Chapter 7
Opportunities Beyond Landscapes

Preamble
This book has focused on geospatial analysis of archaeological landscapes, but such analyses can have implications for researchers in other disciplines as well. In this final chapter, we discuss three examples of such research linkages. In Sects. 7.1–7.3, we present three examples from our own research experience. Finally, in Sect. 7.4, we present an example where we see immense potential for research that can positively impact the protection of built heritage.

7.1 History of Astronomy

Astronomy has been closely intertwined with religion through much of history, and the construction of sacred structures was sometimes based on astronomical principles. For instance, the Egyptians may have aligned the Great Pyramid at Giza to cardinal directions using the circumpolar stars Kochab (Beta Ursae Minoris) and Mizar (Zeta Ursae Majoris) (Spence 2000). Hindu temples in India were also aligned to the cardinal directions, using other methods including Indian Circle (first described before 200 BCE in a treatise on mathematics and geometry called *Katyayana Sulbasutra*) (Sen and Bag 1983). The mathematician and astronomer Brahmagupta (born in 598 CE) noted that the Indian Circle method produced at most 0.5° of error in alignment) and Sripati, another mathematician and astronomer, suggested a correction for this error in 1039 CE or 1056 CE (Mollerup 2012).

Some contemporary Buddhist sacred structures such as the main stupas at Ratnagiri and Udayagiri (located 7 km apart in Orissa) are also aligned to the cardinal directions, but when we conducted a geospatial analysis, we noted that all the temples at Nalanda as well as other Buddhist temples within the same cultural milieu—the

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Mahabodhi at Bodhgaya and central structures in Vikramasila, both in Bihar, India, Somapura in Bangladesh and Samye in Tibet—were oriented more than 4° south of true east. While some sacred structures are aligned to the rising sun, this hypothesis did not explain our observations. On consulting literature from the history of astronomy, we found that several ancient structures are believed to have been oriented towards the rising or setting of certain bright stars including Sirius (the Horus temple on the summit of Djebel Thoth in Western Thebes and the Isis temple at Dendera in Egypt) (Shaltout and Belmonte 2005; Belmonte et al. 2010), Antares (the temple of the Hurlers in Liskeard in England and the Older Erechtheum in Athen, Greece) (Brown 2000; Lockyer 1894[1]), and Spica (the temple of Min in Egypt, and several temples in Greece) (Olcott 1911). Relying on this scholarship, we hypothesized that the nine Buddhist temples under consideration were oriented towards the rise of a star. To identify this star, it was necessary to measure the orientations of the temples accurately.

It is challenging to measure these orientations at ground level for two reasons. First, many of these structures have been restored, so the orientation of a short wall segment may differ from the orientation of the overall structure. Unfortunately, it is difficult to find intact segments of straight walls that are several metres in length. Second, the Mahabodhi and Samye are functioning temples with many ancillary structures built around them, which makes it difficult to make accurate measurements. We therefore relied on high-resolution satellite imagery, which has been effectively used for measuring the orientation of ancient structures in Egypt and China (Shaltout 2014; Klokocník and Kostelecký 2010; Klokocník et al. 2011).

On Google Earth images, we identified and measured the orientations of straight lines at least 30 m long at each temple that align with surviving remnants of an east-west wall or the plinth. Since satellite images can be georeferenced, an added advantage is that geographical north can be established more accurately on these images than at ground level. To minimize measurement error at each site, we examined all pertinent Google Earth images and selected the ones closest to the nadir or direct vertical view (images taken at oblique angles distort the geometry). Our selections were determined visually, based on the parallax created by tall buildings present in the near vicinity of each site. To estimate the orientation of each structure, we identified two near-parallel linear features (walls or plinths) that flank it symmetrically to its north and south and then measured their east-west orientations using AutoCAD.

With these careful measurements, we were able to identify two candidate stars as the target for orienting these nine temples: either Spica or Beta Librae (Rajani and Kumar 2019). Although the latter star is not as bright as Spica, it is part of the Vishaka Nakshatra (lunar mansion) associated with the Buddha's birth. Since there is no prior evidence from the history of astronomy that Indian structures may also have been oriented towards the rise of stars, our interdisciplinary research has advanced our understanding in both domains. We believe the basis of orientation we have

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[1] The methods used by Lockyer for data collection and analysis have been questioned by more recent authors (Papathanassiou 1994; Boutsikas and Ruggles 2011).

proposed has far broader applicability, not only to temples in India but even in other parts of the world where orientation was determined in relation to a specific star. We cannot, however, say whether structures distant from the Indian subcontinent used a similar mode of orientation (Rajani and Kumar 2019). This would be an interesting avenue for interdisciplinary research in future.

7.2 Military History

In the military context, maps can be created either prior to a battle (for planning purposes), or afterwards to analyse successful and unsuccessful decisions made during the battle. This type of analysis can be supplemented by textual records such as accounts by designated military observers. While the battles themselves need not leave visible scars, these spatial records can be a valuable source of information to answer questions of interest to military historians, particularly because maps made for military purposes often use the most accurate map-making techniques of their time.

We now describe how geospatial analysis was used to understand the range of eighteenth-century Mysorean rockets. These rockets were effectively used by the Mysorean army during the Anglo-Mysore wars (1780–82, 1790–92 and 1798–99), which pitted Hyder Ali and his son Tipu Sultan against the British East India Company. Although the British were the eventual victors, they were so impressed by these rockets that Colonel William Congreve led a vigorous technology programme to analyse them in Britain. In 1801–02, Congreve's tests confirmed that these Mysore rockets had more than double the range of the rockets available to the British. The estimates for the range vary according to the type of the rocket from 1000 yards (915 mts) to 1.5 miles (2.4 km). This outstanding performance was chiefly attributable to the iron employed for the casing, whereas European rockets were encased in wood or pasteboard. The high quality of the iron made this the first successful military deployment of such casings, which permitted increased bursting pressures and hence higher propellant packing density and therefore their impressive range (Narasimha 1999). These techniques were used to advance European rocketry with the development of the Congreve rocket in 1805 (Narasimha 1985).

Modern-day military historians seeking to validate the range achievable by Mysorean rockets could study their shape and dimensions: two samples of Tipu's rockets survive in the Royal Artillery Museum in Woolwich, UK, and a large number of casings were discovered recently in Nagara, Karnataka (Shejeshwara and Olikara 2018). However, there are numerous unknowns relating to how these rockets were prepared and fired that makes it challenging to confirm their 2.4 km range.

Fortunately, there is a rich historical spatial record of key battles that can be used to address this question. The events that took place at Srirangapatna on the night of 4–5 April 1799 have been particularly well documented by British soldiers who were part of this event (or by their biographers). This level of detail may partly be because the British were genuinely surprised by the capability of the Mysorean rockets, and partly because several notable military figures participated in this battle, including George Harris, David Baird, Lachlan Macquarie (Lushington 1811; Fortesque 1906; Hook 1832; Anonymous 1852; Macquarie archives[2]), and a young Arthur Wellesley. The latter, who later became known as the Iron Man of Britain and the Duke of Wellington, was reportedly "shell shocked" and disoriented by the sudden attack and explosions caused by Tipu's rockets at the Sultanpettah *Tope* (groves) where his army was positioned (Narasimha 1985).

By georeferencing the map *Seringapatam 1799*,[3] we geographically located the Sultanpettah Tope, the position of the Mysore army (from where the rockets were presumably launched), and the postings of British armies headed by Wellesley, Harris, Stuart, Hart, Shawes, and MacDonald (Fig. 7.1a). This map shows several built features that are identifiable on Google Earth images (and hence serve as good GCPs), including the fort, the gates, an aqueduct, a hill-temple, and several bridges. Features from the georeferenced map, including the Sultanpettah Tope, were then transferred to Google Earth imagery to find their current context (Fig. 7.1b).

With this georeferenced map, we were able to measure the distance between the nearest positions of the Mysore army to the easternmost edge of the Sultanpettah Tope. We were thus independently able to confirm that the range of these rockets was at least 2.48 km (Fig. 7.1b).[4]

7.3 Riverine and Coastal Geomorphology

The shapes of rivers and coastlines can vary over short durations (e.g. due to seasonal changes) and over longer durations (e.g. due to climate change). By identifying palaeochannels and strandlines detected in satellite images, we can sometimes determine the location and shape of a river or a coastline at some time in its past. In order to understand the geomorphology, we may want to determine how long ago this was. Typically, we try to find suitable sedimentary material for dating at the past location, but it can be challenging (or impossible) to select the right material. If the changes have occurred over archaeological timescales and there are built structures whose association with these past locations of rivers and coasts can be established using geospatial analysis, then it is sometimes easier to date these structures (e.g. using historical records or by analysing bricks or wood).

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[2] Macquarie University Library in Australia https://www.mq.edu.au/macquarie-archive/seringapatam/intro.html Accessed 13 May 2020.

[3] Maps and plans illustrating Fortesque's History of the British Army (1906) 4:27.

[4] I am grateful to Prof Roddam Narasimha and Prof H.S. Mukunda for the many discussions about Mysorean rockets.

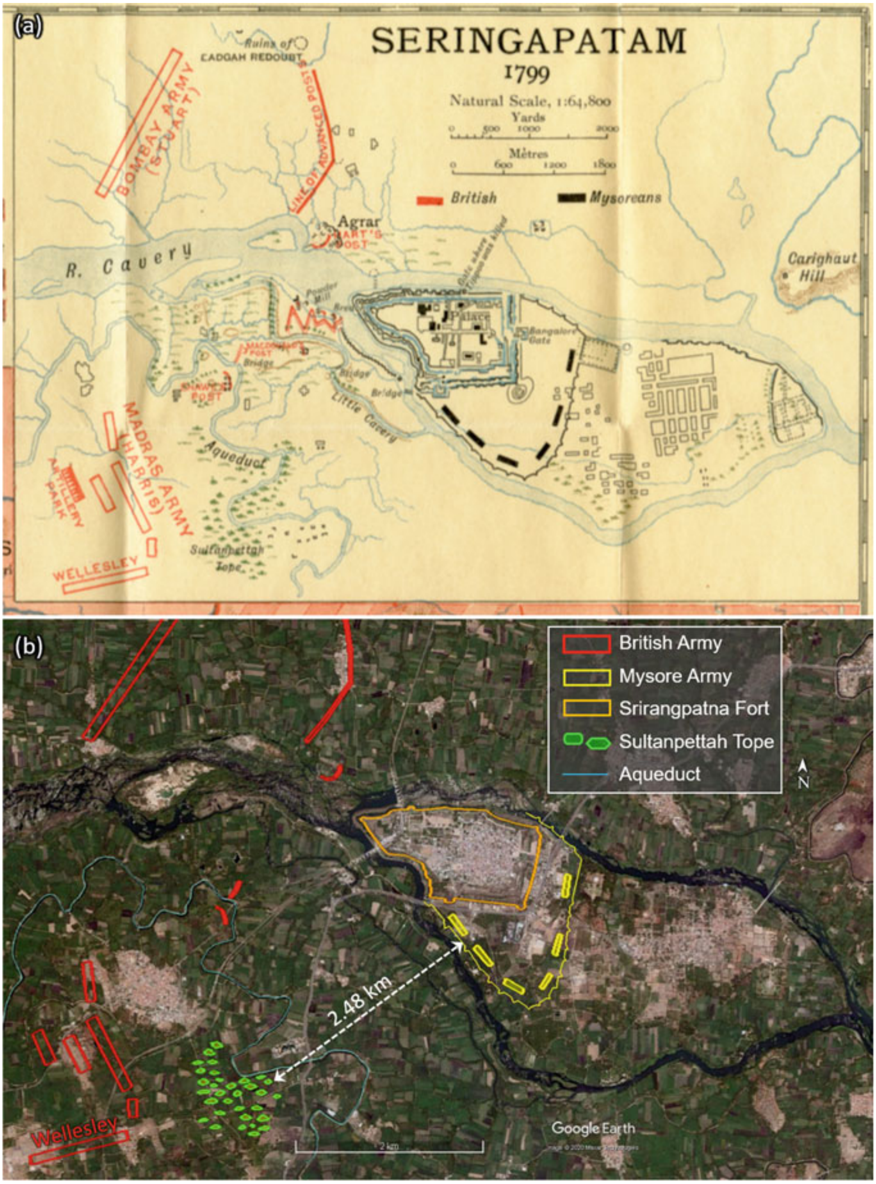

Fig. 7.1 **a** Map showing the postings of British and Mysorean armies in the vicinity of Srirangapatna in 1799 (reproduced from Fortesque 1906). **b** Features from the map in (**a**) georeferenced and overlaid on Google Earth imagery, showing the minimum distance between the position of the Mysore army and the Sultanpettah Tope

7.3.1 Rivers

A straightforward example is Sravasti (Fig. 2.25, Sect. 2.3.6), where the tell-tale curve of the fort wall records the past flow of the River Rapti (which is now about 2 km north of the fort). A more complex geospatial analysis is required to understand the geomorphology of Kosi, one of the Ganga's largest tributaries. It presently joins the Ganga north-east of Bhagalpur in Bihar (just west of the site Vikramasila), but an analysis of satellite imagery and historical maps of the region suggests that this confluence was further east less than two centuries ago (Chakraborty et al. 2010). Geomorphological insights can sometimes be made even for prehistoric sites. For instance, a comparison of the spatial distributions of mature Harappan sites (2200–1700 BCE) versus later Harappan sites (1700–1500 BCE) suggests that the former lay along a major river system (perhaps the fabled Sarasvati River). Palaeochannels suggest that this system dried up, and Rajani and Rajawat (2011) have hypothesized that the lack of water forced later settlements to move west, closer to the River Indus (see Sect. 4.1). This hypothesis, if true, contributes to the geomorphological understanding of the river system by suggesting that it dried up around 1700 BCE. As a final example, while textual records indicate that the Mauryan capital of Pataliputra (see Sect. 4.3.4) was at confluence of River Ganga and River Sone (McCrindle 1877; Cunningham 1871), its precise location is not known. Evidence for its location will enhance both our archaeological understanding as well as our understanding of the morphology of the River Ganga and its tributaries.

7.3.2 Coasts

One reason for dynamic changes to coastlines is sea level variations. We have data on sea levels recorded by tidal gauges from about 1700 CE, but data prior to this is at geological timescales and is typically estimated by extrapolating or interpolating from available data points (Church et al. 2001, 2013; Grinsted et al. 2010).

Auriemma and Solinas (2009) have suggested that careful analysis of archaeological data can offer important clues for understanding the evolution of coastlines in the Mediaeval Period, and Sundaresh et al. (2014) have demonstrated how evidence from coastal archaeological sites can be used to trace changes in coastlines with some accuracy. In addition, we believe that mediaeval and colonial period maritime maps are a relatively untapped source of data about coasts and sea levels. Prior to the industrial era, travel by water was often easier than overland. As a result, marine channels, navigable rivers, and sea crossings were important trade routes for ancient civilizations. This commercial endeavour led to the creation of Portolan charts (the Italian adjective *portolano* means "related to ports or harbours"). These charts were first made in Europe from the thirteenth century CE onwards, and they identified relatively permanent coastal features near ports and harbours (such as forts, temples, and hills) that were visible to sailors (Rajani and Kasturirangan 2013). Such charts, together with textual descriptions, have been published as collections and have contributed to our understanding of highly dynamic coastal features such as the growth of spit bars (Blake 2004; Boer and Carr 1969; Oldham 1925). Boer and Carr (1969) have suggested the use of such charts as a source of valuable information when other kind of evidence is sparse.

In Sect. 5.5, we have described how a seventeenth-century Dutch Portolan chart helped to explain why Mahabalipuram had the name Seven Pagodas. Our analysis technique simulated changes in the sea level to match the coastline depicted in the Portolan chart (Fig. 2.28). This match was further validated by agreement with a palaeostrandline identified in multispectral satellite imagery. By dating this strandline, our research has made a small contribution to understanding the morphology of this coast. We are presently investigating the potential of this technique to identify relative sea levels in the colonial period (sixteenth to twentieth century CE) in a systematic exploration of the entire coastline of India. The results of such studies should provide further data on the shape of past coastlines to assist geomorphologists, oceanographers, and for climatologists in refining existing coastline evolution models. In addition, this line of research can also help in identifying lost or submerged coastal archaeological sites, and in identifying sites that are vulnerable to coastal dynamics.

7.4 The Economics of Identifying and Protecting Built Heritage

Traditionally, identifying the remains of the past and preserving them have both been costly tasks. The first task has conventionally relied on laborious and time-consuming exploration and excavation, but the costs associated with geospatial analysis using remote sensing and GIS technologies have decreased rapidly with the increasing availability of online geoportals and image resources, together with reducing costs of remote sensing data.[5] Further, such analysis is typically far less destructive (Sect. 5.4.5—Talakadu). As noted in Sect. 6.2, these technologies can also be used to define more rational site protection boundaries and can help in enforcing them, potentially reducing the cost of the second task. These trends are expected to continue as the underlying technologies advance.

We close by reflecting on the implications of these trends on the economics of identifying and protecting built heritage in a country like India. Today, the Archaeological Survey of India has identified and protected over 3600 sites, and each state government protects a few hundred more. Some funds can be efficiently utilized to officially recognize thousands of unknown and undocumented remains. For each of these sites, modest additional resources are needed to define site protection boundaries, to raise public awareness about the importance of these sites, and to support

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[5] https://www.nrsc.gov.in/sites/default/files/inline-images/Satellite_Data_Price_List.pdf Accessed 29 Apr 2020.

community-led initiatives to protect these remains (including by creating a public database of these sites and their boundaries, as noted in Sect. 6.3). More expensive forms of enforcing protection boundaries can be reserved for a limited number of sites.

Thus, geospatial analysis is likely to spur new research in understanding the economics of preserving our past. As we noted in a recent talk,[6] it is undeniable that we risk losing some of our cultural heritage due to lack of resources, but losing it due to ignorance—particularly, as the cost of dispelling that ignorance falls—is unacceptable.

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[6] https://www.ted.com/talks/m_b_rajani_clues_in_the_landscape Accessed 30 Aug 2020.

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