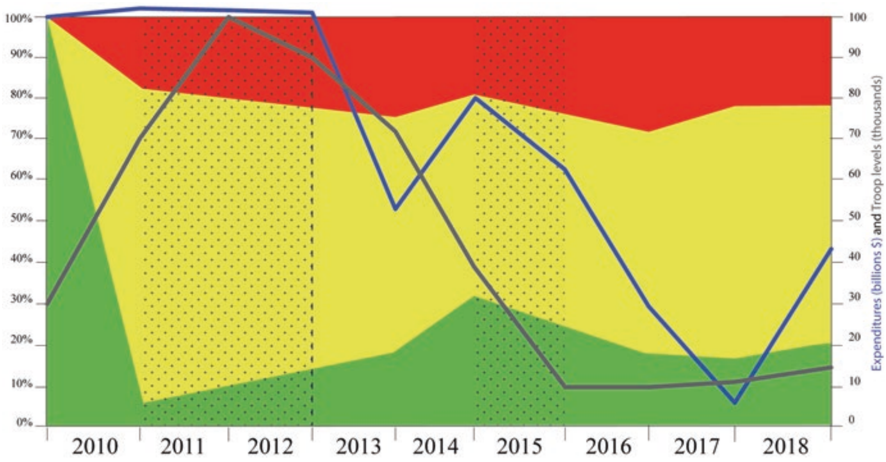

Fig. 14.2 Stacked histogram of the 27 evaluated projects. Green represents "positive" (100% at the end of 2009, assuming all projects were implemented in good faith), yellow are "no change," red are "lost" projects. Stippled areas are years without imagery for evaluation, the vertical-dashed line marks the end of the ADT mission, the blue line is the total US reconstruction expenditures (billions, USD), and the black line is the number of US troops in Afghanistan (thousands)

Three categories based on the original scope of work and the contract developed by the ADT were used to evaluate the projects based on change detection of the imagery: green, yellow, and red (Fig. 14.2). Green projects (positive) continued to operate or appeared to be operating, and development appeared to continue, throughout the period 2009–2019. Yellow projects (no change) followed the scope of work but failed to continue to develop. Red projects (loss or failure) failed to follow the scope of work and/or failed outright. All projects were considered green in the 2009 images because each project was developed and implemented under positive and promising conditions (i.e., each was fully funded, and contracts had been signed).

14.3 Results and Interpretations

Of the 27 projects evaluated (Table 14.1 and Fig. 14.2) over the 2009–2019 decade, 19% ($n = 5$) were considered positive; 60% ($n = 16$), no change; and 21% ($n = 6$), a loss. Only two projects were considered positive for the entire period—the Ghazni Agribusiness Complex (see below) and the Ghazni Minaret Park project. The bulk of the projects were considered no change in that the scope of work or contractual obligations appeared to be completed on the 2010 imagery, with zero growth, changes, development, and/or impacts between 2010 and 2019 (Arbaba National Environmental Park, see below). The Ghazni Demonstration Farm (see below) and the Sanaee High School Agribusiness Education Program projects, for example, were direct failures with no evidence after 2010 of any contracted efforts being initiated or completed.

14.3.1 Ghazni Agribusiness Complex (Positive)

The Ghazni Agribusiness Complex (GAC) was the first project developed and completed by the Texas ADT I in 2008 to help build a lasting relationship with the Ghazni Provincial DAIL (Stewart 2014). At the time of initial development and implementation, this simple project was a small slaughter facility used by local butchers for goats and chickens. The DAIL was aware that this location, near Shams Village, 3 km northwest of Ghazni City, was the locals' slaughter field (Figs. 14.3 and 14.4). The local practice was slaughtering in a dug trench with blood and offal

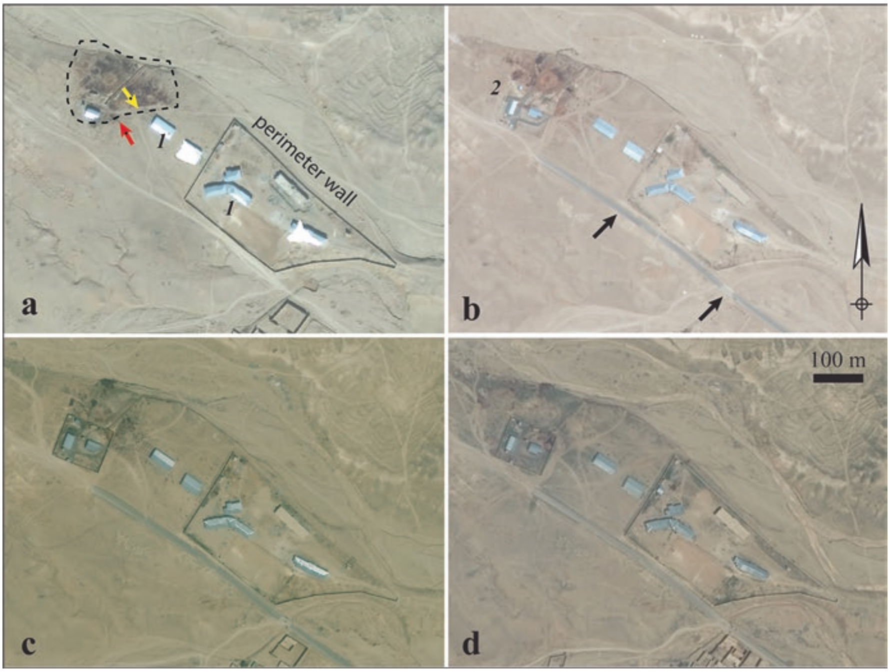

Fig. 14.3 Ghazni Agricultural Complex multitemporal satellite imagery series. (**a**) This 2010 image shows structures built or under construction prior to ADT efforts (1). Additional structures and the perimeter wall were projects supported and implemented by ADT II in 2009. The dashed line represents the slaughter and offal area (blood stains) prior to the 2010 slaughterhouse project. The yellow and red arrows indicate ground photograph locations in Fig. 14.4. (**b**) The 2013 image shows continued building construction (2). The black arrows point to the new road, including a bridge emplacement. The image progression from (**a**) 2010 to (**d**) 2019 shows the changes in the slaughter/offal area. (**d**) By 2019, offal staining is restricted to the walled property of the slaughter facility. (Modified from Terraserver.com; used with permission from PrecisionHawk)

Fig. 14.4 Ground photographs of the Ghazni Agricultural Complex in March 2009. (**a**) This photo looks westerly at the recently built slaughterhouse (red arrow on Fig. 14.3); note the blood-stained ground (especially front left). (**b**) This photo is easterly facing showing the new foundation emplacement for the sales barn (yellow arrow on Fig. 14.3)

left exposed to rot in the sun. This type of slaughter is common in Afghanistan, but the DAIL and the ADT decided to implement a sanitary location for slaughtering small animals. The initial project consisted of a slaughter building and an offal pit for residual collection (Fig. 14.4a). This offal was pumped as needed with waste then transported to an appropriate disposal site. By 2009, ADT II and the DAIL determined that the locals were attracted to this new slaughterhouse, and due to its popularity, demand was greater than capacity with slaughtering continued around the property. A larger facility that could also accommodate cows and camels for sanitary slaughter was warranted.

ADT II, in conjunction with the DAIL and the local Shams Village elders, implemented a new, more expansive project, which included an extension of the current slaughterhouse with an office building, a vehicle barn, a composting barn, a pump truck, and a tractor with trailer. Because the location was becoming a central hub for some agribusiness activities and recognized as such by the community, ADT II proposed a feed mill, a livestock sales facility, and a tanning facility as well. To power these operations, two 24v, 400w (@26mph) wind turbines and eight 12v, 50w microcrystalline photovoltaic solar panels were installed with power stored in 12 12v, 100 Ah maintenance-free, deep-cycle batteries in a locked storage container. The feed mill was envisioned as a place for the DAIL and his agricultural extension agents and University of Ghazni students to experiment with grain for demonstration and training purposes. It included a dry-storage building, a mill, a generator, and a tractor. In late 2009, the facility was already storing grain. The livestock sales facility comprised a covered sales building with a business office and pens for livestock inspection and treatment. The tanning facility was adopted from an unfinished USAID project and enabled locals to produce products from the tanned hides of livestock slaughtered on-site, as opposed to exporting the hides to Pakistan. The facility also functioned as a hide-and-wool storage facility. By 2010, the feed mill, livestock sales facility, and power systems were completed and in full operation.

Site visits as late as December of 2009 confirmed that the first slaughter facility was operational and also that slaughtering was still occurring and offal was collecting in the ditch, as noted above (see blood stains in Figs. 14.3a and 14.4a). It was recognized that this facility needed a new generator and ancillary items. The livestock sales barn had a poured foundation (Fig. 14.4b) and was about 10% complete with the tanning facility and feed mill operational. Within 1 year, the slaughter facility expansion had been approved and was prepared for commencement in the spring of 2011 (DVIDS 2010). Image analysis shows that this project appeared to be completed by 2013 (Fig. 14.3b) inclusive of an asphalt-access road and bridge, an interior walking pavement, and a controlled migration of slaughtering into the slaughter structure (evidenced by the decreasing bloodstains observed on the imagery between 2010 and 2019 on Fig. 14.3). By 2016, the slaughter facility was enclosed by a perimeter wall (Fig. 14.3c). By 2019, nearly all slaughtering appears to have been moved into the facility (Fig. 14.3d). Overall, this project was both an initial success in helping develop new relationships with the DAIL, the local communities, and the US Army and, later, as an entire Agribusiness Complex. Based on the scope of work documents, it is likely that the bridge and access road improvements were constructed between 2010 and 2013 to meet the increasing use of the complex. These improvements were directly related to the support of the local community and not part of the original scope of work.

14.3.2 Arbaba National Environmental Park (No Change)

The Arbaba National Environmental Park (ANEP) is located 2 km east of the city of Ghazni (Figs. 14.5 and 14.6). It was originally conceived by order of the then President of Afghanistan, Hamid Karzai, in 2005.[2] In conjunction with the newly

[2] Proposal number 685, dated 28 May 2005 of the National Environmental Protection Agency and Order number 1017 of Hamid Karzai dated 30 May 2005.

Fig. 14.5 Arbaba National Environmental Park (ANEP) multitemporal satellite imagery series. (**a**) The dashed line on this 2010 image shows the boundaries of the walled ANEP. This area was disused pasture before 2009. The blue transparent polygon (left) encompasses derelict structures and fields that were later revived/improved. The arrows indicate the locations of the ground photographs in Fig. 14.6. Within the ANEP, the radiating light-colored lines are graveled paths and the center circle is the planned location for a central fountain; it was never begun. The bright spot (1) is a white-balance issue associated with the reflective metal roof for the facility storage/entry/guard building. (**b**) This image from 2013 shows basic row planting (2) and the administration building (3). (**c**) This 2016 image shows the roofed administration building, (4) and (**d**) the 2019 image shows the increase in buildings to the west of the park. (Modified from Terraserver.com; used with permission from PrecisionHawk)

adopted Constitution of Afghanistan, Article 15 stated a formal and direct need for the government to protect the environment, so 20 jeribs of land (four hectares) were transferred to Ghazni Province for the development of the country's first national environmental protection park (Stewart 2014). This land transfer languished in the provincial land office register book until September of 2009 when it was formally transferred for the commencement of the park project. This four-year lag was likely related to the timing of the entrance of US Forces into Ghazni Province in 2008, thereby presenting an opportunity for the US Army to help support the project. The project, along with the Ghazni Minarets Park project, was also spurred on by excitement among the city and province populace and local leaders with their selection as the 2013 Asian Capital of Islamic Culture (UNAMA 2013) during which cultural and heritage conservation and preservation were key attractions for the hoped-for tourism boost.

Fig. 14.6 Ground photographs of the Arbaba National Environmental Park's planned location in June 2009. (**a**) This photo looks westerly across the alluvial pasture (black arrow on Fig. 14.5). (**b**) The cut-bank section from the adjacent wadi where the planned gabion-wall section was intended to be constructed (red arrow on Fig. 14.5)

The original scope of work requested by the Afghanistan Environmental Protection Agency and supported by the ADT required the transformation of an open area of alluvial sands (Fig. 14.6a) into a thriving environmental park meant to provide for the permanent preservation of the area's natural condition (antecedent to human influence) dedicated to public education, enjoyment, and inspiration. Not only was the park to be a site for family visits and recreation but also for high-school and university learning in a lab-type environment (e.g., drip irrigation methods or flora identification). The project was estimated to take about 3–4 months and to be completed by the end of 2009, employing two to three full-time workers. To make this park available to *all* people (i.e., *purdah*[3] for females and families), of utmost importance in this traditional Islamic city, a 1100 × 2.4 × 0.6 m perimeter stone wall was built (Fig. 14.5a). This wall was the first part of the project to be completed and required the joint relations of the governments of Afghanistan, the United States,

[3] *Purdah* is the South Asian practice of veiling women and secluding them from public view.

and Poland (Ghazni was in Polish battlespace) in order to garner enough support for its completion. The success of the park hinged on this *purdah* screen or view-blocking stone wall, and its construction amounted to about 80% of the project's cost. Secondarily, an administration building and a guard shack were requested (Fig. 14.5a, b), as well as a pump room and a generator room, a water well, land leveling, walkways, an irrigation system, and the planting of apple, apricot, and almond trees and ornamental plants. A gabion wall was intended to minimize weathering and erosion from flash floods from the adjacent wadi (Fig. 14.6b).

By the summer of 2010 (Fig. 14.5a), progress on the park included the building of the perimeter security wall, administration-guard building, a central fountain, and graveled walkways. Based on the original contract and scope of work, however, progress was approximately 6 months behind schedule. Reports by the Texas ADT IV in May 2011, when there was no imagery, suggested that the project required another 2–3 months for completion (ADTiv 2011). By 2013, the access road had been paved and the foundation of the administration building is visible with subtle evidence of the orchard in the southwestern section of the park (Fig. 14.5b). No foliage is detectable park-wide on any image between 2013 and 2019. By about 2016 (Fig. 14.5c), the administration building appeared complete, but the access road is becoming increasingly covered by lateral transport of wind-blown or washed regolith, and by 2019 (Fig. 14.5d), it is completely buried and disused.

Based on image analysis, the Arbaba National Environmental Park was never fully completed or implemented as planned. Ghazni was the center for Islam in 2013; however, in this security-poor sector of Afghanistan, it is unlikely the park was dedicated. Although the image analysis indicates that the ANEP per se was not completed, some 60,000 m^2 of adjacent structure development commenced around 2011/12 with continual growth up to 2019. It is likely that this development coincides with the park's inception and was based on hopes that it would be the attraction promised by the government. It is probable, too, that security personnel intended to be provided by the park would lend an added layer of protection in this insecure area and thus enhance the likelihood of local development. If this were to happen, it is anticipated that the ANEP may yet become the reality originally envisioned.

14.3.3 Ghazni Demonstration Farm (Loss)

The Ghazni Demonstration Farm (GDF; Figs. 14.7 and 14.8), like the GAC, was an early ADT I project devised in direct consultation with the DAIL and the local communities. It was paramount, as a newly devised unit with a specialized and unique agribusiness mission novel in the Afghanistan battlespace, that ADT I develop good and lasting relationships with the local communities. The aspiration to develop ideas to enable the Afghan people to become agricultural exporters and not just subsistence farmers was directly related to agribusiness concerns. This had been the case before the Soviet invasion in 1979 when Afghan exports included

Fig. 14.7 Ghazni Demonstration Farm multitemporal satellite imagery series with dashed lines enclosing the farm property. (**a**) In this 2010 image, the circle indicates the ADT-supported and implemented access bridge (2008) and gabion wall (2009). The arrows indicate the locations of the ground photographs in Fig. 14.8. (**b**) This 2013 image shows what appears to be a failed effort to plant trees (2) (see the arranged plot in (**c**)), which returned to derelict rectangular plots, and the greenhouses and other support structures (3). (**c**) This 2016 image shows the continued deterioration of the demonstration farm with the white box surrounding the arranged plot where trees were planted. (**d**) The poorly developed cover crops, fields, and plots in 2019 are evidenced by the mottled appearance (4). (Modified from Terraserver.com; used with permission from PrecisionHawk)

sugarcane, sugar beets, fruit, nuts, and wool. In order to meet this goal, a demonstration farm was proposed in the agricultural corridor of flat, alluvial fills of the Khwaja Omari River near Ghazni City. This demonstration farm was meant to train locals in advanced agribusiness techniques and methods, to serve as a center for the DAIL's agricultural extension agents, and to become a place for potential future agriculture fairs. The initial project devised and implemented included an access bridge (Fig. 14.7a), two greenhouses (Fig. 14.7b), a livestock shed and animal pens, a cool-storage facility, a classroom (Fig. 14.8a), a cistern, and wind turbine and solar panel array to power the operation. By early 2009, this project was completed, and the DAIL and local communities (and the new ADT II) were eager to continue relationships and build upon this foundation. After a QA/QC follow-up in March 2009 conducted by ADT II personnel, it was realized that the new gravel-paved access roads needed to be extended to support the weight of heavy truck

Fig. 14.8 Ground photographs of the Ghazni Demonstration Farm in December 2009. (**a**) View looking northeast across plotted conifer saplings with the classroom and cold storage in the distance (yellow arrow on Fig 14.7a). Note the raveled drip-irrigation lines in the middle ground/right and the failure of approximately 50% of the saplings to take root. (**b**) An IED-resistant irrigation culvert. (**c**) A perspective view from the access bridge looking westerly at the recently emplaced gabion wall (white arrow on Fig. 14.7a). (**d**) Westerly view of the recently emplaced and graveled access road with four culvert abutments

traffic. A second-order consequence was that these roads had become an impediment to irrigation-ditch emplacement and the access bridge's wing-wall was being sapped by lateral bank incision by the perennial Khwaja Omari River that it crosses. To address these issues, the ADT II personnel, in conjunction with the DAIL and community elders, decided to emplace five improvised-explosive-device-resistant (IED) culverts (Fig. 14.8b) to allow for unimpeded irrigation flow and to emplace a series of gabion baskets (Fig. 14.8c) as an extension to the bridge's wing wall (Stewart 2014, 2016a, b).

By the summer of 2009, the access-road network had been expanded and graveled (Fig. 14.8d) and the culverts had been installed. The culverts were reinspected in December 2009 and signed off as functional, along with the gabion basket extension to the bridge wing wall. The culverts were engineered to be IED resistant by welding crossed rebar at the openings to prevent bomb emplacement (Fig. 14.8b). This was necessary because the Ghazni area was undergoing significant insurgency-related security issues at the time due to the constructive relationship between the US Army and the local populace. The gabions were primarily meant to prevent additional sapping of the bridge's wing wall and provided an opportunity for a community-wide learning event. The project centered around a qualified engineer teaching local farmers how to emplace the gabion baskets. After being taught, farmers were given empty gabion baskets to use on their properties as a form of payment for the help they provided by emplacing them while undergoing instruction. The entire learning event was promoted and run by Afghans and was publicized on a Ghazni radio station to attract participants and, later, to promote the results.

Based on on-site QA/QC visits throughout 2009, the GDF was assessed to be a relatively active and promotional project requested by the DAIL and the local communities. All projects, up to December 2009, were considered complete with payments submitted to the Afghanistan contractors. Inspections throughout the summer of 2009 revealed failed nursery plantings and kinked and improperly placed and managed drip irrigation lines (Fig. 14.8a). The batteries for the wind turbine and solar panel systems had been stolen. Despite these setbacks, every effort was made to continue operations at the GDF. An examination of imagery from 2010 to 2019 indicates that the entire demonstration farm appears to be increasingly derelict. The access roads, culverts, and irrigation accesses all became worn, covered, and disused, and the attempts at cultivating crops or trees appear to have never taken hold. Multitemporal imagery of local farms around the GDF show crop growth as increased greening as the growing season continued, but, unfortunately, this is not the case for fields within the project boundaries. It is likely that the roads are used by local farmers as shortcuts to other destinations, and the buildings have become either derelict or repurposed (such as happened at a nearby USAID-funded grape-drying facility, which was used as a shed to house goats). In all, this community-partnership project likely failed for the lack of timely access to this centrally located demonstration farm where farmers still live and work in their small communities without much interest or need to head to the city of Ghazni (Groninger et al. 2013).

14.4 Discussion

Overall, the sustainability of the 27 projects evaluated results in a normal distribution with 19% positive, 60% no change, and 21% failed or lost (see Fig. 14.2), which is an improvement compared to results presented in development-aid literature globally and for Afghanistan specifically (Qian 2015; Egel et al. 2016; Kapstein 2017; Radelet 2017; SIGAR 2020). Unexpectedly, there is no connection between project success and external defense and security metrics, which would likely have direct effects, such as troop levels and expenditures (Fig. 14.2). Exclusive of the direct loss due to the myriad problems associated with the full success of all projects (e.g., security or contractor issues) and the slow rise (green area in Fig. 14.2) as projects were developed between 2011 and 2013, there is nearly no variability in project status with time. The slight increase in positive effects in 2014 is due to the unexpected continued development, both road paving, at two already positive projects, the GAC and the Ghazni Minarets.

The projects that failed or were lost were all demonstration-oriented projects (e.g., the Ghazni Demonstration Farm; Table 14.1), which mostly never got off the ground. Despite direct work with and within the communities to develop these projects, it may be that these projects, all of which were presented to the local populace as starter projects to build new community relationships, were seen as ways to open lines of communication and the flow of US aid money into these communities. Initial contact with communities was centered on *shuras*,[4] discussions with the DAIL and local elders, who proposed ideas that would benefit the community as a whole while promising full community acceptance and involvement. Once these projects were started, more specific projects that were more likely to be successful, such as a wool-processing facility, were often requested by the community even though they may not have benefited all equally. In general, these failed projects just never got off the ground—good intentions that were funded but either were never completed or became derelict. The driver was Afghan led, and therefore it was never the intent to have US personnel work on these projects, even if that meant some would never be finished or would fail.

The bulk of the projects developed by the Texas ADT II were considered no change; this is *not* a negative result because these projects were devised and implemented on time (more or less), to budget and remained in basic, planned operations for the following 10 years. Fifty percent (8 of 16; Table 14.1) of the projects that showed no change were either earthen or masonry dams that needed nonstructural repairs, so funds were offered to help maintain their functions (Stewart 2016c). In all, these 16 projects appeared to continue to function as planned yet were not able to spur additional or ancillary development efforts required to be considered positive.

The five positive projects (Table 14.1), such as the Ghazni Agricultural Complex, essentially, are not that much different in their scopes, implementation, locations, or the energies put into their development than the projects that failed or were lost. It is likely the positive outcomes of these projects are attributable to being developed at the right time and in the right place to suit the particular needs of a community that ultimately found real, useful, and promotional value to their intended usage.

The US Army will continue to deploy its forces around the globe (Turse 2017) in support of US interests, and delivering reconstruction aid will continue to be a priority where it supports the military mission (Iyengar et al. 2017). The overall success of development project efforts will be criticized by traditional aid providers, such as Oxfam (2014), as militarized aid that is paradoxical and untenable as a way of providing development efforts globally. Despite this criticism, the ADT mission's efforts were in direct response to needs for humanitarian assistance that could not be met by traditional aid or development agencies because the Taliban and Al Qaeda militants did not recognize the Geneva Conventions or international humanitarian law (Bellal et al. 2011) and the concepts of humanity, impartiality, and neutrality. ADTs were relatively low cost but large in impact. This is in direct contrast to the

[4] *Shura* is an Arabic word for consultation. The Quran and the Prophet Muhammad encourage Muslims to decide their affairs in consultation with those who will be affected by that decision.

many large projects that formal, trained aid agencies (e.g., USAID) have tried to implement and that are often failures from the start (Kapstein 2017).

14.5 Conclusion

Despite spending only 0.03% of the US current total budget on reconstruction efforts in Afghanistan, the ADT mission's overall impact on the communities they served was positive. Some 80% of the 27 remotely sensed projects either have been maintained within the original scope of work or the concept originally proposed or have stimulated ancillary and unplanned, but hoped for, positive results. The ADT mantra to providing agribusiness development in Afghanistan was "small is better," provide to stable communities, and keep it simple, all the while working with and within the local communities through direct, daily conversations. As a result of these efforts, local needs became apparent, as did the ways local people could be supported by Afghan-first projects. This was a natural extension of good people and good planning working for the betterment of Afghanistan. The ADT mission worked this way, years *before* the academic literature appeared to understand that these attitudes and operational needs were a requirement for successful aid efforts (Oxfam 2010, 2014; Egel et al. 2016; Sexton 2016; Iyengar et al. 2017; Kapstein 2017; SIGAR 2018). The effectiveness of these specialized US Army teams has been recognized by the development community and used as a model to develop new and better ways to provide aid. A prime example is the proposed USAID (2018) Rapid Expeditionary Development Teams meant to operate as two-person, civilian-military teams executing a mix of offensive, defensive, and stability operations—all to push USAID efforts into insecure areas and improve their chances of success. The remote-sensing analysis of projects presented here shows that the ADT model was effective and provides evidence to support this model being formally adopted by the US military. The US military should respond to future needs using these unique soldier-expert teams that are able to think beyond military training and provide development assistance in the most dangerous locations on the planet.

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References

Agribusiness Development Team IV (ADTiv) (2011) ADT facilitates several Ghazni projects. https://txadt.wordpress.com. Accessed 15 July 2020

Baker JL (2000) Evaluating the impact of development projects on poverty: A handbook for practitioners. The World Bank, Washington DC

Bellal A, Giacca G, Casey-Maslen S (2011) International law and armed non-state actors in Afghanistan. International Review of the Red Cross 93(881):42-79. https://doi.org/10.1017/S1816383111000051

Defense Visual Information Distribution Service (DVIDS) (2010) Texas ADT IV inspects slaughterhouse for future expansion. https://www.dvidshub.net/image/346770/texas-adt-iv-inspects-slaughterhouse-future-expansion. Accessed 15 July 2020

Egel D, Ries CP, Connable B et al. (2016) Investing in the fight. Assessing the use of the Commander's Emergency Response Program in Afghanistan. Rand Corporation Research Report RR-1508-OSD. https://www.rand.org/pubs/research_reports/RR1508.html. Accessed 15 July 2020

Groninger JW, Ruffner CM, Walters SA (2013) Sustaining rural Afghanistan under limited central government influence. Stability: International Journal of Security and Development 2:1-13

Iyengar R, Shapiro JN, Hegarty S (2017) Lessons learned from stabilization initiatives in Afghanistan: A systematic review of existing research. RAND Labor & Population working paper WR-1191. https://www.rand.org/content/dam/rand/pubs/working_papers/WR1100/WR1191/RAND_WR1191.pdf. Accessed 15 July 2020

Kapstein EB (2017) Aid and Stabilization in Afghanistan: what do the data say? United States Institute of Peace Special Report 405. https://www.usip.org/publications/2017/06/aid-and-stabilization-afghanistan. Accessed 15 July 2020

Luehrs C (2010) Provincial Reconstruction Teams literature review. Prism 1:95-102

Martin MS (2008) The Commander's Emergency Response Program. Joint Forces Quarterly 37: 46-52

Marty FJ (2016) No COIN left in Afghanistan. Small Wars Journal. https://smallwarsjournal.com/jrnl/art/no-coin-left-in-afghanistan-—-or-the-elephant-in-the-room-that-no-one-is-talking-about. Accessed 15 July 2020

National Guard Bureau (NGB) (2014) 2014 National Guard Bureau posture statement: sustaining an operational force. https://www.nationalguard.mil/portals/31/Documents/PostureStatements/2014%20National%20Guard%20Bureau%20Posture%20Statement.pdf. Accessed 15 July 2020

Oxfam (2010) Quick impact, quick collapse. Research Publications, January 3rd. https://www.oxfamamerica.org/explore/research-publications/quick-impact-quick-collapse/. Accessed 15 July 2020

Oxfam (2014) Aid in contested spaces: Afghanistan. Research Backgrounder Series, https://www.oxfamamerica.org/explore/research-publications/aid-in-contested-spaces-afghanistan/. Accessed 15 July 2020

Qian N (2015) Making progress on foreign aid. Annual Review of Economics 7:277-308

Radelet S (2017) Once more into the breach: Does foreign aid work? Brookings, May 8th, blog. https://www.brookings.edu/blog/future-development/2017/05/08/once-more-into-the-breach-does-foreign-aid-work/. Accessed 15 July 2020

Sexton R (2016) Aid as a tool against insurgency: evidence from contested and controlled territory in Afghanistan. American Political Science Review 110:731-749. https://doi.org/10.1017/S0003055416000356

Shields PM (2011) An American perspective on 21st century expeditionary mindset and core values: A review of the literature. In: Henrik F and Gerhard K (eds) Core values and the expeditionary mindset: Armed forces in metamorphosis. Nomos Publishers, Berlin, p 17-34

Special Inspector for Afghanistan Reconstruction (SIGAR) (2018) Stabilization: Lessons from the US experience in Afghanistan. May. https://www.sigar.mil/pdf/lessonslearned/SIGAR-18-48-LL.pdf. Accessed 15 July 2020

Special Inspector for Afghanistan Reconstruction (SIGAR) (2020) Risks to Sustainable Peace in Afghanistan. Testimony Before the Subcommittee on National Security Committee on Oversight and Reform US House of Representatives. https://www.sigar.mil/pdf/testimony/SIGAR-20-24-TY.pdf. Accessed 15 June 2020

StackExchange (2020) Shade and color Hillshade using QGIS. https://gis.stackexchange.com/questions/219246/shade-and-color-hillshade-using-qgis. Accessed 15 July 2020

Stewart AK (2014) U.S. Army Agriculture Development Teams: A grassroots effort in Afghanistan supporting development and tackling insurgency. Science and Diplomacy 3:70-87

Stewart AK (2015) Geological-reasoning training as preparation for the 'thinking warfighter' in the next-generation military. Journal of Military and Strategic Studies 16:1-10

Stewart AK (2016a) U.S. Army Agribusiness Development Teams: The role of the geologist in the counterinsurgency. In: MacDonald E and Bullard T (eds) Military geosciences and desert warfare–past lessons and modern challenges. Springer Science+Business Media, New York, p 221-236

Stewart AK (2016b) U.S. Army-Afghan hydrological development efforts (2008-2014): an improved approach to military aid. In: Wessel G, Greenberg J (eds) Geoscience for the public good. Geological Society of America Special Publication 520, 193-204, Boulder, CO https://doi.org/10.1130/2016.2520(18)

Stewart AK (2016c) Dams in Afghanistan. In: Shroder J, McNamara P, Ahmadzai SJ, Weihs B (eds) Transboundary water from Afghanistan: issues of climate change, apportionment and land-use implications. Elsevier, Amsterdam, p 213-268

Stone R (2013) Soldier-scientists join counterinsurgency in Afghanistan. Science 342(6159):682. https://doi.org/10.1126/science.342.6159.682

Terraserver (2020) PrecisionHawk. https://www.precisionhawk.com/satellite. Accessed 15 July 2020

Turse N (2017) US Special Operations Forces deployed to 135 countries. War is boring. https://warisboring.com/u-s-special-operations-forces-deployed-to-149-countries-in-2017/. Accessed 15 July 2020

United Nations Assistance Mission in Afghanistan (UNAMA) (2013) Ghazni declared Asian capital of Islamic culture, highlighting Afghanistan's rich cultural heritage. 13 April. https://unama.unmissions.org/ghazni-declared-asian-capital-islamic-culture-highlighting-afghanistan's-rich-cultural-heritage. Accessed 15 July 2020

United States Agency for International Development (USAID) (2018) Demand and Feasibility Assessment. https://pdf.usaid.gov/pdf_docs/PA00T6VQ.pdf. Accessed 15 July 2020

Chapter 15
Contemporary Security Threats on the High Seas

Francis A. Galgano

Contents

Abstract Maritime piracy is broadly defined as armed robbery and acts of violence on the high seas or within territorial waters. It represents a significant transnational security problem because of its financial costs, threats to crew safety, and potential security implications. It has thus become an important feature on the global security landscape. Data indicate that it is a global problem but that it is highly spatially concentrated in four regions: East Africa, the Gulf of Guinea, and South and Southeast Asia. More significantly, contemporary trends indicate that violence and hostage taking are increasing, especially in places where it was not previously widespread. Despite international efforts, pirate attacks remain persistently high in places where it has been endemic. Pirate activity appears to be a function of governance, and there are two components to this problem. First, most pirate attacks emanate from poorly governed states. The second factor is related to a fundamental disconnect between international and domestic law and enforcement.

Keywords Piracy · Geography · Governance · Borders · Law of the sea

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15.1 Introduction

Maritime piracy is broadly defined as armed robbery and violence against ships on the high seas or within territorial waters. The threat of maritime piracy has endured and remains endemic in selected waterways. The suppression of maritime pirates has moved to the top of the global security agenda because of its significant financial cost as well as its potential security implications (Struett et al. 2013) and because much of the world's trade and almost all its oil is carried aboard ships. The geography of maritime commerce compels vessels to traverse constricted shipping lanes adjacent to poorly governed states from which pirates can operate with impunity. Ultimately, piracy has added a tenfold increase in maritime cargo and insurance costs; it is thus in the collective interest of the global community to ensure that shipping lanes are stable and safe (World Bank 2013a).

The seizure of the *MV Sirius Star* by Somali pirates on 20 November 2008 brought maritime piracy sharply into global focus (Galgano 2009). The *MV Sirius Star* was carrying more than $100 million in Saudi Arabian oil (APS Review 2008), but more significantly, its capture demonstrated a new and more violent pirate "business model": that is, the seizure of ships and crew for ransom (Coggins 2012). By 2011, Somali pirate attacks reached their zenith when they surged to 237 (Fig. 15.1), accounting for more than half of the world's total at the time. Since then, Somali

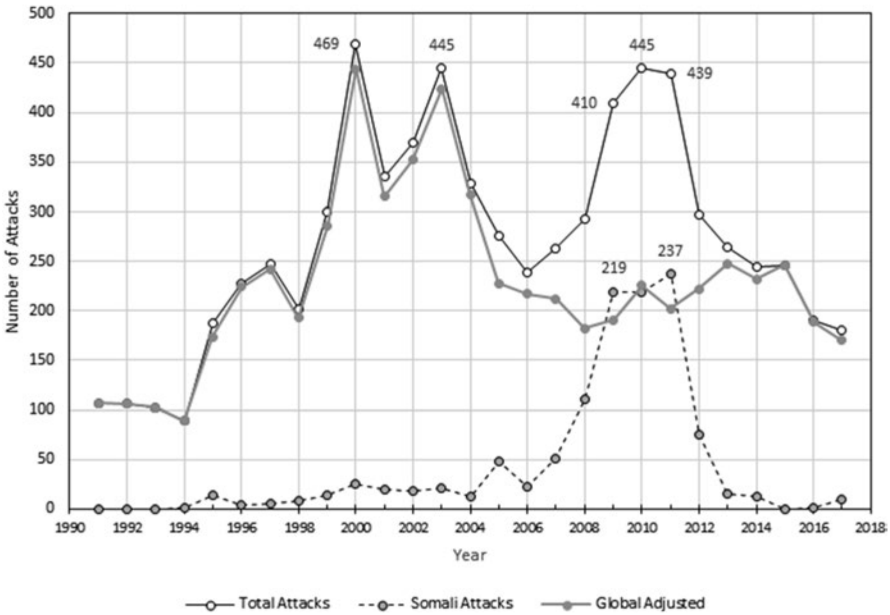

Fig. 15.1 Comparison of global and Somali pirate attacks between 1991 and 2017 adjusted for Somali attacks. (The data are derived from the International Maritime Bureau (IMB 2003, 2008, 2013, 2018a))

piracy has been suppressed as a result of international action. Nevertheless, the *MV Sirius Star* incident and the growth of Somali piracy underscore the complex and detrimental nature of piracy on the security landscape.

There appear to be clear spatial and temporal trends in pirate activity. Piracy is a global problem, but it is spatially concentrated in four regions (East Africa, the Gulf of Guinea, and South and Southeast Asia) and adjacent to seven states (India, Indonesia, Bangladesh, Vietnam, the Philippines, Malaysia, and Nigeria), so geography offers a compelling vantage point from which to assess this problem. Notwithstanding the surge in Somali pirate attacks between 2006 and 2011, piracy is endemic particularly in South and Southeast Asia, where nearly 70% of all pirate activities take place (Galgano 2009). Although the Somali problem has since declined and, globally, pirate attacks have been reduced, they persist in historically problematical areas in waters adjacent to South and Southeast Asian states as well as off the east coast of Africa. Furthermore, new hot spots are emerging in places such as the Gulf of Guinea (IMB 2018a). More importantly, the percentage of crew abductions is increasing in places where it was not formerly prevalent. The security threat of piracy has become more problematic, too, because pirates appear to be well equipped, to have excellent intelligence networks, and to receive advanced warning of ship sailings from corrupt port officials (UN 2014).

This newly demonstrated efficiency is challenging because it forces lengthy and inefficient changes in sea routes and triggers additional costly security measures, which, when combined with direct material losses, represent a considerable risk to global trade (UN 2014). The threat to commerce cannot be understated because some 80 to 90% of global trade moves by sea (Ban 2011). The costs of piracy are compelling. The World Bank estimates that Somali pirates cost the global economy \$18 billion (World Bank 2013a), and at their peak, Somali pirates accounted for 5–10% of the cost of gasoline at the pump in the United States (APS Review 2008). More recently, the Rand Corporation estimated that direct losses, ransom for crew, rerouting of ships, and additional security measures cost the global economy between \$1 and \$1.6 billion annually (UN 2014; Oceans Beyond Piracy 2018).

This paper examines maritime piracy from a geographic perspective using data from the International Maritime Bureau (IMB), which suggest that there are significant contemporary trends. First, pirate activity is spatially concentrated in four regions. Second, although pirate attacks have been reduced globally, violence and hostage taking are increasing, especially in places where it was not previously widespread. Finally, despite international efforts, pirate attacks are persistently high in South and Southeast Asia. There are many economic, societal, environmental, and political dynamics that enable piracy, such as poverty, resource depletion, corruption, and organized crime. Because these causes are as varied as the locations themselves, a comprehensive review of economic, social, and political dynamics is beyond the scope of this paper. On the other hand, a geographic analysis indicates that the highly concentrated nature of pirate attacks is enabled by three key factors: governance, contested borders, and adjacency to chokepoints and shipping lanes.

15.2 Piracy Data and Defining the Problem

Piracy data used herein were collated from annual reports published by the IMB, which is a specialized division of the International Chamber of Commerce (ICC 2019). The IMB was established in 1981 to combat maritime crime and began its Piracy Reporting Center in 1992 in response to growing concern over pirate attacks (IMB 2003). Since 2006, IMB data have been supplemented by the NATO Shipping Centre, which publishes maritime security warnings. More recently, Oceans Beyond Piracy (2018) has published regional reports and assessments. The IMB, however, maintains the most complete global database, which it publishes in quarterly and annual reports. In addition, there is a live piracy map on its website[1] (IMB 2018b).

Figure 15.1 shows reported pirate attacks between 1991 and 2017. There was a 421% increase in the number of attacks between 1994 and 2000, offering compelling evidence that piracy is a persistent security problem. Although the number of attacks has fluctuated since 2000, they remain relatively high, at essentially twice the rate now than when reporting began in 1991. However, there are data limitations that must be understood. Considering the rapid rise in the number of recorded attacks since reporting began, it is reasonable to consider if it is piracy that has increased or if reporting is what has increased. Furthermore, the IMB depends on voluntary reporting and acknowledges that its data may be skewed because they assess that piracy remains underreported, perhaps by as much as 50%. For example, the IMB suggests that the number of incidents in the Gulf of Guinea may be underreported by as much as 62% (IMB 2018a). Nevertheless, IMB data are the best available; and they are accurate and suitable for discerning trends and making cogent geographic analyses.

Several factors contribute to the underreporting of pirate attacks, which is complicated by the dynamics of maritime commerce. Globalization and economic trends have essentially eliminated the existence of traditional, national merchant marine fleets, which confounds the reporting process (World Bank 2013a). For example, a ship might be built in one state, owned by a company in a second, flagged in a third, and chartered to carry cargo by a firm in a fourth. Furthermore, a ship's complement typically consists of a multinational crew (Reinhardt 2007). The question then becomes, who reports the attack? Because maritime pirates may not necessarily threaten the maritime commercial assets of any single state, the incidences are largely underreported (UN 2014).

Furthermore, there is a business model dynamic that may drive underreporting. Prior to the surge in Somali attacks, most incidents followed the so-called Asian Model, i.e., a ship is boarded, the crew is robbed, and some cargoes are stolen. Hostages are seldom taken, and the crew is rarely harmed. The attack is relatively short, and the average loss is about $12,000 (Beckman and Page 2014). Shipping companies are disinclined to report and investigate incidents because, as part of the investigation, the ship could be detained in port for many days at a cost of several

[1] https://www.icc-ccs.org/piracy-reporting-centre/live-piracy-map

tens of thousands of dollars per day, which usually exceeds the cost of the original loss (Luft and Korin 2004). However, Somali pirates initiated a surge in the so-called African Model, which introduced hostage taking for ransom (Fish 2014). For example, during their peak (i.e., 2008–2012), Somali pirates held approximately 3420 hostages—about 78% of the world total (IMB 2009, 2010, 2011, 2012). Exact figures on ransom paid to pirates have not been released by insurance companies, but the One Earth Foundation (Bowden and Basnet 2012) estimates that it approached $800 million during that same period.

Defining what constitutes a pirate attack is a matter of some debate, and that, too, may lead to underreporting. The problem is how piracy is legally defined—Article 101 of the UN Convention on the Law of the Sea (UNCLOS; UN 1982, p. 57) defines it as follows:

(a) Any illegal acts of violence or detention, or any act of depredation, committed for private ends by the crew or the passengers of a private ship or a private aircraft, and directed:

  (i) On the high seas, against another ship or aircraft, or against persons or property on board such ship or aircraft;
  (ii) Against a ship, aircraft, persons or property in a place outside the jurisdiction of any State.

By the very nature of the UN Convention, UNCLOS explicitly defines piracy as a crime that takes place in international space and does not address piracy within territorial waters (Kvashny 2003). Indonesia provides an excellent example to illustrate this point. During 2017 alone, 35 incidents (i.e., 81%) occurred in Indonesia's territorial waters, ports, and estuaries. And on a global scale, 67% of all attacks between 2013 and 2017 occurred within territorial waters. These attacks would thus not meet UNCLOS reporting conditions (IMB 2018a). Consequently, the IMB uses a broader definition to include attacks that occur in territorial waters:

> … any illegal act of violence or any act of depredation, or threat thereof, other than an act of piracy, committed for private ends and directed against a ship or against persons or property on board such a ship, within at State's internal waters, archipelagic waters and territorial sea. (IMB 2018a, p. 3)

15.3 Temporal and Spatial Patterns

The analysis of pirate attack data yields important insights into temporal and spatial patterns. The total number of pirate attacks between 1991 and 2017 are given in Fig. 15.1, which also illustrates those attributed to Somali pirates as well as the global trend adjusted for Somali activity. Overall, pirate attacks have fluctuated but have declined worldwide since 2003 with the caveat of the spike in Somali attacks during the period 2006–2011. Clearly, the surge in Somali pirate activity greatly influenced the global trend during its peak years when it accounted for about half of the global attacks (Fig. 15.1). An analysis of the data also indicates three other compelling trends: (1) as noted previously, pirate activity is highly spatially concentrated in four regions; (2) pirates have remained very active in places in which attacks have been endemic, i.e., in South and Southeast Asia; and (3) attacks are becoming more violent, and hostage taking has become ubiquitous.

15.3.1 The Somali Pirates

Prior to 2006, Somali piracy was rare but began to increase after 1997, particularly between 2006 and 2011 (Fig. 15.1). There were 22 attacks in 2006 and 237 in 2011—a 977% increase. The emergence of the Somali pirates is linked most closely to the collapse of the government, but the root causes for this problem were Somalia's abject poverty and the pervasive presence of armed militias that readily transformed themselves into pirates. Originally, the pirates were fishermen who were defending their fishing areas from foreign intrusion (Baldauf 2008). Somali pirates embraced the African Model and concentrated their efforts on capturing ships' crew for ransom, which was enabled by Somalia's location adjacent to a major shipping lane and the world's second most important oil shipping route (IMB 2003). By their actions, Somali pirates became a new economic elite in a state where the per capita income was less than $600 per year. Between 2012 and 2014, they reportedly collected $360 million in ransoms (World Bank 2013b). Finally, governance underscores the problem in Somalia: this illegal activity flourished because of the near absence of any effective form of governance or law enforcement institutions (Ouko 2008).

The combination of a failed state and the influx of millions of dollars of ransom money merged to enhance the effectiveness of the Somali pirates. They were able to expand their geographic reach despite increased international patrols because they became better armed, better equipped, and better informed. The frequency of attacks and the success of the Somali pirates underscores the risk and vulnerability of global commerce as well as directly threatening crews. Between 2006 and 2010, the number of merchant crew killed, injured, or held hostage by pirates increased worldwide from 317 to 1270, with 91% attributed to Somali pirates (IMB 2012). By 2010, their actions significantly threatened the Bab al-Mandeb, one of the most important maritime chokepoints for oil shipments, which finally prompted concerted international action (Fish 2014).

The seizure in September 2008 of *MV Faina*, a Ukrainian cargo ship carrying tanks and heavy weapons bound for Kenya, alarmed security officials and prompted the UN Security Council to pass a resolution authorizing the use of force on 16 December 2008. The increase in hostage taking for ransom combined with feared links with terrorist organizations, concerns for crew welfare, and growing economic costs finally galvanized the world community, and in January 2009, the UN authorized the creation of Combined Task Force −151 (CTF-151), a multinational naval task force to subdue the pirates (Galgano 2009). The actions of CTF-151 along with regional partners reduced Somali pirate attacks to zero by 2015 (Fig. 15.1). Although multinational naval patrols may have repressed pirate attacks at sea, the Somali situation underscores how this is not a solution to the seminal problem on land, which is economic poverty and unstable political conditions. Unfortunately, declining vigilance has resulted in an increase in renewed Somali attacks during 2017 and the first half of 2018 (Fig. 15.1; Maruf 2017).

15.3.2 Temporal Trends

The episodic surge in Somali pirate activity conceals important background trends; hence, it is useful to adjust the data for Somali pirate activity as in Fig. 15.1. The data indicate that after peaking in 2000 (i.e., 469), global attacks declined and have been relatively constant since 2005, averaging about 200 per year. The decline in global pirate activity after 2000 has been linked to three factors. First, there has been a concerted international effort to curb piracy adjacent to India and Bangladesh and in the waters around the Malacca Straits (Ghosh 2004). Second, there was an increase in patrols and searches of suspicious vessels, especially in the waters of South and Southeast Asia, following the 11 September 2001 terror attacks; researchers suggest that this increased naval action generally reduced pirate activity (Luft and Korin 2004; Reinhardt 2007; Galgano 2009; Coggins 2012). Finally, the stabilization of the number of pirate attacks worldwide can be attributed to increased international cooperation, enhanced information sharing among shipping companies and security officials, and improved on-ship security measures, which include soft weapons (e.g., water jets and antiboarding nets), enhanced communications equipment, as well as placing armed security personnel aboard ships (Beckman and Page 2014).

Although Fig. 15.1 suggests pirate activity has stabilized, it does not necessarily signal a success story. Rather, concerns for crew safety and spiraling economic costs have propelled maritime piracy to the forefront of the global security agenda (Soko 2016). In particular, violence against crew and an escalation in hostage taking since 2000 have generated concern among shipping companies and security officials (Bellish 2013). Prior to the surge in Somali pirate attacks, most attacks were essentially robbery (i.e., the Asian Model), and violence against crew was limited. However, Somali pirates demonstrated the profitability of the African Model, and crew abductions remain relatively high and are increasing worldwide. Figure 15.2 shows total individual crew abductions and individual abductions as a percentage of all individual acts of violence (i.e., assaults, robberies, threats, injuries, murders, and abductions) between 1991 and 2017. It illustrates the increase in abductions coincident with the surge in Somali piracy between 2006 and 2010 and the dramatic rise of individual abductions as a percentage of all violence against crew, suggesting that the abduction of crew for ransom is now a persistent global problem. Despite the decrease in total individual abductions, the percentage of abductions has remained relatively high (i.e., about 91%). Furthermore, abductions are increasing in many areas where it was not historically common, thus suggesting a global shift from the Asian Model to the more problematic African Model. Nigeria is an instructive example that underscores this trend. Figure 15.3 shows the percentage of

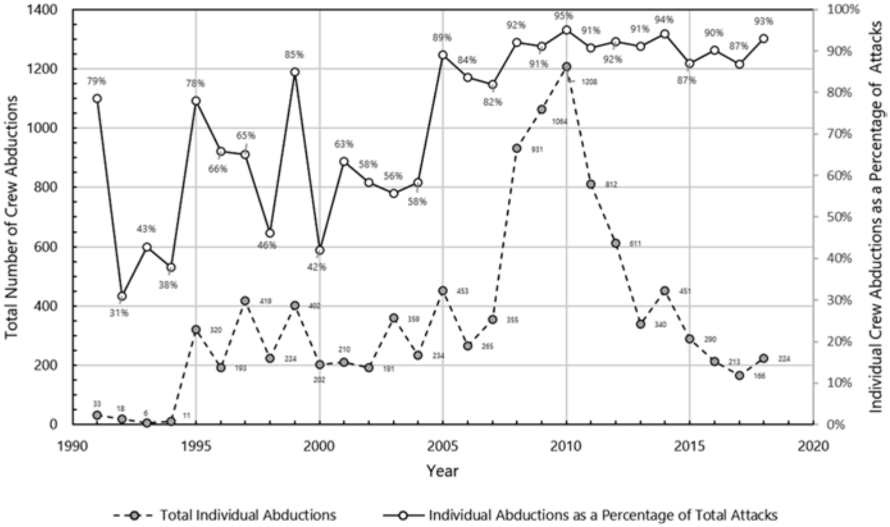

Fig. 15.2 The data indicate the total number of individual abductions of crew by year and individual abductions as a percentage of all individual attacks (i.e., assaults, robbery, threats, murder, and abductions) between 1991 and 2017. (IMB 2002, 2003, 2008, 2013, 2018a)

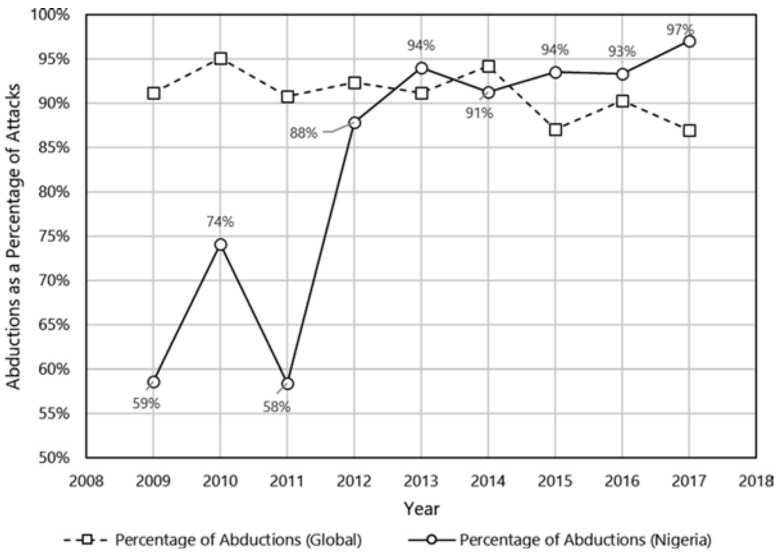

Fig. 15.3 The total number of individual global abductions as a percentage of all individual attacks (i.e., assaults, robbery, threats, murder, and abductions) and the percentage of individual abductions in Nigeria between 2008 and 2017. (IMB 2013, 2018a)

individual crew abductions attributed to Nigerian pirates and the percentage of individual crew abductions worldwide between 2008 and 2017. The data show that the percentage of crew abductions by Nigerian pirates rose sharply between 2011 and 2012 and have continued to increase since then.

The monetary costs are substantial with considerable direct (i.e., ransom, security equipment, rerouting, stolen property, and naval deployments) and indirect (i.e., investment losses and commodity prices) costs. The escalation in pirate-related costs ensures that combating piracy remains an emerging security concern despite a general decline in worldwide attacks (Soko 2016). Estimates vary, but they collectively paint a bleak picture. For example, between 1997 and 2005, pirate attacks cost shipping companies approximately $200 million per year in direct losses (Reinhardt 2007). The spike in Somali piracy added security requirements that cost shipping companies nearly $700 million for crew training and safety equipment annually, and an additional $1 billion was spent on advanced communications and tracking equipment (Nankivell 2004). In total, the World Bank estimates that between 2008 and 2012, Somali pirates cost the world economy $18 billion (World Bank 2013b). The One Earth Future Foundation also examined the added costs of Somali pirates to the global economy. They estimate that the cost was between $7 and $12 billion in 2010 (Bowden 2011), between $6.6 and $6.9 billion in 2011 (Bowden and Basnet 2012), and between $5.7 and $6.1 billion in 2012 (Bellish 2013). More recently, the Rand Corporation estimated that maritime piracy now adds between $1 and $1.6 billion in direct and indirect economic costs to global trade annually (UN 2014; Oceans Beyond Piracy 2018).

15.3.3 Spatial Patterns

On a regional scale, piracy is concentrated in four places: Southeast Asia, South Asia, East Africa, and the Gulf of Guinea (Fig. 15.4), with 83.1% of all incidents taking place in these regions. This is not surprising because piracy has long been endemic to South and Southeast Asia. Figure 15.4 shows that the largest number of attacks has occurred in the waters of Southeast Asia, followed by East Africa. However, the data for East Africa are driven by the surge in Somali piracy between 2006 and 2011, which has generally declined since that time. Piracy has persisted in South Asia and has now emerged in the Gulf of Guinea.

The most recent five-year period (2013–2017) demonstrates the persistent regional concentration of pirate activity (Fig. 15.5) with 72.6% of all attacks in waters off Indonesia, Nigeria, Malaysia, Bangladesh, India, and Vietnam. Attacks in Indonesian waters persist despite concerted activity by regional and international partners to reduce this activity (IMB 2018a). Indonesian attacks are largely a function of geography, i.e., the high concentration of shipping lanes in the area and the fragmented nature of this island state (Fig. 15.6; Calamur 2017). Indonesia is an ideal haven for pirates because it consists of 17,500 islands and has nearly 55,000 km

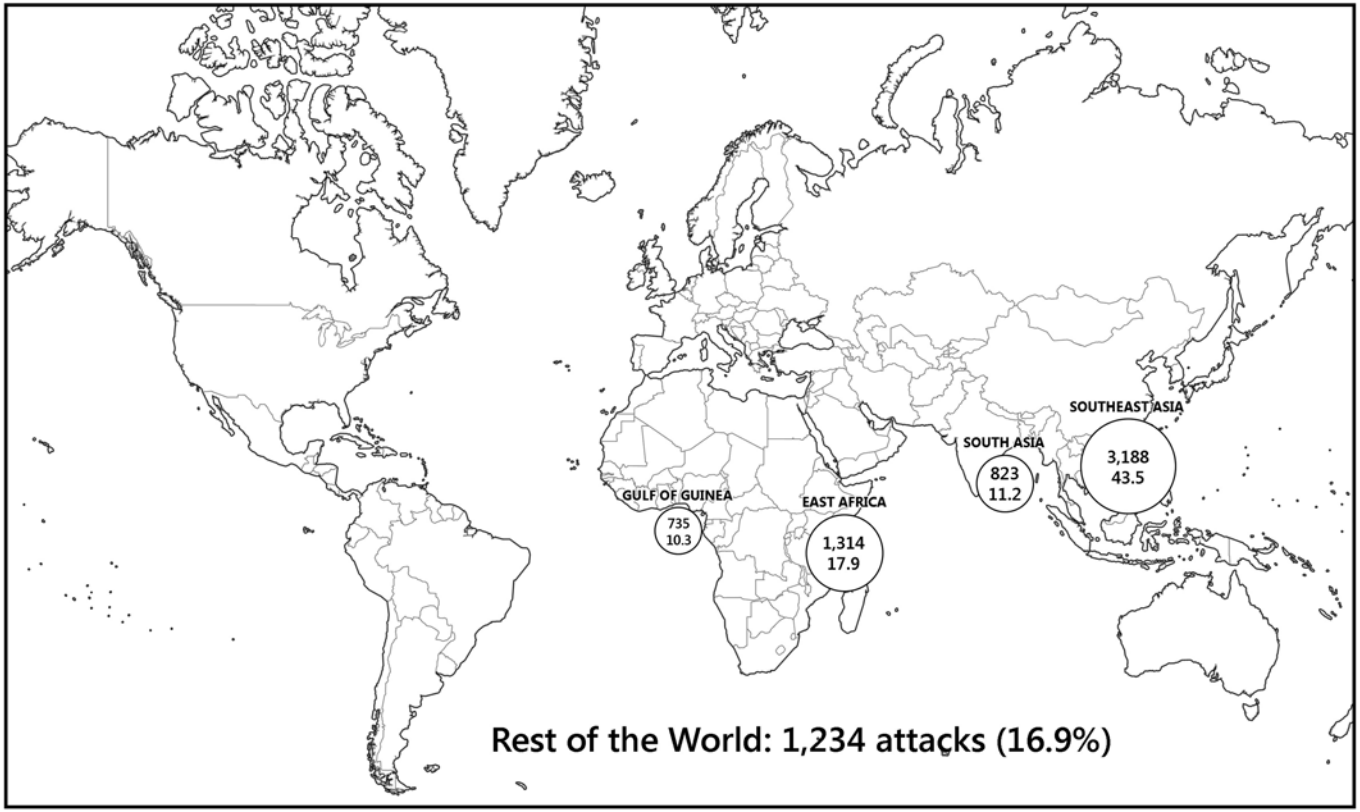

Fig. 15.4 On a regional scale, pirate attacks are concentrated in just four places. The data indicate that 82.9% of all attacks between 1991 and 2017 were concentrated in Southeast Asia, South Asia, East Africa, and the Gulf of Guinea (IMB 2002, 2003, 2008, 2013, 2018a). The upper number in each circle is the total number of attacks, and the lower number is the percentage of the global total

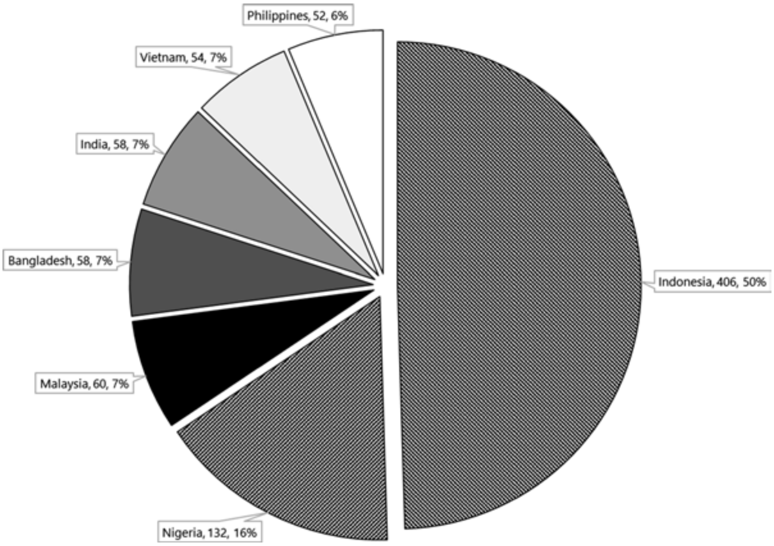

Fig. 15.5 Geographic concentration of pirate attacks during the five-year period from 2013 to 2017. Seventy-two percent (i.e., 820 attacks) were concentrated in these seven locations. (IMB 2018a)

of coastline (Fish 2014). The data (Fig. 15.5) also illustrate the high number of attacks attributed to Nigerian pirates, which is a growing problem (IMB 2018a). Pirate activity has long been endemic to Nigeria; however, the recent increase is attributed to its ongoing internecine conflict (IMB 2018a). Additionally, Fig. 15.4 underscores the high number of attacks in the Gulf of Guinea, which is an emerging hotspot and a matter of concern because the IMB suggests that piracy in this region may be underreported by as much as 62% (IMB 2018a). The suppression of these pirates is problematical because their attacks occur principally in territorial waters, which limits international response options (UN 2014).

15.4 Geographic Analysis

The study of maritime piracy is an academically important exercise in geography because it is a significant transnational security problem and is so highly concentrated geographically. An analysis of long- and short-term trends reveals consistent spatial patterns. The high concentration of attacks in Southeast Asia, South Asia, East Africa, and, most recently, the Gulf of Guinea and, at a state level, in Indonesia, India, Bangladesh, Malaysia, the Philippines, Vietnam, and Nigeria, are explainable, given the realities of maritime geography, contested boundaries, and governance (Galgano 2009). The overarching geographic problem is that pirate attacks are concentrated in contested space, that is, waters in which sovereignty is confused

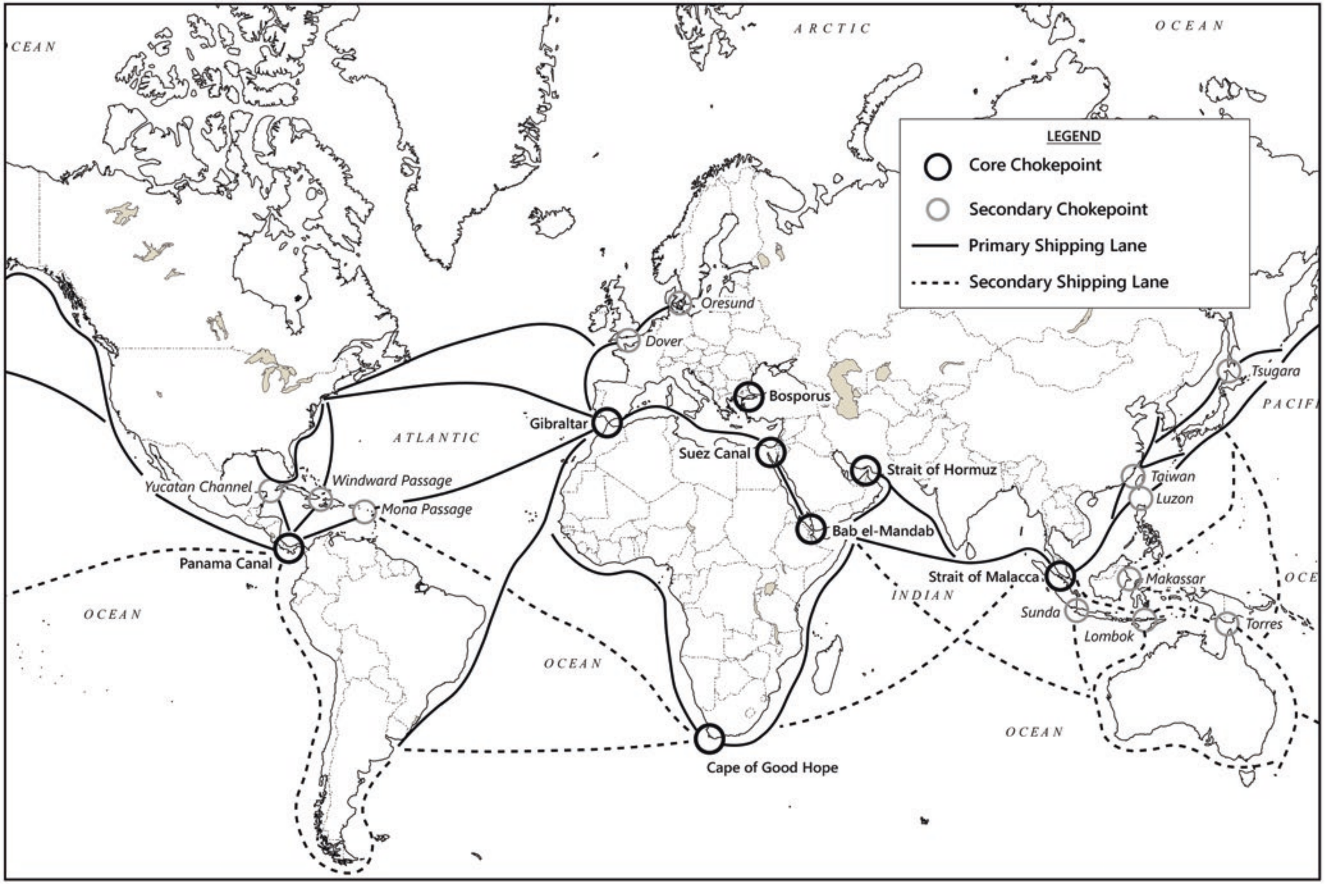

Fig. 15.6 The world's maritime chokepoints and shipping lanes. (UN 2014)

and thus enforcement and international cooperation are difficult. Principally, however, pirate activity is a function of governance, and the problem is twofold. First, most pirate attacks emanate from poorly governed states. The second is related to a fundamental disconnect between international and domestic laws. The oceans are a vast international space considered free to all nations but *belonging* to none—the so-called *mare liberum* principle. In this regard, international law is not robust and does not apply to attacks that take place in territorial waters, making it difficult in practice to control and prosecute pirates.

15.4.1 Maritime Geography

The geographic concentration of pirate incidents (Fig. 15.4) shows the link between pirate activity and chokepoints and shipping lanes. Maritime chokepoints are restricted waters along the most important shipping lanes. There are eight such chokepoints (Fig. 15.6) through which 75% of all seaborne transit occurs (UN 2014). Chokepoints are a well-known concept in transportation geography and are important because they limit throughput capacity, which can be easily exploited by pirates. Chokepoints are narrow and crowded, and ships are forced to slow for safe navigation, making them vulnerable to boarding. For example, the Malacca Strait, which separates Singapore and Malaysia, is only 1.5 nm at its narrowest point and is traversed by some 120,000 ships annually. Nearly one-third of the world's maritime commerce moves through this chokepoint, which includes 70–80% of all the oil imported by China and Japan (McCauley 2018). Pirates that emanate from Indonesia and Malaysia exploit this chokepoint, and combined, they account for 43% of all pirate attacks, which makes it the most dangerous waterway in the world (Calamur 2017).

The world's core and secondary maritime chokepoints are shown in Fig. 15.6, along with the location of primary and secondary shipping lanes. The relationship between these features and the highest incidents of maritime piracy is obvious. Chokepoints and shipping lanes present a vast number of ships that pirates can seize, and these features correlate with the greatest frequency of pirate attacks. The problem is further compounded because chokepoints and shipping lanes are contested spaces with confusing boundaries, resulting in uncoordinated maritime patrols that are largely ineffective (Ouko 2008). Additionally, many states adjacent to these critical chokepoints are among the most poorly governed in the world (Nankivell 2004).

15.4.2 Boundaries and Borders

UNCLOS (UN 1982) delineates seaward boundaries and standard international conventions for governing international space, but it is not universally accepted. Intricate boundary issues in restricted waters—such as in Indonesia—are contested and can be exploited by pirates because of competing sovereignty issues. The problem is made more difficult because multinational cooperative strategies to suppress pirates are often perceived as intrusions on national sovereignty. Consequently, borders and jurisdiction within contested waters are two of the seminal issues leading to understanding the geography and persistence of piracy (Kraska 2011). Narrow waterways in chokepoints and along important sea lanes are typically claimed by more than one state, and cooperation is limited. Despite a relatively high incidence of pirate activity in and around the Malacca, Sunda, Lombok, and Makassar Straits (Fig. 15.6), Singapore, Indonesia, and Malaysia have long been disinclined to cooperate. Consequently, pirates have been able to exploit these chokepoints, and this region persistently manifests the highest incidence of attacks. Although many attacks occur in clearly defined international waters, regional cooperation is difficult to achieve in many of these cases as well. India has taken a leading role in trying to curb the problem, but to date its efforts have been only marginally successful (Ghosh 2004): the Indian Ocean is a vast space, and pirates from many countries converge here. The countries adjacent to the Indian Ocean shipping lane manifest considerable dissimilarity in economic and military capabilities, thus making it difficult for them to contribute to the repression of piracy. Furthermore, some states may (at least inadvertently) enable pirate activity through the cooperation of corrupt officials or, at a minimum, practice benign neglect and turn a blind eye to pirates operating from their territory (McCauley 2018).

15.4.3 Governance

The levels of piracy worldwide have stabilized, but their actions are increasingly violent. Where it has been endemic, piracy has not been effectively reduced, and this trend is essentially a function of governance. Broadly, piracy at sea reflects poor governance on land since its existence appears to be highly correlated to states with emerging economies and/or weak governance (Galgano 2009). Second, piracy at sea occurs in a vast legal loophole. That is, the crime of maritime piracy is defined in the law of nations but not consistently in national laws (Dutton 2013). UNCLOS (UN 1982) indicates that pirates apprehended in international waters are to be arrested and prosecuted in accordance with the apprehending country's laws and national court systems. However, many states do not have domestic laws that explicitly govern piracy (Soko 2016). There is a need for lawmakers to address this need to enable a more coherent regional and global response to piracy.

Law of the Sea

As noted above, most pirate activities take place within territorial waters, ports, and estuaries. This essentially places attacks within territorial waters outside of the UNCLOS (UN 1982) international definition. While limiting the definition in

UNCLOS (UN 1982) to take into account political sensitivities and respect of sovereignty, it leaves vessels in territorial waters vulnerable, especially where piracy is endemic. This highlights the issue of what actions to take regarding piracy committed within the territorial waters of a state. This is an example of piracy *je gentium*; that is, under international law, piracy acts committed within the territory of any state can be prosecuted in the courts of justice of any nation (Soko 2016). Enforcement and prosecution have proven to be problematic because many states with endemic piracy are poorly governed or lack the laws, institutions, or security apparatus to address privacy. Local police and international security forces pursuing pirates into territorial waters is highly problematical (Marchione and Johnson 2013).

The suppression and prosecution of pirates captured at sea are challenging and highlight the fact that international law is not working as needed (Dutton 2013). As noted previously, international waters are free to all nations but *belong* to none. Although UNCLOS (UN 1982) provides an international legal structure to control the crime of piracy, it is not robust. The UN has no operational role in security operations and no legal authority or apparatus to prosecute pirates. For example, Article 105 outlines the legal disposition of pirates captured on the high seas: "The courts of the state which carried out the seizure may decide upon the penalties to be imposed, and may also determine the action to be taken with regard to the ships, aircraft or property, subject to the rights of third parties acting in good faith" (UN 1982, p. 61). Thus, when pirates are captured, they are to be tried under the domestic laws of the state that apprehended them. As stated, the legal disconnect is that many states do not have domestic laws under which to prosecute pirates. For example, in Southeast Asia, only the Philippines and Malaysia have domestic laws against maritime piracy. Thus, existing international law defines piracy, labels it as a crime, yet many states have not incorporated these international norms into their domestic policies and laws (Dutton 2013).

Recent trends indicate increased antipiracy cooperation among international partners. Nevertheless, results are less than expected because of the legal loophole enabling pirate activity. Naval patrols typically refrain from taking pirates into custody, and some states actively discourage their capture. In many cases, pirates are released and return to their criminal activity with little or no punishment. In fact, a report by the UN Secretary-General (Ban 2011) indicates that nine out of ten Somali pirates captured by naval patrols between 2009 and 2012 were never prosecuted and were set free after their initial internment. Consequently, the full deterrence of international law and multinational naval patrols is not being realized (Dutton 2013).

Failing States

Piracy and governance data indicate that pirate attacks are most pervasive adjacent to states with weak governance, illustrated by the relationship between the number of pirate attacks by state (i.e., 1991–2017) and the level of governance using the Fragile States Index (FSI 2018) as an indicator. The FSI is a composite index that delineates governance and identifies failing states—an FSI score greater than 60.0

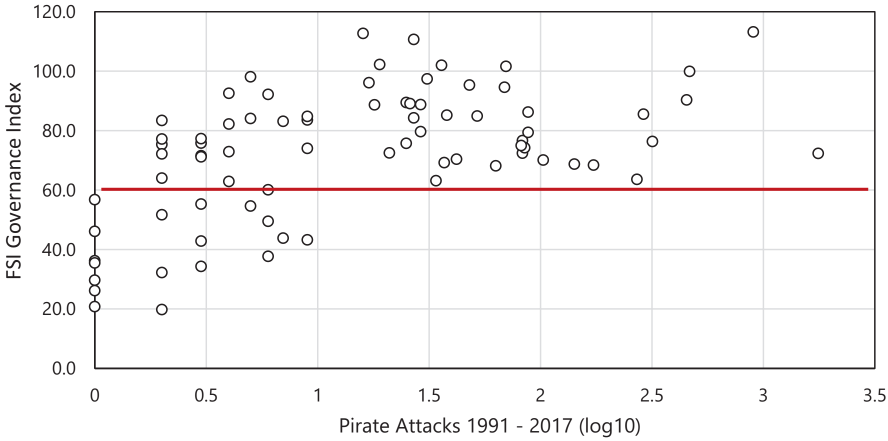

Fig. 15.7 Nexus of governance and pirate attacks from 1991 to 2017. Pirate attack data suggest a link between highly ungoverned states and maritime piracy. A state with an FSI index score >60 is one with significant governance problems. (IMB 2018a; FSI 2018)

suggests that a state lacks the institutions and ability to adequately govern its territory. Figure 15.7 indicates the high incidence of pirate attacks among such states.

The nexus of weakly governed states and important shipping lanes is challenging because these states cannot, or will not, exercise effective sovereignty over their territorial waters or control pirates who emanate from their coastal zones (UN 2014). This inability of a state to provide effective sovereignty over its adjacent waters can be linked to several factors. In some instances, the region is remote and undeveloped and the state lacks the infrastructure or institutions to exert control. In other cases, the state may intentionally relinquish control of a region, or it may lack regulations and legal structures by which it can control a territory (Galgano 2009). Since much of the world's maritime piracy is a function of weak governance, these waters are easily exploited by pirates (Kvashny 2003).

15.5 Summary and Conclusions

Maritime piracy is a transnational security problem because its costs to the global economy are substantial. Contemporary trends suggest that pirates increasingly represent a threat to crew safety, which is an important security concern. Hence, piracy remains at the forefront of the global security agenda. An analysis of recent trends is compelling because the data suggest that the activities of Somali pirates have been successfully repressed and that, globally, pirate activity has somewhat stabilized. However, and significantly, the data also suggest that pirates are increasingly resorting to violence to carry out their attacks and are taking crew members hostage at an increasing rate. On a global scale, more pirates are resorting to the African Model, and hostage taking is becoming ubiquitous, even in places where it was not historically prevalent. Finally, it appears that piracy has not been effectively reduced in places where it has been endemic, and it persists as a significant problem in South and Southeast Asia.

Maritime privacy is highly spatially concentrated in four regions: South and Southeast Asia, East Africa, and the Gulf of Guinea. This is explained by the realities of maritime geography and problems of governance and economic iniquity. There are many social, economic, and political dynamics that enable maritime piracy, such as poverty, corruption, and organized crime. The distinct causes of maritime piracy in places where it is endemic are as varied as the locations themselves. These factors are destabilizing large segments of the world because globalization, and the expansion of the global economy that followed, did not lead to an era of integration and economic prosperity. Rather, the unbalanced nature of economic prosperity has generated pervasive instability in much of the developing world and, when combined with ineffective governance in states adjacent to the world's major shipping lanes, has resulted in persistent and enduring maritime piracy.

First and foremost, pirate activity appears to be a function of governance, and there are two components to this problem. Most pirate attacks emanate from poorly governed states that lack institutions, security forces, and legal structures to suppress pirates that operate from their shores. Additionally, there exists a fundamental disconnect between international and domestic laws and enforcement. International law offers a normative legal structure by which to control piracy, but it lacks adequate enforcement mechanisms. UNCLOS does not compel states to suppress pirate activity in adjacent territorial waters even if the state is aware that the pirates are operating from their shores. State sovereignty makes it difficult for international naval patrols to pursue pirates in territorial waters, and thus the control and prosecution of pirates are highly problematic. More importantly, many states lack complementary domestic laws by which to prosecute pirates once they are captured. This results in many pirates being released, making control and prosecution ineffective.

The cost of maritime piracy exceeds $1 billion per year. Because of the nature of modern maritime commerce, piracy is costly to shipping companies but not necessarily to individual states. Consequently, it has elicited very little international response until recently. International naval patrols may not be a panacea to the problem because maritime piracy is the manifestation of anarchy and economic marginalization on land. The international response to the Somali problem has ultimately suppressed the activities of these pirates at sea, but it has not changed the driving factors that exist within Somalia on land, i.e., pervasive poverty and the inescapable failure of its government to exert effective sovereignty over its territory. Unfortunately, the most recent data indicate that as international vigilance has waned, there has been an increase in Somali pirate activity. Thus, the evidence appears to support the fact that the effective removal of piracy as a significant maritime threat will not be achieved until matters of governance are resolved in failing states. The suppression of pirates on a global scale demands a robust means of enforcing international law.

References

APS Review (2008) The piracy off Somalia. Oil Market Trends, 24 November 2008. http://www.entrepreneur.com/tradejournals/pub/0WDD.html. Last accessed 19 December 2011

Baldauf S (2008) Who are Somali pirates? The Christian Science Monitor, 21 November 2008. https://www.csmonitor.com/World/Africa/2008/1120/p25s22-woaf.html. Accessed 5 December 2008

Ban K 2011. Letter dated 24 January 2011 from the Secretary-General addressed to the President of the Security Council (Somalia - Report of the Special Adviser to the Secretary-General on Legal Issues Related to Piracy off the Coast of Somalia). https://undocs.org/S/2011/30. Accessed 11 June 2020

Beckman R, Page M (2014) Piracy and armed robbery against ships. In: Gill M (ed) The Handbook of Security. Palgrave Macmillan, London, p 234-255

Bellish J (2013) The economic cost of Somali piracy, 2012. Oceans Beyond Piracy Working Paper, One Earth Future Foundation. http://oceansbeyondpiracy.org/sites/default/files/attachments/View%20Full%20Report_3.pdf. Accessed 6 June 2020

Bowden A (2011) The economic cost of maritime piracy, 2010. Oceans Beyond Piracy Working Paper December 2010, One Earth Future Foundation. http://oceansbeyondpiracy.org/sites/default/files/attachments/The%20Economic%20Cost%20of%20Piracy%20Full%20Report.pdf. Accessed 6 June 2020

Bowden A, Basnet S (2012) The economic cost of Somali piracy. Oceans Beyond Piracy Working Paper, One Earth Future Foundation. http://oceansbeyondpiracy.org/sites/default/files/attachments/ECOP%20Full%20Report%202011.pdf. Accessed 6 June 2020

Calamur K (2017) High traffic, high risk in the Strait of Malacca. The Atlantic. https://www.theatlantic.com/international/archive/2017/08/strait-of-malacca-uss-john- mccain/537471/. Last accessed 25 October 2018

Coggins BL (2012) Global patterns of maritime piracy. J. Peace Research 49(4):605–617

Dutton YM (2013) Maritime piracy and the impunity gap: domestic implementation of international treaty provisions. In: Struett MJ, Carlson JD, Nance MT (eds) Maritime Piracy and the Construct of Global Governance. Routledge, New York, p 71–98.

Fish JM (2014) Maritime piracy: north vs. south. Graduate Program in International Studies, Old Dominion University, Norfolk. http://web.isanet.org/Web/Conferences/GSCIS%20Singapore%202015/Archive/ac36734b-4fe3-472a-9a0f-438336424ae6.pdf. Accessed 5 September 2018

Fragile States Index (FSI) (2018) Global Data. https://fragilestatesindex.org/data/. Accessed 6 June 2020

Galgano FA (2009) The borderless dilemma of contemporary maritime piracy: its geography and trends. Pennsylvania Geographer 47(1):3–33

Ghosh PK (2004) Maritime security challenges in South Asia and the Indian Ocean: response strategies. Proceedings of the American-Pacific Sealanes Security Institute Conference on Maritime Security in Asia, 18-20 January 2004, Honolulu, Hawaii, 1-13. Center for Strategic and International Studies, Washington, DC. http://www.navedu.navy.mi.th/stg/databasestory/data/lawabout/law-aboutsea/Maritime%20Security%20Laws%20&%20Frameworks/Maritime%20Security%20in%20SEA.pdf. Accessed 6 June 2020.

International Chamber of Commerce (ICC) (2019) ICC Commercial Crime Services. https://www.icc-ccs.org/. Accessed 15 April 2019

International Maritime Bureau (IMB) (2002) Piracy and armed robbery against ships. Report for the Period, 1 January–30 September 2001. International Chamber of Commerce, London

International Maritime Bureau (IMB) (2003) Piracy and armed robbery against ships. Report for the Period, 1 January–30 September 2002. International Chamber of Commerce, London

International Maritime Bureau (IMB) (2008) Piracy and armed robbery against ships. Report for the Period, 1 January–30 September 2007. International Chamber of Commerce, London

International Maritime Bureau (IMB) (2009) Piracy and armed robbery against ships. Report for the Period, 1 January–30 September 2008. International Chamber of Commerce, London
International Maritime Bureau (IMB) (2010) Piracy and armed robbery against ships. Report for the Period, 1 January–30 September 2009. International Chamber of Commerce, London
International Maritime Bureau (IMB) (2011) Piracy and armed robbery against ships. Report for the Period, 1 January–30 September 2010. International Chamber of Commerce, London
International Maritime Bureau (IMB) (2012) Piracy and armed robbery against ships. Report for the Period 1 January–31 December 2011. International Chamber of Commerce, London
International Maritime Bureau (IMB) (2013) Piracy and armed robbery against ships. Report for the Period, 1 January–30 September 2012. International Chamber of Commerce, London
International Maritime Bureau (IMB) (2018a) Piracy and armed robbery against ships. Report for the period 1 January – 31 December 2017. International Chamber of Commerce, London
International Maritime Bureau (IMB) (2018b) IMB Piracy Reporting Center. https://www.icc-ccs.org/piracy-reporting-centre. Accessed 5 October 2018
Kraska J (2011) Contemporary Maritime Piracy. Praeger, Santa Barbara
Kvashny K (2003) Modern maritime piracy in Asia: a case study of transnational organized crime. Dissertation, University of California
Luft G, Korin A (2004) Terrorism goes to sea. Foreign Affairs 83(6):18-24
Marchione E, Johnson SD (2013) Spatial, temporal, and spatio-temporal patterns of maritime piracy. Journal of Research in Crime and Delinquency 50(4):504–524
Maruf H (2017) Report: Declining deterrence gives Somali pirates a lifeline. VOA News. https://www.voanews.com/africa/report-declining-deterrence-gives-somali-pirates-lifeline. Accessed 6 June 2020
McCauley A (2018) The most dangerous waters in the world. Time. http://time.com/piracy-southeast-asia-malacca-strait/. Accessed 25 October 2018
Nankivell KL (2004) Troubled waters. Foreign Policy 145(12):30-31
Oceans Beyond Piracy (2018) The State of Maritime Piracy 2017. http://oceansbeyondpiracy.org/reports/sop. Accessed 8 August 2018
Ouko D (2008) Rising piracy threatens global trade. New African, November 2008. Last accessed 28 December 2008
Reinhardt CJ (2007) Maritime piracy: sign of a security threat? Mercer on Transport and Logistics 21:16-19
Soko N (2016) Investigating violence against merchant ships' crew members during piracy attacks, from January 2011–March 2016. Master's Thesis in International Business Law, Tilburg University School of Law Tilburg, The Netherlands
Struett MJ, Carlson JD, Nance MT (eds) (2013) Maritime Piracy and the Construct of Global Governance. Routledge, New York
United Nations (UN) (1982) United Nations convention on the law of the sea (UNCLOS). Kingston, Jamaica
United Nations (UN) (2014) Maritime piracy part I: overview of trends, costs, and trade– related implications. Studies in transportation law and policy–2014 No. 1. United Nations conference on trade and development (UNCTAD), New York. https://unctad.org/en/PublicationsLibrary/dtltlb2013d1_en.pdf. Accessed 6 June 2020
World Bank (2013a) The pirates of Somalia, ending the threat, rebuilding a nation. World Bank Regional Vice–Presidency for Africa. http://documents.worldbank.org/curated/en/182671468307148284/pdf/76713-REPLACEMENT-pirates-of-somalia-pub-11-2-15.pdf. Accessed 6 June 2020
World Bank (2013b) Pirate trails: tracking the illicit financial flows from pirate activities off the Horn of Africa. A World Bank Study. World Bank, Washington DC. https://elibrary.worldbank.org/doi/pdf/10.1596/978-0-8213-9963-7. Accessed 6 June 2020

Chapter 16
The Geography of Territorial Disputes in the South China Sea

Mark Stephen Blaine

Contents

Abstract The historically disputed waters in the South China Sea have seen increasingly aggressive behaviour from nations trying to strengthen their claims to disputed areas and to develop/expand offshore resources. Much of this dispute is driven by China's interpretation of the Law of the Sea in terms of the right (or not) of innocent passage through its vast territorial claims in the region. This is an emergent regional issue that should ring alarm bells for all maritime nations.

While many of the countries in the region contemplate legal and diplomatic avenues to address the issues, the international community, led by the USA, has continued to exercise the right of innocent passage by conducting freedom of navigation operations through the area. There has likewise been an increase in political condemnation of China's continued hegemonic tendencies in the South China Sea.

Given that the South China Sea is one of the world's busiest waterways, it must be of particular concern to ships on innocent passage that may unwittingly become involved in the conflict. The use of bilateral and/or multilateral fora should be encouraged to prevent an increase in hostilities and, with the build-up of military forces in the region, even full-scale war.

Keywords Maritime borders · Maritime territorial disputes · Sovereignty · South China Sea · UNCLOS · Freedom of navigation · Sea lines of communication

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16.1 Introduction

Maritime territorial disputes in the South China Sea are contributing to heightened tensions and consequently peace and stability in the region and beyond. Reasons for these disputes abound but may be narrowed to the global competition for scarce resources such as fisheries and fossil fuels; the economic and political rise of China, including its growing assertiveness on the international/regional stage; nationalism; and conflicting legal principles for territorial claims and history, which could be based on emotion (Cronin and Dubel 2013). Emmers (2010) contends that it is very important to see such maritime territorial disputes within the framework of geopolitics. In his extensive analysis of the maritime territorial disputes in the South and East China Seas, he emphasizes the roles of geopolitical attributes such as territory, natural resources and power distributions in understanding such conflicts. Mancini (2013) corroborates Emmers' view and adds the scarcity of natural resources and environmental degradation as further attributes of territorial conflicts.

It is within these parameters that the ongoing maritime territorial disputes in the South China Sea will be examined. There are many such maritime territorial disputes in the world today, but the focus on the South China Sea is due to its current primacy in world media, resulting from differing interpretations of the United Nations Convention on the Law of the Sea (UNCLOS 1982) and the commonality of actors. The region is shown in Fig. 16.1.

16.2 The International Convention Governing Maritime Zones

In order to comprehend the contemporary territorial disputes in the South China Sea, an understanding of the international rules regulating the duties and responsibilities of states in the maritime domain is needed. Gibson (2009) writes that the demarcation and delimitation of the maritime zones throughout the world are internationally governed and enforced by the 1982 United Nations Convention on the Law of the Sea (UNCLOS 1982). This Convention came into force in 1994 and has been ratified by 159 countries. The purpose of the Convention is to establish a comprehensive set of rules to govern the oceans.

UNCLOS (1982) empowers every state to establish specific zones in its coastal region (Fig. 16.2). These zones encompass (1) a territorial sea up to 12 nautical miles (nm) from its shoreline, (2) a contiguous zone up to 24 nm from the shoreline, (3) an exclusive economic zone (EEZ) adjacent to the territorial sea and up to 200 nm from the coast and (4) a continental shelf that is a prolongation of the EEZ to the outer edge of the continental margin up to a maximum of 350 nm. The international Convention is clear in highlighting the rights as well as responsibilities of all states in matters relating to territory in the maritime domain. It is also very clear on the obligatory conflict resolution measures in place for maritime territorial

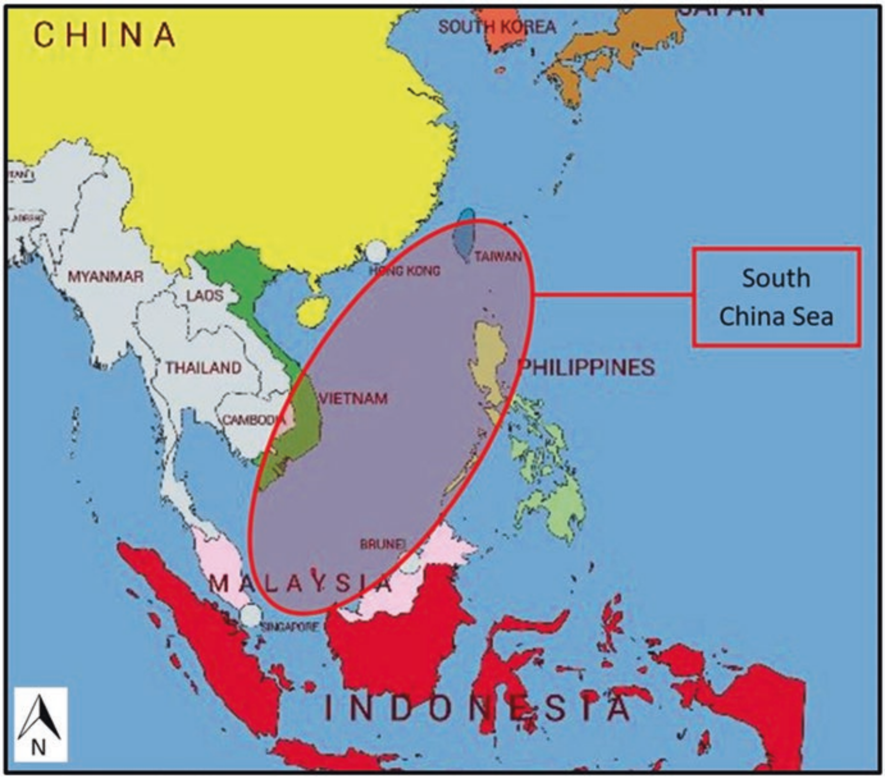

Fig. 16.1 Geographic location of South China Sea

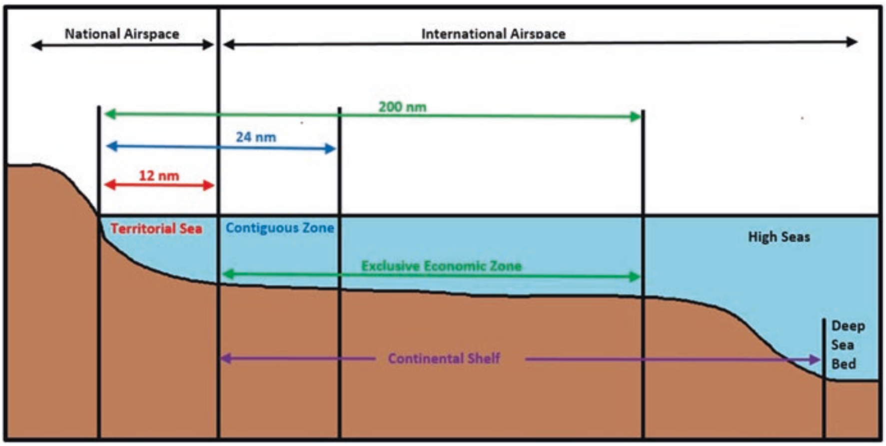

Fig. 16.2 UNCLOS zones; 'nm' is nautical miles

disputes. These are presented in parts II to VI of the Convention, and those pertinent to the South China Sea are briefly summarized below.

Jurisdiction In the territorial sea, the state retains full sovereignty except for rights of innocent passage (Article 2), whereas the contiguous zone provides the state with authority to exercise the control necessary to punish or prevent infringements of its customs, fiscal, immigration or sanitary laws and regulations (Article 33). In the EEZ (Article 56) and the continental shelf zone (Article 77), the state has the right to use living and non-living natural resources, to use the zone for economic purposes and to construct, authorize and regulate the construction of artificial islands and certain installations and structures (Articles 60, 80 and 81). All states, however, have the right of innocent passage (freedom of navigation) and overflight (Article 79).

Navigation Foreign ships have the right of innocent passage in the territorial zone as long as it is not prejudicial to the peace, good order and security of the applicable state. All ships have freedom of navigation in the EEZ and the continental shelf zone (Part II, Section 3, and Part III, Section 3).

Oil, Gas and Mineral Resources The state has the exclusive right of exploitation in its territorial zone (Article 2). The state has a similar right in the EEZ and the continental shelf zone, except where it would conflict with recognized sea lanes (Article 56).

The High Seas The ocean and seabed as well as the subsoil beyond these limits of national jurisdiction are for the common heritage and use of mankind; these areas are commonly referred to as the high seas and are governed by Part VII of the Convention. Article 87 defines six freedoms of the high seas as navigation, overflight, laying of submarine cables or pipelines, construction of artificial islands and installations, fishing and scientific research. The seabed, ocean floor and subsoil underlying the water of the high seas are known as the Area that is subject to the legal regime of UNCLOS and covered in Part XI of the Convention.

Artificial Islands, Installations and Structures in the EEZ Article 60 regulates the exclusive right of a coastal state to construct and to authorize and regulate the construction, operation and use of artificial islands, installations and structures in the EEZ. The coastal state has exclusive jurisdiction over such islands, structures and installations, including jurisdiction with regard to customs, fiscal health, safety and immigration laws and regulations. Such artificial islands and structures do not have the status of islands and can therefore not have any of the territories (zones) highlighted above. It must, however, be borne in mind that the authority to construct such islands or installations is reliant on the successful claiming and demarcating by the coastal state of such EEZ.

Conflict Resolution and Dispute Settlement Article 74 of the Convention stipulates that the delimitation of the EEZ between states with opposite or adjacent coastlines should be effected by agreement on the basis of international law, as referred to in Article 38 of the Statute of the International Court of Justice, in order to achieve an equitable solution. Should no agreement be reached within a reasonable period of time, the states concerned should resort to the procedure provided in Part XV and Annexes V, VI, VII and VIII of the Convention. It is to be noted that when a state ratifies UNCLOS, it is automatically subjected to the dispute settlement mechanism of UNCLOS. The state's participation in the dispute settlement is thus mandatory. UNCLOS does, however, provide states with the option of choosing one of four dispute settlement bodies: the International Tribunal for the Law of the Sea, the International Court of Justice, an Arbitral Tribunal constituted in accordance with Annex VII or a Special Arbitral Tribunal constituted in accordance with Annex VIII (Article 287). Article 296 stipulates that any decisions will be final and are to be complied with by all parties to the dispute.

16.3 Strategic Importance of the South China Sea

A Council for Foreign Relations Report (Anon 2020) highlights the geostrategic importance of the South China Sea region. The value of trade passing through the region in 2016 was approximately US$3.3 trillion, and around 40% of global liquefied natural gas passed through the same area in 2017. The US Energy Information Administration (USEIA 2018) further states that more than 30% of global maritime crude oil trade (or approximately 15 million barrels per day) transited the region in 2016 (Fig. 16.3).

It is therefore important for the region to remain stable and that sea lines of communication are protected. Such "good order at sea" allows free and unhindered access to commerce in one of the busiest maritime trade routes in the world, fosters peace and stability among the maritime nations in the Asia Pacific, ensures compliance with rules based on regional norms, ensures the right of innocent passage and allows unhindered access to commercial entities operating in the area (Anon 2020).

Dolven et al. (2014) note that territorial disputes between the various role players in the South China Sea are mostly centuries- and decades-old, whereas the emergent conflict has come more to the fore in recent years. The disputes between China, Taiwan, Brunei, Malaysia, the Philippines and Vietnam concern mainly the Spratly and Paracel Island groups. Most of the disputes revolve around possession and maritime boundary claims (Dolven et al. 2014).

The maritime region of East Asia and its historically disputed waters have since 2005 seen increasingly hostile conduct from littoral nations trying to strengthen their claims to the disputed areas and to develop and expand offshore natural resources. (Dolven et al. 2014). This escalation should be of particular concern to the international community as it may directly affect the right of innocent passage in one of the world's busiest waterways, may negatively affect sea lines of communication and could have a major impact on the global economy. Zagoria and Daniels (2012) further warn that this state of affairs could be exacerbated by the fact that two of the largest economies of the world (China and Japan) as well as seven of the

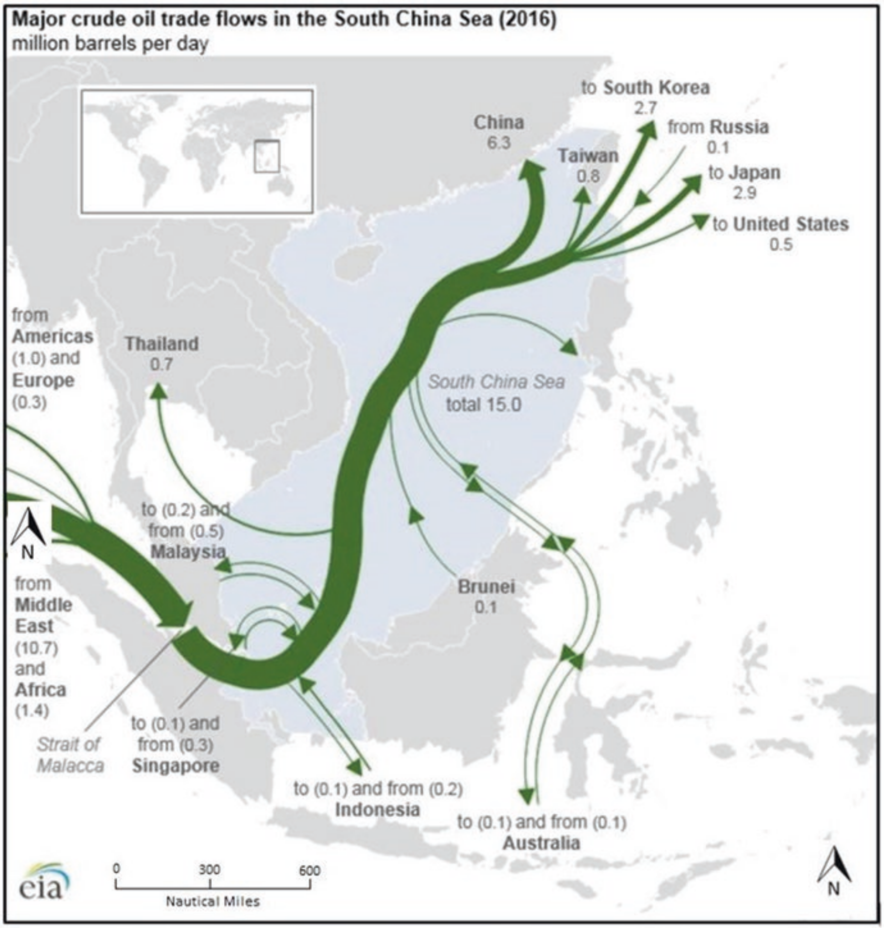

Fig. 16.3 Major crude oil trade flows in the South China Sea in 2016 (USEIA 2018)

largest militaries[1] are located in this region. As more nations get involved and dispatch more ships and military forces to the region, it could ultimately lead to military confrontation and, at the extreme, war.

A panel discussion on maritime disputes in Asia sponsored by the National Committee on American Foreign Policy on 3 December 2012 highlighted the deteriorating maritime security situation in the region (Zagoria and Daniels 2012). It identified factors that exacerbate the security situation, such as strategic mistrust mainly between China and Japan, regional history dealing mainly with past battles, security treaties mainly involving the United States, nationalism accentuated by recent elections and political changes in the region, and increasing Chinese

[1] China, Japan, South Korea, Indonesia, Vietnam, Taiwan and North Korea.

assertiveness in the region (Zagoria and Daniels 2012). A cursory scan of articles and research on security in East Asia confirm that the very same complicating factors still exist today.

The geostrategic importance of the South China Sea region is thus obvious. As more and more role players come to the fore, the likelihood of confrontation increases with corresponding strategic security implications. Any confrontation will lead to disruptions of the world economy as well as social insecurities.

16.4 Drivers of Conflict in the South China Sea

As noted above, major territorial disputes in the South China Sea involve mainly China, Taiwan, Malaysia, Vietnam and Indonesia. The overlapping territorial claims (EEZ) can be seen in Fig. 16.4. It should be noted that all of the parties mentioned are signatories to UNCLOS and have submitted their maritime territorial claims accordingly.

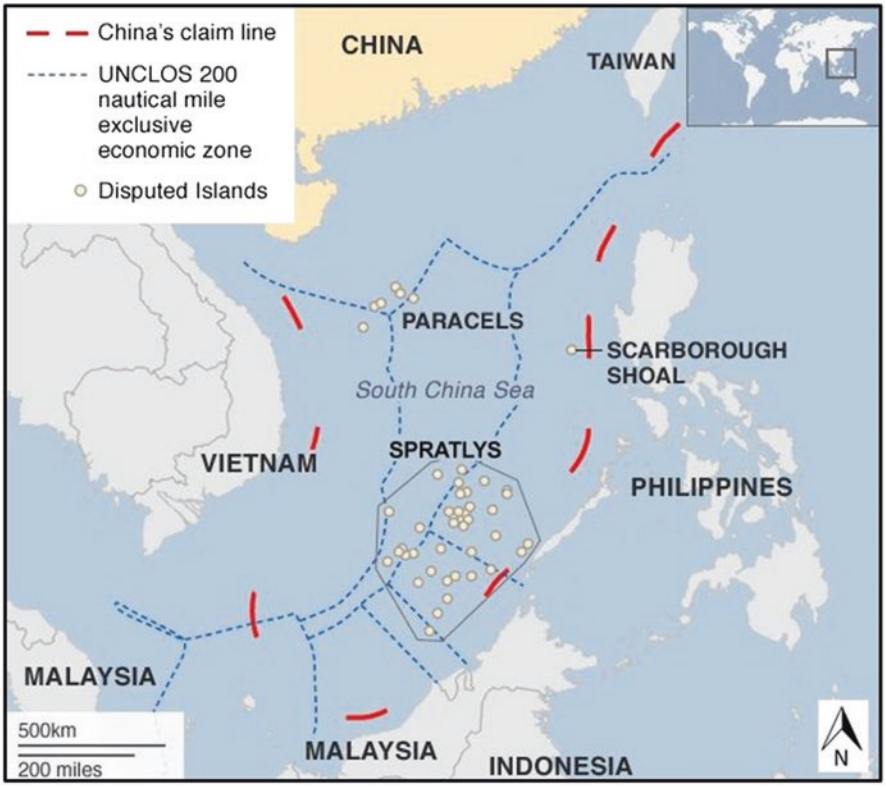

Fig. 16.4 Maritime claims in the South China Sea (UNCLOS 1982; CIA 2020)

16.4.1 Oil and Natural Gas

Many of the littoral countries of the South China Sea have fossil fuel deposits in their respective maritime zones. The USEIA estimates that the South China Sea contains approximately 28 billion barrels of discovered and undiscovered oil resources and approximately 266 trillion cubic feet of discovered and undiscovered natural gas resources (Anon 2012). Chinese estimates for the region are approximately 213 billion barrels of oil and approximately 2000 trillion cubic feet of natural gas resources (Anon 2012). Daiss (2016) contends that this discrepancy could be attributed to the age of the US Geological Survey assessments (1993/1994) upon which the USEIA estimates are based as well as the fact that new technology would make the extraction of deeper oil and gas more profitable.

Cunningham (2014) contends that the South China Sea has a huge potential for oil and gas, but that current tensions will hamper the development of these resources for the foreseeable future. Most exploration companies will continue to steer clear of these lucrative, but contested, areas due to warnings from China in this regard (Cunningham 2014). This should be seen in conjunction with strong nationalist feelings in China regarding their presumed sovereignty over the contested areas. The oil and natural gas reserves for the South China Sea are shown in Fig. 16.5.

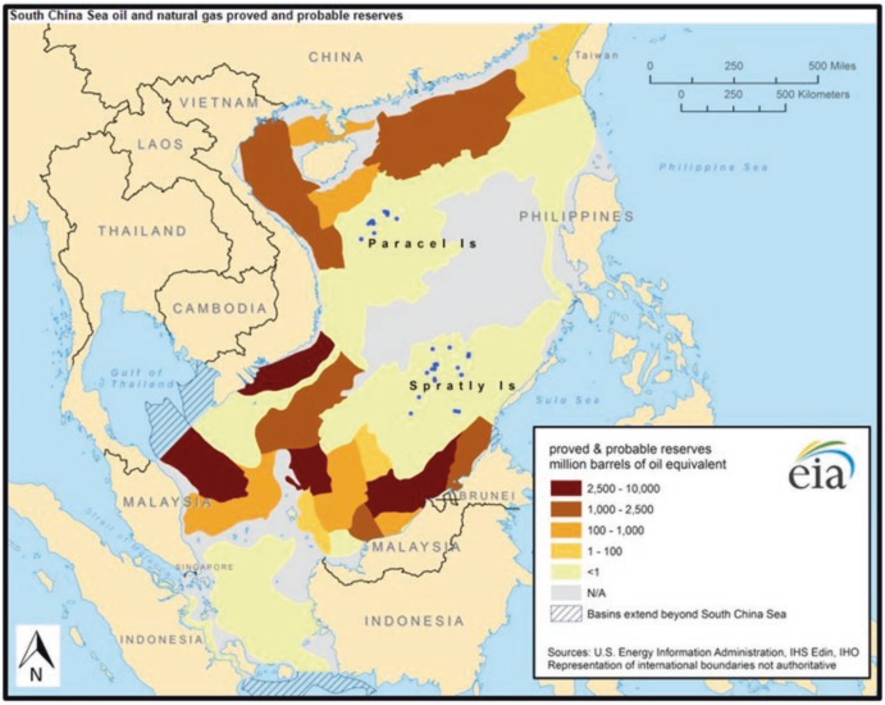

Fig. 16.5 South China Sea oil and natural gas reserves (USEIA 2013)

16.4.2 Fisheries

Fabinyi (2015) contends that natural resources are the key driver of the territorial dispute between China and the Philippines in the South China Sea. Whereas oil and natural gas are the most valuable and high-profile natural resources, the disputes over fishing rights in the area may be equally important. He postulates that China uses diplomacy and propaganda coupled with military means, (un)favourable trade agreements, and fishery poaching to achieve its objectives. In his opinion, China uses a "salami slicing tactic", which involves small, seemingly insignificant actions that over time add up to create a major strategic advantage. In terms of trade, China has gained access to Philippine fishery resources, providing limited economic benefit to the Philippines and more benefit to Chinese traders. The weak governance of the Philippines has resulted in wide-scale poaching by Chinese vessels, mostly for endangered, high-value species, such as live reef fish, in Philippine waters (Fabinyi 2015).

Till (2013) contends that China perceives the littoral seas of the South China Sea as vital to its economic prosperity because resources such as fish are critical to its developing human needs. He indicates that this would be in line with China's 12th Five-Year Plan of March 2011, which places greater emphasis on the development of marine interests and industries. He also suggests that the same could be said for countries such as Vietnam and the Philippines. China has updated the five-year plan for 2016–2020, which is in line with the above (China 2016).

The South China Sea, like many others, is a fragile environment with overfishing and pollution posing major threats. Zhou (2020) notes that China initiated an annual fishing moratorium in large areas of the South China Sea in 1999 with the aim of sustaining and protecting fishery resources in one of the world's biggest fishing grounds. This moratorium runs through the summer months and is normally enforced by the Chinese Coast Guard. Although past focus was on discouraging Chinese fishers, China stated that from 2020, other nations would also be prohibited from fishing in the demarcated region, which incorporates the EEZs of other littoral states in the region (Zhou 2020). Till (2013) contends that the unilateral implementation of moratoriums by individual countries, due to lack of consensus, contributes to escalating tensions between countries and is more pronounced when such regulations are imposed in contested areas.

16.4.3 Contested Areas

It is evident that natural resources play a great role in the disputes in the South China Sea. They are, however, not the only drivers of conflict in the area and should be considered in conjunction with maritime geographic posturing as well as economic and political pressure applied mainly by China.

The contested areas in the South China Sea cover mainly the Spratly and Paracel Islands, as well as the Scarborough Shoal. The focus here will be on the two island groups due to their prominence with respect to ongoing, current confrontations.

Most of the contested claims in the area stem from China's "nine-dash line". It is shown on Fig. 16.4 as nine, prominent, red dashes defining the outer perimeter of the South China Sea and bounds almost the entire maritime region. It specifically includes the Spratly and Paracel Islands, which fall within the EEZ claims of several other countries in the region (Fig. 16.4). Mollman (2016) contends that the line was first noticed on a 1947 map published by the Republic of China. It originally had 11 dashes and covered almost the entire South China Sea. The Chinese Communist Party adopted the map in 1949 and subsequently removed two of the dashes to exclude the Gulf of Tonkin as a gift to Vietnam. This map remained uncontested until China submitted it to the United Nations in 2009 to counter a Vietnamese claim on an extended continental shelf. China's submission included a note stating that it has indisputable sovereignty over the islands in the South China Sea and adjacent waters and enjoys sovereign rights and jurisdiction over those waters and the seabed below. The submission drew objections from mainly Vietnam, Indonesia and the Philippines due to its non-compliance with UNCLOS, which only allows countries to claim an EEZ of up to 200 nm (Mollman 2016). The Paracel Islands lie approximately 220 nm southeast of Hainan, China, and the Spratly Islands lie approximately 788 nm south of Hainan.

In terms of sovereignty and military force, China has continually referred to its nine-dash line and has even increased its military capability in the area through a process of land reclamation on several reefs (Mollman 2020). They use this process to coerce opponents into relinquishing claims and to strengthen China's position in any future talks.

Westcott (2016) writes that the Philippines approached the Permanent Court of Arbitration in The Hague in 2013 for a ruling on its right to exploit the waters near islands and reefs it occupied in the South China Seas. He summarized the three main points considered by the Court: firstly, whether certain features were islands, reefs, low-tide elevations or submerged banks (which would determine the extent of the claim(s) according to UNCLOS); secondly, what exactly the Philippines could claim according to the Convention (so as to judge the validity of China's claims); and, lastly, whether China had infringed on Philippine territory through its fishing and construction activities in the region.

On 12 July 2016, the Court ruled in the Philippines' favour on the main counts, which was seen as a diplomatic loss for China and a huge win for the Philippines. The Court determined that China (1) had no historical rights to the area demarcated by the nine-dash line; (2) the features of the individual Spratly Islands could not generate extended maritime zones, and neither could the islands generate such zones as a collective; and (3) China had violated the Philippines' sovereign rights in its EEZ by hampering economic activities, building artificial islands and failing to prevent Chinese fishing vessels from operating in the area. China has continued to ignore the final and legally binding judgement and used its economic, political, and military power to compel others in the region to ignore the judgement (Doan 2019).

Although UNCLOS dictates that any such rulings are binding on the states concerned, there is currently no enforcement mechanism. China has consistently refused to accept the ruling and has continued with its actions in the region. It has, however, sought bilateral and multilateral talks to alleviate the problem (Perlez 2016).

Two island groups, the Spratly and Paracel Islands (Fig. 16.4), in the South China Sea are a particular concern within the context of this emergent conflict. Each group has a unique history of territorial claims and importance that shape their geopolitical importance.

Spratly Islands

The Spratly Island group consists of approximately 100 low-lying islands, rocky outcrops and coral reefs. Most of these islands are submerged at high tide and can be seen as uninhabitable in a natural state. This makes them unimportant in the UNCLOS regime as no country would be able to claim any EEZ in this regard. The Philippines, Malaysia, Taiwan, Indonesia and Brunei lay claim to parts of the island group (Fig. 16.4) due to their proximity to their territorial waters (Hays 2012). Pletcher (2015) notes that islands and rocks are spread over an area of approximately 409,000 km^2. The largest of the islands is around 36 hectares, but there is no permanent human habitation. The Spratly Islands exchanged ownership many times from 1933 (France) to 1951 when Japan renounced ownership, after which Taiwan, Vietnam and China all declared themselves the rightful owners. The Philippines added a further claim in 1955 due to its proximity in terms of UNCLOS (Pletcher 2015).

China has since 1951 laid claim to the entire Spratly Island group stating that it has historical right to the islands dating back 2000 years. This claim is vehemently refuted by Vietnam as it contends that China had never claimed sovereignty over the islands and that Vietnam actively ruled over them since the seventeenth century (Zhao 2011).

Since 1970, Vietnam has had permanent deployments on three of the islands; Taiwan, on one; the Philippines, on seven islets (even building an airstrip on one); and Malaysia, on one of the reefs. These occupations should not be seen as permanent because the occupants are regularly replenished and replaced by new personnel. China forcibly removed a Vietnamese contingent from one of the islands in 1988 and in 2014 started building artificial land on some of the reefs and atolls (Pletcher 2015).

The Spratly islands are important to many of the neighbouring countries because of their geostrategic value, as previously discussed. China is seen as the hegemon in the South China Sea and needs the territory to expand its maritime domain so as to control one of the busiest and most economically important waterways in the world.

Paracel Islands

The Paracel Islands (Fig. 16.4), consisting of around 130 small coral islands and reefs, are situated about 355 km east of central Vietnam. The islands are low and barren and lack fresh water. None exceeds two and a half square kilometres, and there are no permanent human residents (Britannica 2013). The island group features on early seaborne trade charts, mostly as a dangerous area for navigation. The Chinese Qing Dynasty declared in 1898 that the Paracel Islands did not belong to any state – a proclamation that would soon be retracted – and sent expeditions in 1902 and 1908 to formally claim the islands for the empire (Zhao 2011).

The island group is currently claimed by China, Taiwan and Vietnam. Britannica (2013) indicates that it was annexed by French Indochina in 1932 and subsequently occupied by Japan during the Second World War. Japan renounced its claims to the territory in 1951. Chinese troops occupied one of the islands in 1947, while Vietnam continued to operate a weather station on another island in continuation of French Indochina activities. The discovery of oil in the subsoil of the ocean in the area in 1974 caused military confrontation when Vietnam contracted with foreign oil companies. As a result, China attacked the Islands and assumed control of the entire archipelago (Britannica 2013).

Skirmishes

The BBC (2012) and Day (1982) indicate that there were many skirmishes before 2000 that contributed to heightened tensions, most notably between China and Vietnam in 1974 and 1988, when Vietnam lost 70 and 60 troops, respectively. The overwhelming Chinese force and absence of allies for Vietnam resulted in China taking complete control of all of the islands in the Paracel group. Since 1988, there have been numerous attempts by Vietnam to persuade China in international fora that it too had a claim to the islands. China has since consolidated its position on the islands with a military building programme and troop deployments (Zhao 2011).

Since 2010, the following additional, significant actions have occurred:

- In September 2010, Chinese vessels apprehended Vietnamese fishing vessels near the Paracel Islands and also launched new maritime patrol vessels in the South China Sea in October of the same year (BBC 2012).
- In a stand-off with the Philippines in 2012, China compelled the country to yield control of the Scarborough Shoal (Doan 2019).
- China has conducted enormous expansion projects on the Spratly Islands since 2013, culminating in the militarization of the area and the deployment of military equipment and personnel (Doan 2019).
- China has in the recent past continued with reclamation work and subsequently deployed weapon systems and military personnel to both island groups, even landing long-range bombing aircraft on the disputed islands (Doan 2019).
- In 2014, China started exploration with a drilling rig in the Paracel Island area close to Vietnam, which led to widespread anti-Chinese protests in the country (BBC 2012).
- China pressured Vietnam politically to discontinue oil and gas exploration in the disputed areas of the South China Sea in 2017/18 (Doan 2019).
- China is currently engaged in dredging sand to build artificial islands on reefs hundreds of kilometres from its mainland in the Spratly and Paracel Island groups, creating since 2013 approximately 1295 hectares of new land in the Spratly Islands alone (Doan 2019).

Island Building

China is not the only country in the region to be engaged in artificial island building. The Asia Maritime Transport Initiative (AMTI 2020) provides extensive coverage of such presence and building endeavours by the respective countries. China has around 20 outposts in the Paracel Islands and seven in the Spratly Islands. Malaysia has enlarged five such islands in the Spratly Island group, including building a landing strip on one of the islands. The Philippines occupies a total of nine such areas in the Spratly Island group with one aircraft runway. Taiwan has one such outpost in the Spratly Island group, which also houses a runway. Vietnam occupies around 50 outposts across the South China Sea. It has reclaimed new land at many of the areas that it occupies (AMTI 2020).

16.5 International Responses to Confrontation

After the legal outcome of the 2016 dispute between the Philippines and China, the United States bolstered its Freedom of Navigation (FON) operations in the South China Sea. FON operations refer to navigation rights enjoyed by all users in the EEZs and on the high seas around the world. Navigation includes naval vessels and air patrols in the exercise of innocent passage in territorial waters and through archipelagic waters, transit passage through straits, navigation and overflight rights in the EEZ and high seas, as well as the use of the EEZ and high seas for military purposes. Kuok (2016) contends that the United States needs to be proactive in the South China Sea by regularly asserting maritime rights, widely reporting on such rights, making visible all diplomatic protests to such rights, quietly persuading other states to join such operations and clarifying any Memos of Understanding between the US and China regarding rules of behaviour during such operations. This should be done in conjunction with renewed efforts to get China to desist from its expansive, illegal claims.

Larter (2020) gives a brief summary of the extent of US FON operations in the South China Sea. Two such exercises were conducted in 2015 and three in 2016 during the Obama administration. The Trump administration has seen a gradual increase in such activities: six were conducted in 2017; five, in 2018; and nine, in 2019. Activity has increased in 2020 when the US, for the first time, deployed two aircraft carrier groups to the region in July. China retaliated by sending a brigade of aviation forces to two of the islands it administers in the Paracel archipelago (Shinkman 2020). This action also heralded the first time the United States has publicly condemned China for not complying with the outcome of the legal UNCLOS judgement regarding its expansive claims in the South China Sea (Ruwitch 2020).

The US has also persuaded other countries to become involved in FON operations in the South China Sea (Werner 2019). The United Kingdom, Japan, New Zealand, Australia, Canada, India and France have all stepped up their operations in the region.

16.6 Discussion

In his comprehensive study on energy resources in the South and East China Seas, Weinberger (2015) states that an incident in which China drilled for deep-sea oil in Vietnamese territory on 2 May 2014 is instructive because it illustrates their resolve to assert control over the seabed in the region. He postulates that this should be seen in conjunction with the rapidly growing Chinese economy and the commensurate requirement for oil and gas to drive its growing transport and energy sectors. The exploration for oil in the contested areas should also be seen as China's quest for an available, affordable, reliable and diverse oil supply. Weinberger sees the Asia Pacific sea beds as contributing to Chinese energy security due to its proximity, allowing it to minimize risks through military and political strength.

In addition, Mancini (2013) notes that territorial conflicts have a wide variety of causes, such as material interests, cultural interests, resources, geopolitical rivalry, power relations between nations, national ideologies and economic interests. He suggests that disputes should be seen in terms of power relations as territory is fundamentally a power base for a nation. His assumption is that rising powers will have more aggressive postures towards disputed territories and would be further driven by resource scarcities as the population expands and the economy continues to grow rapidly. This appears to be the basis for China's aggressive stance in the South China Sea.

16.7 Conclusions

The South China Sea is a very important waterway that has huge economic value in terms of the traffic that transits the region, the value of its fisheries as well as the probable huge concentrations of hydrocarbon deposits below the subsoil. The region has seen a marked increase in levels of tension in issues pertaining to territorial disputes during the last few years in which China can be seen as the common denominator. The nine-dash line used for its claims of vast areas of the South China Sea is a particular cause of conflict. UNCLOS has specific regulations for the claiming of maritime boundaries, and although all of the nations involved in the disputes are signatories to the Convention, not all comply with its dispute resolution outcomes, which are binding in terms of the Convention. China has specifically ignored the outcome of the 2013 dispute and continued to display its might in terms of coercing East Asian nations politically, economically and militarily. In this regard, China's continued island building and harassment of fishermen and energy exploration companies in the EEZs of other sovereign nations have created more tension in an already volatile region.

There are many drivers for the territorial disputes, including nationalism, identity politics, history, material interests, cultural interests, resources, geopolitics, power relations, national ideologies and economic interests. These should be read in conjunction with China's need to assert itself in protecting the vital maritime trade routes and energy resources in the South China Sea.

The international community has not been idle, and specifically the United States has been garnering support from allies and has been conducting FON operations in the region to protect its sea lines of communication and exercise the rights of innocent passage. The US and other nations have recently started pushing back politically by publicly and officially condemning China's continued hegemonic tendencies in the region.

The altercations highlight a gradual but important escalation of actions, especially by China. It is evident from the list of actions given above that the increase in tension and hostilities is becoming more pervasive and concerning. These types of actions could easily lead to a real military confrontation if no suitable solution is found. Due to the countries being unable to resolve the territorial disputes, the region will remain underexplored and its energy resources will be underdeveloped. It is also reasonable to speculate that as new deposits of natural gas and oil are found in or near the contested areas, the persistence and intensity of these confrontations are likely to increase.

The solution to the stand-off is not simple and will require a good deal of diplomacy and possibly even economic coercion to get nations to accept the international dispute resolution mechanisms. The use of bilateral, multilateral and regional fora should be encouraged to prevent an increase in hostilities and, with the buildup of military forces in the region, even full-scale war.

References

Anon. (2012) South China Sea oil and natural gas resources. http://www.globalsecurity.org/military/world/war/spratly-oil.htm. Accessed 10 June 2012

Anon. (2020) Territorial disputes in the South China Sea. Council on Foreign Relations. https://www.cfr.org/interactive/global-conflict-tracker/conflict/territorial-disputes-south-china-sea. Accessed 11 January 2020

Asia Maritime Transparency Initiative (AMTI) (2020) Occupation and island building. https://amti.csis.org/island-tracker/. Accessed 15 July 2020

BBC (2012) Q&A South China Sea dispute. 27 October. https://www.bbc.co.uk/news/mobile/world-asia-pacific-13748349. Accessed 5 April 2015

China (2016) The13th Five Year Plan for economic and social development of the People's Republic of China. Promulgated on 16 March 2016. https://en.ndrc.gov.cn/policyrelease_8233/201612/P020191101482242850325.pdf. Accessed 28 August 2020

Cronin R and Dubel Z (2013) Maritime security in East Asia: boundary disputes, resources and the future of regional stability. https://www.scribd.com/document/179165715/Maritime-Territorial-Disputes-and-East-Asia-2. Accessed 15 July 2020

Cunningham N (2014) Why oil and gas in the South China Sea won't be developed. Economonitor. https://oilprice.com/Energy/Energy-General/Why-Oil-and-Gas-in-the-South-China-Sea-Wont-Be-Developed.html. Accessed 8 June 2015

Daiss T (2016) Why the South China Sea has more oil than you think. Forbes 22 May. https://www.forbes.com/sites/timdaiss/2016/05/22/why-the-south-china-sea-has-more-oil-than-you-think/#581efeaedd8f. Accessed 15 July 2020

Day A (ed) (1982) Border and territorial disputes. Longman, Essex
Doan XL (2019) China's contradictory words and deeds. Asia Times 4 June. https://www.asiatimes.com/2019/06/opinion/chinas-contradictory-words-and-deeds/. Accessed 15 January 2020
Dolven B, Kan SA and Manyin ME (2014) Maritime territorial disputes in East Asia - Issues for Congress. Congressional Research Service, Washington DC
Emmers R (2010) Geopolitics and maritime territorial disputes in East Asia. Routledge, New York
Encyclopedia Britannica (Britannica) (2013) Paracel Islands, South China Sea. https://www.britannica.com/place/Paracel-Islands. Accessed 15 July 2020
Fabinyi M (2015) China and the South China Sea resource grab. The Diplomat August. http://thediplomat.com/2015/02/china-and-the-south-china-sea-resource-grab/. Accessed 10 June 2015
Gibson J (2009) Maritime security and international law in Africa. African Security Review 18(3):60-70
Hays J (2012) China and its claims over the Spratly islands and South China Sea. http://factsanddetails.com/asian/cat63/2sub5/entry-4274.html. Accessed 15 July 2020
Kuok L (2016) The US FON Program in the South China Sea. East Asia Policy Paper 9. Center for East Asia Policy Studies, Brookings Institution, Washington DC
Larter DB (2020) In challenging China's claims in the South China Sea, the US Navy is getting more assertive. Defense News 5 February. https://www.defensenews.com/naval/2020/02/05/in-challenging-chinas-claims-in-the-south-china-sea-the-us-navy-is-getting-more-assertive/. Accessed 15 July 2020
Mancini F (2013) Uncertain borders: territorial disputes in Asia. Italian Institute for International Political Studies, Analysis No. 180
Mollman S (2016) The line on a 70-year-old map that threatens to set off a war in East Asia. Quartz 8 July. https://qz.com/705223/where-exactly-did-chinas-nine-dash-line-in-the-south-china-sea-come-from/. Accessed 15 July 2020
Mollman S (2020) China's South China Sea plan unfolds regardless of the coronavirus. Quartz 9 May. https://qz.com/1849207/chinas-south-china-sea-plan-unfolds-regardless-of-coronavirus/. Accessed 15 July 2020
Perlez J (2016) Tribunal rejects Beijing's claims in the South China Sea. New York Times 12 July. https://www.nytimes.com/2016/07/13/world/asia/south-china-sea-hague-ruling-philippines.html. Accessed 15 July 2020
Pletcher K (2015) Spratly Islands: reefs, shoals, atolls, and islets, South China Sea. https://www.britannica.com/place/Spratly-Islands. Accessed 15 July 2020
Ruwitch J (2020) US rejects Beijing's maritime claims in the South China Sea. National Public Radio 13 July. https://www.npr.org/2020/07/13/890464319/u-s-rejects-beijings-maritime-claims-in-south-china-sea. Accessed 30 July 2020
Shinkman P (2020) China, US escalate forces, threats in South China Sea. US News and World Report 20 July. https://www.usnews.com/news/world-report/articles/2020-07-20/china-us-escalate-forces-threats-in-south-china-sea. Accessed 30 July 2020
UNCLOS (1982) UN General Assembly, Convention on the Law of the Sea, 10 December, available at: https://www.refworld.org/docid/3dd8fd1b4.html. Accessed 26 October 2021
US Central Intelligence Agency (CIA) (2020) The World Factbook. https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html. Accessed 15 July 2020
US Energy Information Administration (USEIA) (2013) Contested areas of South China Sea likely have few conventional oil and gas resources. http://www.eia.gov/todayinenergy/detail.cfm?id=10651. Accessed 10 June 2015
US Energy Information Administration (USEIA) (2018) More than 30% of global maritime trade moves through the South China Sea. 27 August. https://www.eia.gov/todayinenergy/detail.php?id=36952. Accessed 15 July 2020
Weinberger J (2015) China seeks to dominate off-shore energy resources in the South and East China Seas. International Association for Energy Economics, Second Quarter, p 17-20
Werner B (2019) Future China Sea FONOPS will include Allies, partners. US Naval Institute News 12 February. https://news.usni.org/2019/02/12/41070. Accessed 15 July 2020

Westcott B (2016) Philippines vs China: Why the South China Sea ruling may change Asia. CNN 12 July. https://edition.cnn.com/2016/07/04/asia/south-china-sea-un-case-explainer/index.html. Accessed 15 July 2020

Zagoria SZ and Daniels R (2012) Panel discussion on maritime disputes in Asia: finding peaceful solutions. National Committee on American Foreign Policy. https://www.ncafp.org/2016/wp-content/uploads/2013/03/ncafp-panel-discussion-report-dec-3.pdf. Accessed 21 July 2020

Zhao S (2011) China's territorial disputes in the South China Sea and East China Sea. http://www.china-briefing.com/news/2011/05/31/chinas-territorial-disputes-in-the-south-china-sea-and-east-china-sea.html. Accessed 5 April 2015

Zhou L (2020) Beijing's South China Sea fishing ban threatens to raise tensions with rival claimants. South China Morning Post 8 May. https://www.scmp.com/news/china/diplomacy/article/3083572/beijings-south-china-sea-fishing-ban-threatens-raise-tensions. Accessed 15 July 2020

Chapter 17
Geological Considerations for Military Works in the Afrin Battlespace, Syria

M. H. Bulmer

Contents

Abstract To defend against the Turkish Armed Forces (TAF) in the newly formed Afrin Region, Kurdish parties and militias constructed trenches, observation towers (OTs), cut-and-cover hardened tunnels (CCHTs) and underground facilities (UGFs) along the border between Turkey and Syria and throughout Afrin. The Kurdish militia was a light infantry force with limited artillery, improvised armoured vehicles, no combat engineers and no air power. The use of subterranea was a direct response to the increasing need for concealment and protection to improve survivability against munitions used by the Syrian Government Forces, TAF, the Islamic State of Iraq and Syria, and their affiliates. Defences were constructed in mountains of limestone, sandstones and marls and in valleys in alluvial terraces and conglomerates, lithologies very favourable for digging and tunnelling. The scale of Syrian Kurdish works represents significant defensive construction projects, which required financing (US$400,000 for a 300-m long CCHT), experienced and skilled works teams with project managers, site foreman, plant operators and construction crews. Materials used were rebar, forms and concrete, all needed in large volumes. At the start of Operation Olive Branch in January 2018, Turkish airstrikes and artillery targeted OTs, CCHTs and UGFs. Their use of combined arms overmatched Kurdish defensive positions in the Afrin Region.

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Keywords Trenches · Tunnels · Excavation · Limestone · Afrin · Syria

17.1 Introduction

Afrin, located in northwest Syria on the border between Syria and Turkey, consists of the Syrian part of the Kurd Mountains (Fig. 17.1), the autonomous region of the Shabha area and a large part of the Manbij plain. The Afrin Region is bordered by the Euphrates Region to the east, Kilis Province of Turkey to the north and Hatay Province of Turkey to the west. Kurd Mountains are part of the Limestone Massif of northwest Syria. The mountains are a southern continuation into the Aleppo plateau that is in turn a continuation of the highlands on the western part of the Aintab plateau. The River Afrin surrounds Kurd Mountains from easterly and southerly directions (Fig. 17.2a). It drains south between the plain of A'zaz to the east and Mount Simeon to the west. The River Aswad separates Mount Kurd in the Kurd Mountains from Mount Amanus in the Nur Mountains to the west.

The Afrin Region for Syrian Kurds had two subordinate cantons, the Afrin Canton and the Shahba Canton. The Afrin Region was first declared autonomous under the name of Afrin Canton in January 2014 (Firat News 2014) but was later

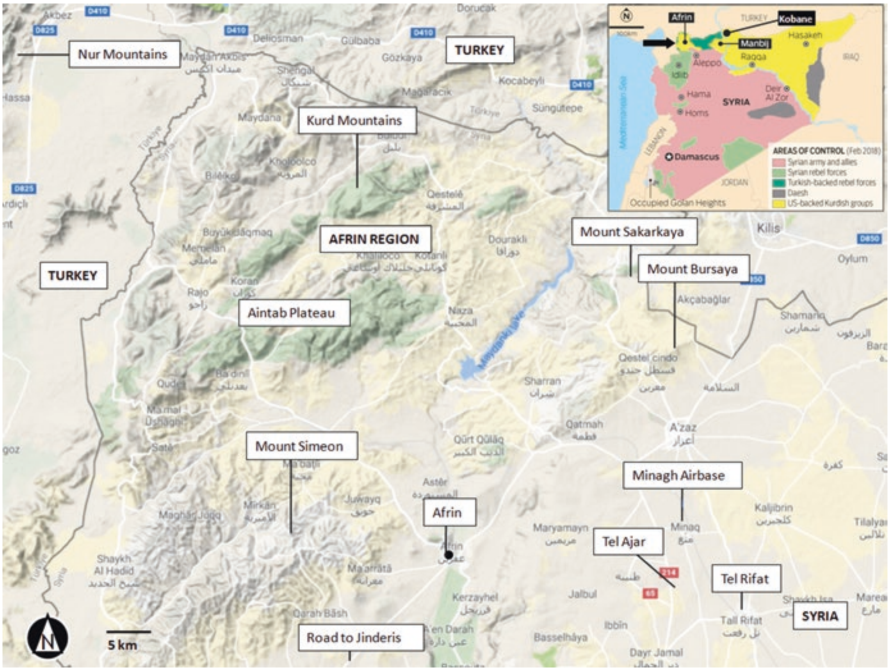

Fig. 17.1 Topography around the Afrin Region. The inset shows areas of control in February 2018. (Modified from Gulf News 2019)

renamed the Afrin Region during the subdivision congresses held in July and August 2017. The administrative centre of the region was the city of Afrin.

17.2 Background

The Arab Spring was a series of anti-government protests, uprisings and armed rebellions during 2010. It began in Tunisia and spread to Libya, Egypt, Yemen, Syria and Bahrain. In Syria, public protests against the Assad regime by the Syrian opposition were initially minor; the first large demonstrations began in March 2011 (World Bank 2017), and in the following months, they spread and increased in size within the country. By the summer of 2011, armed conflict had started between the Ba'athist Syrian Arab Republic led by President Assad, supported by domestic and foreign allies, against the domestic rebel Free Syrian Army (FSA) and foreign forces along with terrorist groups opposing the Assad regime, and each other, in

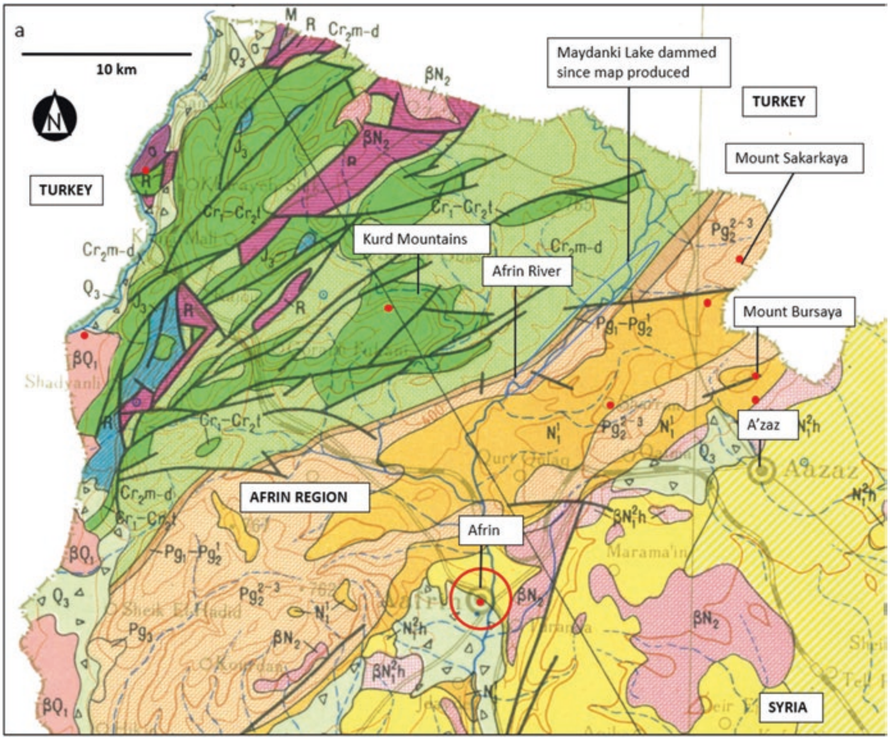

Fig. 17.2 (**a**) A portion of the 1:500,000 scale geological map of northwest Syria Afrin Region. (Modified from Sheet 1, SMI 1964) on which known subterranean military works locations are shown (red dots). (**b**) Legend for the 1:500,000 scale geological map

Fig. 17.2 (continued)

varying combinations.[1] After the Syrian Government Forces (SGF) pulled out of Afrin in 2012, Kurdish People's Protection Units (YPG) militia and Women's Protection Units (YPJ), founded in 2011 as a light infantry force with limited military equipment and few armoured vehicles, took responsibility for its defence.[2] The administrative centre of the region was the city of Afrin. Afrin became the westernmost of three regions of the Syrian Kurdish Autonomous Administration of North and East Syria, also known as Rojava. The YPG/YPJ did not initially take an offensive posture in the Syrian Civil War and were able to maintain trust with both the SGF and its neighbouring rebel groups. That same year, Syrian refugees were attempting to cross the Syrian border into Turkey to flee the advance of SGF against the rebel FSA. SGF attempted to block the flow of refugees and supplies for

[1] By April 2013, tensions between Al-Qaeda and Islamic State of Iraq and Syria heightened when the Da'esh caliph Abu Bakr al Baghdadi instructed his fighters to expand from Iraq to Syria to reclaim control over Jabhat al-Nusra. Over the summer and fall of 2013, IS's aggressive posture toward other jihadists led to heightened tensions, which escalated into infighting in January 2014 and ignited the so-called jihadi civil war. The following month, al Zawahiri officially expelled IS from his AQ network.

[2] In July 2012, the YPG/YPJ had a standoff with Syrian government forces in the Kurdish city of Kobane and the surrounding areas. After negotiations, government forces withdrew and the YPG took control of Kobane, Amuda and Afrin.

insurgents coming across from Turkey (Oweis and Sezer 2012). As a result, the Afrin Region and YPG/YPJ, as its fighting force, were threatened by SGF (and possibly Russia), the Turkish Armed Forces (TAF), the Islamic State of Iraq and Syria (IS) and their affiliates.

IS, who did not recognise the Syrian Kurdish Afrin Region, gained control of large parts of northern Syria in 2014 and advanced into Iraq. On 13 September 2014, IS advanced into Kobane to capture the autonomous region of Kobane Canton and the city of Kobane, capturing over 350 Kurdish villages and towns by 2 October 2014 and displacing 400,000 Kurds. In early 2015, the YPG/YPJ defeated IS and affiliated terrorist groups during the Siege of Kobane, where they received air and ground support from the United States and other Combined Joint Task Force (CJTF) – Operation Inherent Resolve militaries. At the end of August 2015, the al-Nusra Front (the official Syrian branch of al-Qaeda[3] made up of Syrian jihadists fighting against the SGF and its affiliates) shelled the Syrian Kurdish villages near Jindires town in the Afrin countryside (Fig. 17.1; ARA News 2015). The YPG/YPJ held that ground and returned fire into northern Aleppo even though a truce had been reached between the YPG/YPJ and al-Nusra seven months prior and al-Nusra was attempting to engage the SGF and its affiliates located in the same area. This exemplifies how fluid fighting was with numerous actors pursuing their own objectives, which at times meant they engaged groups that they had previously been fighting. An additional actor was created in October 2015 with the founding of the Syrian Democratic Forces (SDF) composed primarily of Kurdish, Arab and Assyrian/Syriac militias, as well as some smaller Armenian, Turkmen and Chechen forces. The SDF fought under the leadership of the YPG/YPJ. In February 2016, in response to the Battle of Aleppo, the SDF moved east out of Afrin to secure supply routes and captured the Menagh Military Airbase and the town of Tel Rifaat (Fig. 17.1). In response, TAF shelled SDF positions across the border to protect the city of A'zaz. In 2017, Russian troops stationed themselves in Afrin as part of an agreement to protect the SDF and YPG/YPJ[4] from further Turkish attacks. This now included an additional actor, the Turkish-backed Free Syrian Army (TFSA)[5] formed 30 December 2017. At the same time, Russia and Turkey planned airstrikes on Idlib (Fig. 17.1, inset) to drive out al-Nusra (TRT World 2017). According to a Pentagon spokesperson, in November 2017 a verbal agreement was made between Washington and Moscow to create an air space deconfliction zone (BBC News 2017). Under the

[3] Its goals were to overthrow Bashar al-Assad's government in Syria and to create an Islamic emirate under sharia law. The tactics of al-Nusra Front differed from IS; whereas IS alienated local populations by demanding their allegiance and carrying out beheadings, al-Nusra Front co-operated with other militant groups and declined to impose sharia law where there had been opposition. Al-Nusra presented itself as moderate in comparison to IS.

[4] The updated December 2016 constitution of the Autonomous Administration of North and East Syria names the SDF as its official defence force.

[5] The TFSA is different from the FSA. The official aims of the TSFA are to assist Turkey in creating a 'safe zone' in Syria. At its formation in A'zaz, it proclaimed itself a National Army. The FSA fought against the TSFA.

agreement, the US considered the area to the north and east of the Euphrates River US designated, whereas Russia had the freedom to patrol west of the river.

To try to defend the Afrin Region against TAF, SGF, IS, al-Nusra as well as other terrorist groups, the Syrian Kurds constructed trenches, observation towers (OTs), cut-and-cover hardened tunnels (CCHTs) and underground facilities (UGFs) along the border with Turkey and throughout the region. The construction of military works in the Syrian Kurdish Afrin Region may have been undertaken by Kurdish parties (KCK/PKK/PYD[6]) and militias (SDF/YPG/YPJ), IS (plus affiliates) as well as al-Nusra, all of whom had previous experience constructing them. At the start of Turkey's Operation Olive Branch[7] in January 2018, the Russian Defence Ministry withdrew its troops and military police from the Afrin Region to avoid conflict with TAF.[8] The US and CJTF militaries that supported the SDF/YPG/YPJ in its fight against IS[9] did not provide air power over Afrin to counter that of the TAF. In 2021, the conflict remains active and the SGF has regained control of much of Syria except for the northern Syrian Kurdish-controlled region (Court and Hond 2020), part of which was occupied by TAF and TFSA during the Turkish offensive Operation Peace Spring, which began on 9 October 2019, after US forces withdrew east (McKernan 2019) on 6 October 2019.[10] This has forced the Kurds to negotiate with the Assad regime (Gulf News 2019). TAF and their proxies occupying the Afrin Region are now frequently targeted by insurgent groups.

[6] The Kurdistan Communities Union (KCK) is a Kurdish political organisation that serves as an umbrella group for all the democratic confederalist political parties of Kurdistan, including the Kurdistan Workers' Party (PKK) and Democratic Union Party (PYD). The PKK and all its affiliates are considered as terrorist organisations by Turkey with evidence of deliberate targeting of civilians. NATO refers to the PKK as a terrorist entity. In the United States a case had been made for removing the Kurdistan Workers' Party (PKK) from the State Department's list of Foreign Terrorist Organizations (FTOs) would create conditions for greater security cooperation between the United States and the PKK in the fight against the Islamic State in Iraq and Syria (ISIS) (https://www.lawfareblog.com/case-delisting-pkk-foreign-terrorist-organization). In 2020, the supreme court of Belgium ruled that the PKK was not a terrorist organisation, instead labelling the group as an actor in an internal armed conflict (https://www.brusselstimes.com/belgium/92787/belgian-government-defies-ruling-of-its-supreme-court-on-pkk/).

[7] Operation Olive Branch was a cross-border military operation conducted by the TAF and TFSA in the Afrin Region. The air war and artillery barrages ended as the TFSA entered the city of Afrin on 18 March 2018.

[8] The Russian Foreign Ministry expressed concern at the assault and called for restraint. (Gall 2018).

[9] Turkey recognises the YPG, YPJ and SDF as an extension of the PKK however other nations such as the UK have not proscribed the YPG as a terrorist organisation (https://www.gov.uk/government/publications/proscribed-terror-groups-or-organisations-2).

[10] The Trump administration ordered American troops to withdraw from northeastern Syria, where the United States had been supporting its Kurdish allies (BBC News 2019).

17.3 Geology Around Afrin

Syrian Kurdish military works were constructed in mountains of limestone, sandstone and marl and in valleys in alluvial terraces and conglomerates (Fig. 17.2; SMI 1964). These lithologies are very favourable for digging and tunnelling. The Kurd Mountains are composed mainly of hard rock, Upper and Lower Cretaceous sandstones, limestones and dolomites; and chalky limestones and marls. The Afrin Valley is underlain by softer rock, Middle and Upper Eocene soft chalk-like and hard nummulitic limestones. Mount Bursaya (855 m asl), Mount Sakarkaya (774 m asl) and mountains southwest to Afrin are composed of Lower Miocene marine limestones, marls, clays, conglomerates and sandstones. The city of Afrin sits astride Tortonian limestones, marls, conglomerates, sandstones and Quaternary alluvial terrace pebble beds and conglomerates. The geology and climate around Afrin are favourable to the formation of dolines, caves and sinkholes. Dozens of Palaeolithic caves have been identified in the Afrin valley (Akazawa and Nishiaki 2017).

17.4 Military Works

Military works in the Afrin Region were constructed on both the Turkish side of the border and on the Syrian-Kurdish side. Using handheld images, media reports, drone as well as satellite imagery, it has been possible to determine how these military works were constructed as well as how and why they evolved. The factors of shape, size, shadow, tone, associated features and movement in images were used to interpret design features, characteristics and activities (Hamshaw Thomas 1920). Associated features were often critical to interpreting the function and signature equipment, such as excavators, and allowed distinctions between different combatants (TAF, TFSA, SGF, IS, al-Nusra, Russians, rebels and YPG/SDF/YPJ) to be identified. Where identifiable, Hamshaw Thomas factors have been used for dimensional analysis to determine the time, materials, volumes and costs needed to construct military works.

Turkey utilised the full resources of the state controlled by President Erdogan in its programme of military works. The Syrian Kurds threatened by Turkish invasion into the Afrin Region, as well as from SGA forces, IS and al-Nusra terrorist groups, undertook their own programme of military works. However, as a newly autonomous region, it did not have the structures, organisations or levels of finances of its opponents. Despite these imbalances, the Syrian Kurds carried out significant defensive construction projects of defensive trenches, OTs, CCHTs and UGFs, which required financing and experienced and skilled work teams with project managers, site foreman, plant operators and construction crews. Given the size and number of UGFs being constructed across Afrin by the Syrian Kurds, there was a critical need to tunnel faster driven by the need for concealment and protection to increase survivability. As observed in the IS tunnel programme in Iraq (Bulmer 2019), moving from hand tools to tunnel machines is a logical progression to meet this necessity. These machines required even more financing and more experienced and skilled tunnel teams with project managers, tunnel foreman, tunnel machine operators, along with construction crews experienced in shoring and lining the tunnels creating hardened UGFs. Materials used in defensive trenches, OTs, CCHTs and UGFs were rebar, wooden forms and concrete with large volumes of each required, as well as water. The costs to the Syrian Kurds, when applied across the military works undertaken, add up to 10s to 100s of millions of dollars. This was not being generated within the autonomous Afrin Region, indicating outside financial support. The Turkish media interpreted the US Defense Department 2019 assistance for Syria as allocating $550 million[11] to the YPG, and this went to covering costs of the military works (Gurses and Butler 2018). They also claimed that the concrete used by the Syrian Kurds was being supplied from the French-owned Lafarge Cement Syria Factory in the Province of Aleppo (Ahval News 2018). Examinations of the costs and availability of materials associated with construction, therefore, provide an insight into an aspect of the ongoing conflict that has received limited attention (Bulmer 2021). However, these costs, which resulted in tangible defensive trenches, OTs, CCHTs and UGFs for Syrian Kurds, provided only a short-term gain in concealment and survivability when matched against TAF state-funded expenditure on armour, artillery and air power to damage or defeat these structures during Operation Olive Branch. There was a considerable increase in Turkey's 2018 budget for Defence, taking it to an estimated $10.6 billion (Defence Turkey 2018). Financially, Turkey's actions in Afrin were not without consequence: on 7 March, Moody's Investors Service downgraded Turkey's debt (Financial Times 2018), warning of erosion of checks and balances under the leadership of President Recep Tayyip Erdoğan and saying that the Afrin offensive, having strained relations with the US and drawn the country deeper into the Syrian civil war, had added an extra layer of geopolitical risk.

17.4.1 Turkey

In 2016, Turkey began constructing a wall along the border with northern Syria to stop IS bombing teams crossing into Turkey, as well as to block the flow of refugees from Syria and stop supplies for insurgents and terrorist groups coming across from Turkey (Fig. 17.3; Chohan 2018; Ozturk 2018). An examination of satellite imagery at visible wavelengths shows a road following the border and a band of "no-man's" land on the Turkish side marking the eastern border with the Afrin region (Fig. 17.3a). The contract to build 828 km of concrete wall was awarded to TOKI, Turkey's state-owned construction enterprise. The wall (Fig. 17.3b) is composed of 7-tonne concrete segments, each 3 m high and 2 m wide delivered by rail and on flat-bed

[11] All $ figures in this paper refer to US dollars.

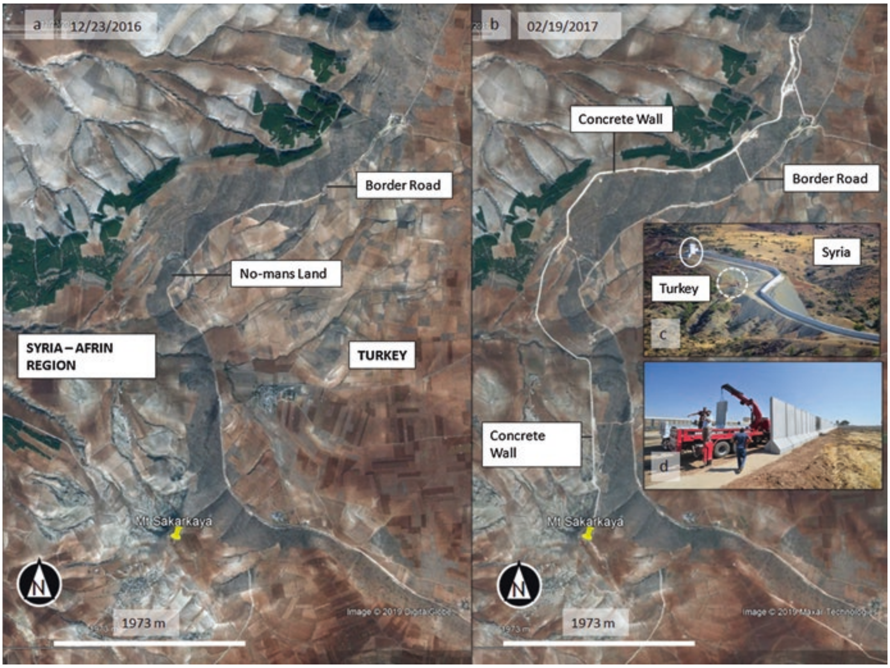

Fig. 17.3 (**a**) WorldView EO image acquired 23 December 2016 over the border between Syria and Turkey around Mount Sakarkaya in northwest Syria. (**b**) WorldView EO image acquired on 19 February 2017 over the same area as image (**a**) showing a concrete wall built by Turkey. (**c**) A section of the concrete wall built on a gravel embankment. (Modified from Ozturk 2018). The white oval indicates an automated OT and the dashed white oval, a flat-bed tractor-trailer with a crane. (**d**) A flat-bed tractor trailer off-loading a concrete block. (From Daily Sabah 2016)

tractor-trailers and lifted into position with a crane (Fig. 17.3c, d). By December 2017, 781 km of wall had been constructed requiring 390,500 concrete segments. In spring 2018, the wall was finished, comprising 414,000 segments (Bulmer 2021). To first order, costs for 414,000 segments, using the global concrete pricing of \$120/0.76 m^3, ranged from \$39.2 million for 0.1-m thickness to \$196.1 million for 0.5-m thickness. This rises to \$65.3 million for 0.1-m thickness then \$326.8 million for 0.5-m thickness calculated using the concrete pricing of \$200/0.76 m^3 (Bulmer 2021). Included in the border wall construction were 120 border OTs (Fig. 17.3c), each of a standard design 15 m high with a diameter of 7 m, each computerised with an alarm and automated firing systems for the weapon systems contained in them (Turkey News 2016). In November 2017, as the border wall construction continued, TAF had excavated trenches on limestone slopes up Mount Bursaya and Mount Sakarkaya, angling up to the Syrian Kurdish defences as part of the preparations for the launch of Operation Olive Branch at the start of 2018. The US military and anti-IS coalition monitored but did not intervene.

17.4.2 Autonomous Afrin Region

The YPG/YPJ was a light infantry force with limited artillery, improvised armoured vehicles, no combat engineers and no air power to counter TAF. Initially, defensive positions on the Syrian side of the border with Turkey, constructed by the Syrian Kurds on the crest of the limestone ridge along the Turkey/Syria-Afrin Region border, were much less sophisticated than on the Turkish side (Fig. 17.4) but underwent rapid design and material improvements to attempt to incorporate lessons learned from the blast and impact effects of weapon systems used by TAF, TFSA, SGF, IS, al-Nusra and their affiliates. Unlined and unsupported defensive trenches collapsed if an artillery round or missile struck near them, burying defenders. The use of concrete and rebar reduced collapses and meant that TAF air and artillery strikes had to hit a trench directly. Roofing over the trenches to create CCHTs also concealed the defenders from TAF and made targeting more difficult. Changing angles, alignment and dimensions in trenches and CCHTs were all measures introduced to advantage the defenders and disadvantage the attackers in face-to-face trench warfare, features reminiscent of the World War I trenches (Jones 2010; Doyle 2017). The increasing use of subterranea was a direct response by the Syrian Kurds to having no air power, needing to avoid detection from Turkish air assets and increase survivability from air and artillery strikes. At the start of TAF Operation Olive Branch in January 2018, many of these Syrian Kurdish military works were still under construction, as evidenced by the photos taken by Turkish media from captured positions.

Fig. 17.4 View from the Turkish side of the border over a defensive wall to the Syrian side on 17 January 2018. Defensive positions constructed on the crest of the limestone ridge can be seen on the Syrian side. (Modified from Chohan 2018)

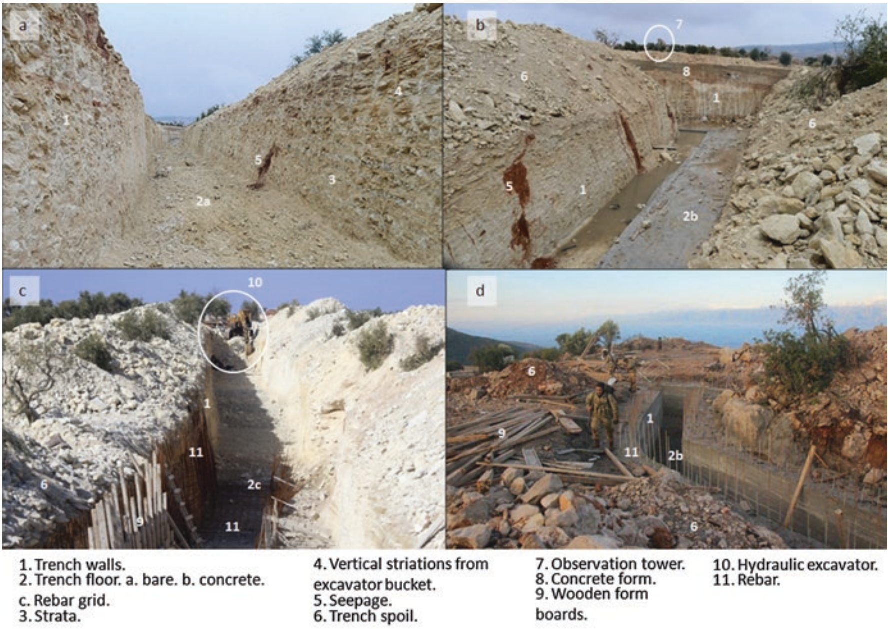

Fig. 17.5 (**a**) Syrian Kurdish trench excavated in horizontally bedded limestone with marls using a machine. (Modified from Vatan 2018). (**b**) Syrian Kurdish trench in chalky limestone with marls dug using a mechanical excavator prior to a concrete floor being poured. The white oval shows an OT. (Modified from Yeni Safak 2018b). (**c**) The white oval shows a tracked excavator digging a Syrian Kurdish trench with a small 305-mm bucket. (Modified from Takvim 2018). (**d**) Concrete-lined Syrian Kurdish defensive trench in limestone on Mount Bursaya. (Modified from Southfront.org 2018)

Cut-and-Cover Trenches

Digging in the different lithologies by the Syrian Kurds was undertaken using hand tools and machine excavators. Defensive trenches excavated on Mounts Sakarkaya and Bursaya (Fig. 17.2) show the horizontally bedded limestone with marls to be coherent enough to support near-vertical walls (Fig. 17.5a). The 5-m-deep dig in Fig. 17.5a appears to be fresh when captured by TAF in 2018, with only minimal water seepage (Fig. 17.5a component 5) and no ponding. Within trenches 5–7 m deep and 3.5 m wide (Fig. 17.5a, b), reinforced concrete was used to construct hardened tunnels 1.5 m wide and 2 m high with sides 0.9 m thick. This started with pouring a concrete floor (Fig. 17.5b component 2b), then the walls and finally the roof. These defensive trenches and hardened tunnels, which ran for tens, hundreds and thousands of metres (Fig. 17.5b–d), had raised OTs (Fig. 17.5b component 7) and changes in trench line angles as part of the defensive design (Fig. 17.5d). Horizontal rebar pieces were wired to vertical pieces in the walls once wooden form boards were installed (Fig. 17.5c, d components 9 and 11), and a concrete roof was poured to provide overhead protection. The hardened walls and roof were then

Fig. 17.6 (**a**) Unlined Syrian Kurdish defensive trench in chalky limestone with a rock floor and reinforced concrete overhead protection. (Modified from Yeni Safak 2018a). (**b**) Syrian Kurdish CCHT with multiple firing points. (Modified from Yeni Safak 2018c). (**c**) View of Syrian Kurdish CCHT combined with an OT on Mount Bursaya. (Modified from Southfront.org 2018). (**d**) Syrian Kurdish pillbox at Mount Bursaya. (Modified from Prima News 2018)

back-covered with spoil (cut-and-cover (C&C)), creating CCHTs (Fig. 17.6a, b). Design evolutions can be observed in the same Syrian Kurd trench locations where the trench looks hand dug and the rock floor follows the topography (Fig. 17.6a components 1a and 2a). The dimensions are 1.0 m wide at the floor and 1.5 m deep with an additional 0.5 m of reinforced concrete having been added, enabling defenders to stand rather than crouch (Fig. 17.6a, b component 3). In several locations, Syrian Kurds constructed "double-deck" CCHTs. Figure 17.6b shows a Syrian Kurdish CCHT with dimensions 2 m high and 1.5 m wide with multiple firing points. The design enables defenders to move easily through the tunnel network unseen with much-improved protection compared to earlier designs. Syrian Kurdish OTs and pill boxes, constructed of reinforced concrete (Fig. 17.6c, d component 5), were connected to CCHTs and had ventilation, electrical wiring and living areas. CCHTs have been identified linked to UGFs with command centres, hospitals, dormitories, weapons, ammunition and vehicle storage areas reminiscent of World War I (Jones 2010; Doyle 2017).

Using images, such as Figs. 17.5 and 17.6 and satellite imagery such as WorldView (Fig. 17.3), it has been possible to determine how Syrian Kurdish trenches were constructed as well as how and why they evolved to CCHTs connected into fixed defensive lines. Where identifiable, Hamshaw Thomas factors have been used to undertake dimensional analysis to determine the time, materials,

Table 17.1 Calculated volume (*V*) of material (without bulking) to be excavated for 5-m- and 7-m-deep trenches over lengths (*L*) of 50–1000 m

Trench *L* (m)	Removal for 5-m deep *V* (m^3)	Removal for 7-m deep *V* (m^3)
50	875	1225
100	1750	2450
500	8750	12,250
1000	17,500	24,500

Table 17.2 Calculations for the number (*N*) of bucket removals for 5-m-deep trenches 50–1000 m long using different standard sizes of excavator buckets. *L* is length, and *V* is volume (without bulking)

Trench *L* (m)	*V* (m^3) for 5-m-deep trench	*N* of 305-mm buckets	*N* of 406-mm buckets	*N* of 508-mm buckets	*N* of 619-mm buckets	*N* of 762-mm buckets	*N* of 914-mm buckets
50	875	10,658	8349	6060	4829	3635	2915
100	1750	21,315	16,698	12,119	9658	7270	5829
500	8750	106,577	83,492	60,596	48,289	36,352	29,147
1000	17,500	213,155	166,985	121,191	96,578	72,705	58,294

volumes and costs needed by the Syrian Kurds to construct CCHTs (Hamshaw Thomas 1920). The dimensions of a Syrian Kurdish trench line (5–7 m deep and 3.5 m wide; Fig. 17.5) can be used to calculate the volume of material to be excavated from lengths 50–1000 m (Table 17.1) with spoil banked on either side (Fig. 17.5b, c).

In operational planning, rates of machine excavation are an important metric and of great significance to determining where any plant available to the Syrian Kurds was best utilised given the threat of Turkish invasion. Excavation rates for a range of bucket sizes can be used to calculate the number of bucket fills required for 5-m-deep trenches over distances of 50–1000 m (Table 17.2). The excavator visible in Fig. 17.5c (component 10) has a small, 305 mm bucket. To dig a 5-m-deep trench, 3.5 m wide along a 300-m length, such as one at Mount Sakarkaya (Turkey News 2018a), using this bucket (0.0821 m^3 capacity) would have required 63,946 individual bucket lifts. The number of individual bucket lifts for the same trench depth and length reduces to 36,357 for a 508-mm bucket (0.1444 m^3capacity) and to 17,488 for a 914-mm bucket (0.3002 m^3 capacity).

Using the rates of machine excavation (Table 17.2), the total time required for digging a 5-m-deep, 3.5-m-wide trench using rates of 4.8 m^3/hour (slow), 6.1 m^3/hour (average) and 7.1 m^3/hour (fast) can be calculated, as well as the time taken using an eight- or 10-hour work shift per day (Table 17.3).

Calculations of the time required to dig (Table 17.3) can then be matched to the different bucket sizes (Table 17.2) to determine the excavation time required. This is a critical consideration for the construction being undertaken with the constant threat to the Syrian Kurds of being attacked (Table 17.4). For an excavator

Table 17.3 Total time required to dig a 5-m-deep, 3.5-m-wide trench using a 914-mm bucket. Tr is trench; *L*, length; *V*, volume (without bulking); *T*, total; H and Hr, hours; and *e*, excavation rate

Tr *L* (m)	*V* (m^3) for 5-m-deep Tr	*T* Hrs $e = 4.8\ m^3$/hour (s)	*T* Hrs $e = 6.1\ m^3$/hour (av)	*T* Hrs $e = 7.1\ m^3$/hour (f)	*T* 8 H shifts $e = s$	*T* 8Hr shifts $e = av$	*T* 8Hr shifts $e = f$	*T* 10Hr shifts $e = s$	*T* 10Hr shifts $e = av$	*T* 10Hr shifts $e = f$
50	875	182	143	123	23	18	15	18	14	12
100	1750	365	287	246	46	36	31	36	29	25
500	8750	1823	1434	1232	228	179	154	182	143	123
1000	17,500	3646	2869	2465	456	359	308	365	287	246

Table 17.4 Total time required to dig a 5-m-deep, 3.5-m-wide trench using a 305-mm bucket at three different excavation rates and over an eight-hour shift. Tr is trench; *L*, length; *V*, volume (without bulking); Hrs, hours; and *e*, excavation rate

Tr *L* (m)	V (m^3) for 5-m-deep trench	Hrs $e = 4.8\ m^3$/hour (s)	Hrs $e = 6.1\ m^3$/hour (av)	Hrs $e = 7.1\ m^3$/hour (f)	Total eight-hour shifts $e = 4.8\ m^3$/hour (s)	Total eight-hour shifts $e = 6.1\ m^3$/hour (av)	Total eight-hour shifts $e = 7.1\ m^3$/hour (f)
50	875	2220	1747	1501	278	218	188
100	1750	4441	3494	3002	555	437	375
500	8750	22,204	17,472	15,011	2775	2184	1876
1000	17,500	44,407	34,943	30,022	5551	4368	3753

(Fig. 17.5c) to dig a 5-m-deep trench, 3.5 m wide along a 300-m length using the small 305-mm bucket (rated capacity = 0.0821 m^3) would have required 13,322 hours excavating at 4.8 m^3/hour (slow rate); 10,483 hours, at 6.1 m^3/hour (average rate); and 9007 hours, at 7.1 m^3/hour (fast rate). It is clear that using a bucket this small was not optimal but may reflect the urgency under which the Syrian Kurds were constructing them, making use of what was available. Examining working hours per day for this same bucket translates to 1665 eight-hour shifts excavating at 4.8 m^3/hour; 1310, at 6.1 m^3/hour; and 1126, at 7.1 m^3/hour. If two eight-hour shifts were run per day, this is 833 days excavating at 4.8 m^3/hour; 655 days, at 6.1 m^3/hour; and 563 days, at 7.1 m^3/hour. Two eight-hour shifts in a single day would have required two excavator operators to sustain the pace of working.

Operating after dusk requires lighting that would have revealed the Syrian Kurdish position to TAF, making it vulnerable to an airstrike or artillery, but if that risk were taken, then operating two ten-hour shifts per day, a total of 666 days would be required for excavating at 4.8 m^3/hour, 524 days for 6.1 m^3/hour and 450 days for 7.1 m^3/hour. These calculations highlight not just the need for skilled excavator operators but also the significance of access to the biggest bucket (Table 17.2) suitable to the task, as well as more than one excavator. These calculations (Table 17.3) highlight the significance of having skilled excavator operators and raises the question as to how many such individuals existed in the autonomous Afrin Region.

Once the trenches were excavated, rebar was installed and tied on the floor (Fig. 17.5b) and then on the walls (Fig. 17.5c) prior to concrete being poured to create the reinforced sides and bottom to the HTs (hardened tunnels). Lastly, the ceiling rebar was tied (Fig. 17.5d component 11) and then concrete poured on it to make a reinforced top to the HT (Fig. 17.6a, b). Costs of single-bar rebar ($0.75/0.3 m based on the 2019 global price) range from $5917 for a 50-m single-bar reinforced CCHT and $35,500 for a 300-m single-bar reinforced length (Bulmer 2021). The total volume of concrete needed to complete two walls, ceiling and floor for a 50-m CCHT, is 315 m^3; for 300-m, 1890 m^3; and for 1000-m, 6300 m^3. The costs of concrete at a global average price at the time of $120/0.76 m^3 range from $49,737 for a 50-m length of tunnel; $298,421 for a 300-m length; and $994,737 for a 1000-m length. At a concrete cost of $200/0.76 m^3, 50 m of CCHT costs $82,895; 300 m, $497,368; and 1000 m, $1.65 million (Bulmer 2021). The use of dimensional analysis to determine the time, materials, volumes and costs needed by the Syrian Kurds to construct CCHTs reveals the large infrastructure investment undertaken using modern construction techniques. The costs, when applied across the construction of trenches, CCHTs and OTs, reveal millions of dollars in expenditure.

Underground Facilities

In addition to C&C techniques, the Syrian Kurds also constructed UGFs as part of the defence around Afrin (Fig. 17.7) using tunnelling techniques to increase overhead protection by increasing the depth below ground. The use of subterranea in Afrin, as well as in Kobane and Manbij (Fig. 17.1) in Rojava (Turkey News 2018b;

Fig. 17.7 (**a**–**c**) Entrances to Syrian Kurdish UGFs in the mountains around Afrin constructed in a chalky limestone. (**a** and **c** modified from NTV 2018, **b** modified from Syria Call 2018). (**d**) Room in a Syrian Kurdish UGF in the mountains around Afrin with 100-m tunnels. (Modified from Syria Call 2018).

Seligman 2019), increased as a direct response to having no air power and needing to avoid detection and increase survivability against munitions used by SGF, TAF, IS, al-Nusra and their affiliates. Entrances to Syrian Kurdish UGFs in the mountains around Afrin (Fig. 17.7a–c) constructed in chalky limestone (Fig. 17.2) show that the spacing between vertical and horizontal rebar is small, indicating weak rock (Fig. 17.7a, b component 1b). Wooden forms need to be added before the concrete pour unless it was to be sprayed on. The floor appears to be concrete (Figs. 17.7a component 2a and 17.7b component 2b). UGFs incorporated design features such as camouflage and concealment, reinforced portals, defensive hard points and thick burster layers (Fig. 17.7a–c), all features of 1914–18 European trench warfare (Doyle 2017) and the 1930s French Maginot Line (Kaufmann et al. 2011). The most sophisticated UGFs had dormitories, hospitals, armouries, kitchens, latrines and command centres complete with CCTV, solar panels, computers, phones, electricity, respirators and ventilation, all of which facilitated underground occupation for long periods. Rooms in one facility (Kar 2018a), likely a command centre, are 100 m long with additional tunnels emerging off them connecting to rooms for offices, dormitories, kitchens, medical centres, weapons and vehicle stores. The dimensions are big enough for Syrian Kurdish forces to store vehicles and artillery. One room has marble tiles on the floor and concrete-reinforced arches (Fig. 17.7d components 6 and 7), possibly designed as an alternate centre of government for the leaders of the Autonomous Region. A large underground hospital was built in Afrin city centre with a 50-m access tunnel (Daily News 2018b).

As with the trenches, OTs and CCHTs, the scale of the UGFs represents significant defensive military work construction projects undertaken by the Syrian Kurds. Images in media reports of UGFs captured by TAF and TFSA during Operation Olive Branch show that many were still under construction (Fig. 17.7a, b, c) but did not reveal how those subterranean spaces had been excavated. Given the size and number of UGFs being constructed across Afrin, the need for the Syrian Kurds to tunnel faster was critical, and moving from hand tools to tunnel machines is a logical progression to meet this necessity. Images and media reports were therefore examined to identify signature tunnelling equipment. The existence of tunnel boring machines (TBMs) being used by the Syrian Kurds was to be expected, given that others had been captured from IS in and around Mosul in 2016 (Bulmer 2019).

Improvised Tunnel-Boring Machines

On 20 March 2018, a series of 400-m Syrian Kurdish tunnels around Afrin were captured by TAF and TFSA (Kar 2018b). One tunnel complex (el Homsi 2019), situated mid-slope in an area of olive grove below CCHTs on the ridge top (Fig. 17.8

Fig. 17.8 (**a**) View of a tunnel entrance in the mountains around Afrin. (**b**) Inside the tunnel entrance are a Bobcat, a BMCH and an ITTBM. (**c**) View of the wheeled part of the BMCH. (**d**) View of the extendable and multiaxial boom-mounted cutting head. (Modified from Nsubuga 2018)

components 7 and 8), contained a Bobcat front loader, a boom-mounted cutting-head machine (BMCH) and a tracked tunnel boring machine (TTBM) (Fig. 17.8 components 10, 11, 12). The ramp down to the tunnel entrance was camouflaged with a sewn disruptive pattern sheet (Fig. 17.8a component 3). Inside the tunnel entrance (Fig. 17.8b), the hard limestone ceiling is unsupported, indicating a strong, stable rock mass (Hoek et al. 2000) that would provide good overhead protection from attacking artillery and airstrikes. The Bobcat, BMCH and TTBM work in a combined manner. The main function of the Bobcat is spoil removal (Fig. 17.8b component 10). The low profile BMCH (Fig. 17.8c component 11) has an extendable boom arm with a multiaxial, rotating, cutting head with teeth and is used to move around a tunnel face (Fig. 17.8d components 11 and 14). It creates a rectangular, arched or trapezoidal tunnel profile (Fig. 17.8b, c, d) and can work in either hard or soft rock (Gagne and Fuerst 2016). The motor on the BMCH is powered by an umbilical cable that runs to a three-phase generator identified outside the tunnel entrance that eliminates engine emissions in the tunnel (Fig. 17.8a, b component 6). The wheeled part of the BMCH (Fig. 17.8c component 11) does not look like standard mining machines and is thus likely improvised. However, the actual boom-mounted cutting head (Fig. 17.8d component 14) is likely to be commercial.

Based on an analysis of images and video, the TTBM is improvised (ITTBM) with a design very similar to ITTBMs captured from IS outside Mosul, which

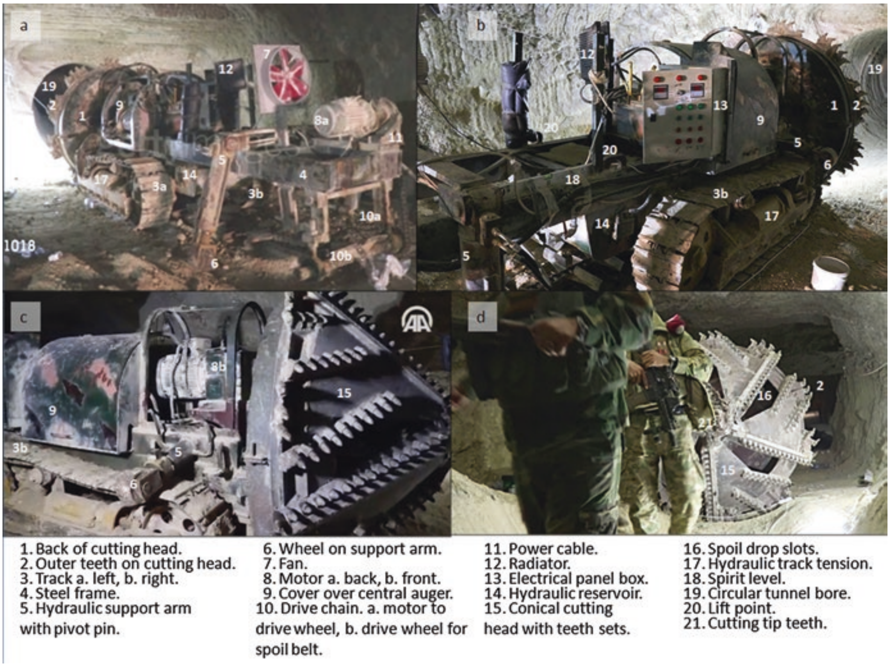

Fig. 17.9 (**a**) Rear left-side view of the ITTBM in situ in a tunnel in Afrin. (**b**) Rear right-side view. (**c**) Forward right-side view. (Modified from Antonopoulos 2018). (**d**) Front view of the cutting head. (Screenshot from Son Kale Twitter.com 2018)

tunnelled in poorly consolidated materials (Bulmer 2019). Design differences reflect improvements making it likely to be more effective in the soft rock geology of Afrin. The existence of the ramp into the tunnel (Fig. 17.8a component 1) shows that the ITTBM was driven to the rock face rather than lowered down a shaft. Electric motors on the ITTBM are powered by an umbilical cable that runs to a three-phase generator outside the tunnel entrance that eliminates engine emissions in the tunnel (Fig. 17.8a–c component 6). The ITTBM bores a circular tunnel (Fig. 17.9a, b component 19) using a conical cutting head (Fig. 17.9c component 15). This shape is a commercially available "Christmas tree'" design with 216 individually replaceable tooth sets that come in sets of five on the cone with 12 sets on the perimeter of the head (Fig. 17.9d component 21).

Using TAF soldiers for scale (Fig. 17.9d), the cutting head radius appears to be approximately 1-m, and an examination of the teeth angles as well as orientation (Fig. 17.9c component 15) shows that the direction of cut rotation is from the operator in a clockwise direction. The nose of the cutting head has four large teeth (Fig. 17.9d component 21) with a central auger running back through the ITTBM. Seven vertical spoil drop slots, each positioned between rows of cutting teeth along the head (Fig. 17.9d component 16), empty the spoil into the central auger. The teeth (Fig. 17.9c component 15) appear to be set up for use in poorly consolidated material and are thus well suited for tunnelling in the soft rocks of Afrin (Fig. 17.2). The design appears less suitable for the greater hardness and higher compressive strengths of the Lower and Upper Cretaceous rocks in the mountains.

The ITTBM is mounted on two metal tracks (Fig. 17.9a components 3a and 3b). There are drive sprockets on either side at the front closest to the cutting head for better traction and control as well as a hydraulic track tension system (Fig. 17.9a, b component 17). Spoil created at the cutting head dropped from a short central auger (Fig. 17.9a component 9) onto a spoil conveyor (Fig. 17.9a components 3a and 3b) that runs to the rear of the ITTBM. The spoil is then moved away by the Bobcat. The auger is chain driven by a motor-powered flywheel (Fig. 17.9a components 10a and 10b). Based on conditions in the tunnel (Fig. 17.8), the spoil would have been dry. There are four hydraulically controlled arms, each with a wheel at the end, that pivot from the frame of the ITTBM (Fig. 17.9a, b, c components 5 and 6). One pair is located just behind the cutting head and the other at the back of the ITTBM. The function of these arms in the horizontal position is to provide lateral stability as the ITTBM advances, controlling for roll and yaw. In the vertical position, they control pitch. A standard builder's spirit level on the right side of the ITTBM (Fig. 17.9b component 18), set horizontally on the steel frame behind the main control box, provides pitch control during tunnelling. The control panel (Fig. 17.9b component 13) has an ignition switch and colour-coded indicator lights that connect to a circuit panel. Two motors, one at the front, which drives the cutting head (Fig. 17.9c component 8b), and one at the back, which drives the spoil conveyor (Fig. 17.9a component 8a), have wiring that runs back from three-phase terminal boxes to the circuit panel. The cover over the central auger is painted in the camouflage pattern of the YPG (Fig. 17.9c component 9).

Table 17.5 Volume (without bulking) and tonnage of spoil generated by the ITTBM with a 1-m radius cutting head over tunnel lengths (*L*) of 25–500 m and the number of dump trucks required for removal. *V* is volume without bulking, and mt is metric tonnes. The tonnage is based on dry coarse sand

	L (m)	*V* (m^3)	Tonnes mt	16 m^3 trucks
(I)TTBM	25	78	125	8
	50	157	251	16
	100	314	502	31
	200	629	1006	39
	300	942	1508	59
	400	1257	2011	79
	500	1571	2514	98

The circular bores (Fig. 17.9a, b, d component 19) are tall enough to walk in and large enough for a small vehicle. The rock mass class (Bieniawski 1976) appears to be I – very good rock - with a rock mass rating of 81–87. This estimate of rock quality is based upon the apparent absence of tunnel support. The geology is ideal tunnelling rock, weak enough to use the ITTBM but strong enough to be self-supporting. Dryness is the key to stability. The tunnel is a clear demonstration of Syrian Kurdish expertise in geology, mining and tunnelling.

Tunnelling Rates

The advance rates for tunnelling by the BMCH at Afrin are unknown, but those from a commercial roadheader MT270 Tunnel Miner (hard-rock conditions), which has a comparable boom-mounted cutting head, can be used to provide a first-order estimate. Used in limestone (Gagne and Fuerst 2016) similar to the hard nummulitic limestones of the Afrin valley, tunnelling rates averaging 8 m/day provide a reasonable estimate for a rate of advance, giving 40 m for a five-day week and 56 m for a seven-day week.

Using a 1-m estimate for the radius of the cutting head on the ITTBM and the 400-m length of one of the tunnels captured on 20 March 2018 (Fig. 17.8), 2011 metric tonnes of spoil would have been generated (Table 17.5). Moving this volume off-site would have required 79 trucks each with a capacity of 16 m^3 (Table 17.5). The Bobcat (Fig. 17.8b component 10) would have been able to take the spoil out of the tunnel for loading. Loading dump trucks would have been a signature activity that TAF air assets would have looked for to detect tunnel construction. Loading at night would have reduced the chances of detection but would still have been detectable to sensors at infrared wavelengths.

As with the advance rates for the BMCH, those for the ITTBM at Afrin (Fig. 17.9) are also unknown, but rates from a Robbins Small Boring Unit with a comparable cutting head and dimensions (Anon. 2017) can be used to provide a first-order estimate. Given the nature of the soft rocks present in Afrin (Fig. 17.2) and at the site of the captured ITTBM (Fig. 17.8), advance rates of 24 m/day for the ITTBM seem

Table 17.6 Rates of boring advance for the ITTBM captured in Afrin based on rates of a Robbins SBU with a comparable 1-m radius cutting head. Volume (without bulking) and tonnage of spoil generation by the ITTBM over lengths (*L*) of 25–500 m and the number of dump trucks required for removal. *V* is volume without bulking; mt is metric tonnes. The tonnage is based on dry coarse sand

Advance rate m/day	Advance rate m/week	Tunnel *L* (m) in 1 year	*V* (m^3)	Tonnes mt	16 m^3 trucks
6	30	1560	4903	7845	306
12	60	3120	9806	15,689	613
18	90	4680	14,709	23,534	919
24	120	6240	19,611	31,378	1226
30	150	7800	24,514	39,223	1532
42.2	211	10,972	34,876	55,802	2180
45	225	11,700	36,771	58,834	2298

realistic (Table 17.6). Using this rate and assuming two ten-hour shifts for each of five days each week, leaving four hour/day for maintenance, it would have taken 23 days to bore a 400-m tunnel. Its effectiveness in hard limestone is uncertain. This first-order estimate shows that although an ITTBM is faster than the BMCH, they have different capabilities that complement each other and provide a very effective combination for tunnelling in hard and soft rocks.

As with the construction of the trenches, OTs and CCHTs, running multiple tunnelling teams at the same time to construct UGFs would have required knowledgeable, skilled and competent project managers to oversee them. The level of training for tunnel workers would be related to the tunnel construction methods. Crews working in a tunnel would have probably endured heat, dust, noise, poor visibility and machine breakage, with constant risks of tunnel collapse, all of which necessitated discipline and teamwork. No evidence has been found that they had to deal with high water flows from the rocks in which they were tunnelling (Figs. 17.8 and 17.9). Images of the tunnel interiors of Syrian Kurdish tunnels captured by TAF (Figs. 17.7, 17.8 and 17.9) indicate that the tunnel face operators were skilled, with the most skilled being the operators of the BMCH and ITTBMs (Figs. 17.8 and 17.9). If these machines were operated in two shifts a day, then two teams of trained operators were required. Where the highly skilled manpower originated is unknown, but thousands of western volunteers brought relevant skills to support the Syrian Kurds (Hall 2019). Based on an examination of the Bobcat, BMCH and ITTBM, a team likely consisted of an operator for each machine, tunnel engineer, mechanic and on-call geologist. In addition, these machines would have needed a robust supply of spares, oils, lubricants and fuel for the generator. Similar to the construction of trenches, OTs and CCHTs, the use of dimensional analysis to determine the time, materials, volumes and costs needed by the Syrian Kurds to tunnel to create UGFs reveals large infrastructure investment undertaken using modern construction techniques. The costs related to creating tunnels and UGFs reveal millions of dollars in expenditure in addition to that on trenches, CCHTs and OTs.

17.5 Fighting in the Mountains

Turkey, having completed the concrete border wall in December of 2017, launched the military incursion Operation Olive Branch across the Syrian border into Afrin on 20 January 2018. The aim was to defeat the Syrian Kurdish forces, which had been fighting IS with the backing of the anti-IS coalitions but whom Turkey now saw again as terrorists. Heavy Turkish shelling and airstrikes forced many Kurdish villagers to flee to natural caves in the mountains. Many of these caves belong to local residents who built their homes at the entrance, incorporating them. Locals took in those fleeing the shelling (Sheikh Ali 2018). TAF combat engineers used armoured tracked excavators (Fig. 17.10a components 1 and 2) with drill attachments (Fig. 17.10a white oval) and large buckets (Fig. 17.10a white dashed oval) at least 914 mm wide (see Table 17.2) to excavate trenches on the limestone slopes of Mount Bursaya and Mount Sakarkaya to assault the Syrian Kurdish defences. Armoured fighting vehicles provided protection as the excavators worked

Fig. 17.10 (**a**) Trench excavated by TAF 10 November 2017 on a limestone slope using armoured tracked excavators. (Modified screenshot from https://www.youtube.com/watch?v=5UajSoNxMwI). (**b**) Syrian Kurdish concrete reinforced cylindrical OT on Mount Sakarkaya destroyed by either an air or artillery strike, revealing the rebar mesh. (Modified from Yeni Safak 2018b). (**c**) Entrance to a Syrian Kurdish CCHT at Mt Bursaya captured by TAF and TFSA. (Modified from Prima News 2018). (**d**) TSFA fighter in a Syrian Kurdish CCHT at Mt Sakarkaya. (Modified from Daily News 2018a)

(Fig. 17.10a component 4). The loose limestone rocks made the going on the slope difficult for infantry (Fig. 17.10a), so once Operation Olive Branch was launched, these trenches were extended to provide protection for TAF and TFSA forces as they advanced up to the Syrian Kurdish fixed trenches, OTs, CCHTs, and UGFs. TAF, a NATO member supported by TFSA, attacked the Syrian Kurdish positions using German-made Leopard2A4 Main Battle Tanks, American-made 203-mm M110A2 and 155-mm M52-Ts self-propelled howitzers, and Turkish-made TR-122 Sakarya multiple launch rocket systems, with airstrikes by American-made, multi-role fighter aircraft F-16C/Ds with American-made AIM 120 advanced medium-range air-to-air missiles, all - monitored in real time by drones. The US military and another NATO member in the CJTF, Germany, watched as the TAF weapon systems bought from them were used against the YPG/SDF/YPJ, their foremost ally in the fight against IS. They monitored but did not intervene to support the Syrian Kurds in Afrin by countering TAF air superiority. This was in part due to the air space deconfliction zone with Russia, since Afrin is west of the Euphrates and in the Russian zone, and the complexity of Turkey being a CJTF member.

At the start of Operation Olive Branch, the primary targets for Turkish airstrikes were Syrian Kurdish OTs, CCHTs and UGFs (Fig. 17.10b–d). Assaulting the rocky mountain terrain proved difficult for TAF armour, but artillery and airstrikes supported infantry fighting to the summits. The use of counter-trenching enabled the infantry to remain protected until they were close enough to climb out and assault the Kurdish defensive positions. This trench warfare was reminiscent of World War I (Jones 2010; Doyle 2017). Against this combined assault, and with no air power, armour or sufficient heavy weapons, the light infantry force of the YPG/SDF/YPJ and its defensive positions were inadequate, and on 28 January 2018, TAF and TFSA captured Mount Bursaya (Fig. 17.10c); Mount Sakarkaya was captured on 1 March 2018 (Fig. 17.10d). The use of combined arms by TAF and TFSA over-matched Syrian Kurdish defensive positions and their light infantry weapon systems. Once these had been captured, TAF and TFSA moved down from the mountains into the Afrin valley and urban spaces.

17.6 Fighting in Urban Spaces

Syrian Kurdish trenches and CCHTs constructed in and around villages, towns and cities in Afrin utilised the existing urban infrastructure, adapting it to create obstacles, blocks, hazards and kill zones. In the city of Afrin, a ditch network (Fig. 17.11a, b component 2), was excavated in the alluvial terrace pebble beds and conglomerates using front-end loaders and excavators (Temizer 2018). The spoil bunds were on the city side of the ditches just inside the main road along the edge of the city (Fig. 17.11b component 2). The 7-m-wide ditches likely served as hasty tank obstacles and were overlooked by high-rise buildings on the edge of the city (Fig. 17.11a, b component 1), enabling defenders to target advancing forces with interlocking fields of fire (Fig. 17.11). Similar to other cities where fighting

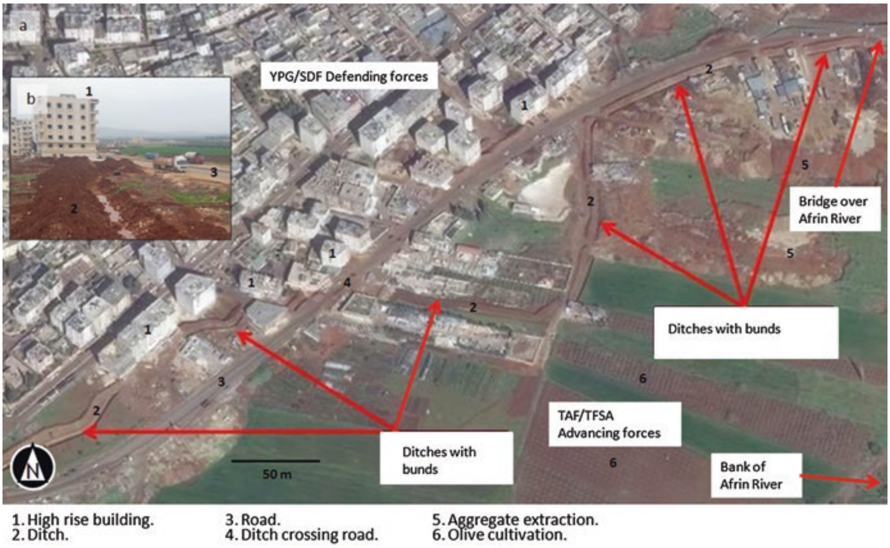

Fig. 17.11 (**a**) Defensive works on the east side of Afrin River in the city of Afrin. (**b**) Ditch and bund on the eastern edge of Afrin city. (Modified from Syria Live Map 2018)

occurred in Syria and Iraq, these buildings were connected by tunnels (Bulmer 2019), allowing defenders to move under protection and without being observed. TAF and TFSA ground forces attacked Syrian Kurdish towns and cities in the Autonomous Afrin Region using the same weapons as were used in the mountains. Again, the US, CJTF militaries and Russia monitored but did not intervene to support the Syrian Kurds. In the city of Afrin, the Afrin River formed a natural obstacle, and the bridge over the river was a critical choke point. But again, the defensive measures and light infantry force of the YPG/SDF/YPJ proved inadequate, and on 18 March 2018, TAF and TFSA captured the city centre of Afrin (Gall and Barnard 2018).

17.7 Conclusions

To meet the threats from the SGF, TAF, and TFSA, as well as from IS, al-Nusra and their affiliates, an extensive programme of military works was undertaken by the Syrian Kurds across the Autonomous Afrin Region as a core part of their military defensive measures. In the mountains, these were constructed between 2016 and 2019 in limestones, sandstones and marls and in valleys in alluvial terraces and conglomerates. These lithologies are very favourable for digging and tunnelling, and the construction incorporated lessons learned from the effects of weapon systems used by TAF, TFSA, SGF, IS, al-Nusra and other terrorist groups. Defensive trenches, OTs, CCHTs and UGFs enabled Syrian Kurdish forces to avoid detection from TAF air assets; provided protection from artillery and air munitions, plus potential chemical fallout; and allowed them to attack, delay and defend against ground forces.

Syrian Kurdish military works in the mountains defended the main high ground on the border with Turkey. In the valleys, these were constructed to defend the villages, towns and cities in Afrin, making effective use of the geology. They demonstrate that the Syrian Kurds possessed geological, engineering, construction and tunnelling knowledge. The scale of their military works programme and demand for plant as well as materials would have necessitated co-ordination with the wider economic activity in the Rojava as well as in Iraqi Kurdistan. This mirrors the IS tunnel programme in Iraq that was co-ordinated across the “caliphate” (Bulmer 2019). Undertaking the military works at the same time that the YPG/SDF/YPJ was fighting IS, al-Nusra, SGF, TAF and TSFA required knowledgeable, skilled and competent project managers to complete them. Costs calculated for the military works undertaken by the Syrian Kurds constructing defensive trenches, OTs, CCHTs and UGFs add up to 100s of millions of dollars. Such finance was not being generated within the Autonomous Afrin Region, indicating outside financial support that Turkish media attributed to the United States and France.

In the construction of defensive trenches, OTs, CCHTs, and UGFs, moving from hand tools to machines, can be seen as a logical progression driven by the need for the Syrian Kurds to create concealed and survivable spaces from TAF air and artillery strikes. Similar to IS, the Syrian Kurds demonstrated engineering and mechanical skills, including making weapons and up-armoured vehicles (Bulmer 2019). These, when combined with geological knowledge, enabled them to fabricate tunnel boring machines. Therefore, the capture of Syrian Kurdish tunnelling machines should not have been unexpected, given the extensive use of tunnelling in both Syria and Iraq by IS, al-Nusra their affiliates and anti-Assad rebels, all of whom lacked air power and needed protection and concealment to improve their survivability. Based on similarities in the designs of tunnel boring machines captured from IS in Mosul, rebels in Douma (Muraselon 2018) and YPG/SDF/YPJ in Afrin, it is possible that fabrication expertise moved between different rebel and terrorist groups across Syria and Iraq. Although not on the scale of IS, the Syrian Kurds could purchase parts and expertise from around the world (CAR 2016), either on the open or black market.

Trenches, OT, CCHTs and UGFs enabled the YPG/SDF/YPJ and unarmed Syrian Kurdish civilians to survive underground for long periods against air and artillery strikes. Fighters were able to defend from hardened positions and to surface behind, in flanking positions, or amongst advancing enemy forces. This proved effective in an insurgency, but during Operation Olive Branch, when fighting a modern military, this was insufficient to overcome TAF and TSFA combined airstrikes, artillery, armour, combat engineering and ground assaults. Unlike the Peshmerga and Iraqi forces that fought IS in Iraq (Bulmer 2019), TAF and TFSA were equipped and trained to find, secure and deny or destroy trenches, OTs, CCHTs and UGFs. Images from Turkish media of positions captured by TAF and TSFA during Operation Olive Branch show that many were still under construction. The light infantry force of the YPG/SDF/YPJ and designs of fixed military works could not be modified fast enough to effectively defend against TAF and TSFA.

Trenching and tunnelling expertise that came into the Syrian uprising from conflicts in Gaza and Lebanon (Cohen et al. 2017; Bulmer 2019) has been enhanced by IS, al-Nusra and affiliates in Iraq and Syria and by anti-Assad forces, as well as by Syrian Kurds, as the conflict has continued. Inputs have also come from Russian, Syrian, Iranian, Turkish and US militaries, as well as from commercial construction and tunnelling machines already in Syria but manufactured around the globe that were claimed by combatants for their use. It should be anticipated that military works and TBMs plus BMCHs, and the accompanying expertise, will continue to develop in current and future battlespaces.

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References

Ahval News (2018) Foreign cement company providing material for YPG fortifications. 10 February. https://ahvalnews.com/afrin/foreign-cement-company-providing-material-ypg-fortifications-islamist-newspaper. Accessed 25 July 2020

Akazawa T, Nishiaki Y (2017) The Palaeolithic cultural sequence of Dederiyeh Cave, Syria. In: Enzel Y, Bar-Yosef O (eds) Quaternary of the Levant: Environments, Climate Change, and Humans. Cambridge University Press, Cambridge, p 307–314

Anon. (2017) Project categories: small boring unit. The Robbins Company. http://www.therobbinscompany.com/project-category/small-boring-unit/. Accessed 25 July 2020

ARA News (2015) Nusra militants shell Kurdish areas in Syria's Afrin, Kurds respond. http://aranews.net/files/2015/08/nusra-militants-shell-kurdish-areas-in-syrias-afrin-kurds-respond/. Accessed 8 December 2019

Antonopoulos P (2018) Uncovered: Tunnel diggers in Afrin. 21 March. https://fort-russ.com/2018/03/uncovered-salafist-tunnel-diggers-in-east-ghouta/. See note found in Afrin, not East Ghouta. Accessed 26 August 2020

BBC News (2017) Syria war: US says flares fired at Russian jets. 14 December. https://www.bbc.com/news/world-middle-east-42358150. Accessed 21 July 2020.

BBC News (2019) Trump makes way for Turkey operation against Kurds in Syria. 7 October. https://www.bbc.co.uk/news/world-middle-east-49956698. Accessed 25 July 2020

Bieniawski ZT (1976) Rock mass classification in rock engineering. In: Bieniawski ZT (ed) Symposium Proceedings of Exploration for Rock Engineering, 1:97–106

Bulmer MH (2019) Geological considerations of contemporary military tunnelling near Mosul, Northern Iraq. In: Rose EPF, Ehlen J, Lawrence UL (eds) Military aspects of geology: fortification, excavation and terrain evaluation. Geological Society of London Special Publication 473, p 241-265

Bulmer MH (2021) Using EO to understand the significance of cement production infrastructure in the Syrian conflict. In: Singhroy V (ed) Advances in Remote Sensing Infrastructure Monitoring. Springer Remote Sensing/Photogrammetry, Springer Nature, Switzerland. Chapter 14, https://doi.org/10.1007/978-3-030-59109-0_14, p307-354

Chohan K (2018) Turkey installs security system on Syria's Afrin border. 19 January. https://en.zamanalwsl.net/news/article/32355/. Accessed 25 July 2020

Cohen R, Johnson DE, Thaler DE et al. (2017) From cast lead to protective edge. RAND Corporation, Santa Monica, CA

Conflict Armament Research (CAR) (2016) Tracing the supply of components used in Islamic State IEDs. Evidence from a 20-month investigation in Iraq and Syria. Conflict Armament Research February. http://www.conflictarm.com/reports/tracing-the-supply-of-components-used-in-islamic-state-ieds. Accessed 25 July 2020

Court MC, Hond CD (2020) Is this the end of Rojave? The Nation 18 February. https://www.the-nation.com/article/world/rojava-kurds-syria/. Accessed 25 July 2020

Daily News (2018a) Turkish army clears YPG tunnels, bunkers in Syria's Afrin. 29 January. https://www.hurriyetdailynews.com/turkish-army-clears-ypg-tunnels-bunkers-in-syrias-afrin-126459. Accessed 25 July 2020

Daily News (2018b) Turkish army discovers secret tunnel leading to underground hospital wing in Afrin. 25 March. http://www.hurriyetdailynews.com/turkish-army-discovers-secret-tunnel-leading-to-underground-hospital-wing-in-afrin-129259. Accessed 25 July 2020

Daily Sabah (2016) Turkey-Syria border wall to be completed by mid-2017, Defense Minister says. 2 November. https://www.dailysabah.com/turkey/2016/11/02/turkey-syria-border-wall-to-be-completed-by-mid-2017-defense-minister-says. Accessed 25 July 2020

Defence Turkey (2018) Considerable increase in Turkey's budget for Defence 2018. Issue 79. https://www.defenceturkey.com/en/content/considerable-increase-in-turkey-s-2018-budget-for-defense-2897. Accessed 28 July 2020

Doyle P (2017) Disputed earth: geology and trench warfare on the Western Front 1914-1918. Unicorn Publishing Group, London

Financial Times (2018) Moody's downgrades Turkeys debt. 8 March. https://www.ft.com/content/18004182-2263-11e8-9a70-08f71579130. Accessed 27 July 2020

Firat News (2014) Democratic autonomy has declared in Afrin canton in Rojava. Mednuce.com 29 January. https://web.archive.org/web/20180706022020/http:/mednuce.com/en/haber/2344/democratic-autonomy-has-declared-in-afrin-canton-in-rojava.html. Accessed 25 July 2020

Gagne B, Fuerst T (2016) Tunnel boring below Montreal: a case study of urban tunnelling through hard limestone. In: Tunnel Association of Canada, 2016 Annual Conference Capitalizing on underground infrastructure, 17-18 October. https://35r8vq1qfmha1cecht1675qy-wpengine.netdna-ssl.com/wp-content/uploads/2014/08/9_Rosemont_TAC2016.pdf. Accessed 25 July 2020

Gall C (2018) 72 Turkish jets bomb U.S.-Backed Kurdish Militias in Syria. The New York Times 20 January. https://www.nytimes.com/2018/01/20/world/middleeast/turkey-bombs-kurds-syria.html. Accessed 25 July 2020

Gall C, Barnard A (2018) Syrian rebels, backed by Turkey, seize control of Afrin. The New York Times 18 March. https://www.nytimes.com/2018/03/18/world/middleeast/afrin-turkey-syria.html. Accessed 25 July 2020

Geological map of NW Syria (SMI) (1964) 1:500,000. Sheet 1. Syrian Ministry of Industry, Department of Geological and Mineral Research. V.O. Technoexport, Moscow.

Gulf News (2019) What is next for Syria's Kurds? 7 January. https://gulfnews.com/world/mena/what-is-next-for-syrias-kurds-1.61228298. Accessed 12 July 2020

Gurses E, Butler D (2018) U.S. funding of the Syrian YPG militia will impact Turkey's decisions: Erdogan. Reuters 13 February. https://www.reuters.com/article/us-mideast-crisis-syria-turkey-usa/u-s-funding-of-syrian-ypg-militia-will-impact-turkeys-decisions-erdogan-idUSKBN1FX0XP. Accessed 25 July 2020

Hall R (2019) They came to Syria to fight ISIS. Now they want to stay. The Independent 25 February. https://www.independent.co.uk/news/world/middle-east/isis-syria-soldiers-kurds-ypg-turkey-britain-a8793081.html. Accessed 25 July 2020

Hamshaw Thomas H (1920) Geographical reconnaissance by aeroplane photography, with special reference to the work done on the Palestine Front. The Geographical Journal, 55(5):349-370

Hoek E, Kaiser PK, Bawden WF (2000) Support of underground excavations in hard rock. Mining Research Directorate, Ontario, Canada

Home Office (2021) Proscribed terrorist groups or organisations. 16 July. https://www.gov.uk/government/publications/proscribed-terror-groups-or-organisations-2. Accessed 18 July 2021.

el Homsi H (2019) Anadolu Agency captures YPG/PKK tunnels in Syria's Afrin. 20 March. https://www.gettyimages.com/detail/video/tunnels-used-by-ypg-pkk-terrorists-were-found-in-syrias-news-footage/936161018. Accessed 25 July 2020

Jones S (2010) Underground warfare 1914-1918. Pen & Sword Books Ltd, South Yorkshire, England

Kar N (2018a) Huge underground base of terrorists found in Afrin. Anadolu Agency 15 April. https://www.aa.com.tr/en/middle-east/huge-underground-base-of-terrorists-found-in-afrin/11189.77. Last Accessed 27 December 2019

Kar N (2018b) Free Syrian Army locates tunnels used by terrorists in Syria's Afrin Region. Anadolu Agency 20 March. https://www.aa.com.tr/en/middle-east/anadolu-agency-films-ypg-pkk-tunnels-in-syria-s-afrin/1094483. Accessed 25 July 2020

Kaufmann JE, Kaufmann HW, Jankovic-Potocnik A et al. (2011) The Maginot Line history and guide. Pen & Sword Books Ltd, South Yorkshire, England

McKernan B (2019) Turkey launches military operation in northern Syria. The Guardian 9 October. https://www.theguardian.com/world/2019/oct/09/turkey-launches-military-operation-in-northern-syria-erdogan. Accessed 25 July 2020

Muraselon (2018) Syrian forces seize large tunnel driller, machines for manufacturing mortars in S Damascus. 24 May. https://en.muraselon.com/post/42520/Syrian-forces-seize-large-tunnel-driller-machines-for-manufacturing-mortars-in-S-Damascus. Accessed 29 July 2020

Nsubuga J (2018) Secret 'terror tunnel' found in Syria after coalition forces take control of city. Metro News 20 March. https://metro.co.uk/2018/03/20/secret-terror-tunnel-found-syria-coalition-forces-take-control-city-7402389/. Accessed 29 July 2020

NTV (2018) Afrin'de bin teröristi alacak yer altı karargahı bulundu. 15 April. https://www.ntv.com.tr/galeri/turkiye/afrinde-bin-teroristi-alacak-yer-alti-karargahi-bulundu,eDOTFR31EEqhcutVCy51rA. Accessed 26 August 2020

Oweis KY, Sezer C (2012) Syrian refugees brave mines, machineguns to reach Turkish sanctuary. Reuters 6 April. https://www.reuters.com/article/syria-turkey-border/syria-refugees-brave-mines-machineguns-to-reach-turkish-sanctuary-idUSL6E8F60LY20120406. Accessed 25 July 2020

Ozturk B (2018) Turkey's Great Wall and its archenemy on the Syrian border. SETA Foundation 24 January. https://www.setav.org/en/turkeys-great-wall-and-its-archenemy-on-the-syrian-border/. Accessed 25 July 2020

Phillips D & Berkell K (2016) The case for delisting the PKK as a Foreign Terrorist Organisation. 11 February. https://www.lawfareblog.com/case-delisting-pkk-foreign-terrorist-organization (accessed 17 May 2021).

Prima News (2018) Operation Olive Branch to Afrin. 29 January. https://www.primanews.org/2018/01/operation-olive-branch-afrin-2/. Accessed 9 December 2019

Seligman L (2019) Kurdish fighters mount counterattack using network of tunnels. Foreign Policy 15 October. https://foreignpolicy.com/2019/10/15/syrian-kurdish-fighters-mount-counterattack-turkish-sdf-network-of-tunnels/. Accessed 25 July 2020

Sheikh Ali H (2018) Mountain caves become safe haven for Syrian Kurds fleeing Turkish military operation in Afrin. http://www.xinhuanet.com/english/2018-02/09/c_136962920.htm. Accessed 25 July 2020

Son Kale (2018) March 20. https://twitter.com/SonKaleTurkiye2/status/976070402727399424?ref_src=twsrc%5Etfw%7Ctwcamp%5Etweetembed%7Ctwterm%5E976074178402095104%7Ctwgr%5E&ref_url=https%3A%2F%2Fwww.redditmedia.com%2Fmed

iaembed%2F85si1f%3Fresponsive%3Dtrueis_nightmode%3Dfalse. Accessed 26 August 2020. Original longer version https://www.youtube.com/watch?v=4bXz1-u0eN no longer available.
Southfront.org (2018) Permanent defenses of Kurdish forces captured by Turkish Army on Buysata Mount (Videos, Photos). Maps and Conflict Database. https://maps.southfront.org/permanent-defenses-of-kurdish-forces-captured-by-turkish-army-on-bursaya-mount-videos-photos/. Accessed 25 July 2020
Syria Call (2018) Tremendous tunnel and headquarters in Afrin dug by YPG militias. 16 April. https://nedaa-sy.com/en/news/5530. Accessed 28 July 2020
Syria Live Map (2018) AA released map of the defense systems of YPG in Syria's Afrin during Olive Branch Op. 7 March. https://syria.liveuamap.com/en/2018/7-march-aa-released-map-of-the-defense-systems-of-ypg-in. Accessed 25 July 2020
Takvim (2018). Afrin'de teröristlerin gizlendiği labirent tüneller bulundu. 7 February. https://www.takvim.com.tr/galeri/guncel/afrinde-teroristlerin-gizlendigi-labirent-tuneller-bulundu/10. Accessed 25 July 2020
Temizer S (2018) YPG/PKK trench prevents civilians from leaving Afrin. Anadolu Agency 14 March. https://www.aa.com.tr/en/middle-east/ypg-pkk-trenches-prevent-civilians-from-leaving-afrin/1088961. Accessed 25 July 2020
The Brussels Times (2020) Belgian government defies ruling of its Supreme Court on PKK. 30 January. https://www.brusselstimes.com/belgium/92787/belgian-government-defies-ruling-of-its-supreme-court-on-pkk/ (accessed 25 July 2020).
TRT World (2017) What is behind Turkey's plan in East Afrin? 3 July https://www.trtworld.com/mea/turkeys-operation-in-east-afrin-392760. Accessed 25 July 2020
Turkey News (2016) Security wall partially completed on Turkey's Syrian border. News Service 19 October. https://www.yenisafak.com/en/gundem/security-wall-partially-completed-on-turkeys-syrian-border-2550353. Last accessed 29 December 2019
Turkey News (2018a) PKK digs trenches, tunnels in futile attempt to escape Turkey's Afrin Op. News Service 1 March. https://www.yenisafak.com/en/world/pkk-digs-trenches-tunnels-in-futile-attempt-to-escape-turkeys-afrin-op-3135794. Accessed 25 July 2020
Turkey News (2018b) Terrorist YPG/PKK fortifying tunnels in Manbij, Syria. 27 December. https://www.yenisafak.com/en/news/terrorist-ypg-pkk-fortifying-tunnels-in-manbij-syria-3470257. Accessed 25 July 2020
Vatan (2018) Afrin'den son dakika görüntüleri geldi! 28 February. http://www.gazetevatan.com/afrin-den-son-goruntuler-geldi-1146901-gundem/. Accessed 28 July 2020
World Bank (2017) The toll of war. The economic and social consequences of the conflict in Syria. The World Bank Group, Washington, DC
Yeni Safak (2018a) US-backed PKK/PYD terrorists use 'double-deck' tunnels in Afrin. 14 February. https://www.yenisafak.com/en/world/us-backed-pkk-pyd-terrorists-use-double-deck-tunnels-in-afrin-3104672. Accessed 28 July 2020
Yeni Safak (2018b) PKK dug trenches, tunnels in futile attempt to escape Turkey's Afrin Op. 1 March. https://www.yenisafak.com/en/world/pkk-digs-trenches-tunnels-in-futile-attempt-to-escape-turkeys-afrin-op-3135794. Accessed 28 July 2020
Yeni Safak (2018c) Terror groups construct tunnels in Afrin with European funds, support. 5 March. https://www.yenisafak.com/en/world/terror-groups-construct-tunnels-in-afrin-with-european-funds-support-3136060. Accessed 28 July 2020

Chapter 18
Current Operational Challenges and Innovative Approaches for Military Geo-Services from an Austrian Perspective

Friedrich Teichmann

Contents

Abstract Current operational challenges for military geo-providers may be grouped into eight trends. (1) Globalization results in a basically global area of interest for nations and, for interoperability between units, requires appropriate standards and metadata for geo-products. (2) High Speed requires a quick decision-making process and rapid geo-support, including a fast innovation cycle for technological advancements. (3) With Modern Warfare, additional relevant geo-factors are emerging in connection with new threats, like asymmetric or cyber warfare. (4) Budget Control involves cost control for the geo-services and demands innovative solutions and synergies between the actors in the field. (5) Digitalization includes the transformation from analogue to digital, with new opportunities like simulations and virtual reality, and future developments in machine to machine, Big Data, and data exploitation, especially with artificial intelligence. (6) Geo and Space should establish a close connection, because satellite navigation and Position-Navigation-Timing solutions are critical geo-services; in addition, Earth observation/remote sensing is a key enabler for modern geo-products. (7) The Information Society and network-enabled capabilities merge people, information, and technology. (8) The High Complexity of modern missions requires a comprehensive approach, including cooperation and partnerships, and promotes pooling and sharing.

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18.1 Introduction

Operational requirements in the field of military geosciences are quite challenging to define. There are several key factors to consider, including state-of-the art of technical options versus actual operational requirements, fast innovation cycles, complex scenarios, specialized service providers, and security/classification. In this chapter, some critical aspects are addressed which could result in discussions between the relevant stake holders being initiated. In addition, initial recommendations or ideas for future activities with respect to innovative approaches are provided.

The interaction between a customer/consumer and his/her producer/service provider is fundamentally different between the open civilian world and the government domain, especially in the security services. The civilian relationship between the customer and his/her producer, for example, a map manufacturer is primarily governed by market forces, such as supply and demand, and is usually expressed as a certain price for the product or a fee. The government world, however, is primarily triggered by tasks and orders and is not regulated chiefly by the associated costs (this relates to the fundamental non-question in the security domain: How much money is our security or are our lives worth?).

Based on the constitution of the Federal Republic of Austria (BV-G 2015, para 79), the tasks for the Armed Forces are as follows:

> The primary objective of the Austrian Armed Forces is the military defense of Austria. Other tasks include defending constitutional institutions, preserving law and order and providing humanitarian aid in case of natural catastrophes. Because of Austria's membership in the United Nations, the European Union and the Partnership for Peace (PfP) Program, foreign assignments have notably increased in importance.

The geo-service provider for national security or defense forces must therefore act as an enabler for the troops and deliver the products necessary to support the scenarios defined by the legal framework and not follow supply and demand. International missions, such as those under the NATO, EU, or UN umbrella, have an additional complexity for operational requirements because interoperability in the field between national forces is a *must* for mission success.

Over recent decades, homogenization of the various national military requirements for operations, including “Geo,” has been conducted on the national level and also by both NATO and the EU (the European Defense Agency and the European Union Military Staff), but the current centerpieces are still national perspectives. Therefore, the current operational challenges for military Geo will be discussed from an Austrian perspective herein. A general analysis of the majority of other European or Western countries, however, would most likely result in comparable conclusions. In addition, Geo will be treated very broadly, including all fields related to the geoscience world and that contribute to a Recognized Environmental Picture (REP) for the mission area. NATO defines an REP as a quality-controlled information base for geospatial, meteorological, and oceanographic data (GEOMETOC) (Teufert and Trabelsi 2006; Joos 2012).

The primary current trends affecting Geo in military operations and the challenges of the national service providers are summarized herein. The discussion is mainly based on the extensive experience of the author, whose thoughts are primarily personal and does not represent the national opinion.

18.2 Current Trends

As a result of detailed observations and interdepartmental and international discussions, the following eight general trends were determined to highly influence today's military operational environment and affect especially the geo-providers (Table 18.1): Globalization, High Speed, Modern Warfare, Budget Control, Digitalization, Geo and Space, Information Society and High Complexity. However, this list is not complete, and every new development might add an additional factor or trend, or the importance between these factors might shift over time or from mission to mission.

Table 18.1 Current critical trends and developments, and their primary effects for the geo-provider for security or military missions[a]. These factors can also be interpreted as obstacles that need to be overcome in order to achieve information superiority in the field

Trend	Relevant effects and factors, especially for the geo-service providers
Globalization	Global area of interest, interoperability, standards, metadata
High Speed	Quick decision-making and fast innovation cycle
Modern Warfare	New threats (asymmetric or hybrid warfare, cyber), special legal aspects
Budget Control	Cost control and innovative solutions, synergies
Digitalization	Analogue to digital, simulations, virtual reality, machine to machine (M2M), Big Data operations, data exploitation, especially artificial intelligence (AI)
Geo and Space	Global Navigation Satellite Systems (GNSS) and Position-Navigation-Timing (PNT) services, earth observation/remote sensing
Information Society	Internet, social media, network-enabled capabilities (NEC), digital natives (persons very familiar with the digital world, who grow up in a digital society)
High Complexity	Comprehensive approach, cooperation and partnerships, pooling and sharing, additional actors in the mission

[a]These factors are based on the author's observations and experience and, due to a lack of relevant publication, could not be cross-referenced

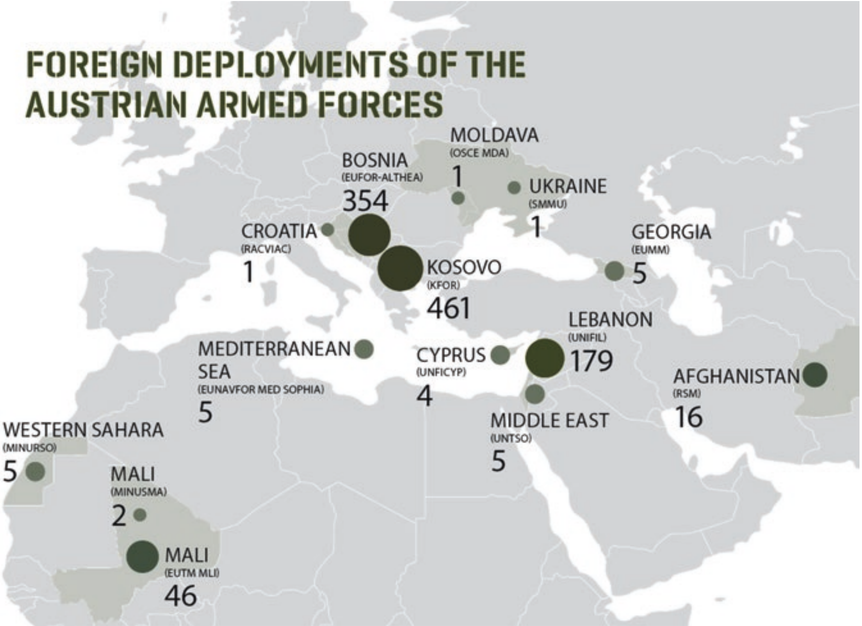

Fig. 18.1 Foreign deployments of the Austrian Armed Forces as of December 2019. (http://www.bundesheer.at/english/introle/introle.shtml; Austrian Armed Forces photograph, © Austrian Armed Forces 2020. Used with permission from Press Department/Ministry of Defence, Vienna, Austria)

18.2.1 Globalization

In order to illustrate the effects of Globalization, the current mission areas of the Austrian Armed Forces are shown in Fig. 18.1. These mission areas in Europe, Africa, and Asia are examples of the ongoing international commitment of nations in addition to the tasks within the national territory.

Even a small country like Austria is currently deploying its soldiers to approximately 15–20 different mission areas (Fig. 18.1) in addition to various national tasks (for example, humanitarian assistance, disaster relief, and border security), for which geo-products need to be provided. The national or military geo-service provider has a tremendous task to deliver the standard packages necessary (Fig. 18.2a) for supporting units in the field, including maps and qualified geospatial data with regard to weapons and navigation systems for all these regions. The result is a current geo-requirement to deliver products and data for an almost global area of interest, and not just one or two predetermined areas.

In addition, since most missions are combined (i.e., they involve more than one nation), interoperability is vital. Therefore, it is of upmost importance, that all necessary standards (e.g., geo-datum, coordinate system, map projections) are satisfied. This also includes the complex field of metadata, especially for digital services, which needs to be addressed and homogenized. Agreeing on common standards, for

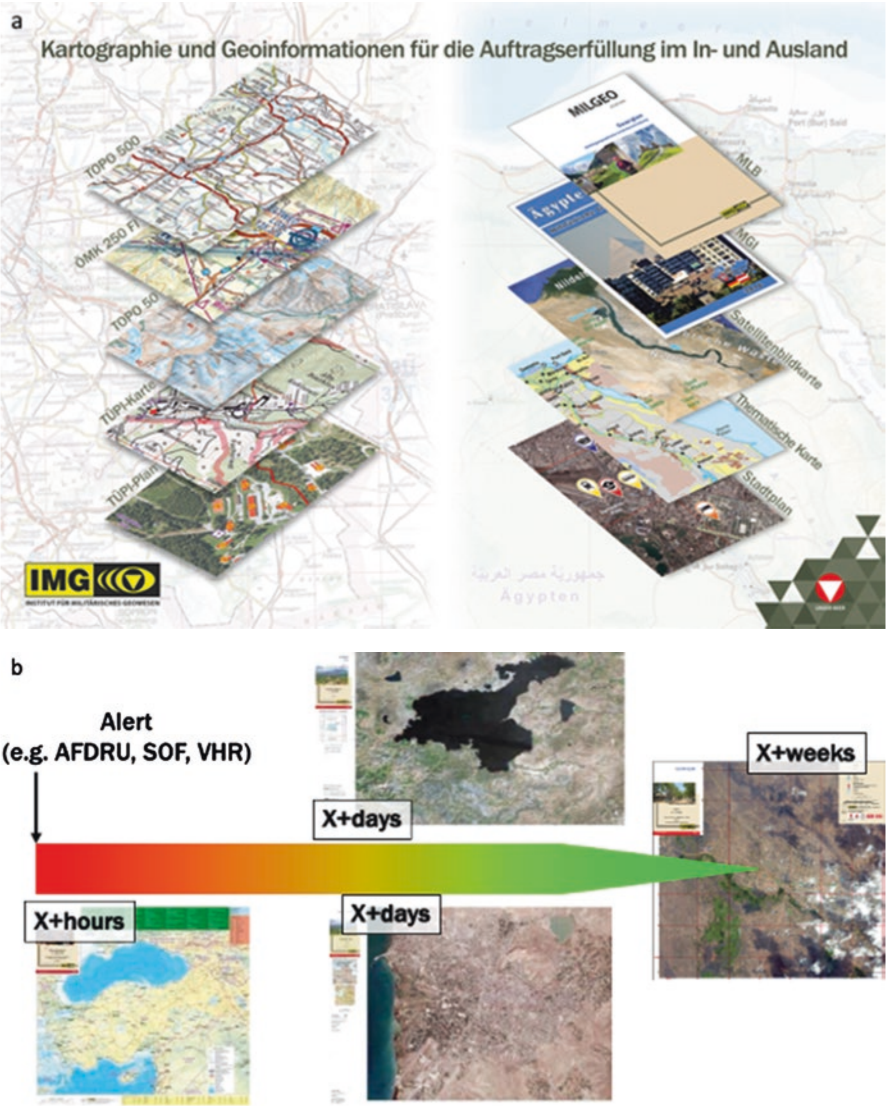

Fig. 18.2 (**a**) The standard geo-support package for current operations (example of the product range of the Institut für Militarisches Geowesen (IMG), Bundesheer (Geospatial Institute, Austrian Armed Forces)). (**b**) Sequence for geo-support in time-critical missions such as evacuation procedures or disaster relief (regional overview products available within hours, high-resolution and mission-specific products within the next days, and continuous improvement especially of the relevant theme layers)

example, in geo-services, requires, among others, clear vision, the willingness to make compromises, and detailed technical knowledge and also time – standardization working groups, especially international ones, require long-term perspectives.

The consequence of Globalization for the geo-providers is the need to deliver products and data almost worldwide. This must be done in standardized formats that will support the interoperability between nations participating in combined missions.

18.2.2 High Speed

The almost global reach of current operations is multiplied by the required quick decision-making cycle at all levels. In order to be successful in the operations, speed is of the essence. Therefore, geo-support also needs to deliver, ideally in real time, all the necessary data to provide and produce the REP, thereby contributing to information superiority in the field. The portfolio of the geo-providers needs to include especially (1) standardized maps and charts (Fig. 18.2a), (2) critical geo-information for the mission area, like country books (Fig. 18.2a), (3) specialized products like high-resolution satellite imagery, multi-spectral assessment analysis, and intuitive 3D models, and (4) digital geo-data for all weapons and navigation systems used in the mission or by platforms operating in the mission area (e.g., an Unmanned Aerial Vehicle (UAV)). Specific products need to be available within hours of the alert or the request for information (RFI) and then be supplemented with more detailed materials like very high-resolution maps or satellite imagery analysis within the next hours or days (Fig. 18.2b).

Not only is the decision cycle turning faster and faster, but also technological innovations in GIS and geospatial production processes are taking place very rapidly. Due to strong cross-links to IT, ongoing technological advancements in GIS, Web-Service delivery, or GEOMETOC data for complex systems are developing, according to Moore's Law, i.e., the capability for duplication within every few years. This includes not only enhanced hardware and software for the geo-producers, but also new products like 3D, web applications, and multispectral analysis. Special care must be given to this fast innovation cycle in order to deliver state-of-the-art products and therefore to contribute to information superiority on the battlefield or during disaster relief missions.

The consequence for geo-providers with regard to High Speed is the need to be able to deliver very quickly, resulting in a, perhaps additional, rapid production line with a very high readiness status and the ability to integrate fast technical innovations into the provider's organization. This requires a very close tie to academia and R&D.

18.2.3 Modern Warfare

The last two decades have seen a tremendous change in operational scenarios. From the simple friend versus foe of past times, modern scenarios include a whole set of various actors with potentially changing alliances. This starts with an elastic or unclear entry threshold for the conflict by implementing, among others, hybrid warfare[1] elements, where the clear distinctions between pressure and threat, security measures, information campaigning, manipulation, or armed conflict are absent. Hybrid warfare, as found in many ongoing current conflicts, is especially difficult to handle in the cyber and information domains, which are both closely related to the activities of the modern geo-service providers.

Although the various aspects of modern hybrid warfare are intensely debated academically as well as operationally (Dengg and Schurian 2016), the demand for correct geo-related information for modern warfare is ever increasing. One of the key contributions from Geo is the complete or holistic REP for the mission. The modern demands for the REP are not limited to the standard geo-factors like terrain or the status of the lines of communication (LOC); there are a myriad of other factors in hybrid warfare, some with very strong links to Geo that need to be taken into account. The Cold War tank battle scenario required the support of a limited and structured set of geo-factors like terrain and elevation, LOC for air, roads or rail, and climate and vegetation. The proper delivery of the necessary geo-products for these older, standard, military scenarios was tested and trained for in yearly exercises and optimized in numerous lessons learned/lessons identified processes. Just as the focus moves away from the traditional battle tank scenario, geo-support nowadays also has to evolve to support a holistic security view such as the status of the critical internet providers, monitoring of public geo-info portals (e.g., Google Maps or Open Street Map (OSM)), or the location of the high-speed connection hubs. One of the most demanding and challenging tasks for the current national geo-providers is identifying these new geo-factors, for which modern products and services need to be created and delivered to support information superiority.

The consequences for the geo-providers with regard to Modern Warfare are the need to plan, collect, process and exploit, analyze and produce and, finally, disseminate and integrate not only the hard-core geo-factors related to physical combat, but also the countless and constantly changing additional geo-factors influencing the security perspectives of a society related, for example, to propaganda, manipulation, or misinformation must be addressed.

18.2.4 Budget Control

As noted previously, national security geo-service providers are not primarily governed by market forces like supply and demand (and the resulting fees or prices), but by tasks, orders, and scenarios. Resources, especially budget and personnel, however, are some of the most important factors for proper service provision. At least three aspects must be addressed within a budget paragraph to identify options

[1] Hybrid warfare is a combination of conventional warfare, irregular warfare, and cyber warfare along with other methods of influence such as fake news.

for efficient service delivery: (1) resource versus target/mission versus service, (2) innovative solutions, and (3) synergies.

Resource vs. target/mission vs. service A fair and constructive analysis with an agreed outcome is needed within the organization to specify which resources, e.g., budget or personnel, will be allocated for the geo-service provider. This needs to be in alignment with the target and mission, as well as the expected service the geo-provider is ordered to deliver. If there is a mismatch between the expected services and the resources assigned to the provider, then this needs to be addressed immediately and the consequences, such as missing maps or the unavailability of geo-data for the weapons or navigation systems (due to of insufficient geo-resources), communicated transparently.

Innovative solutions New technological developments also provide opportunities for innovative solutions. This requires not only the knowledge and identification of alternative solutions but also flexibility within the entire organization. Thinking "out of the box" is usually quite difficult for hierarchical organizations like military or security forces. A culture for open mindedness, like interaction with academia or innovation hubs, needs to be promoted in order to follow this path.

Synergies Parallel to the evolution of our military scenarios, the group of consumers of geo-services has evolved from a military-focused to a more holistic security-aspect-encompassing security domain. It is therefore logical to look for cooperation between the different organizations involved in a mission as well as to identify synergies (e.g., data exchange or production) among the various geo-service providers.

The consequence of Budget Control for the geo-providers is the need to establish a suitable resource versus target/mission versus service plan. This plan should be paired with open minds for innovative solutions and synergies between different players.

18.2.5 Digitalization

Digitalization is a very broad topic; therefore, the discussion here will be on aspects pertaining directly to geo-providers. Over the last two decades, we have seen an evolution from an analogue portfolio of the geo-service providers, followed by a combination of digital and analogue products and services, and finally, a shift in priorities toward digital functionality. This is driven, among others, by our NEC vision and implementation in weapons systems and in the military operating environment. The old world of analogue maps, however, cannot be eliminated or substituted for by digital services, because power outages or partial blackouts are among the most dangerous threats to society. Therefore, geo-service providers need to take special care to work and deliver in both analogue and digital worlds.

With the advent of digitalization and numerous novel systems (e.g., weapons and navigation), new customers (see Sects. 18.2.3, 18.2.7, and 18.2.8) who have interest in geo-data are emerging almost daily. These systems range from hand-held devices like tablets or "Battle Field Management Systems" to autonomous systems and end with complex systems of systems. The core system for Command and Control (C2), the C2 Information System (C2IS), fuses the terrain and environment (REP) with all relevant functional area services (FAS), for example, logistics. They thereby produce a digital image of the battlefield. In IT service terms, the REP is combined with all FAS within the C2IS and delivers a common operational picture (COP) as a key enabler for information superiority. The modern geo-provider is not only responsible for delivering the REP into the C2IS but also most FAS demands, either directly via the REP or indirectly via designated geo-data such as terrain or LOC (e.g., roads). Between the central C2IS and all the supplementary digital weapons and navigation systems, no modern military or security systems can function without Geo!

Especially interesting for security applications are the current developments in 3D visualization and virtual reality (Fig. 18.3). Together with powerful simulation programs, completely new possibilities and opportunities are opening up. These are especially relevant for intelligence analysis, mission planning, and optimized execution. Modern simulation systems are among the most challenging topics for the geo-providers because of the ongoing high demand for environmental data.

The currently most interesting advances among digital trends are M2M arrangements, "Big Data," and data exploitation algorithms, especially when combined with AI or similar approaches. For each of these new developments, qualified geo-data is at the core of the analysis tools. Examples include satellite imagery or routing-capable vector data. In particular, the combination of Big Data and artificial intelligence tools will have great impact on various fields in the near future, keeping in mind the vast amount of satellite imagery that is currently collected.

The consequence for the geo-providers with regard to the trend Digitalization is the need to support both the analogue and digital worlds with the required services. Focus will continue to increase in the digital area by providing geo-data for C2IS, FAS, and numerous weapons, navigation, and simulation systems. New developments in Big Data, AI, and M2M might result in very powerful combinations for delivering unequalled geo-services but will also require additional resources to exploit.

18.2.6 Geo and Space

The dependence of the civilian society, military forces, and security operations on space-based technologies has increased over the last decades. In this sense, space technologies have been identified as critical also for Europe, and in order to close the gap and develop the necessary technologies, the EU Framework Program for Research and Innovation Horizon 2020 issued the "SPACE-10-TEC-2020 Technologies for European Non-Dependence and Competitiveness" (ESA 2019).

Fig. 18.3 Current developments in 3D geospatial models and virtual reality (VR). (**a**) Combination of screenshots from four different 3D models from tactical to urban warfare scenarios; the html format with limited GIS analysis functions (zoom, rotation, line of sight, or distance measuring) enables simple viewing (no additional software needed) in any standard browser. (**b**) Screenshots from within a virtual reality system: scenarios range from terrain to urban setting to buildings; the VR-controller can be seen at the bottom of the images and various active graphical inserts or analyses produced during the VR-session can be included; this tool is especially useful for terrain or geospatial evaluation and training

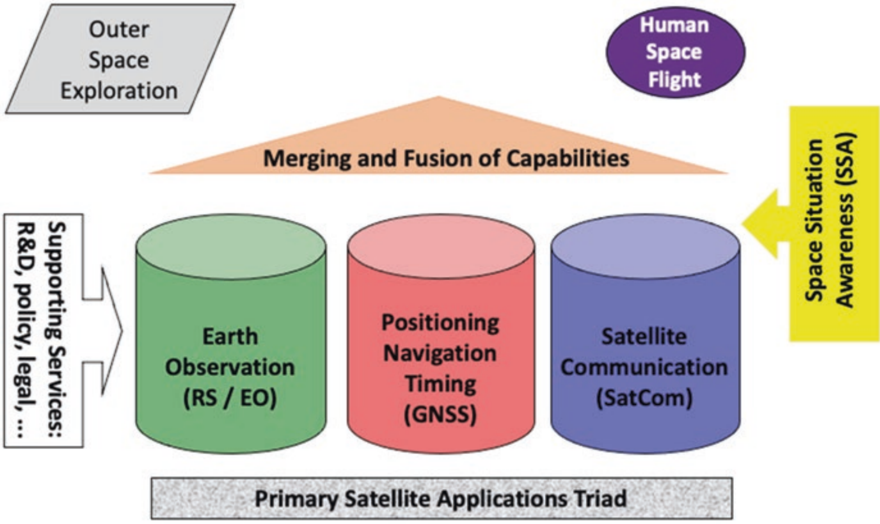

Fig. 18.4 The primary satellite application triad is earth observation, satellite navigation, and satellite communication. Merging and fusion capabilities provide added value to the primary triad service. New developments in space situational awareness (NATO 2015) might extend the REP into space by adding space weather. Outer space exploration and human space flight are added to complete the picture of the space portfolio

The logical development for this reliance of the military on space technologies led, among others, to the establishment of the US Space Force (Anon. 2020a) in 2019, with France creating a new Space Command (Commandement de l'espace) in 2020 (Parly 2020) and NATO declaring space, alongside air, land, sea, and the cyber world, as a new warfighting domain: "We have declared space an operational domain for NATO, recognizing its importance in keeping us safe and tackling security challenges, while upholding international law" (NATO 2020).

Particularly interesting for all geo-providers are the GNSS and PNT services, as well as services with regard to earth observation and remote sensing (Fig. 18.4). As discussed above, a key data source for numerous geo-products or services is satellite imagery in the visible range as well as data from RADAR/SAR sensors. Contrary to UAV or aerial photography, where access to airspace over the area of interest is needed, satellites have the advantage of "freedom of movement" and therefore can operate over closed territories. Just as with many other innovations, satellite-based remote sensing possibilities have increased enormously over the last few years. More and more companies and image providers have launched modern sensors in the sky, and these sensors deliver an ever-increasing quality and quantity of images. The four standard remote sensing resolutions – spatial, spectral, radiometric, and temporal – describe the quality of the image or service. Spatial resolutions are currently pushed, even for commercially available data, below the meter range (e.g., www.maxar.com, www.digitalglobe.com); spectral wavelengths include very interesting new bands for multispectral analysis (combinations of images from different

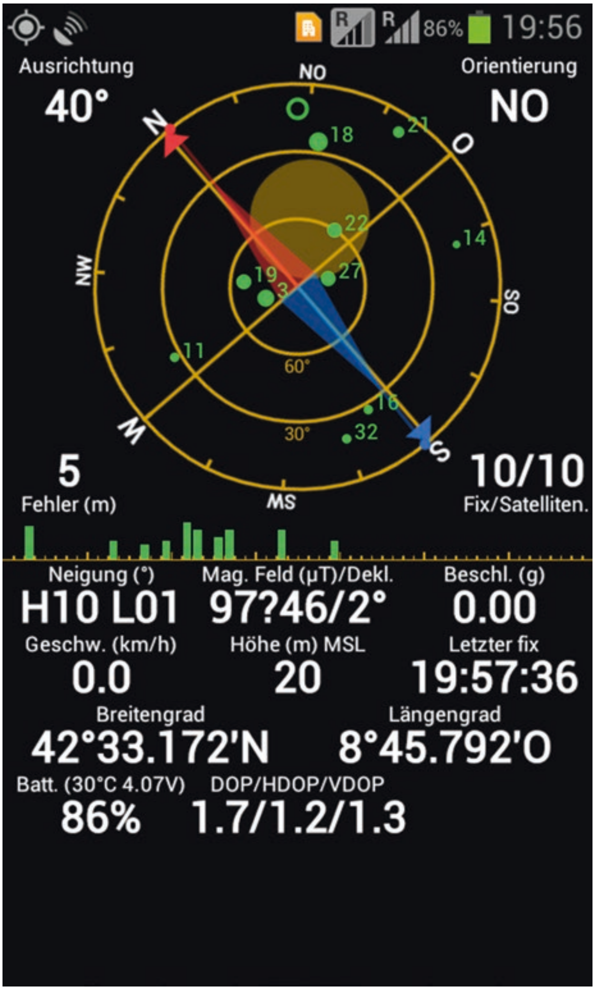

Fig. 18.5 Screenshot of a GNSS Android application, showing various satellite positions as well as the calculated coordinate solution (degrees North and East) with various parameters like geographic orientation, position calculation error, or signal strength

wavelengths); radiometric resolutions allow detailed classification; and the multi-constellations (satellites in complementary orbits) currently being implemented would potentially allow almost continuous real-time coverage.

Situated between Geo and electronic warfare is the specialty field of PNT, provided primarily by satellite navigation systems (Fig. 18.5). Due to worldwide availability, fairly cheap implementation and being very cost-effective at user level, the penetration and dissemination of satellite-based PNT, especially provided by the US

GPS, are extremely high in both the civilian and military worlds. Special care needs to be applied to safeguard our critical PNT solutions against inadvertent attacks such as frequency interference or offensive adversary actions like jamming and spoofing (e.g., Kuusniemi 2012; Intertanko 2019; Anon. 2020b; Ofcom 2020).

The consequence for the geo-providers with regard to the factor Geo and Space is that a closer tie between these two fields is needed, because satellite imagery is a key geo-data provider, and satellite navigation for PNT is a key enabler and a critical geo-service for most missions.

18.2.7 Information Society

Today's information-oriented society, with the most prominent exponents being the internet and social media, also has had great effect on how geo-providers need to deliver their data and products. Open source (OS) data or "open" services for Geo (e.g., Google Maps, Bing, OSM and Wikipedia, to name just a few) combined with fast and immediate access lead to a competing knowledge base, particularly in the geo-world, that is freely available for everyone. However, OS data/services have serious disadvantages compared to the services delivered by the professional military/security geo-providers: they lack scenario-oriented standardizations and mission-specific designs and quality, but even more significant, there are deficiencies in confidentiality, integrity, availability, and qualify control of the data. This distinction might not always be obvious and needs to be strongly promoted for every critical activity. However, the information-oriented society also provides opportunities for new developments. Crowd sourcing (e.g., for geo-products, Map Action, the humanitarian mapping charity (https://mapaction.org/)) is a very interesting option, where, in the best of both worlds, supervised quality assurance by a professional agent is brought together with the drive and energy of volunteer corps.

In the security sphere, the concept of NEC (Alberts et al. 2010) tries to match people, information, and technology. For example:

> The main objective of the NNEC programme, illustrated by the slogan "Share to Win", is to initiate a culture change that begins with people. Interacting with each other and sharing information will lead to better situational awareness and faster decision making, which ultimately saves lives, resources and improves collaboration between nations. (Anon. n.d.)

One final thought on information security and a younger generation, the digital natives, is that it might not be enough for the military geo-providers to deliver perfect maps and charts to all units if the knowledge of how to read these maps is limited in a generation growing up exclusively with navigation apps. Geo-providers might need to pay close attention to the average analogue map reading skills of their new customers, who are growing up in an almost completely digital world.

The consequence for the geo-providers with regard to Information Society is analogous to that of risk management. Certain factors are an opportunity, like crowd sourcing; others are high-risk developments, such as a parallel and uncontrollable information hub, including Geo.

18.2.8 High Complexity

One key difference between modern scenarios and the anticipated tank battles from the Cold War is a contemporary comprehensive approach and the current extensive cooperation and partnerships. This obviously leads to pooling and sharing of tasks between the additional stake holders and players involved in the mission. However, pooling and sharing only works if all elements take on part of the burden and do not overload one partner with tasks while the others just consume! As discussed under Globalization and Information Society, geo-providers need to adapt their products to be useful for all relevant players and not just for the armed forces. This might lead to the need for a new layout/content on the maps, additional grid or coordinate systems, new modes for distribution or delivery or changing the style or the legend on the products. Furthermore, the geo-services provided to the mission might have to be broadened or deepened to include additional topics or layers to cover all RFIs.

The consequence for the geo-providers with regard to High Complexity is analogous to that of Information Society. Certain factors provide opportunities, like pooling and sharing; others, such as a complex, novel set of consumers of geo-services are of high risk.

18.3 Conclusion

Eight different trends (Table 18.1) describe the primary current operational challenges for military Geo and innovative approaches. These eight aspects can be grouped into three clusters: (1) interoperability and cooperation, (2) technical and engineering, and (3) business and management and need to be in synchronization with the strategic planning.

Interoperability and cooperation Combined missions and effect-based operations demand a high level of interoperability. Geo-support is at the core of C2 and the COP; therefore, "operating off the same map" and delivering an REP are of critical importance for interoperability and mission success. This can be supported through the integration of all geo-branches (e.g., geography, cartography, geology, morphology, petrology, glaciology, hydrology, and also the three larger subject areas of Geo, Met, and Geophysics).

Technical and engineering Globalization and digitalization result in faster, worldwide, and higher resolution requirements for geo-providers, a new set of products (e.g., spatial point clouds from laser scanning or 3D visualization and virtual reality), and a close link to space technologies, which includes navigation warfare. If geo-services are carried out comprehensively and follow modern trends, a major step toward information superiority is achieved. However, the side effect of these new products is not only a massive increase in cyber threats against production lines and distribution networks but also directly to services like Geo-Web or GNSS.

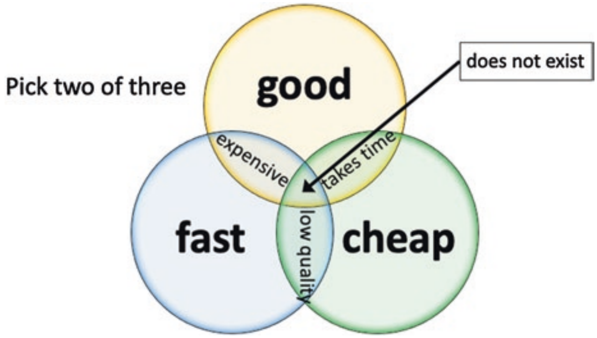

Fig. 18.6 The magic triangle addresses the key business aspects in a very simplified aspect: only a combination of two is possible; hence, a combination of good, fast, and cheap aspects is impossible (see also https://wagnercompanies.com and http://www.pyragraph.com)

Business and management New requirements and modern products from the geo-providers will involve additional resources, e.g., manpower and budget, which need to be addressed during service planning. One potential measure is a detailed resource versus target/mission versus service process (Fig. 18.6).

The proper delivery of geo-support for security and military missions has experienced substantial change in recent decades, merging analogue and digital components with know-how, and is currently subjected to and affected by a variety of global trends and developments. Geo-providers' support and expertise in data handling and management, use of appropriate security measures, and ability to adapt to meet the needs (both known and perhaps yet to be known) of the consumer are critical for mission success on any level. Innovative and interesting new approaches make it possible to master dynamic, even multi-dimensional, Geo data, providing the possibility to handle complex situations.

References

Alberts DS, Huber RK, Moffat J (2010) NATO NEC C2 Maturity Model. Center for Advanced Concepts and Technology for DoD Command and Control Research Program, Arlington, VA. http://dodccrp.org/files/N2C2M2_web_optimized.pdf. Accessed 1 September 2020

Anon. (2020a) United States Space Force. Military Advantage. https://www.military.com/space-force. Accessed 1 September 2020

Anon. (2020b) Information about GPS jamming. https://www.gps.gov/spectrum/jamming/ Accessed 27 October 2020

Anon (n.d.) NATO Network Enabled Capability. https://www.nato.int/cps/en/natohq/topics_54644.htm?selectedLocale=fr. Accessed 27 October 2020

Dengg A, Schurian M (2016) Networked insecurity - hybrid threats in the 21st century. Landesverteidigungsakademie/Institut für Friedenssicherung und Konfliktmanagement, Vienna. http://www.bundesheer.at/wissen-forschung/publikationen/publikation.php?id=799. Accessed 1 September 2020

European Space Agency (ESA) (2019) Horizon 2020 SPACE-10-TEC-2020 Technologies for European Non-Dependence and Competitiveness. https://ec.europa.eu/research/participants/data/ref/h2020/other/guides_for_applicants/h2020-supp-info-space-10-18-20_en.pdf. Accessed 27 October 2020

Federal Chancellery (B-VG) (2015) Federal Constitutional Law. Vienna. https://www.ris.bka.gv.at/Dokument.wxe?ResultFunctionToken=5a77e635-ed0d-444a-b10c-d604eba0d28c&Position=1&SkipToDocumentPage=True&Abfrage=Erv&Titel=&Quelle=&ImRisSeitVonDatum=&ImRisSeitBisDatum=&ImRisSeit=Undefined&ResultPageSize=100&Suchworte=federal+constitution&Dokumentnummer=ERV_1930_1. Accessed 1 September 2020

Intertanko (2019) Jamming and spoofing of global navigation and satellite systems (GNSS). https://www.maritimeglobalsecurity.org/media/1043/2019-jamming-spoofing-of-gnss.pdf. Accessed 1 September 2020

Joos G (2012) GIS in Defense. In: Kresse W, Danko DM (eds) Springer Handbook of Geographic Information. Springer-Verlag, Berlin, p 821-833

Kuusniemi H (2012) Effects of GNSS jammers and potential mitigation approaches. http://www.unoosa.org/documents/pdf/psa/activities/2012/un-latvia/ppt/3-14.pdf. Accessed 27 October 2020

North Atlantic Treaty Organizaion (NATO) (2015) NATO Network Enabled Capability. https://www.nato.int/cps/en/natolive/topics_54644.htm. Accessed 1 September 2020

North Atlantic Treaty Organization (NATO) (2020) NATO's approach to space. https://www.nato.int/cps/en/natohq/topics_175419.htm. Accessed 27 October 2020

Office of Communications (Ofcom) (2020) GPS jamming exercises. https://www.ofcom.org.uk/spectrum/information/gps-jamming-exercises. Accessed 27 October 2020

Parly F (2020) Communiqué_Florence Parly acte la création du Commandement de l'espace au sein de l'Armée de l'air. https://www.defense.gouv.fr/salle-de-presse/communiques/communique_florence-parly-acte-la-creation-du-commandement-de-l-espace-au-sein-de-l-armee-de-l-air. Accessed 27 October 2020

Teufert JF, Trabelsi M (2006) Development of NATO's recognized environmental Picture. In: Carapeza EM (ed) Proceedings of the SPIE vol 620. Sensors, and Command. Control, Communications, and Intelligence (C31) Technologies for Homeland Security and Homeland Defense V. https://doi.org/10.1117/12.669131. Accessed 1 September 2020

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Elena Dai Prà, Nicola Gabellieri, and Matteo Boschian Bailo

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The original version of this chapter was inadvertently published with author name discrepancies. The authorship of this chapter has been updated as "Elena Dai Prà, Nicola Gabellieri, and Matteo Boschian Bailo".

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Index

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