Chapter 14
Military Activities: Warfare and Defence

Zoltán Ilyés

Abstract Human landforms created for the purposes of defence include defence lines, fortifications, etc. and have preventive or protective roles and were mostly built in peacetime in a planned way. They are based on strategic concepts of war conduct, reflecting contemporary technical standards. On the other hand, wars also bear significant direct geomorphologic impacts: warfare actions often result in degraded areas. The impacts of bombs, mines and grenades produce negative and positive landforms of various sizes, reflecting the scale, destroying power and ballistic features of the explosive. Their persistence and visibility depend on the physical conditions (soil and bedrock, climate, vegetation, relief and type and intensity of land use). Examples are provided for historical defence structures (earthworks, defence walls, medieval ramparts and fortresses), landscape transformations during World Wars I and II as well as the geomorphic impacts of modern wars and nuclear tests.

Keywords Defence constructions · Fortresses · Trenches · Battlefields · Nuclear weapons

14.1 Classification of Landforms of Warfare Origin

Anthropogenic landforms deriving from warfare and defence are usually classified into two major groups according to their formation, development and function. On the one hand, facilities for the protection of strategic points, villages, towns and regions (ramparts, fortification lines, earth mottes, military roads and air bases, etc.) are distinguished as man-made landforms for the purpose of defence. Defence lines, fortifications, etc. have preventive or protective roles and were mostly built in

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peacetime in a planned way. Their construction was based on systematically defined strategic concepts of war conduct, reflecting contemporary technical standards. On the other hand, degraded areas often result from warfare actions as significant direct geomorphologic impacts. The impacts of bombs, mines and grenades produce smaller or larger negative and positive landforms reflecting the scale, destroying power and ballistic features of the explosive. Their persistence and visibility depend on the physical conditions (soil and bedrock, climate, vegetation, relief and type and intensity of land use). Explosions, especially in high mountains, can trigger various mass movements including rockfalls. Moving large amounts of ammunition and technical tools by human or animal power or by machines for military actions involves a range of semi-natural processes. (According to Mortensen (1954/1955), semi-natural processes spring from conditions previously created by human action and follow natural laws over a long period of time. In this respect, it is similar to natural geomorphic evolution, only triggered and maintained by human impact. A similar interpretation is voiced by Szabó (1993).) As a result of treading, for instance, linear microforms develop; mass movement processes are occasionally triggered in arid or semiarid areas; aeolian action locally intensifies (Nir 1983). During warfare actions, damage is done to certain technical structures such as railway embankments, roads, tunnels, dams, barrages and channels. After clearing away the ruins of war and piling the debris, major rubble heaps were formed all over Europe.

Surface alterations taking place at military training grounds cannot be referred into either of the above groups, as they are undoubtedly planned and localised; however, during practising ‘real’ but imitated military actions affecting a relatively small area, renew man-made landforms continuously (Fehn 1997).

The distinction and classification of anthropogenic landscape elements of military origin are aggravated by the fact that they are mostly combined with other engineering structures. In medieval times ramparts and early earth mottes were constructed by combining pile-works or earth-filled drag-structures; the construction of rock fortifications also demanded the transport of significant amounts of rocks and earth; ramparts were usually supported by stone and brick-works. In the 20th century, most bunkers and fortress lines were built of reinforced concrete; however, for creating their final form remarkable earthworks were carried out: large amounts of earth were piled up on their top or along their walls, steep slopes were created, tank-traps and moats were lined with concrete. Consequently, to obtain an overall picture on man-made landforms with military-defence functions, research methods and documentation techniques from disciplines like the history of arts and architecture, conservation of historical monuments and archaeology should be applied.

Cultural geography traditionally interpreted landscape as a ‘palimpsest’ and intended to explore, date and assess the contributions made in various times to the present-day cultural landscape. (A palimpsest is a manuscript from which former writings were scraped out and re-written once or repeatedly. Earlier writings preserved in details and in poor quality can be made visible and read by applying special techniques.) The palimpsest metaphor, in general, neatly refers to the historical evolution and morphogenetic approach to cultural landscapes as well as the reconstruction opportunities of cultural landscape history ‘layer by layer’ (Hard 1973). The studied historical remnants are preserved in rather diverse functions, dimensions and quality, both in time and space. Anthropogenic geomorphological research significantly contributes to such studies traditionally (Hard 1973; Schlüter 1926). Elements related to defence, border security and military strategy are apparent in a higher density in cultural landscapes, commonly – and sometimes unreasonably – referred into *military, defence or march landscape* types (Erdősi 1969 after Bondarchuk). Such landscapes or landscape sections can be regarded as a kind of a ‘military palimpsest’.

Anthropogenic geomorphology can play a major role in the identification and inventory of remnants, severely damaged and hardly recognisable (see aerial archaeology). Another topic covered is the classification of blasted bunkers, ruined defence facilities (often disregarded in academic studies). The sphere of competency of anthropogenic geomorphology also has to be clarified in this respect. A solution may be a regulation introduced in Germany where ruined structures as well as their traces in microtopography are protected as archaeological sites and underground historical monuments (Bodendenkmal).

14.2 The largest Defence Line: The Great Wall of China

The Great Wall of China built for more than 2,000 years is the world’s largest anthropogenic structure for its length and mass. It has a length of 7,240 km, ranging from the coasts to the east of Beijing and in the north-west to Gansu Province, sometimes in a number of parallel lines. Some of its sections around Lake Lop-Nor have been recently discovered, and its signal-towers can be traced to Kashgar where it secured the former Silk Road. The main wall section is 2,400 km long. Data on the construction of the first section of the Great Wall of China are available from the period between 1100 and 223 B.C. An important phase of construction began between 221 and 207 B.C., under the rule of the Qin Dynasty when the area had to be protected from nomads attacking from the north – primarily against the Xiongnu tribes. Wall sections surrounding Beijing were erected of burnt brick and ashlar stones during the Ming Dynasty between 1368 and 1644 against the Mongols, following the crests of mountain ridges. The gap between walls was filled up with earth, stones and limestone onto which 4–5 layers of bricks were placed. Although some wall sections have been restored since the beginning of the communist era (1949), considerable amounts are still in poor condition. The Wall is often quarried for stones for constructions in the nearby villages; great amounts of stone are also used for road surfacing.

The Great Wall was built in various dimensions, by various techniques and from various building materials. However, a trapeze-shaped cross-section is apparent almost everywhere. To increase efficiency, along some sections outer trenches and ramparts were made. Around Beijing, the walls are 4–8 m wide and 7–8 m high, and watch-towers 12 m in height were erected at a few 100 m intervals. According to estimations, ca. 25,000 watch-towers were built along the Great Wall of China and communication was provided by further 15,000 signal-towers.

So-called earth mottes were built of loam (loess or clay); in more humid regions they were almost entirely erased by erosion. In the western sections, the wall was constructed by overlapping reed and tamarisk branches, as well as sand and gravel, followed by the strong compaction of these layers. Along some sections, loam, in order to improve its stability, was mixed with straw and rice. Facing sporadic rains and deflation, the walls are still 3 m high and 4 m wide at some locations after 2,000 years.

14.3 Defence in the Roman Empire: Limes and Earth Ramparts

In addition Late Bronze Age and Iron Age *earth mottes*, *ramparts* and the *rectangular Celtic earthworks*, defence constructions of the Roman Empire are also significant geomorphological features. Even the Roman legions participating in conquests established march-camps and temporary command posts fenced round with palisades. To secure the stabilised empire and hinterland necessary for further conquests, *fortified camps* (castrae, castellae) and watch-towers were established that were part of the limes, i.e. the centrally planned defence line of the Roman Empire. These military camps, mostly rectangular in shape and facing the enemy with their shorter side, were supported by trenches and palisades.

From a geomorphologic point of view, ditches and mounds along the *limes* are the most significant. One of the most spectacular in Europe, also part of the UNESCO World Heritage is the limes in Germany, morphologically well visible at many locations. The best preserved sections of this limes, 584 km in length, with about 1,000 watch-towers and 100 castellae protecting Upper Germany and Raetia from German attacks, are found in the Taunus Hills and along the northern border of Wetterau (Fig. 14.1). Here, the limes functioned as the border between settlements during the Middle Ages, thus they were further deepened and maintained for the protection of the given territories.

Hadrian's Wall, erected between 122 and 128 A.D. against the Picts of Scotland, is 120 km in length, and located near the border between Scotland and England. The *Antonine Wall* to the north between the Firth of Forth and the Firth of Clyde was built of stones and peat in 142 A.D.

Csörsz' Trench (at some locations, referred to as Devil's Trench) in the Great Hungarian Plain was built by the Sarmatians initiated by Emperor Constantine with help by the Roman Empire between 322 and 332 A.D. The trenches are 2–4 m deep and 5–9 m wide, were made by the Sarmatians. Embankments were erected with 7–10 m basal width and 2.5–3 m height. They include, at many locations, up to 4 quasi-parallel rampart lines running in a distance of 3–15 km from each other, surrounding the Great Hungarian Plain from the north and the east in a total length of about 550 km. It protects an area of approximately 60,000 km^2 protected (Fig. 14.2). To the development of the Csörsz' Trench, ca. 15 million m^3 earth had to

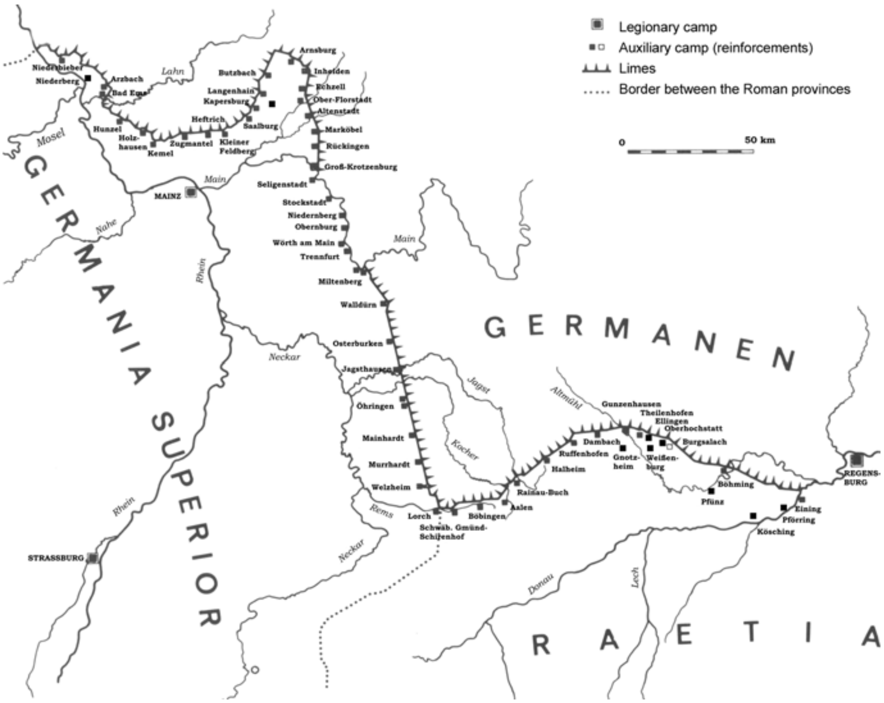

Fig. 14.1 Reconstruction of the limes in Germany (source: http://www.die-roemer-online.de/index.html?/militaer/limes/limes.html)

be removed. In some places, the watercourses were also incorporated in the defence system (Frisnyák 1988; Marjai 1965).

14.4 Medieval Ramparts and Fortresses

Medieval times witnessed the continuation of the construction of earth ramparts relevant for anthropogenic geomorphology. A remarkable monument is the earthworks of *Offa′s Dyke*, 20 m wide and 2.5 m high, constructed along the boundary of the Kingdom of Mercia in England and Wales in the 8th century. Of the many Medieval ramparts and earth fortifications found in the Carpathian Basin, the *earth motte of Szabolcs* (Plate 14.1), a former administrative centre, is outstanding regarding both its dimensions and significance. To construct the ramparts of this earth motte, irregularly triangle-shaped with a length of nearly 800 m and a height of 15–20 m, but even of 25–30 m at some sections, a vast amount of timber was used. Its present volume is estimated to be 326,000 m^3 (Frisnyák 1990).

Rock castles, fortresses, citadels, watch-towers, stone walls and their ruins from the Middle Ages and the Modern Age are traditionally studied by experts of the protection of historical monuments and archaeology, among the elements of the built

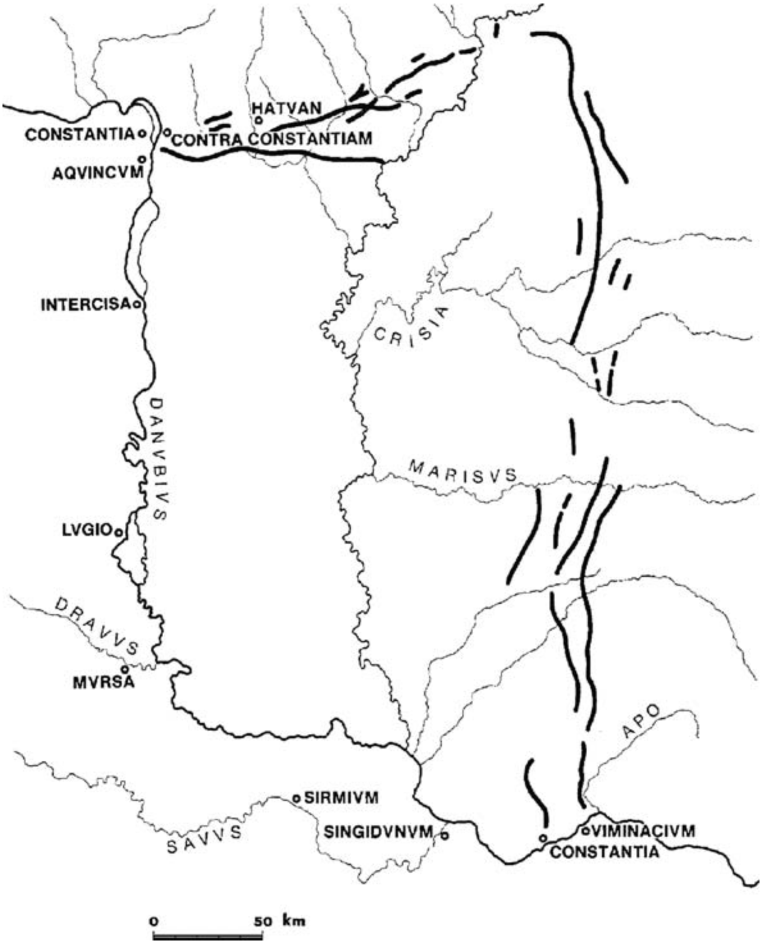

Fig. 14.2 Rampart systems in the Great Hungarian Plain in the 3rd and 4th centuries A.D. (Visy 1989)

cultural landscape. The study of mounds with the ruins of such structures, accompanying excavation landforms rampart systems and earth mottes are also within the sphere of study of anthropogenic geomorphology.

14.5 Earthworks in the Modern Age

From the point of view of anthropogenic geomorphology, the various *earthworks* of *the Modern Age* are also challenging. The primary military function of earthworks in the Modern Age was to shield against bullets. According to the directions of the enemy's fire-power, various designs were in use for earth entrenchments (e.g. epaulement, traverse, rear). The ramparts were made up by the gun post,

Plate 14.1 The earth motte of Szabolcs (source: http://jam.nyirbone.hu/)

the inner trench, the outer trench and the glacis (Fig. 14.3). Apparently, not all of these were entirely constructed as the structural complexity of the ramparts was influenced by the military situation and the time available. The identification of the original forms is made more complicated by ensuing geomorphic processes.

Redouts are 4–5-sided embanked ramparts giving protection against the fire of more powerful cannons. Their size depends on the power of besiegers and the number of cannons; they were usually constructed for 1–2 companies of infantry and 4–8 field cannons (Plate 14.2).

The most impressive example of the fortress architecture in the Low Countries is the Fortress of *Bourtange* (Plate 14.3) near Groningen. This fortification system constructed of earth exclusively was built during the Eighty Years' War, between 1580 and 1593 to the order of the Prince of Orange to isolate Groningen occupied by the Spanish. In front of the broad moat, a low dike (faussebraie) was erected; it was supported by a number of external ramparts (crowns), three-sided corner bastions /horn as well.

The most famous and productive planner of fortifications was *Marshall* Sébastien le Prestre de *Vauban* (1633–1707) of France, using the innovations of the previous centuries in defence systems being the most complex and diverse, geometrically precisely composed and the most adjusted to the geographical conditions. The best known among his 300 fortresses in France, is the *Neuf Brisach* (Neubreisach) in Alsace built between 1699 and 1703.

Among the earthworks of historical Hungary of great strategic importance, the *fortification system of Komárom* (Komarno) is worth of special attention. Of the Medieval and Early Modern Age fortresses reconstructed during the 19th century,

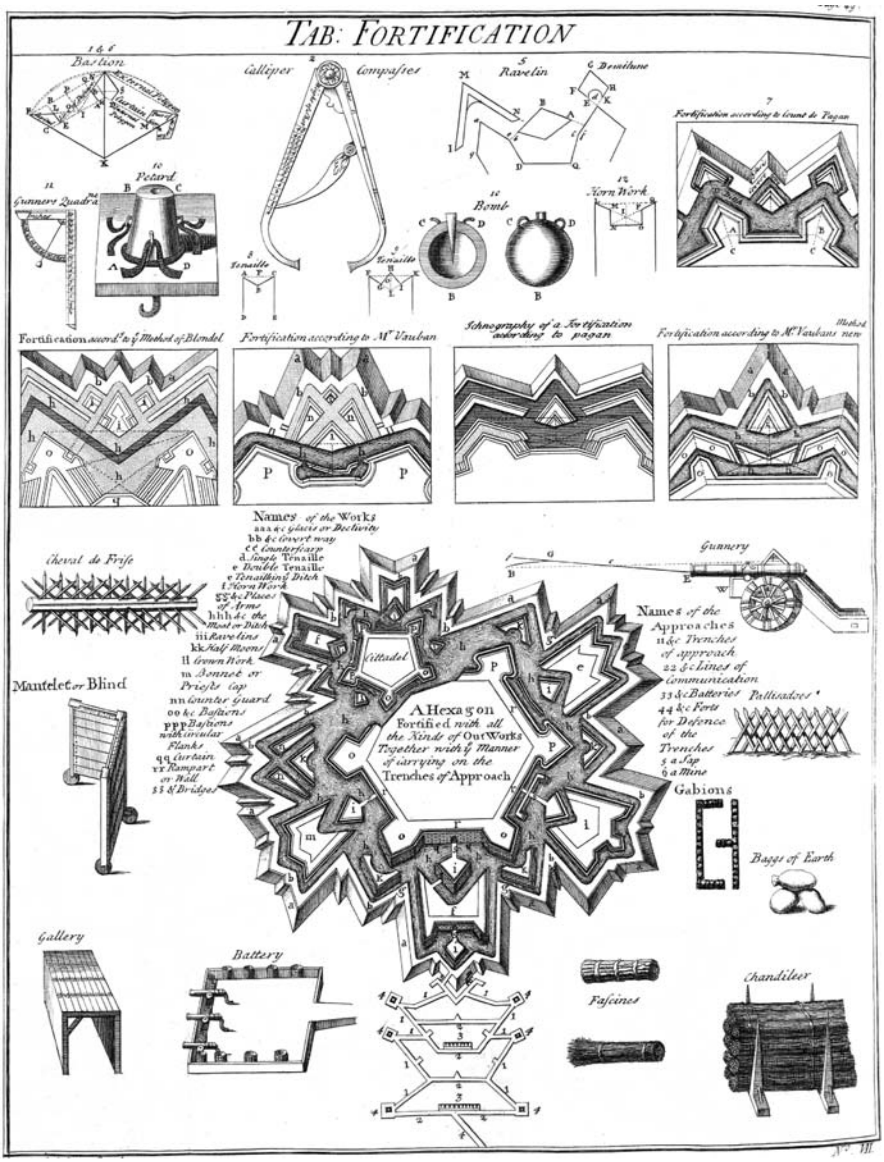

Fig. 14.3 Ramparts of the modern age (source: http://theudericus.free.fr/Vauban/Vauban.htm)

closed traverse-shaped Fort Monostor (Plate 14.4), built between 1850 and 1871, is considered to be the largest of modern Central European fortresses. This building complex covered by earth covers an area of approximately 70 ha and was constructed as a labyrinth of ramparts, bastions and underground casemates built of stone and brick (Gráfel no date).

Plate 14.2 Austrian redout from the 18th century in the Ghimes Pass, at the former Transylvanian-Moldavian boundary – today the County of Bacău, Romania (Ilyés 2004)

Plate 14.3 The Fortress of Bourtange (Sources: http://www.pixdaus.com/pics/1211860758iFwLnst.jpg)

Plate 14.4 Fort Monostor in Komarno (source: http://hu.wikipedia.org/wiki/F%C3%A1jl:Kom%C3%A1rom_Fortress_03.jpg)

Fortresses began to lose their strategic importance as early as the late 18th century. Fast, flexible invasion troops during the Napoleonic wars simply avoided the old defence systems. Fortifications were reconstructed primarily in large towns and strategic junctions of supply routes. Moreover, the major battlefields (Leipzig, Jena, Waterloo) also witnessed significant anthropogenic transformation.

14.6 Anthropogenic Geomorphological Impacts of World War I

The increasing fire-power, military technique innovations and positional warfare at many fronts lasting for years caused extraordinary military landscape transformations during World War I. The most spectacular example is the *battlefield of Verdun*. As a result of the massive artillery attacks, this battlefield was transformed into a cratered landscape within a few months. German troops alone fired 1,350,000 tonnes of grenades during the 30 war months and killed 1,000,000 people. On each hectare ca. 50 tonnes of splinters are buried underground even today. Following the seizure of *Fort Douaumont* (Plate 14.5) of key strategic importance by the Germans, the most intensive fights took place on the left bank of the Meuse River: during the battles around ‘Dead Man’s Dump’ and ‘Dump No. 304’, ca. 40 million bullets and mortal shells were dropped (two on each square metre) to reshape the surface. ‘Dump No. 304’ deepened 16 m during the battles of spring 1916.

During the wars of the 20th century, especially due to the positional warfare in World War I, *trenches* and the various automatic rifle and machine gun posts established at battlefields and defence lines are remarkable monuments of human landscape transformation. Trenches provide shelter against machine-gun bullets

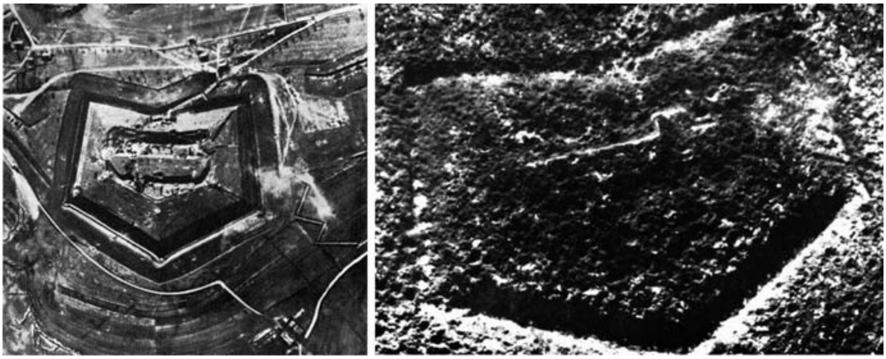

Plate 14.5 Pre- and post-battle aerial photos of Fort Douaumont (Sources: http://upload.wikimedia.org/wikipedia/commons/0/0e/Fort_Douaumont_Anfang_1916.jpg and http://www.freeinfosociety.com/media/images/3645.jpg)

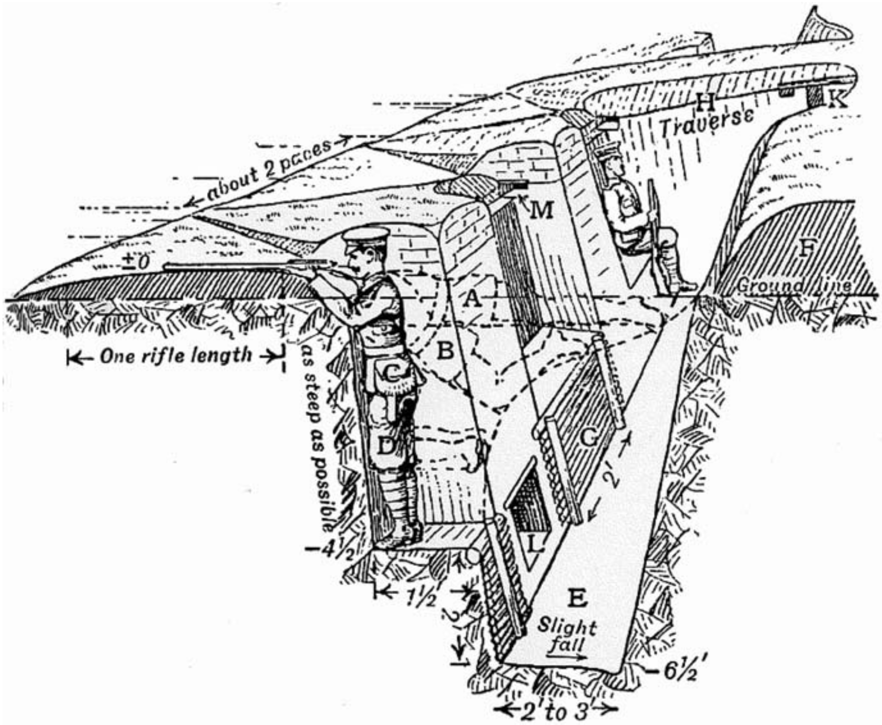

Fig. 14.4 The structure of a fire trench (1914) (source: http://upload.wikimedia.org/wikipedia/commons/e/ef/Trench_construction_diagram_1914.png)

and grenades and the opportunity for soldiers to securely fire, mostly in standing or kneeling positions (Fig. 14.4). The breastworks were originally supported by sandbags. Trenches often had a zig-zag planform in order to ensure better defence against grenades and enemy attacks. Such trenches are classified, according to their functions into operational, communication, cross, attack and reserve types; these functions has had an influence on the formation and texture of the trench systems still seen today.

The intense fighting between the Austro-Hungarian and Italian armies along the Italian front during World War I resulted in significant changes in the landscapes of the Southern Alps region (the Isonzo region, the Dolomites). Mountain roads were undermined. One of the best known symbols of battles is the 2,462 m high *Col di Lana* (Buchenstein) in the Dolomites that was blown up by Italian divisions on the night of 17–18th April 1916. About 5,000–5,500 kg explosives were stockpiled in two bomb bays; due to the explosion a dual crater, 25 m wide, 35 m long and 12 m deep was formed. Between 1916 and 1918, 34 similar explosions occurred along the mountain fronts of Tirol alone.

Bomb bays also formed on the western front. The limestone region along the *Somme River* was especially suitable for underground tunnel driving. The tunnel divisions of the British Army, mostly of civilian miners, drilled tunnels to place explosives. The front along the Somme witnessed two vast explosions beneath the German posts on 1st July 1916: one of them at La Boisselle and the other at Beaumont-Hamel (Hawthorn Ridge). At La Boisselle a 'crater' 30 m in depth and 90 m in width, still preserved today was formed.

Along with the development of military techniques, *road and railway construction for military purposes* also resulted in new landforms.

14.7 Landscape Transformation by Warfare in World War II and the Preceding years

Following World War I, defence lines, concrete-cored fortification and bunker systems (e.g. Maginot Line, Westwall or Siegfried Line) were constructed to counteract large-scale attacks and invasions across Europe. Further examples Atlantikwall and Ostwall, the fortification system constructed on the border of the Republic of Czechoslovakia by the Germans in the 1930s and the Árpád Line built in the Carpathians in the 1940s.

In addition to defence lines, more spectacular concrete and stone bunkers and fortifications of the modern age, traces of fire trenches (by today, partly filled up) as well as depressions of machine-gun nests, anti-aircraft batteries and tank-traps are still visible today. Gunpits were linked by trench systems. Remnants of the sites of field kitchens and signal posts surrounded by earthworks or planated as well as those of military barracks destroyed during military actions and in post-war times are similarly identifiable.

In the battlefields of World War II, the traces of impacts of bullets have been preserved. On maintained, regularly mown mountain meadows, microtopographic textures of depressions at the sites of grenade impacts as well as the flabellate-shaped ones of hummocks of explosion in origin at their opposite side are easily observable (Ilyés 2004; Rathjens 1979).

Interventions destroying *flood prevention facilities* and *dams of hydro-power plants* are considered to be among the geomorphological impacts of wars, or in a more direct sense, strategic planning and defence. During World War II, the Germans, in fear of the allied invasion, caused inundations by ruining dams and embankments along the coasts of Belgium and the Netherlands. In autumn 1944, the allies, by bombing the Westkapelle Dam, thought to be the most solid structure in Europe at that time, flooded the Isle of Walcheren. Such floodings for military purposes between 1940 and 1945 impacted about 230,000 ha in the Netherlands (Nir 1983; Dávid 1998).

Barrage dams on the rivers Möhne, Eder and Sorpe in North Rhine-Westphalia were attacked by special bombs by the Royal Air Force at the dawn of 17th May 1943. This intended to disable weapon manufacturing capacities in the Ruhr Region. With the exception of the one on the Sorpe River, all dams were damaged; the water sometimes 12 m deep caused serious damage in the neighbouring towns and killed about 2,000 people. On the 48 m high dam of the River Eder, a 70 m wide and 22 m deep hollow was formed following a bomb explosion, causing the flow 8,000 m^3 water per second (in total 160 million m^3). Due to the immense amount of water running down, hundreds of houses, factories, railway lines, roads and bridges were damaged or drifted away, and a vast lake was formed at the estuaries of the Schwalm-Eder and the Eder-Fulda, and in the Kassel Basin (http://de.wikipedia.org/wiki/Edersee).

Rubble heaps (Trümmerberge, Schuttberge) raised following the bombings in World War II are found in many European cities (Szabó 1993). Only in Germany, in 1945, 400 million m^3 of rubble had to be removed. Such rubble mounds in Berlin include the 15% of the total amount of rubble in Germany. In the Park of Friedrichshain, two rubble heaps piled on bunkers are found, i.e. the kleiner (smaller) and grosser (greater) Bunkerberg. In these two ‘hills’, approximately 1 million m^3 of rubble was piled.

14.8 Geomorphological Impacts of Modern Wars

Modern wars, due to the transportation of considerable amounts of ammunition, transform the surface over large areas. Mainly military roads and air bases are involved as well as degradation caused by military vehicles should be mentioned. Constructions carried out by the American army in Vietnam, made soil exposed at large areas resulting in significant rates of erosion. On the other hand, the slopes and stepped slopes resulting from construction works were further shaped by monsoon rains and deflation (Nir 1983).

Between 1963 and 1971, in South Vietnam and in the neighbouring Laos and Cambodia, the American forces sprinkled herbicides estimated to be 72 million litres (of which 44 million litres was the chemical Agent Orange containing dioxine, still causing severe health problems). On 17.8% of South Vietnam’s area (i.e. 3,004,000 ha), the primary aim of actions to burn the foliage of forests and mangrove forests was to eliminate shelters, supply bases and food-producing agricultural areas of partisans. The large-scale deforestation resulted in inundations in the rainy season and soil desiccation and deflation in the dry season. Soil eroded from areas of high relief causing the formation of laterite surfaces where forests could hardly rejuvenate. In lowlands, accelerated deposition of fine alluvial sediments and silt further increased flood hazard (Le Cao no date).

As a consequence of the technical progress in warfare, the increasing role of flexible, mechanised troops and the spreading of air warfare, 'position warfare' based on fire trench and bunker systems known from World War I has became outdated in the mid-20th century. Another reason for this was that during World War II, such fortification and bunker systems fell short of expectations and were easily passed by invasion forces. Notwithstanding, some examples of military actions based on trenches and bunkers can be found from the second half of the 20th century. The war between Iraq and Iran in 1980–1988, as a whole, was similar to the trench battles experienced during World War I, as both forces had significant artillery but a relatively small number of armoured divisions. Defence by trench lines did not prove to be sufficient during the First Gulf War following the occupation of Kuwait. With support provided by the air forces and armoured bulldozers, such defence lines (http://de.wikipedia.org/wiki/Grabenkrieg) were simply buried by the American forces. Similar trench war took place between Ethiopia and Eritrea. Today, ceasefire lines secured by traditional trench systems and bunkers are found between South and North Korea, and between Pakistan and India (in Kashmir).

The most accelerated and greatest geomorphologic transformations of modern warfare were caused by the testing of *nuclear weapons*. In addition to the bombing of Hiroshima and Nagasaki, which caused damage unimaginable so far, between 1945 and 1998, 2057 nuclear weapon tests were carried out. The fire power of all nuclear power testing carried out to date equals that of 1 billion tonnes of TNT. Of the 2,057 nuclear weapon explosions, the total fire-power of the 1,529 underground explosions was ca. 82.5 mega-tonnes. The first nuclear bomb was blown up on 16 July 1945 under the supervision of Robert Oppenheimer in Alamogordo (New Mexico); following the explosion of this 19 kilo-tonne bomb, a crater 800 m wide and 3 m deep was formed while the desert sand melted into a greenish-coloured glass. This crater was filled up in the 1960s. One of the largest crater resulted from the Sedan test carried out on 6th July 1962 at the test site in Nevada. The 104 kilotonne nuclear bomb was emplaced in a depth of 193 m. This explosion removed 12 million tonnes of earth and left behind a crater 390 m in diameter and 97 m in depth (Goin 1991).

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