RESEARCH ARTICLE

Geospatial Analysis of Historical Cartographic Data of Kollam Fort

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Abstract

The port of Kollam (Quilon) in Kerala had been an important trading centre for many centuries. Its significance as a landing point for traders is evident from its colonial history when there were repeated attempts to take over possession of this location. Being an important site, Kollam was frequently mapped by Europeans from the sixteenth to nineteenth centuries. The historical maps and views of Kollam contain vital information about the history, archaeology and geography of the area. Remote sensing and GIS can provide a real-world spatial context to these archived geographical documents of varied scales and types, drawn at different times spanning more than four centuries. The present study harnesses the potential of RS and GIS in integrating information present in the maps of such heterogeneous nature to advance the historical and archaeological knowledge of the Kollam fort. The integration of the maps of the different time, scale and style with the help of RS and GIS yielded information that was previously unknown. The present study has discovered the extant remains of the Portuguese and the Dutch fort that were not identified before and contributed to the scholarship on the construction, restoration, the extent and usage of the fort during its occupation by various European powers.

Keywords Kollam · Quilon · Historical maps · Colonial forts · Remote sensing

Introduction

Kollam in Kerala, India, has historically been an important trading port. The port was confined to the promontory, now called Thangassery, which is 3 km west of Kollam Junction railway station. This port was frequently visited by Chinese and Arabic as early as the seventh and eighth century (The Imperial Gazetteer of India 1908). It had also been of great interest to Portuguese, Dutch, British (each spelt the toponym differently; Covlao/Covlam, Coylan/Coylang and Quilon, respectively) and local South Indian during the colonial period (Aiya 1906), which in India spanned from sixteenth to twentieth centuries. Portuguese established a *factory*[1] in Kollam in 1503 (Mathew 2017). Francisco de Almeida, the first Portuguese viceroy to India, had conquered this place in 1505 and a fortress called Fort

St. Thomas was built in 1519 (Diffie 1977; Mathew 2017) which was later expanded to a larger fort (see 'The Fortaleza and the Portuguese Fort' and 'The Portuguese Fort (PF)' sections). In December 1658, the fort was captured by Dutch United East India Company and then was re-occupied by the Portuguese in April 1659. In December 1661, Dutch finally took control of Kollam (Schilder et al. 2006), which they held for over a century. In 1795, Dutch factories and possessions were taken over by English East India Company (Aiya 1906). The port and the surrounding coastal stretch have been frequently mapped by Portuguese (sixteenth and seventeenth century), Dutch (seventeenth and eighteenth century) and British (eighteenth and nineteenth century) at different scales and for various purposes. The maps have potential to enhance our understanding of the archaeology of the area. However, they sometimes may also have 'inaccuracies' due to primitive cartographic techniques, selective representation, agenda or purpose of making the map, the skill of cartographer and scale or coverage (Gupta and Rajani 2020). Errors can also be caused during subsequent copying or reproduction (for instance, reverse printing or copying

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[1] *Factory* is a colonial term for entrepôt.

erroneous features from an old map), and further in the way the maps are stored, for instance, folding, stretching, shrinking, deformation of paper/other material upon which they are made (Davidson 1986). Therefore, they need to be studied with care to avoid misreading and misinterpretation.

Remote sensing data are widely used to detect surface and sub-surface archaeological features and also for monitoring of encroachment activities in the vicinity of protected and unprotected/unrecognized sites (Sever and Irwin 2003; Parcak 2009; Baibatsa 2014; Gupta et al. 2017). GIS can transform historical cartographic data to the real-world coordinates and make their study more systematic. Geospatial analysis of historical maps has been found crucial in bringing out new archaeological insights (Scott et al. 2013; Rajani 2021). Integration of archival material such as bird's eye view, paintings, maps of a different time, styles and scales (including maps that are not-to-scale) in a remote sensing and GIS environment has potential to render new knowledge that is otherwise lying unrecognized in these old archival materials.

With this background, the present study explores the value of geospatial analysis in integrating historical maps and views of varied dimensions and types, and extracting archaeological information to identify the extant remains of the colonial Kollam forts; and further to enhance historical knowledge of the region by advancing the understanding of construction, extension and restoration of the fort and its importance during the Portuguese, Dutch and British periods. The study also discusses critical aspects and challenges in the methodology and significance of such studies.

Study Area

The study area includes a small coastal stretch in Kollam District of Kerala State, India. The Kollam fort is situated on Thangassery Point, a promontory of laterite rock abutting the sea. The extent of the fort for the present study is determined by using colonial maps which depicts the fort extending from shore of Thangassery promontory to around 800 m inland (Fig. 1). A small portion of the Portuguese fortress, which is known as Thangassery Fort or Fort St Thomas, was declared as a Protected Monument by Archaeological Survey of India (ASI) in the 1980s. These remains lie at 8° 52′ 54.1″ N 76° 34′ 06.4″ E and occupy an area of ∼ 0.1 acre, which is a very small fraction of the original fort area (see 'The Portuguese Fort' and 'The Dutch Fort' sections). During the field-visit, laterite deposits are observed in pockets along the Thangassery promontory exposed to the seawater.

Fig. 1 Study area. Satellite Image Courtesy: Google Earth, Maxar Technologies, June 10th, 2018

Methodology

A unique methodology had to be adopted for this study involving three distinct steps: (1) data collection and acquisition, (2) understanding the content and context of old maps, (3) geospatial analysis. Following are details of each step:

Data Collection and Acquisition

The data used in this study are historical maps, paintings, views and very high-resolution (VHR) satellite images. Historical maps have been gathered from various places and sources. These maps are on different scales and of various types. In this study, we have included only maps that show the fort area in full or part, and excluded small-scale maps that mark Kollam only as a point feature. The dates of maps (used in the present study) range from the mid-sixteenth century to the late nineteenth century. A chronological list of all historical maps analyzed in this study with their thumbnails and respective sources are tabulated in 'Appendix'; specific ones are referred in this manuscript and figures with the word 'Map' suffixed with the serial number. For example, serial no. 1 is the bird's-eye view dating from 1558 to 1563 CE, which we refer as Map 1. For the remote sensing analysis, historical satellite imageries available in Google Earth Pro (from January 2003 to February 2019) have been used.

Understanding the Content and the Context of Old Maps

During the colonial period, Kollam was largely mapped by Portuguese, Dutch and British. A few copies of the maps were also produced by French. Content of the maps, such as orientation, annotation, toponymy, scale, and the context of the history of the time they were made, their mapping style and the purpose they served, have been examined so that information can be derived meaningfully. They have been categorized based on who made them (Portuguese, Dutch, French and British) that has also conveniently put them into chronological order.

Portuguese Maps

The earliest map of colonial Kollam is a Portuguese hand-made bird's-eye view dated 1515 ('Appendix', Map1; Correa 1858; Algeria et al. 2007). Another map made by João Teixeira (Map 2), published in 1630 has characteristics of both bird's-eye view and plan map. A fortress (a fortified palace of a citadel) and a fort (a fortified defensive structure stationed with troops) wall with bastions are depicted in a perspective view, while the other features are represented in a plan map style. António Bocarro's map (Map 3) of 1635 is similar to Teixeira's map, looks like an artistic copy (with intricate architectural details), but does not depict map elements such as title, north arrow and labels which is present in Map 2. In the Maps 1, 2 and 3, Kollam is variedly spelt as *Coullam, Covlam* and *Covlaō*, respectively. We have not found any Portuguese map of Kollam that were made after these. Portuguese maps do not have planimetric accuracy and hence cannot be georeferenced. However, they are rich with spatial information such as in arrangement and depiction of manmade structures (architectural details of buildings, fort and layout of roads) contextualized along with the shape of the coastline consisting of a rocky promontory with a bay to its east and has been found useful in visual analysis.

Dutch Maps

The Map 4, dated 1672, is the first available Dutch bird's-eye view of Kollam (Baldaeus 1672). This is the only Dutch map that shows the Portuguese fort wall (this wall is henceforth referred to as PF) and the plan of a revised fortification (consisting two demi and one complete triangular bastions) that was later built by the Dutch; we will refer to the Dutch Fortification as DF. The Map 6, dated 1687, is the earliest available planimetric map of Kollam with all the main elements of a map (like title, scale, north arrow, label and legend). It has a graphical scale of fifty *rijnlandse roeden* which is equivalent to 188 m on the ground (one rijnlandse roeden = 3.767 m). The georeferencing accuracy (described in 'Georeferencing' section) of the map indicates that it was made with planimetric survey technique. Some of the maps dating from the mid-eighteenth century (Maps 9, 10 and 11) seem to be copies of Map 6 with fresh annotation as they have very little new content. This was a regular practice for producing copies at a time when opportunities for collecting fresh data were few and far between. There are three other medium and small-scale maps of the Dutch fort—Map 7 by Hans Georg in 1697, Map 13 by Graaf, Joh. Wilh. De in 1767 and Map 14 by an anonymous cartographer in 1720. All of these maps depict prominently the typical triangular shape bastion of the DF showing the importance of the fort at that time. In most of the Dutch maps, Kollam is spelt as Coylan except few where it is referred as Koylang.

French Maps

The only French map we found of this area is made by Jacques Nicolas Bellin in 1747 (Map 10), was, in fact, the first historical map of Kollam that we examined in the present study and only after initial interrogation we

realized that it was a mirror-reversal copy (similar maps made by Bellin were also published in 1750, 1755, 1756 and 1764 [ref description of Map 10 in 'Appendix']). Recognizing 'original' versus a mirror-reversal[2] is of significance particularly to the present study (Fig. 2a). Identification of the shape of the coast and traces of the fort as depicted in Map 10 was attempted on a satellite image. As the map was a reverse copy, the patterns did not match and we first mistakenly assumed that the landscape had changed beyond recognition. Later, through further archival exploration, we found maps with correct orientation made by other Dutch cartographers (mentioned in the previous section). This interesting observation also emphasizes that some of the historical maps can have such big errors and hence, should be used with utmost care. Printmaking techniques use a printing plate (metal or wood) to produce multiple copies of the same image that requires the image on the printing plate to be reversed from what must be printed (like in a rubber stamp). Unless the engraver skillfully incises or cut the mirror-image of the actual map, the finished print would become a mirror image as in case of Bellin's map.

British Maps

We did not find any British map of Kollam fort except small-scale map of 1829 (Map 15) where the triangular bastioned fort is only symbolically represented but with the name *Tungumshery* (also spelt as *Tangacheri* or *Tangachery* elsewhere). In this map, the name *Quilon* is attributed to the then small settlement 2 km east of DF and it forms the core of what is present-day city of Kollam. Map 18, dated 1883 is an admiralty chart which apart from the features on land (like streets, canal, settlement and trees) gives soundings and contours of underwater topography in the sea and inland lakes. This map does not mark DF but instead has a fresh layout of five parallel roads running west–east (as though striking out the old and replacing a new floor plan) with the area annotated as Tangacheri and a road (*Tangacheri Road*) connecting it to the settlement Quilon. The map also marks a dotted boundary that seems to coincide with PF's layout, hence, has been considered for the present analysis. The scale of the map is in English miles (1 English mile equivalent to 2.1 km) and sea miles (1 sea miles equivalent to 1.8 km). Absence of the DF in British map may indicate a lack of its importance it had during that time. Since the remains of

DF are visible on recent satellite imagery and ground even now (see 'Visual Interpretation of Satellite Image' and 'Identifying Remain of Old Fort and Ground-Truthing' sections) they would have been only more conspicuous in 1883 when Map 18 was made. However, Suganya and Rajani (2020) have reported that British map dating from 1878 of Agra had deliberately omitted marking old city-wall when there is other evidence of the wall's existence at the time and has posited that selective inclusion of features in a map was a practice at the time.

We also noticed a significant advancement in map-making practice from Portuguese (seventeenth century) to Dutch (seventeenth–eighteenth century) to the British period (nineteenth century) in India. Portuguese seemed to have mapped the fort mainly for the record purpose, while Dutch made these maps mostly for planning and strategic purposes. British were interested in extensive and detailed mapping of offshore, onshore and inland areas and no detailed mapping of the fort as it was insignificant for them.

Geospatial Analysis

Visual Interpretation of Satellite Image

Knowledge of the scale has been crucial to focus on the correct extent on the satellite image, otherwise one would be puzzled about the size and extent of the structure especially in case of shoreline where the shape of the shore looks similar at different scales. The satellite images were brought to the scale of the map and then investigated for further analysis. Identification of visual traces of the tri-angular bastion fort structure (marked in Maps 5 and 6) was carried out using interpretation keys such as shape, pattern, texture, shadow and association. Many Google Earth images are available for this area dating from 2003 to 2018. Although the fort structure is hard to discern in the images, the signature of the wide moat on the north was discernable. The visibility of this cropmark[3] varies; how-ever, they are more conspicuous in images from before 2011 when the fort area was comparatively less interfered by recent human activities.

Identifying Remain of Old Fort and Ground Truthing

The identified potential location of the remains of the fort from visual analysis (described in 'The Dutch Fort' section below) was marked on GIS software and then

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[3] Cropmark is one of the main interpretation keys used for satellite image based archaeological exploration. Positive cropmark shows excess growth of vegetation over a ruin or a buried ditch like features. Negative crop marks show retarded growth of vegetation over a buried hard structure.
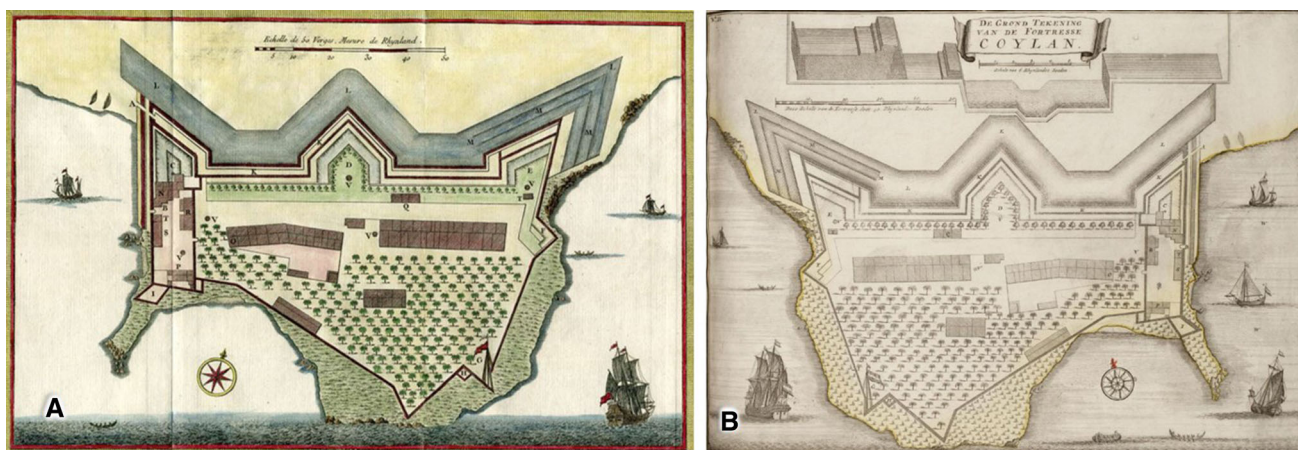
Fig. 2 Kollam fort **a** Erroneous mirror reversal map made by Jacques Nicolas Bellin in 1745; **b** a proper copy made by Francois Valentyn, 1724

Table 1 Details of georeferencing of selected maps

Map no. (based on 'Appendix')	year	TT[a]	Total GCPs	Errors (m)			Pixel size (m)
				RMSE[b]	Highest residual	Lowest residual	
Map 6	1687	P1	11	8	15	1	1
Map 12	1766	P1	9	9	16	2	0.14
Map 14	1720	P1	9	24	41	3	4
Map 18	1883	P1	15	13	23	2	4

[a]Transformation type

[b]Root mean square error

uploaded to a handheld sat-nav device to navigate on the field during the survey conducted in December 2019. The presence of the ruins of the fort was recorded photographically and their location in the handheld GPS device, which were later used for georeferencing.

Georeferencing

For GIS analysis, all the maps and satellite images must be aligned on the same spatial reference so that they can then be quantitatively analyzed. Georeferencing is the process of assigning real-world coordinates to each pixel of a given raster image by using ground control points (GCPs) whose coordinates are known or can be ascertained either from a georeferenced image/map of the same area or in situ ground measurements using handheld GPS devise. The satellite view of March 25 2009, available in Google Earth Pro was selected as the base image for the study area. It was saved with maximum resolution and the saved image was georeferenced using GCPs from the same image in Google Earth Pro, and accuracy of < 1-pixel RMSE was achieved. Large- and medium-scale maps (viz. Maps 6, 12, 14, 18) with unique information were georeferenced using coordinates of identifiable features on the base image.

Maps with oblique views (Maps 1–4) were analyzed visually and were not georeferenced as they are unsuitable for planimetric measurements. The details of georeferencing accuracy achieved for each map are listed in Table 1. Efforts were made to identify maximum numbers of GCPs; however, their numbers in some maps were limited due to unavailability of stable recognizable common features. In addition, it was a challenge to find GCPs that were well distributed across the whole map canvas. In most cases, we could find well-distributed GCPs, but for Map 14 they were clustered only in the fort area, which resulted in a large distortion in parts that were away from the Fort. Brovelli and Minghini (2012) have stated that there is no way to know the polynomial order best for any given map in advance and that one has to try and evaluate the quality of the chosen transformation by making the visual comparison between georeferenced historical map and the recent map/image being used and/or by analyzing residuals of GCPs statistically. In this study, the decision has been made through visual comparisons by making the map layer semi-transparent on top of the base image. Polynomial order 1 is found to be giving the best output for all the georeferenced maps.
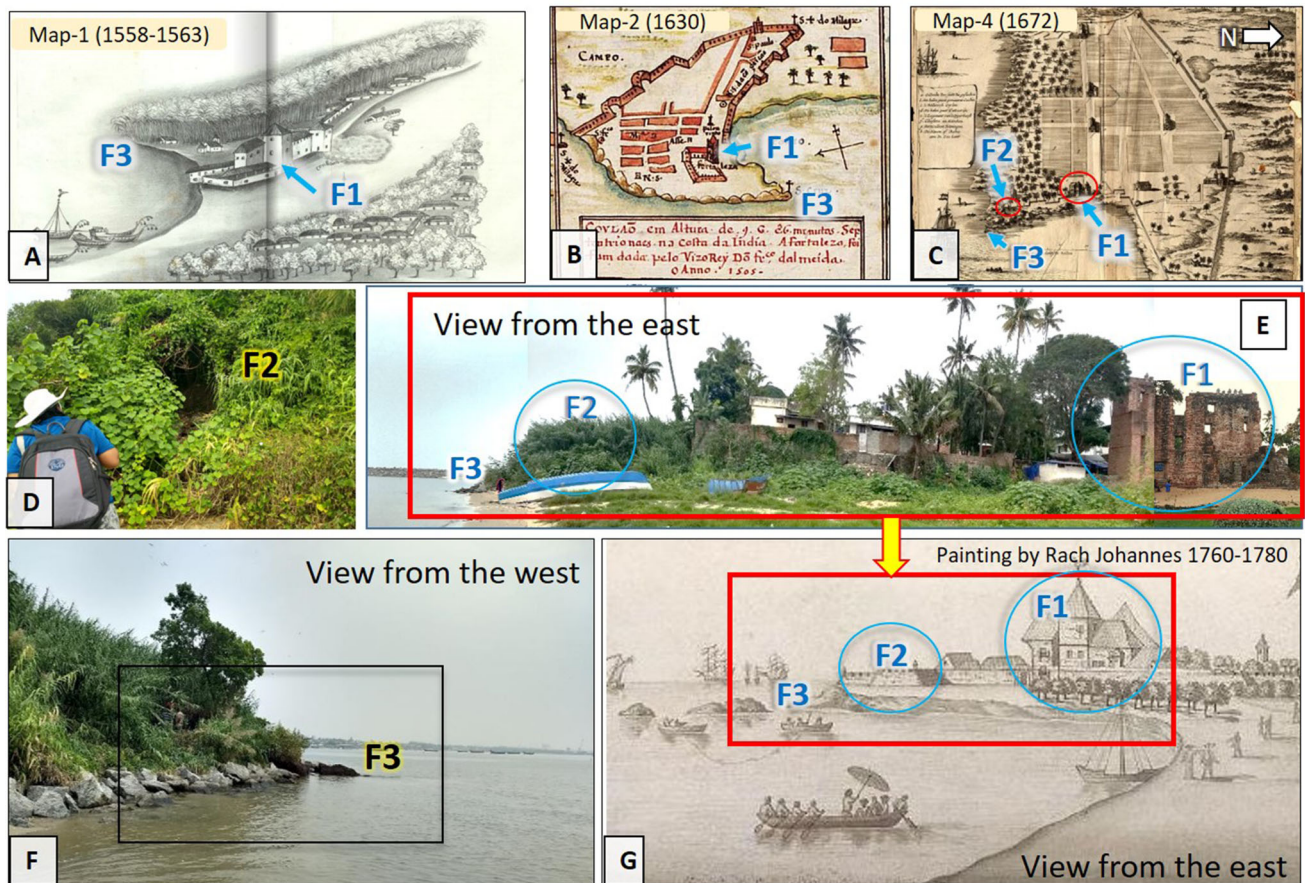
Fig. 3 Maps and paintings depicting the fortress which is the oldest colonial structure, and laterite deposit; F1 is the fortress; F2 is the location of a bastion identified in Dutch maps and validated on ground; F3 is laterite outcrop depicted variedly in old maps and paintings. (refer 'Appendix' for maps). Source of painting [G]: https://www.atlasofmutualheritage.nl

Digitization and Overlay analysis

The outline of the fort was traced using the georeferenced maps (listed in Table 1) in QGIS (an open-source GIS software), and then, the digitized vector file (traced outline) overlaid on the base image.

Map Integration

The historical maps used in this study are heterogeneous in terms of their content, scale and style. There are 2-dimensional plan maps, sea charts and other general maps, bird's-eye view map with 3D building structures; coastal views and drawings from 1558 to 1883 CE. Here, the term 'map integration' is used for combining the information obtained collectively from a variety of historical maps to enhance the archaeological understanding of the study area. In the present study, this is achieved by combining visual interpretation of non-georeferenceable oblique maps and views with geospatial analysis of georeferenced maps, and

also historical text records. Our analysis is sensitive to the chronology of various sources.

Results

Analysis of historical maps provides interesting aspects about the mapping of Kollam from the sixteenth century to the nineteenth century and new insight of Portuguese Fortification (PF) and Dutch Fortification (DF). The geospatial study of historical maps has explored the unidentified structural remains and helped in revealing various aspects of the colonial settlement such as spatial and temporal dimensions, occupancy, chronology and importance. The results are discussed as follows:

The *Fortaleza*

The oldest bird's-eye view dated 1515 (Map 1) depicts only a building complex (with a three storeyed turret) of the factory that is also seen in Teixera's map labeled as
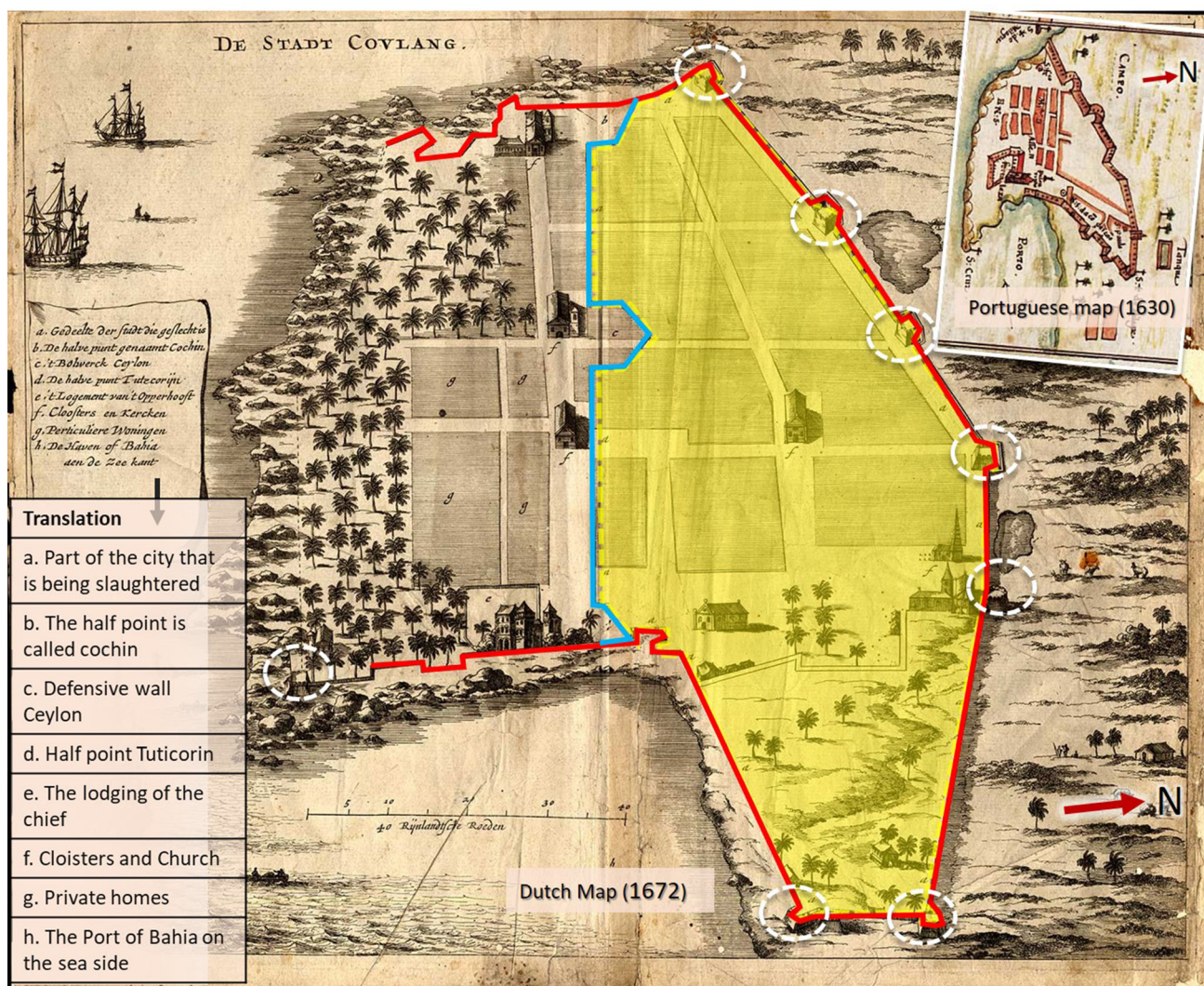
Fig. 4 Map 4 which records the extents of original Portuguese fort (marked in red) with 8 bastions (highlighted with white circles) in context of the plan of the downsized Dutch fort with 3 bastions (marked in blue); the yellow watermark is of the area of Portuguese fort demolished by Dutch. Inset is a Map 2 for comparing the shape of Portuguese fort as depicted in both these maps

'fortaleza' (fortress in Portuguese). This *fortaleza* has more architectural details in Map 3 and is also marked in the earliest Dutch plan (Map 4) (see F1 in Fig. 3). This turreted building is also clearly depicted in a eighteenth century Dutch painting (F1 in Fig. 3g), at present this building is in ruin and is protected by ASI (F1 in Fig. 3e). The similarity in architectural details in various sources mentioned above together with the location of its remains on the ground and in the layout of various maps suggests that the remains of the 'fortress' protected at present are the oldest colonial structure built by Portuguese as a factory in 1503 and later repaired to a fortress named as Fort St. Thomas in 1519 (Logan 1887).

The Portuguese Fort

The maps dating from 1630 and 1635 (Maps 2 and 3) mark a layout of several structures outside the 'fortress' indicating the expansion of the Portuguese settlement which must have demanded construction of a fort-wall further north protecting the larger settlement. These two maps show a fort-wall (PF), about 500 m north of the fortress, protecting the town from north and north–east directions. This structure is also marked in Map 4, a Dutch map of 1672 (Fig. 4). In fact, the depiction of PF in this Dutch map perfectly matches the description given by Johan Nieuhof who visited Kollam in January 1662, a month after Dutch captured the fort from Portuguese. Nieuhof describes that the city was fortified with an 18 to 20-foot-high stone wall
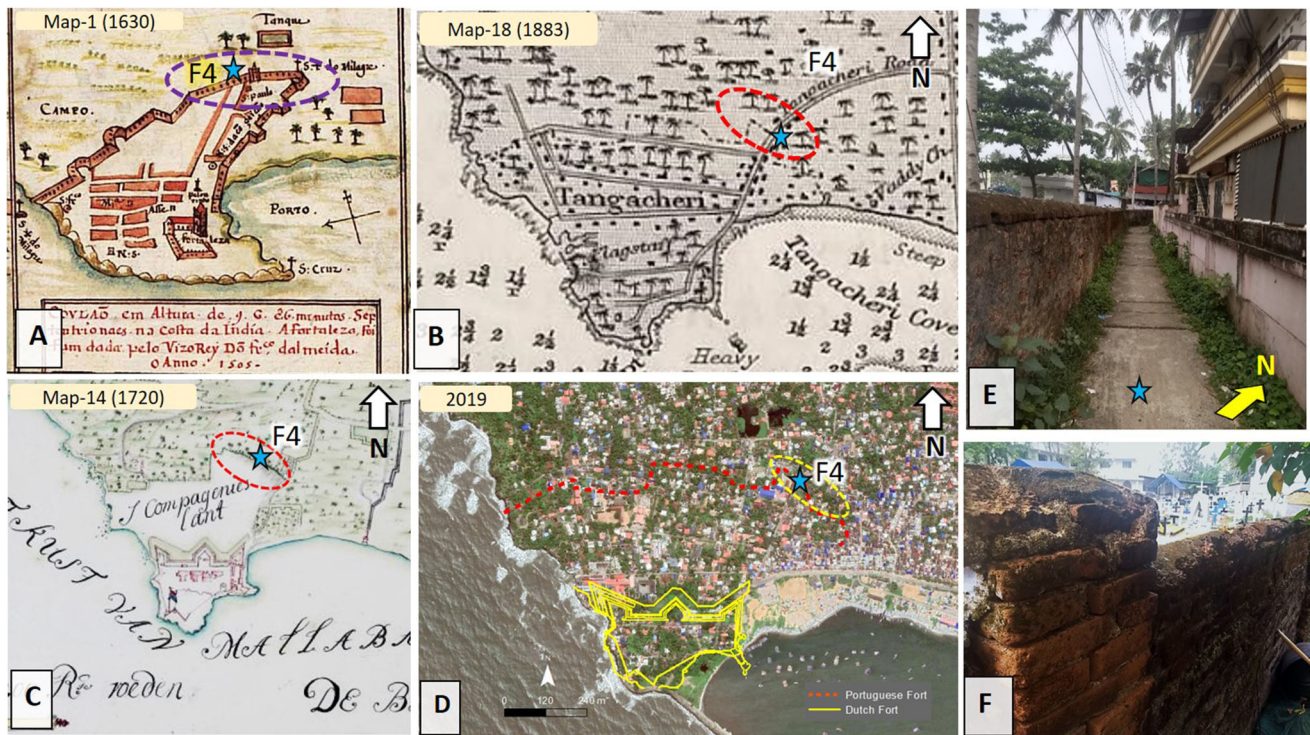
Fig. 5 Location of remnant of old laterite wall in old maps and satellite image (F4 in **a–d**) and ground photograph (**e, f**) (Satellite Image Courtesy: Google Earth, Maxar Technologies, June 10th, 2018)

with 8 bastions (Nieuhof 1744, 207) (Fig. 4) The structure of PF is nonexistent in the subsequent maps (see Maps 14 and 18), where it is replaced with territorial marking. For instance, in Map 14, a 1720 Dutch map, the identified extent of the PF represented as a boundary of the *company's land*. Schilder et al. mention it as a boundary of the former Portuguese town (Schilder et al. 2006, Vol VI; ref Map 14). The British map (Map 18) of 1883 also marks a dotted line that follows the similar shape; however, no information is provided in the map explaining that dotted line (Fig. 5b). Parts of this dotted line can be seen as linear cropmarks on high-resolution Google Earth satellite imagery when the two layers are overlaid and analyzed (Fig. 5d). On the ground, an old laterite wall was observed along this line extending on the north–west direction following the cropmark; this wall also formed a compound-wall of a sixteenth-century Portuguese Cemetery (Fig. 5e, f). A Portuguese church is also identified in the map of 1672 (Map 4) at this location adjacent to the wall. Evidence from the maps, remote sensing analysis and field suggest that the boundary marked in the Dutch and the British map (Maps 14 and 18) corresponds to the extent of PF. However, an alternative boundary of PF is delineated using street patterns in Rajani 2021. Rigorous field exploration is required to find out any extant remains of PF along with scientific dating of carefully extracted material from the

wall. The area of the fort, measured from the identified extent, is around 85 acres with a north–south and east–west extent of around 600 by 950 m, respectively.

The Dutch Fort

Subsequent to Dutch taking over the possession of the fort in 1661, reduction of the size of the PF was ordered in 1665 to reduce the cost of maintenance. A fort (DF) reduced in the area but enhanced in strength with three bastions (a triangular bastion in the centre flanked by two demi-bastions) on the land side was built under the instruction of Nieuhof (Nieuhof 1744). The testimony of this event is preserved in a Dutch map of 1672 (Map 4). One of the most accurate, detailed and possibly the original map of the earliest construction of the DF is by Hans Georg Taarant (1687, Map 6). The approximate north–south and east–west extent of this DF are 270 m and 370 m, respectively. The fort was further reduced from the south-west side by the mid-eighteenth century as depicted in the Zijnen, D's map (Map 12, 1766) (see Fig. 6). Records of orders to reduce the fort's size and strengthening the parts of it have also been found in the historical accounts (Galletti 1911; Schilder and et al. 2006). For the identification of fort remains, Taarant's map has been used (Map 6, ref 3.2.2). Positive cropmark of the central triangular bastion

Fig. 6 Approximate extents of the Portuguese and the Dutch forts (Satellite Image Courtesy: Google Earth, Maxar Technologies, June 10th, 2018)

Fig. 7 a Dutch plan map of Kollam fort; b outline of the plan map overlaid on the crop mark traced in the satellite image with location of other identified features; c rampart of the fort; d, e old structures on the central bastion, f step-like rampart of fort to the North and g Rampart of the fort being used as road. (Satellite Image Courtesy: Google Earth, Maxar Technologies, June 10th, 2018)

of DF and the moat along it has been observed in Google earth images (Fig. 7b). Subtle traces of other bastions and rampart have also been observed. However, these crop marks were very faint and not readily visible. The road layout in the Thangassery area marked in British map (Map 18) was matched with roads marked in Google Earth, and then, crop marks were identified by spatial association.

Since satellite image analysis mainly indicated the presence of moat, we were not sure of finding any

structural remains of the wall. However, on the ground we found that the main road that runs east–west lay on top of the remains of the rampart from where the three bastions are projected northward. Ground truthing of the traces confirmed the presence of the vegetation strewn remains of the fort (Fig. 7d, e). Broad-step like rampart has been noticed along with the three bastions (Fig. 7g). The wide linear space south of three bastions, depicted as F9 in Fig. 7, is a rampart of laterite bricks. The central bastion

has ruins of British cemetery (Fig. 7b). The portion opposite to it in the southern direction has ruins of Dutch cemetery. We have also found two huge and tall pillars of laterite bricks standing north side of the British cemetery on the central bastion (Fig. 7e). Unfortunately, no information on these pillars was found. The land on its south was sloping downward and many modern structures (such as houses, resort) were built on top of old ruins, indicating that the ruins of old settlement is smothered by the modern settlement.

The approximate area of the fort in the Taarant's and Zijnen's map is measured to 18 acres and 7.5 acres, respectively. The fort lost its importance during the British period who took over the settlement in 1795, effacing the plan of DF by laying a road that ran east–west, one of them over the rampant of DF (Fig. 5f) and establishing a cemetery on the central bastions.

Discussion

This section discusses—the critical aspect of studying maps of different time and dimension; challenges in incorporating historical cartographic record in RS and GIS; and the significance of the present study.

Critical Aspects of Historical Maps

Methodical study of maps can derive vital information from the seemingly 'unimportant' and 'inaccurate' maps and on contrary, inadequate knowledge of maps can misinform us. Availability of a large number of historical maps gave us scope to extract the principal components though choosing the most reliable and informative ones and the available information on the date, originality, scale and the content of the map found to be the basis of such selection. There have been an advantage of having maps of different scale, time and of varied perspectives and dimensions (2D, 3D or combination of both). For instance, regional maps are found useful to provide the spatial context of the area and in placing the large-scale plan maps in its geospatial context accurately. Maps of Portuguese fort which are planimetrically inaccurate and are more like bird's eye view represents the fort in different perspectives and dimensions. Such rare documents of the time with unique perspectives, which may look insignificant at first sight, are found to be valuable sources of information of the time. Therefore, seemingly inaccurate maps should not be discarded without a careful examination of its content, temporal and spatial context. At the same time, one should also be aware of the possible errors, such as—a map whose content is copied from an earlier map but published after several decades of the original one may mislead us

about its temporal context. This also suggests why it is important to do an extensive archival work and carefully corroborate information derived from maps with other sources.

Challenges in remote sensing and GIS analysis

RS and GIS provided an environment to integrate spatial information present in the various types of cartographic documents and have brought historical maps into the real-world space so that they can be studied in the present context. However, there are certain challenges while bringing historical maps into a GIS platform. Such as, assigning of the real-world coordinates to these maps especially if the target site is not conspicuous from the top due to the encroachment by wild vegetation or human activities. Therefore, sometimes, visual inferences and logic become the only way to identify probable GCPs. Despite that, reliability of georeferenced maps can be judged based on RMSE value and visual analysis of how well the map fits with the cropmarks and the topography of the land (see Table 1). The inherent inaccuracies and flaws, that maps sometimes may have, are dealt by using maximum numbers of maps available for different dates to check the consistency in the content, and satellite images helped in locating and validating the identified features.

Significance of the Present Study

The study has provided new insights about Kollam Fort that is not available in other historical records. The analysis reveals that the Portuguese fortification of the town was extensive and about four times the area of the Dutch fort thereof. The oldest part of the fort and one of its eight bastions are still surviving; however, the Dutch demolished the northern fortification in 1665 to reduce the fort to one-fourth of its size and then built a fort wall with triangular bastions (see 'The Dutch Fort' section). Later they reduced it further to almost half in mid of eighteenth century. Central bastions and ramparts of the Dutch fort are found to be existing in dilapidated condition and are known only as British Cemetery. More recent encroachment of parts of the fort remains is observed in the historical imageries of Google Earth Pro. It is surprising to see that a very small part of the Portuguese fortress is a well-known tourist spot and has been preserved and maintained by the authorities, whereas a substantial portion of the fort has been left unnoticed and unattended. The reasons could be lack of information and knowledge about the existence of the fort remains and more importantly, the change of land use in historical times (central bastion converted into British Cemetery) creating another layer of the history of a later period causing the fort remains to descend into oblivion.

The results of the study also led us to question the authenticity of some of the literature on history. For instance, incorrect measurement of the extent of the Dutch fort in a nineteenth century record (1 by 2½ furlong = ~ 201 by 503 m) and information on submergence of a part of Fort Thomas in the sea in a mid-twentieth century record (Rea 1897, 61; Cotton 1946, 178). Analysis of all the cartographic documents does not reveal any possibility of submergence of the Portuguese fort; in fact, the east side of the promontory has gained land in recent decades (this deposition is the result of the construction of two breakwaters at Kollam).

Conclusion

The present study has made several original contributions. Here, we classify them into three groups—archaeological finding, methodological approach and pointers for future research—and summarise on each of them below.

The archaeological findings are: (1) The ASI protected site at Kollam is a remnant of a turreted 'fortress' originally built by Portuguese in 1503 and later strengthen to a forteleza in 1519; (2) the approximate location of the Portuguese fortification of the town has been geospatially delineated and ground-truthing has revealed promising evidence (see 'The Portuguese Fort' section); (3) extensive ruins of the Dutch fort is still extant in the site (see 'The Dutch Fort' section) which has been unrecognized and neglected for centuries; and (4) this study has contributed to the scholarship on the construction, restoration, the extent and usage of the fort during its occupation by various European colonies.

Our methodological approach and the resulting outputs: (1) The present study demonstrates that historical graphical records—such as maps, paintings and views of different time, style and dimension—are an important source of geographical and historical information of the time they were surveyed and/or drawn; (2) a careful study of such records can produce congruous outputs; (3) RS and GIS provide a real-world spatial context for these historical graphical records making them uniquely valuable for archaeological explorations; this, in turn, facilitates addressing historical inquiries related to the location and extent built structures and their occupancy; (4) The method used in the present study can be applied for other sites for which such material is available.

Finally, this study has pointed to (1) extant remains of the Portuguese and Dutch structures whose material can be accessed for scientific dating and other analysis; (2) specific locations where an elaborate field exploration and architectural conservation can be pursued; (3) the fast encroaching urban land use further smothering archaeological remains and the dire need to mitigate the same. (4) Further advanced geospatial analysis can be undertaken for identifying specific details of the fort remains that are buried under vegetation through data acquired via drone-based and terrestrial laser scanner and for the digital documentation and virtual reconstruction of the site.

Compliance with Ethical Standards
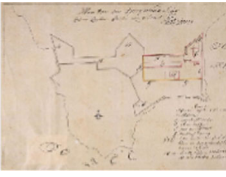
Conflict of interest None.

Appendix

List of historical maps of Kollam fort.

Map no.	Map	Map source and remarks
1		Hand-made drawing of the Portuguese fortress of Caulao (Quilon), by Gaspar Correia, for his book 'Lendas da Índia', written between 1558–1563 and first published in 1858, Volume II, Page no. 394. Accessed on October 2nd, 2019 from purl.pt/12,121/3/var-2326/var-2326_item3/index.html#/412
2		A Portuguese map, 'A feitoria de coulao foi fundada por Afonso de Albuquerque em 1503'. From the Atlas- 'Taboas Geraes De Toda a Navegação' authored by Albernaz, João Teixeira, Active, Jeronimo De Attayde, and Francisco De Seixas Y Lovera. Publishing year: 1630. Accessed on July 15th, 2019, from: https://www.loc.gov/resource/g3200m.gct00052/?sp=11

Map no.	Map	Map source and remarks	Map no.	Map	Map source and remarks
3		A Portuguese map, from the Atlas- 'Livro das plantas de todas as fortalezas, cidades e povoaçoens do Estado da India Oriental' by António Bocarro in 1635. Accessed on 15th July from https://purl.pt/27184/3/#/279	7		Part of a Dutch map, titled 'De waare afbeelding van de lage landen der Kust Malabaar enz., beginnende boven de fortresse Cranganoor en strekt tot verby de fortresse Coylang enz..Overige topografische namen vermeld op deze kaart: Apare, Patij, Allapaar, Aiwike', created by Hans Georg Taarant in 1697. Accessed on July 5th, 2019 from: https://www.atlasofmutualheritage.nl/nl/De-kust-Malabaar.2644
4		A Dutch map, entitled 'De Stadt Covlang' from a book titled ''a True And Exact Description Of The Most Celebrated East-India Coasts Of Malabar And Coromandel; As Also Of The Isle Of Ceylon; … with the draughts of their idols, done after their originals', by Philip Baldaeus, translated from the High-Dutch, printed at Amsterdam, 1672. Accessed on July 16th, 2019, from https://archive.org/details/trueexactdescrip00bald/page/n147	8		A Dutch Plan map, titled 'Affbeeldinghe hoedanigh de afsnyding off verkleyninge van d'fortresse Coylan gedaen en van zyn tegenwoordigh corpus gesepareert staat te werden', This is a map of the construction work on the fort with the removal of part of the existing fortifications by Anonymous, made in 1703. Accessed on July 20th, 2019 from: https://www.atlasofmutualheritage.nl/en/Representation-Fort-Coylans-reduction-size.2605
5		A Dutch map, titled 'T' Fort Coylan' represents situation of the fort in 1678, but the map was drafted after 1690, by Isaac de Graaf, for the Atlas Amsterdam. Map and information source Atlas of Mutual Heritage. Accessed on July 20th, 2019, from: https://www.atlasofmutualheritage.nl/en/Maps-forts-Cananor-Cranganor-Coylan-Calicoilan.2583	9		A Dutch map titled 'De Grond Tekening van de Fortresse Coylan' by Francois Valentyn, 1724. Accessed on July 10th, 2019 from: https://www.atlasofmutualheritage.nl/en/Map-fort-Coylan.5843
6		A Dutch map, titled 'D'Grond Teekening van de Fortresse Coylan', created by Hans Georg Taarant, a land surveyor/map maker, in 1687. Accessed on July 16th, 2019, from: https://www.atlasofmutualheritage.nl/en/Representation-Fort-Coylan.2604			

Map no.	Map	Map source and remarks
10		A French map, titled 'Plan de la Forteresse de Coylan' by Jacques Nicolas Bellin, 1747. Accessed on June 3rd, 2019 from: https://www.columbihal/bellinquilon/bellinquilon.html
		Links of its copies published in different years (last accessed on August 25th 2020):
		1750—https://www.ebay.com/itm/1750-Kollam-Kerala-India-Indien-map-view-plan-Kupferstich-antique-print-Bellin-/143688505019
		1755—https://www.antiquemapsandprints.com/plan-de-la-forteresse-de-coylan-kollam-kerala-bellinschley-1755-old-map-406360-p.asp
		1756—https://commons.wikimedia.org/wiki/File:1756_Bellin_Map_of_Kollam_Fort,_Kerala,_India_-_Geographicus_-_Coylan-bellin-1756.jpg
		1764—https://www.mapandmaps.com/en/india-sri-lanka-ceylon-old-antique-maps/386-kollam-kerale-quikon-india-antique-engraving-1764.html
11		A Dutch map, titled 'De Grond Tekening van de Fortresse Coylan' by the Van Keulen family in 'De Zee En Land-Caarten en Gizigeten van steeden en landvertooningen van oost-indien', 1752. Accessed on July 2nd, 2019 from: https://www.columbia.edu/itc/mealac/pritchett/00routesdata/1700_1799/malabar/quilon/quilon.html
12		A Dutch map, titled 'Plan van een geprojecteerde Logie binne Coylan', created by Zijnen, D. in 1766, representing plan of construction of new fortifications and new lodge buildings. Accessed on July 5th, 2019 from: https://www.atlasofmutualheritage.nl/en/Map-lodge-Coylan.2606
13		Part of a Dutch map titled 'Particuliere Kaart van een gedeelte der Kuste Malabar of de strekking der rivieren van Chettua tot Coylan', created by Graaf, Joh. Wilh. de in 1767. Accessed on July 5th, 2019 from: https://www.atlasofmutualheritage.nl/nl/Kaart-gedeelte-kust-Malabar-deel-A.6099
14		A Dutch map, titled 'Plaan van fortres en cituatie van Coylan' by Anonumous, 1720 (date referred from Schilder G [et al.] 2006, Vol VI). Accessed on July 5th, 2019 from: https://www.atlasofmutualheritage.nl/en/Map-Coylan.6284
15		Snippet of a British map, from the 'Atlas of India' published [London]: J. Walker, 1862. The map444 is published by James Horsburgh (Hydrographer) in 1st May 1829. Accessed on July 20th, 2019 from: https://www.loc.gov/resource/g7650m.gct00196/?sp=22&r=0.31,0.181,0.097,0.042,0
16		Part of British Admiralty chart, titled 'Sheet XII. West Coast of India. Malabar Coast from 9° 53′ to 8°. 40′ North Latitude … 1850–2' published [London]: J. Walker, 1866. Accessed from British Library, Shelfmark: Cartographic Items Maps SEC.12.(750.)
17		A British map, titled 'Quilon Road', Surveyed by Lieyt. A.D. Taylor, L.N. 1858, corrected to 1879. The map is found as inset of a British Admiralty chart titled 'Sheet XII. West Coast of India. Malabar Coast. (Quilon Road. Surveyed … 1858. Corrected to 1879. 1 sea mile[= 56 mm.]). Accessed from British Library, Shelfmark: Cartographic Items Maps SEC.12.(750.)

Map no.	Map	Map source and remarks
18		A British map, titled 'Quilon Road', Surveyed by Nav. Lieut, T.C. Pascoe, R.N, 1883. The map is found as inset of a British Admiralty chart titled 'Sheet XII. West Coast of India. Malabar Coast. (Quilon Road. Surveyed … 1883. 1 sea mile[= 55 mm.])'. Accessed from British Library, Shelfmark: Cartographic Items Maps SEC.12.(750.)

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