Ground survey to aerial survey: methods and best practices in systematic archaeological explorations and excavations

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Geospatial archaeology is gradually gaining a place of priority in the field archaeology of a variety of archaeological sites during the last decade and a half in India. In accordance with the changing emphasis in the aims and methods of archaeological investigations within and outside the Indian subcontinent and with the availability of scientific and technical expertise in India, application of non-destructive and efficient field techniques has become inevitable. Collaborative research programmes between archaeologists (both Indian and foreign) and experts in geospatial techniques have demonstrated the vast scope of geospatial archaeology in India. Results of such investigations summarized in this article show the efficacy of geospatial archaeology and its potential for ushering a new era of field archaeology in India.

Keywords: Field walking, geophysical techniques, geospatial archaeology, ground and aerial surveys.

Introduction

ARCHAEOLOGICAL sites are a major source of information for reconstructing the ways of life of ancient societies. The term 'culture' is defined by archaeologists as a phenomenon that is unique to humans and includes all aspects of human behaviour and its relationship with the dynamic environment. Theory and methods are vital to defining the aims and objectives of archaeological research, which over the last few decades has witnessed significant intensity of debate on formulating theories and arriving at generalizations. These debates have led to the diachronic development of archaeology as a scientific discipline with humanistic approach, as reflected in the normative (pre-1960), processual (1960s onwards) and post-processual or processual–cognitive archaeologies (1980s onwards).

The archaeological cultures were identified based on the group of artefacts, and each group was identified as a separate culture, and based on stratigraphy, arranged them one after another. These material cultures were equated with human cultures with an assumption that artefacts are expressions of ideas or norms or expressions of shared ideas. Normative archaeology limited itself to organizing the groups of artefacts in a chronological sequence and showing the impact of diffusion through arrows on maps, leading to a new culture. Normative archaeology viewed culture as unchanging and that change occurred under outside influence or through diffusion[1].

The 1960s and 1970s debates in archaeology ushered in developing theories and appropriate methods to test these theories to be able to enhance the scope of the filed in terms of reconstruction of (a) culture history, (b) culture change and (c) culture process. Although this was in practice among archaeologists of the culture history school, it became an explicit goal of the new archaeology. Indian archaeology is no exception to this. Each of these aims made it possible to recover the past as completely as possible, otherwise thought to be beyond the scope of contemporary archaeological methods. Therefore, it is no exaggeration to emphasize on theory building and testing as one of the best practices of archaeological exploration and excavation, also known as problem-oriented research. It should be noted that emphasis on problem-oriented research was advocated long before the emergence of the new archaeology in India by Wheeler.

The new archaeology began to explore multiple ways of not only procuring archaeological data, but also of looking at the archaeological records and developing different approaches. It argued that mere accumulation of systematic data was inadequate, and emphasized on the need to go beyond data collection and description. It argued for scientific and anthropological approach. The emphasis on science led to the use of data to test the hypothesis about the way the world worked. Hypothesis-building and testing transformed archaeology as a science of the past. The new archaeology emphasized on (a) looking at the state of past cultures from the perspective of cultural evolution, wherein cultures evolved from one state to another – band to tribe to state; (b) looking at culture as an extra somatic means of adaptation, i.e. unlike animals, humans adapt to an external environment

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through culture, and (c) reconstructing the culture process; why culture change occurred and how it occurred. This necessitated the use of systemic or functional models. There was increasing realization that theory/theories and methods to test them are all essential to expand and develop our understanding of the past. Archaeologists are expected to treat artefacts as texts and read them to uncover the complexity of past societies.

One of the ways in which archaeology was certainly becoming more and more scientific was in its techniques. The post-War period had witnessed refurbishment of field methods in archaeology and the benefits of using aerial photographs to identify sites on a macro scale. This had also led to an explosion in the number of scientific techniques – the use of computers, dating methods, geomorphology, geophysical techniques, environmental analysis, etc. This development in the use of scientific techniques was a core concern of the new archaeology and these techniques have provided more and more data of potential use in the study of the past. Despite these advantages the focus of archaeologists began to lean towards people's thoughts in the 1980s and began to find ways to look at cognition within the general framework of processualism[1].

Field archaeology: approaches to discovery and rediscovery

During the course of these developments, archaeology developed its own theories, methods and objectives. While dealing with the recovery of the material remains archaeology has developed a range of methods. It has borrowed and adopted techniques from other disciplines and has made them very much its own. Thus archaeology is different from history in that it requires material remains from archaeological sites and not just written descriptions of these remains. Hence the primary requirement is the location of archaeological sites in the landscape. Field archaeology plays a pivotal role in the location or rediscovery of lost archaeological sites by employing non-destructive methods and through problem-oriented research designs and innovative field techniques for gathering and documenting material data.

In India a large number of historical sites were rediscovered by colonial archaeologists, both amateur and professional. These sites were not lost, but were known to local people and travellers who visited these areas from time to time and left behind information in their travelogues. Some of the prehistoric sites such as mounds (e.g. ashmounds and ancient settlements) and burial complexes were known to the local people by different names, and tapping them for information has been productive for systematic documentation and further research. Knowledge of sites also exists in previous archaeological research reports. National and state-level archaeological institutions have engaged themselves in systematic surveys and documentation of antiquities and monuments, based on village-to-village surveys.

In colonial India a study of travelogues and literary accounts found it necessary to establish a national agency to rediscover India's past. Following this, village-to-village surveys were systematically organized to prepare up-to-date documents of ancient sites, monuments and antiquities. Annual reports of work carried out during the previous year were regularly published. The practice of village to village survey has continued till date. Inventory of monuments and antiquities, National Mission on Monuments and Antiquities and National Monuments Authority are laudable efforts to maintain a registry by the Archaeological Survey of India (ASI), with contributions from state departments and universities. Museums across the country have large collections of antiquities of all time periods in an unpublished form, and museum records may reveal the much needed information on locations of the finds.

Therefore, the range of documents available to archaeologists in their search for ancient sites is enormous, thus helping in collecting information on archaeological sites. For example, revenue records of the colonial times are a veritable source of information on archaeological sites. Similarly, maps prepared by colonial surveyors are the authentic documents of ancient sites and modern topographic maps continue to include this information. They not only mark historical sites, but also prehistoric burial complexes and mounds.

Place name studies are relevant in planning archaeological explorations, especially prehistoric ashmounds and settlements of the Neolithic and Megalithic periods. Place name suffixes provide interesting clues on the existence of prehistoric sites in the neighbourhood. There are numerous examples of success stories based on such studies in southern India.

Field archaeology: explorations

Exploration and excavation are the two major components of any field archaeological research design and are mutually exclusive. Systematic ground surveys for locating archaeological sites, extent of archaeological activity, culture history of the settlement, etc. can be conducted prior to excavation and sometimes in lieu of excavation. This has been carried out at a number of archaeological sites all over the country. Simple random sampling, stratified random sampling, systematic sampling and stratified systematic unaligned sampling are well-known methods applied prior to launching excavations. Among the numerous examples mention should be made of the Vijayanagara Metropolitan Survey project at the World Heritage Site of Hampi, the Bellary and Kurnool Districts archaeological projects and survey of Palaeolithic landscapes in the Vindhyas and the Hunsig-Baichbal valleys, to name a few[2].

Chemical analysis of soils associated with human activity in the landscape helps determine the duration and intensity of human activity in the past, reflected in the greater concentration of natural elements like carbon, nitrogen, fluorine and phosphate. Phosphate analysis of anthrosols from a number of archaeological sites of the Neolithic and Chalcolithic, as well as historical sites has been carried out in India[3]. One of the earliest examples of systematic ground renaissance in search of Harappan sites was undertaken by Ghosh of ASI along the dry bed of River Ghaggar in Rajasthan. Similar survey along River Chautang in districts Hanumangarh and Ganganagar in Rajasthan also revealed many Harappan sites. Archaeological sites and artefacts are being discovered accidentally by developmental projects. The discovery of one of the largest Harappan cemeteries at Sanauli in western Uttar Pradesh is a classic example, wherein levelling operations for agricultural purposes brought to light a series of skeletal remains, ceramics, stone bead and copper object of the Late Harappan period[4].

Locating archaeological sites

Aerial and remote sensing surveys: Since the last World War beginning with the use of aerial photos a number of advanced remote sensing techniques have come into field archaeology as spin-offs from developments in space and aeronautic science[5]. Archaeologists searching for new sites use satellite images, drone operations and geophysical methods. These can be used in various combinations and are key elements of geographical information systems (GIS). Geophysical survey methods are part of remote sensing surveys and a non-destructive method of site investigation. They have found application extensively in Indian archaeology. Resistivity surveying, magnetometry, ground-penetrating radar, acoustic reflection and thermal sensing are in use; among them resistivity surveying and magnetometry are the most common. A series of workshops to train up and coming archaeologists in India have been organized by IIT Kanpur and National Remote Sensing Agency, Hyderabad.

Aerial surveys, and more particularly, documenting complete sites and excavations, can be traced back to World War I and military reconnaissance[5]. The pioneering works of Crawford in England, Father Antoine Poidebard in Syria and Erich Schmidt in Iran ushered this new field, which started with the principle of taking near vertical and oblique angled aerial photographs in different light conditions, to discover, locate and document archaeological sites and monuments. The airborne photography was later modified to suit the documentation necessities of archaeologists, and low-altitude photography played a crucial role in our understanding of excavated structures and monuments. The photographic equipment can be mounted in a balloon, kite, ladder or a boom mast depending upon the necessity. Depending upon the availability of high-resolution equipment and area to be surveyed, different features like crop and soil marks in a landscape are clearly observable in aerial photographs that may indicate burial features[6]. Considerable advancements have been made in aerial photographic techniques; with the development of drone technology or unmanned aerial vehicles, low-altitude aeromodelling can be achieved. Further, the drones can also be fitted with different sensors like thermal, infrared and light detection and ranging (LiDAR) to enhance the images to even detect subsurface features like ditches, moats, etc. Aerial reconnaissance using the airborne and satellite images have their own disadvantages in detecting the subsurface features. This can be overcome by remote sensing by 'using ... electromagnetic radiation in the visible, near infrared, short infrared and thermal infrared of which thermal infrared is more suitable,… for detecting surface anomalies correlated with subsoil surface'[7]. The use of conventional film-based approach of NIR aerial reconnaissance to interpret crop marks in the identification of archaeological remains is also a recent attempt[8]. LiDAR or airborne laser scanning is an important tool for investigation of large swaths of landscape, which is effective even in densely forested areas as indicated by successful examples from Angkor Wat[9,10] and Mayan site of Caracol, Belize[11].

In the Indian context, aerial photographs from the sites of Tughlaqabad (Figure 1)[12], Sisupalgarh (Figure 2)[13], are the best examples of the use of such techniques in the documentation of archaeological sites. It is interesting to

Figure 1. Aerial photograph of Tughlaqabad taken in 1945.

note the significant changes in the landscape around Sisupalgarh between the images taken in 1948 and the recent Google Earth image. The aerial photograph of 1948 (Figure 2) shows open areas inside the fort and all around, whereas the recent Google Earth image clearly (Figure 3) shows the extensive development and encroachment of areas close to the site. However, an interesting feature in both these images is the presence of water bodies on the four corners of the fort, and another to the northwest of the fortification. Google Earth is a latest and simple tool for not only understanding various aspects related to terrain and geographical locations, but is also helpful in locating archaeological sites, and in some to observe more features that are not easily observable on ground[14]. Thakuria *et al.*[14] demonstrated the usefulness of Google Earth

Figure 2. Aerial photograph of Sisupalgath, Odisha taken in 1948.

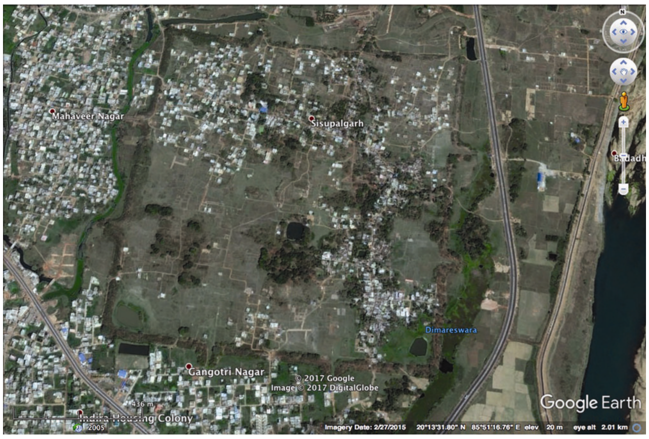

Figure 3. Google Earth image of Sisupalgarh in 2016.

images to understand the nature of construction at the site of Talpada, while at Lathi, a potential archaeological site was discovered. Tools like Google Earth combined with GIS also help in generating a predictive model for locating archaeological sites, as demonstrated by Gillespie *et al.*[15] in the case of edicts of Mauryan ruler Asoka. They used an algorithm known as Maxent to understand the relationship between known Asokan edicts and predicting potential areas of edicts based on similar habitat.

One of the best examples for the use of remote sense data in archaeology is the delineation of several palaeochannels of the river Sarasvati in Haryana and Rajasthan (India) and Bahawalpur in Pakistan by several scholars[16–22]. The existence of palaeochannels in Haryana, Punjab, Rajasthan and Bahawalpur has long been known as a result of ground surveys carried out by Oldham[23] and Oldham[24]. A large number of archaeological sites located on them were documented by Stein[25], Ghosh[26] and others. Confirmation of these palaeochannels by remote sense data is a classic example of additional and complementary data such as continuity, and existence of multiple palaeochannels could be established. Recently, Rajani and Rajawat[27] attempted superimposition of archaeological sites on SRTM DEM combined from satellite data to create a digital terrain model of the lost Sarasvati river, and in order to understand relict levees vis-à-vis archaeological sites of Harappan Civilization. This study has opened up the potential of the region for future research.

Ground surveys: Routine exploration of a terrain and landscape with a well-conceived research design is the most simplest and inexpensive mode of conducting field archaeological research. Exploration, though time-consuming, is more productive and less destructive, rather than excavation of a host of sites. Any systematic exploration methodology for locating and pinpointing archaeological sites and artefacts is incomplete without a well-planned ground survey. If the remote sensing surveys give a broader perspective of archaeological landscapes, it is the ground survey which can confirm the observations drawn from aerial surveys. The traditional approaches for archaeological explorations consist of village-to-village surveys or district surveys for documenting 'material remains' of the past to be able to reconstruct culture history of the region under consideration. The concept of surveying entire landscapes, which also enabled identification of agricultural land use, lynchets (parallel heaps of stones marking boundary of fields), buried tracks, roads and buildings was an important feature of European field archaeology[28]. The use of suitable sampling strategies to survey an entire landscape and statistical methods is an essential aspect in any exploration programme.

The exploration methodology in the Indian subcontinent during the 19th and most part of the 20th century, consisted of visiting places of historical and architectural (monumental) importance, often mentioned in ancient literature and travelogues, both Indian and foreign, draw plans and elevations and publish them as tour diaries or reports. The 22 volumes published by Alexander Cunningham starting from 1871 onwards are the best document of such surveys. One of the earliest problem-oriented multidisciplinary surveys in the subcontinent is credited to the Yale–Cambridge Expedition by de Terra and Paterson[29]. Further linear river surveys carried out along the dry bed of the Sarasvati by Ghosh[26], and several other surveys as part of Ph D programmes were equally productive in filling geographical gaps in the distribution of pre- and protohistoric sites. The focus on more and more systematic and integrated site surveys is now the standard approach which has helped in systematic collection of artefacts and information pertaining to settlement pattern, raw material distribution, industrial activities, provenance studies, etc.

Several examples of minimalistic intervention in the form of exploratory surveys followed by sample collections were made and to a large extent excavations were optional. One such example is the project entitled 'Herder's monuments: ashmounds of southern Deccan Neolithic'[30]. A regional approach was adopted in this project to understand the periodic cycles of activities of Neolithic ashmounds in southern India, particularly in Karnataka (Ballari, Raichur and Kalaburgi districts) and Ananthapuram district in Andhra Pradesh (AP). The objectives of this project were geoarchaeological and phytolith investigations to understand: (a) the cyclic events, (b) nature of the ashmounds in terms of ritualism and/or symbolism, (c) human settlements associated with them, and (d) reconstruction of contemporary vegetation. In view of the fact that such sites are subject to consumption by modern developmental activities, agricultural expansion and vagaries of nature, salvaging the vital evidence becomes inevitable. Further this project envisaged systematic integrated data collection on ashmounds through (i) collating information arriving from the fieldwork, which involved documenting each ashmound, drawing site plans, gridded systematic survey transects of endangered sites and (ii) computational strategy involving integration of available cartographic, digital maps and satellite imageries to evolve a digital cartography, photographic archive and GIS platform for landscape analysis and visualization. Some of the most important sites like Sanganakallu were surveyed in detail using the total station to document the present condition of the site and preserve it in a digital format. This survey was the first of its kind, which helped in developing a GIS-based interpretive tool for the ashmounds of South India.

The Sanchi Survey Project of Shaw[31] aimed at understanding the Buddhist monastic settlement in terms of spread of religion, urbanization, state formation, economic change, agricultural activities, networks for trade and communication. The survey methodology consisted of exploring an area of 750 sq. km around the monastic complex at Sanchi[32]. The methodology of the survey consisted of intensive exploration of the defined area, collection of sediments from dams and reservoirs, mapping and systematic remote sensing[31]. The survey led to documenting 35 Buddhist sites, 145 settlements, 17 irrigation dams, and over 1000 sculptural and architectural fragments associated with Hinduism, Jainism and local cults[32]. This investigation helped in understanding the role of Buddhism in establishing the novelty of agricultural practices and water management measures during the 2nd BCE (also see page 1918, this issue).

The Anuradhapura (Sri Lanka) investigations by Coningham *et al.*[33] are an excellent example of surface survey methodology. As pointed out by these authors, the traditional approach of investigation is more concentrated on the specified site itself without taking into consideration the role of immediate and distant precincts. The methodology consisted of an intensive survey of an area of about 50 km radius from Anuradhapura, to document and map the location of non-urban sites, and collection of samples for analyses. Random transect lines each measuring 10 km criss-crossing this area covering all aspects like rocky outcrops and ridges, streams and rivers, grasslands, forests, tanks, villages, chena (swidden agriculture) and paddy fields were drawn[33]. A team of ten archaeologists walked along these transects and recorded topography, vegetation, land use, resources and cultural features[33]. The cultural features, indicated by artefacts, ceramics and lithics were documented, sketched and their GPS locations were marked. Material and sediment samples were collected for analysis. This survey was also extended to the Malwatu Oya river to understand the nature of settlements along the banks and also identify points of transport as this river connected the city to the coastal areas. The survey helped in identifying various categories of sites like ceramic scatters, monastic, stone pillars and walls, metal-working areas, conical holes on rock outcrops, megalithic burials, stone bridges and anicuts and modern sites.

Similar field-walking surveys were carried out at Sanganakallu Neolithic site in the Ballari district of Karnataka and multiculture site of Jwalapuram in Kurnool district AP, prior to launching excavations at these two site-complexes.

Geophysical survey of archaeological sites: Significance of the role of scientific instrumentation techniques in archaeological reconnaissance hardly needs emphasis, be it in the form of a simple handheld GPS for recording location details of artefacts to structures, or also sophisticated equipment like drone and laser scanners. One of the advantages of geophysical tools is that it can cover large areas of landscape for detecting the buried architectural features[34,35].

There are two categories of geophysical methods[36,37], viz. passive and active methods. The passive methods measure the 'amplitude of nearly steady magnetic, gravitational and electrical perturbation fields, generated by buried features, are measured at the sensing device'. In the active methods, 'artificial seismic, electrical and electromagnetic (inductive and impulsive) signals are emitted by the device, which then senses the return signals, more or less altered by the typical responses of the subsurface features'[36]. Under the passive method, magnetic prospecting (magnetometry)[38], gravitational surveying[36] and self-potential (SP)[39] techniques are used for detecting buried features. Among these, SP is considered to be the least, expensive geophysical method in detecting archaeological features as demonstrated by Smith and Mohanty at Sisupalgarh.

The techniques under active methods[40] are (i) seismic or acoustic[39], (ii) electromagnetic, (iii) resistivity or galvanic[39] and (iv) ground-penetrating radar (GPR). The seismic method involves transmission of sound waves and measurement of the time of the reflected waves-based on density variations of buried features. The acoustic method is a similar technique, which is based on higher frequency sound reflected by voids or objects of higher density than that of the surrounding soils[40]. The second technique is also categorized as non-conducting electromagnetic (EM) or induction method[36] that ranges from simple metal detectors to sophisticated soil conductivity meters[40]. The galvanic or soil conduction electrical method works on the principle of conduction/non-conduction of soil and buried features (particularly stone)[36], and a resistivity profile is created with the help of multiplexed electrode arrangements. The ground-penetrating radar or GPR is considered as a better technique compared to the other three, the range of detection being from a few millimetres to several metres beneath the earth's surface. GPR works on the principle of transmitting different wavelengths of radar signals and then measuring the continuity/discontinuity of reflected signals depending upon the properties of soil conditions and buried features.

The use of electrical resistivity and magnetic gradiometry at Sisupalgarh by Smith and Mohanty[41] helped in prospecting an area of 13 acres, which revealed the presence of a 300 m long section of ancient road and its associated side streets and structures. The efficiency of GPR and other geophysical methods in prospecting a large area, which otherwise is not possible by regular excavation methods, a slow and expensive methodology by its nature, is an advantage for archaeological sites, as has been indicated effectively by Smith and Mohanty[41] at Sisupalgarh.

At the Early Historic site of Ahichchhatra, Sravanthi *et al.*[42] carried out GPR prospecting in order to assess the extent of buried features across at least four sites of this vast city, two of them with high resolution (Figure 4). Ahichchhatra is dated from the 2nd millennium BCE to 14th century CE and has witnessed several phases of development and settlement expansion. The GPR method seems to be the only cost-effective, most suitable and less time-consuming methodology for such a site when compared with excavation. Another interesting and important aspect of this survey is the testing of anomalies obtained from GPR profiling through excavation. In one of the areas subject to GPR profiling (grid 1), a trough indicated by anomaly proved to be a collapsed and sunken structural phase[42]. The other three profiles obtained through GPR indicated closely spaced deserted walls which could be related to common dwelling (grid 2), single wall which having more intersections and also forming a part of the dwelling (grid 3), and compacted surfaces that could have been used as walkways (grid 4)[42].

The Lothal Revisitation Project is another example of geospatial archaeology in India[43]. Combined remote sensing and ground surveys, in which various non-invasive geophysical techniques were used, this project aimed 'to detect different natural and artificial subsoil features, complemented by series of core drillings to determine the shifting of palaeo-channels and shorelines', to reconstruct the palaeogeography around Lothal during the Late Mid-Holocene and the hydraulic structures that interfaced the site with the surrounding environmen[43]. Lothal is a well-known Harappan Civilization site with evidence of occupation during the second half of the 3rd millennia BCE (Figure 5). This site has revealed the presence of a twin-fold habitation surrounded by fortification, craft-activity areas, the warehouse, maritime trade and external contacts, cemetery and a dockyard. The techniques used in the investigations include[43] geomorphological, remote-sensing analysis of the area around Lothal '3D digital elevation model … using relative kinetic GPS', 'magnetic survey of the non-excavated archaeological area using cesium magnetometer'. The magnetometer survey showed three prominent anomalies: (i) baked-brick embankment canal running east–west and perpendicular to the dockyard, probably connecting the nearby palaeo-river to the dockyard (anomaly A); (ii) an architectural complex consisting of rooms along a narrow street and separated by lanes to the northeastern area (anomaly B), and (iii) a possible monumental gateway or a large drainage outlet to the southwestern corner of the acropolis (anomaly C). Frenez also carried out 'test trenches' in the areas of anomalies, which largely confirmed with the findings (Figure 6). Thus application of non-invasive techniques of unexcavated areas at Lothal had not only reduced the time spent in speculative excavations to find buried features, but rather using the geophysical techniques to first understand the subsoil features and then proceeding to limited excavations with maximum output.

Geophysical investigation at the Harappan site of Dholavira, in Kachchh, Gujarat is a noteworthy example. Excavations at the site had revealed monumental architecture

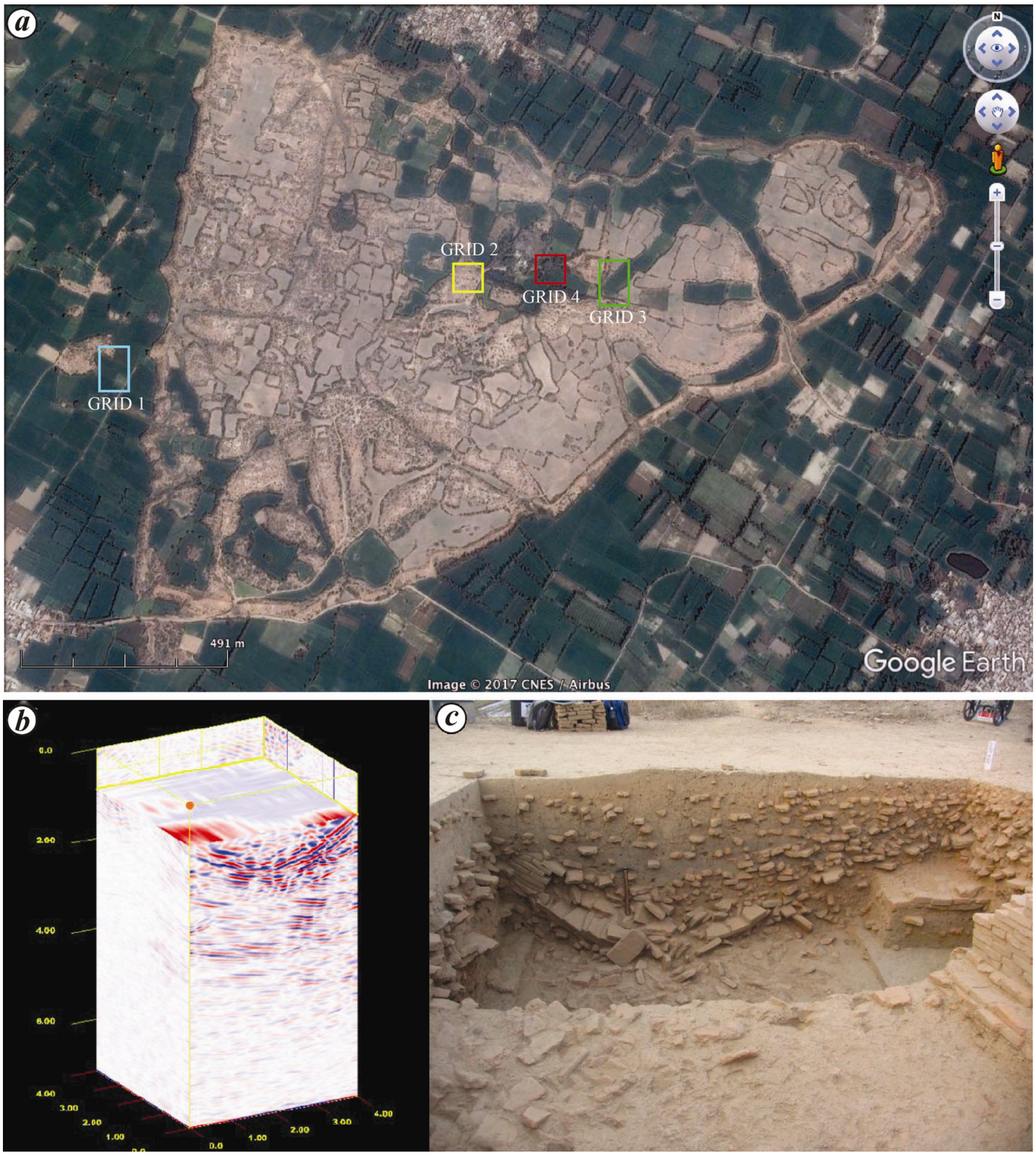

Figure 4. *a*, Google Earth image of Ahichchhatra showing location of the four grids (after Sravanthi *et al.*[41]). *b*, GPR profile of grid 4 (courtesy: Javed Malik). *c*, Excavation in Grid 4 confirming the slump observed in the GPR profile (courtesy: Bhuvan Vikrama).

and water management systems. The GPR prospecting carried out during three site visits by scientists of IIT-Gandhinagar helped in understanding the vast buried remains in the unexcavated portions of the site[44,45]. A vast and flat area to the east of East Reservoir and to the north–northwest of the Manhar River, was divided into four designated areas (area A (171 × 135 m), area B (117 × 132 m), area C (36 × 72 m), area D (36 × 18 m)), and GPR probing was carried out (Figure 7). Area C, which lies immediately to the south of the Lower Town was also considered for probing as it was covered with a sheet of water during flash floods and heavy rains. Area C is also flat and devoid of any prominent above-ground architectural features (Figure 8), and similar to areas A, B and D. GPR investigations brought to light T-shaped parallel walls with a spacing of 7–8 m between them in area A and to the east of the area a set of parallel walls with a north–south alignment along with a spread of rubble, which may be collapsed walls[44,45]. The overall findings from the investigations indicated the presence of shallow and smaller reservoirs to the east of East Reservoir, possibility check dams, and fallen walls forming rubble and scattered debris[44,45].

The above discussion clearly indicates the necessity of a thorough study of the entire landscape through surface reconnaissance, involving traditional as well as geospatial techniques, to arrive at a broad-based understanding of landscapes in general and the archaeological site in particular. Such an approach will help in identifying potential areas to be studied in detail. The case

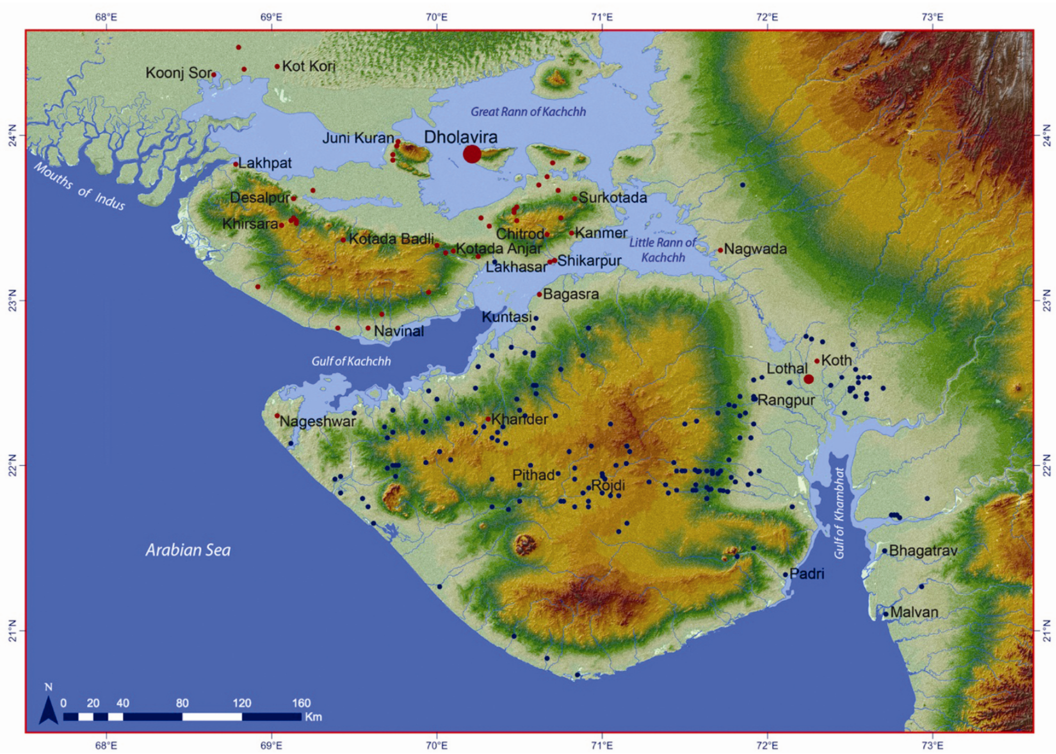

Figure 5. Location of Harappan and Sorath Harappan sites in Gujarat and Lothal.

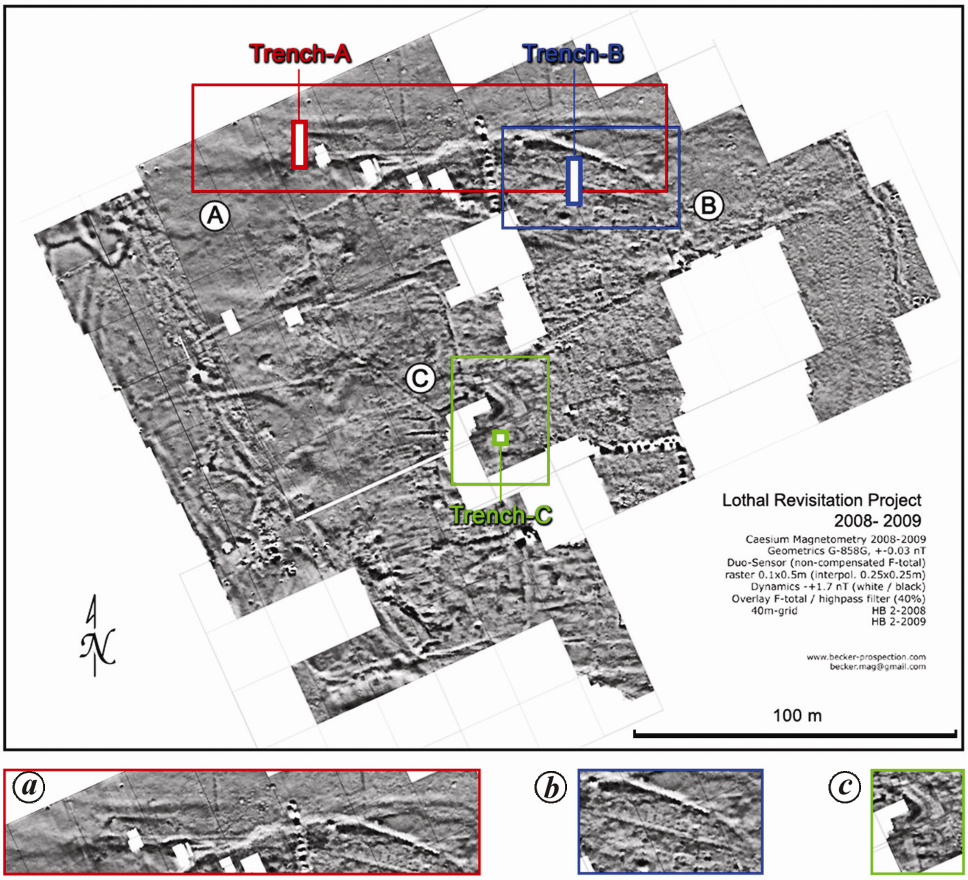

Figure 6. Photomosaic of the magnetograms obtained during Lothal Revisitation Project showing the major anomalies and location of three trenches (courtesy: Dennys Frenez).

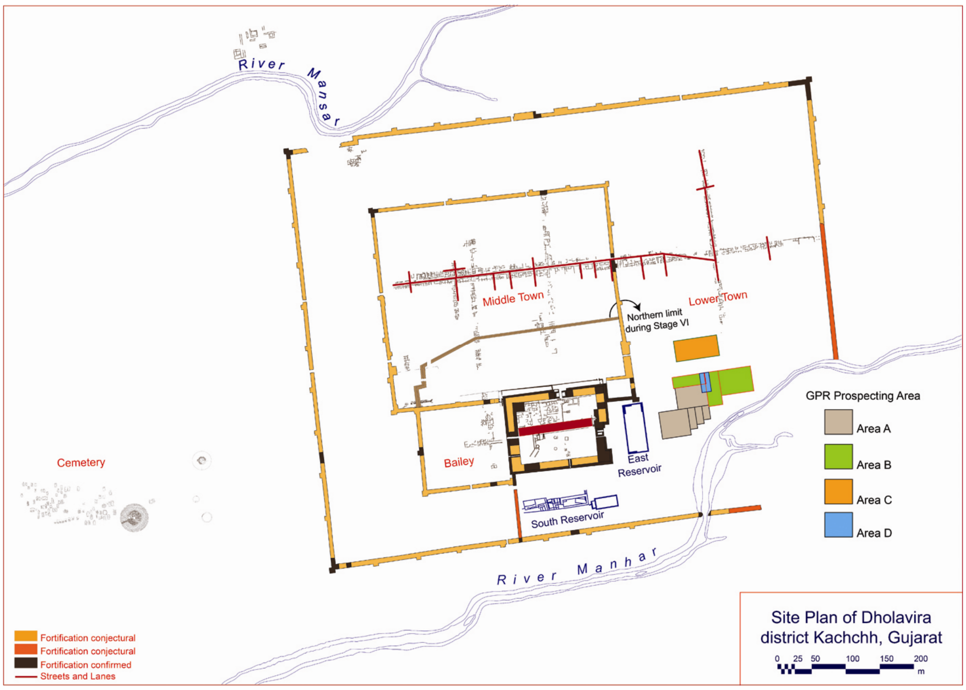

Figure 7. Site plan of Dholavira showing the locations of GPR investigations.

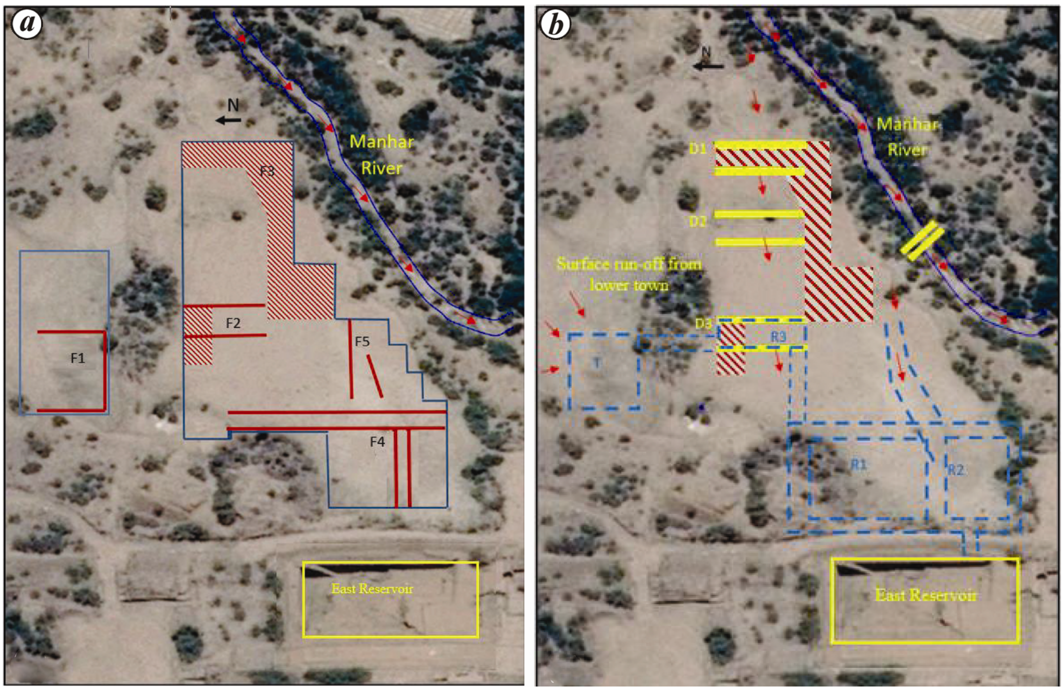

Figure 8. ***a***, Features observed from the GPR investigations. ***b***, Interpretations based on the observation of anomalies from GPR investigations (courtesy: Mantu Majumdar and Silky Agrawal).

studies and examples presented here clearly point to the advantage of such surveys, which are inexpensive and less time-consuming than the actual excavation. The GPR investigations at Lothal and Dholavira are clear indicators of advantages helping in revealing several features, which were missed by conventional excavation methods.

Excavation of archaeological sites

Excavation of any archaeological site, be it systematic or sophisticated, is destructive, as it is irreversible. It has to be, therefore, carried out with utmost scientific attention, including documentation and analytical strategies.

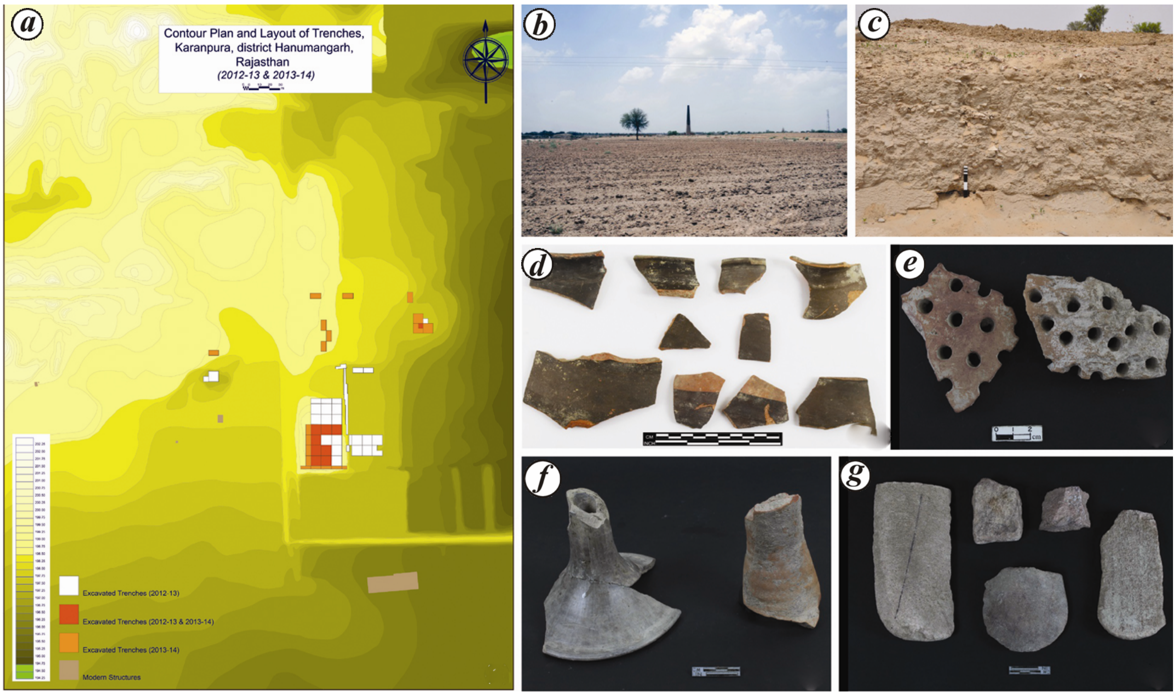

Figure 9. ***a***, Contour plan of Karanpura, Hanumangarh district, Rajasthan showing excavated trenches; ***b***, ***c***, Surface morphology showing levelling and agricultural operations. ***d–h***, Finds from the exploration before excavation.

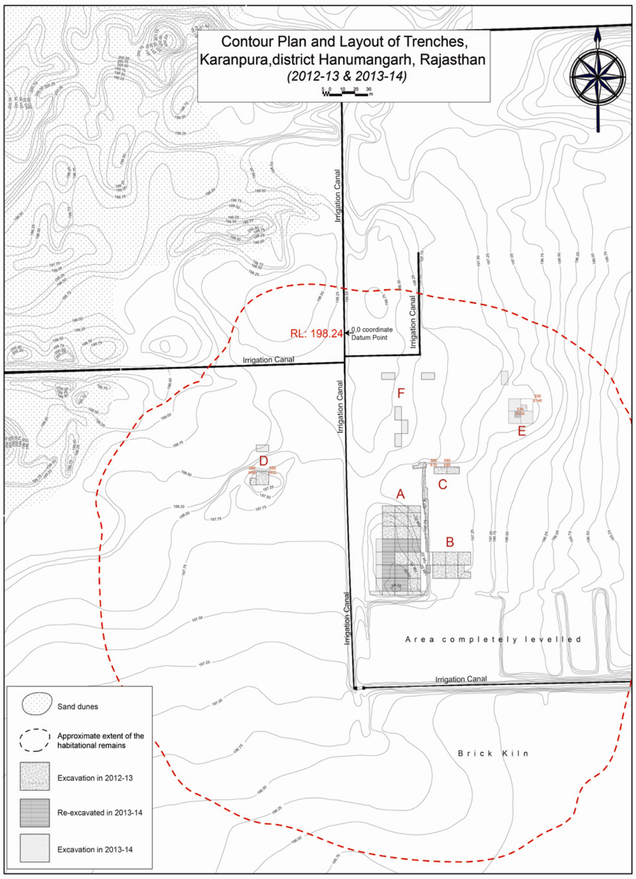

Figure 10. Site layout of Karanpura showing details of different areas of excavation.

According to Barker[46] '… study of a site by excavation is an unrepeatable experiment' and clearly states that excavation is destruction. During the early days random diggings brought to surface buried remains. Because of dig and pick methods credible information could not be obtained. In other parts of the world, extensive excavations, not based on scientific principles, were being carried out at Pompeii, a Roman city which was buried beneath nearly 6 m of volcanic ash originating from Mt. Vesuvius in 79 CE.

The works of James Hutton and Charles Lyell, both geologists, formed the basis of the principles of stratigraphy and uniform itarianism (i.e. present is key to the past). The concepts of the 'three age system' by Thomson and 'typological sequencing' of General Pitt-Rivers and John Evans, through which artefacts could be placed in a chronological or developmental sequence, were revolutionary in nature[2]. Pitt-Rivers is also credited for the introduction of proper recording of archaeological finds from excavation, irrespective of their nature and importance. Similarly, Flinders Petrie also employed meticulous recording procedures for his excavations in Egypt during the 1880s, and also introduced a relative dating technique for artefacts known as 'seriation dating'. Proper stratigraphic excavation was still elusive and even though methodological recording processes were followed, the interrelation between structures, artefacts and other features like pits, dumps, postholes was less understood, which prevented the development of a proper chronological sequence of a site. The Wheeler–Kenyon era saw the emergence of detailed section drawings delineating each and every deposit and also drawing an interface between them, numbering them individually from top to bottom, correlating these deposits with the structural finds and other activities like pits, dumps, postholes, and rodent activities to arrive at a total stratigraphical sequencing of a trench and site. The methodology of excavation by Wheeler is known as grid-square method, which was employed to control the digging as well as to record the features in a systematic manner. This method was also employed to excavate horizontally as well as vertically, so that the former can be used to open up a large area in case of knowing the horizontal layout of the settlement[46]. However, the method of leaving intermediary sections often posed issues while excavating prehistoric sites as observed by Hatt in his excavations of an Iron Age site at Norre Fjand[46]. The 'area excavation' soon followed as an alternative for open areas with shallow deposits where several intermediary balks representing sections were found redundant[47]. However, for large sites with multicultural occupations, area excavation alone is insufficient, and a combination of different strategies needs to be adopted. The methodology developed by Harris, popularly known as Harris matrix or Harris–Winchester matrix, is followed by archaeologists for deeply stratified strata represented by multicultural sites[48].

Harris also proposed 'laws of archaeological stratigraphy' which, according to him are the basis of any deposit in an archaeological excavation, viz. (i) law of superposition, (ii) law of original horizontality, (iii) law of original continuity and (iv) law of stratigraphical succession[48]. Apart from the correlation of different units representing archaeological site formations, samples are collected from each deposit to understand a plethora of information of various aspects of human occupation. Archaeologists working in the field adopt a combination of excavation methods. The paucity of funds often prevents archaeologists to excavate on a large-scale and excavation is reduced to a few vertical trenches, in which the occupational history of the site can be traced. The excavation strategy also depends on the objective of the project. Thus, if the layout of the city or town has to be understood rather than the occupational history of the entire site, a horizontal layout is followed, while having an intermediary section or not is entirely according to the needs of the excavator. Therefore, a more flexible approach is necessary and according to the necessity and objective of the excavation project archaeologists adopt either vertical or horizontal or open-area excavation methodology. In all the cases, the principles of stratigraphy are meticulously followed, drawing correlations between each individual deposit, their interrelationship, which can be represented either in the form of detailed section drawings of the digs, or a Harris matrix representing all units of deposit is drawn, exhibiting the stratigraphic relationships of a site[48].

Excavation of a multicultural site

Any excavation, without following the principles of stratigraphy is unscientific. The method of layout of trenches and adopting strategies regarding leaving intermediary balks for sections or open-area excavation may be site-specific. However, digging has to strictly follow the principles of stratigraphy, to fully understand the site formation process, various anthropogenic and natural interventions, activities that occurred post abandonment of a site. As seen above, in order to understand the complexities of a multicultural site, the methodology proposed by Harris appears more appropriate. Excavation of the Harappan site at Karanpura, Hanumangarh district, Rajasthan by V.N.P. is cited as an example here.

Pre-excavation research

The selection of a site for excavation, which is an expensive and time-consuming exercise, needs to be done carefully with clearly framed research objectives in mind. Location and identification of a site using different methodologies are part of pre-excavation research. The Harappan site at Karanpura was already known to archaeologists, and its nature and potential were assessed before V.N.P. carried out a detailed surface reconnaissance. Karanpura is located on the dry bed of the Drishadvati river, a tributary of the Ghaggar[48]. The site was visited several times before the actual excavation was started in order to understand its nature, potential and importance. The presence of artefacts, ceramics, bones, all lying scattered on the surface could not be observed at Karanpura, which was highly disturbed due to agricultural encroachment and brick manufacturing activities (Figure 9). A large portion of the site has suffered damage because of levelling operations, and a sizeable chunk of archaeological deposit, nearly 1.5 m had already been dug out. As a result the archaeological site presented a vast flat area, with exposed sections due to cutting of canals revealing cultural deposits, including ceramics and bones. The site was also under cultivation during the visit, and therefore a large quantity of terracotta bangles, beads of agate-carnelian, baked bricks, ceramics belonging to Mature Harappan and Early Harappan periods could be collected from the upturned soil. Documentation of these artefacts and other remains from the surface indicated the broad time span covered by the site.

The material culture of the site was compared with the already explored and excavated sites in the region; a settlement pattern map was also prepared. The other excavated Harappan sites like Sothi, Siswal, Dabri, Nohar, etc. were visited and their antiquities were found similar to those at Karanpura. All these sites also preserved evidence of Early Harappan phase of occupation. Further, sites like Bhadra, Karoti, Jhansal, located in the

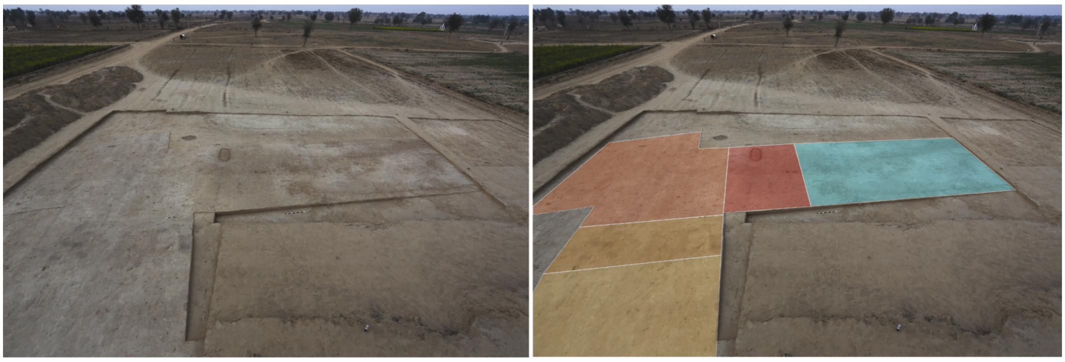

Figure 11. (Left) Example of open area excavation showing a corner of sun-dried fortification. (Right) The same fortification delineating different colours of sun-dried brick; they are only an indication of boundary and not actual colours.

EXCAVATION RECORDING SHEET

SITE	TRENCH	DATE

Operation Area
Reference Peg
Digging
(i) Started at (cm)
(ii) Ended at (cm)

LOCUS (any new feature) — LAYER / PIT / DUMP / STRUCTURE / FLOOR / DRAIN / PLASTER / POST-HOLE / GHOST WALL

Colour (Munsell soil chart)

Composition

Clay ( ) | Silt ( ) | Sand ( ) | Pottery ( ) | Gravel ( ) | Stone ( ) | Brick-bats ( )

Pebbles ( ) | Any other (*speficy*)

Texture | Fine ( ) | Medium ( ) | Coarse ( )

Context

Mode of deposition

Observation

RELATION WITH OTHER LOCUS: (*A drawing should be supplemented*)

POTTERY (*detailed description for outstanding features to be given separately*)

Type(s)	Red ( )	Grey ( )	Black ( )	( )	( )	( )
Individual count						
% of each type						
Weight						
% of thick / thin						
Preservation condition						
Hand / Wheel made						
Slip / Wash						
Burnishing / Polishing						
Texture (*fine, medium, coarse*)						
Firing (*well, medium, ill fired*)						
Decoration(s)						
Graffiti, if any						

Important Shapes

STRUCTURE(S)

Location

Dimensions | Length | Width | Height | No. of courses

Stone ( ) | Mud ( ) | Mud Brick ( ) | Burnt Brick ( ) | Wattle & daub ( )

Others (*specify*)

Orientation

Stratigraphy, relation with other locus and structures

Locus

Other structures

Context (*specify whether wall, fortification, room, or other*)

Masonry | Course ( ) | Random rubble ( ) | English Bond ( )

Mortar | Mud ( ) | Lime ( ) | Others (*specify*)

FLOOR

Relation with other locus and features

Nature | Mud ( ) | Lime ( ) | Brick ( ) | Brick-on-edge ( ) | Stone ( )

ANTIQUITY (*detailed list to be provided*)

No. of antiquities found

Nature | Coin ( ) | Bead ( ) | Bangle ( ) | TC Figurine ( ) | Stone ( )

Sculptural fragment ( ) | Others (*specify*)

SIGNIFICANT ACTIVITIES (If any)

Roots ( ) | Rodent ( ) | Burrow Hole ( ) | Insects ( ) | Human ( ) | Erosion ( )

Deposition ( ) | Others (specify)

SAMPLES COLLECTED OR NOT? | YES | NO

Botanical

Soil

Carbon

Raw materials

DRAWING RECORD (*drawings of plan, section, elevation, structures done or not*)

Reference No.

PHOTOGRAPHIC RECORD (*photographs of plan, section, structures done or not*)

Camera used

Reference No.

GENERAL OBSERVATION OF THE FEATURES

RESUME OF THE EXCAVATION

MATRIX DIAGRAM ILLUSTRATING THE STRATIGRAPHY

TRENCH SUPERVISOR

Figure 12. Excavation recording sheet used during the Karanpura excavation.

neighbourhood of Karanpura were also visited, which revealed early historical remains. Explorations along the Drishadvati indicated the presence of human habitation from the 3rd millennium BCE to early historic times, with breaks in between during the 2nd millennium BCE. The desiccation of this river also coincides with the drying up of River Sarasvati, the palaeochannels of which are represented by the rivers Ghaggar in the upstream and Hakra in the downstream. The necessity of a salvage operation was felt as the site was subject to multiple occupation and ownership and was found to have been subject to agricultural expansion and encroachment. It was also hard to convince the local villagers to spare the archaeological site, as agriculture was the option available

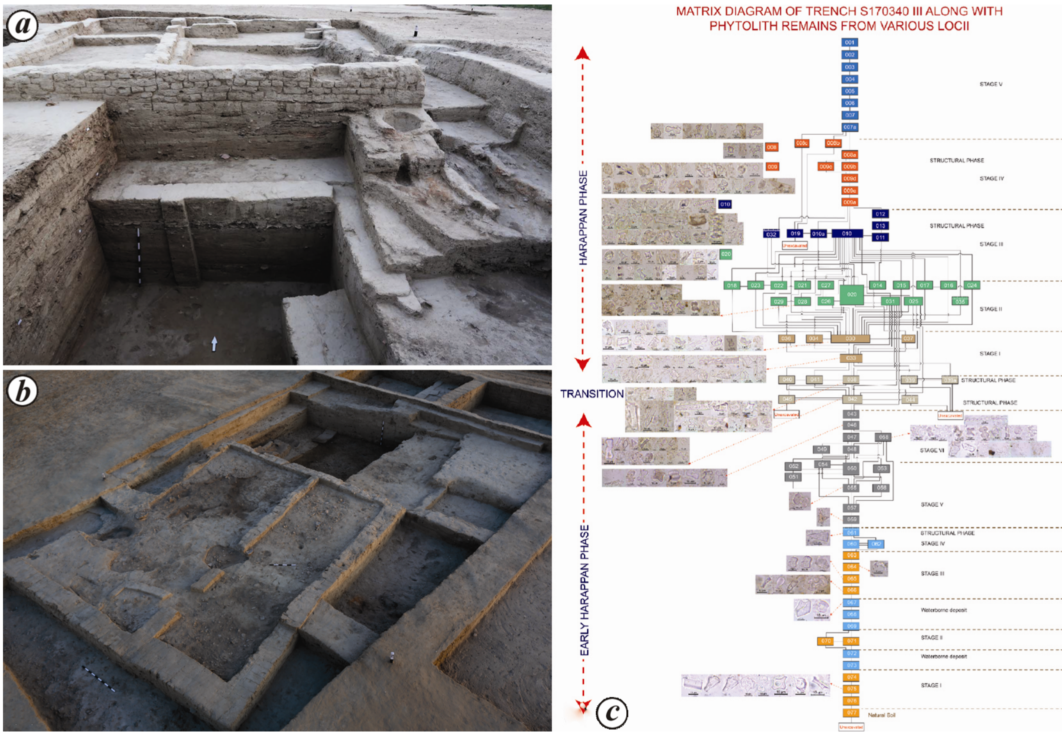

Figure 13. ***a***, Example of a vertical trench showing different phases of structures and occupational levels. ***b***, A complete house of Harappan phase excavated initially within a grid and later removing the intermediary balks to understand it horizontally. ***c***, Harris matrix of the vertical trench shown in (***a***), documenting the stratigraphical units and their correlations in Karanpura.

to them; and with the availability of canal irrigation, more areas were likely to come under cultivation. The archaeological remains were carefully recorded and surface features plotted on a contour plan, to understand the present condition and also to record what alterations and modifications are still being made (Figure 10). This approach was essential to document and illustrate not only the natural features in and around the site, but also man-made interventions that altered the landscape.

Methodology

The approximate extent of the site measures 400 (NS) × 420 (EW) m, thereby occupying an area of 16.8 ha at its maximum occupation. For the purpose of excavation planning, a 0, 0 coordinate was fixed on a permanent point on the irrigation canal at the central portion of the site, with a relative level of 198.24 m. Then the site was gridded with 10 × 10 m squares, to the north, south, east and west of the 0, 0 coordinate; thereby their locations can be pinpointed. For example, a grid located 100 m east and 50 south of 0, 0 coordinate, can be labelled as S50E100. The grids were then subdivided into four quadrants, each measuring 4.25 × 4.25 m. However, it is emphasized here that the intermediary balks representing the section of each grid were removed as the excavation progressed in order to have an uninterrupted understanding of the horizontal layout of house complexes and portions of the town. It was, therefore, a combination of grid-square methodology and open area excavation (Figure 11). The excavation was planned in such a way to have maximum information of both the horizontal layout of Harappan/Early Harappan town as well as vertical stratigraphy, understand the complete history of the site. As the site was under severe threat of obliteration and levelling, it was planned to obtain necessary details from every portion of it; therefore six different areas were selected for excavation, i.e. as areas A to F.

The Harris matrix system of excavation was followed wherein each feature or deposit, be it a structure, hearth, posthole, layer, ditch, dump, was identified as 'locus' and given a separate and continuous number, recording its details in 'excavation recording sheet' (Figure 12). For each locus a separate excavation recording sheet was prepared, with drawings and photographs showing the location and orientation. The colour coding of each deposit was designated according to the Munsell Soil Colour chart. A Harris matrix of each individual grid was prepared, and in particular the key grids, wherein a complete sequence of cultures was identified. This matrix diagram is the representative stratigraphic correlation of individual locus (features or deposits) and hence a chronological sequence of events from the earliest to the most recent (Figure 13).

The most difficult part of the excavation is the recognition of unbaked and sun-dried bricks that were used for the construction of structures by the Karanpura Harappans.

Figure 14. ***a***, Example of excavating faunal remains; here two limb bones of cattle species were found outside the house complex. ***b***, Mandible of cattle. ***c***, Part of pelvis and scapula of rhino, Karanpura.

Even though the clay used in the sun-dried bricks was different from the surrounding soil deposits, the colour completely matched with it and hence there was difficulty in identifying them. Different approaches were adopted for the identification. Observations were made during early morning in the winter season, as due to variation in absorption of moisture by the sun-dried bricks and surrounding soil deposits, outlines could be delineated. However, in most of the cases, water was sprayed over the bricks and surrounding soil to differentiate them, and once the outline was discernible, efforts were made to mark the individual bricks, their orientation and extent of structures. Once the walls and parts of rooms were identified, the house blocks were exposed on a horizontal basis to understand the layout of the town and to find additional features like fortification, streets flanking the house blocks and storage areas, hearths, tandoors in some cases, floors and other features within the rooms. Documentation of the excavated remains includes both drawings and photographs by the grid supervisor. Further, drawings were also made with the help of professional draughtsman and photographers to record each feature.

Soil samples were collected for multidisciplinary palaeoenvironmental and palaeobotanical (phytolith, pollen and diatom) studies. Soil from various deposits was also subjected to froth floatation to recover micro-charcoal and archaeobotanical (charred grains) remains. Artefacts recovered from the dig were labelled and their context recorded for further studies. Raw material samples were collected separately for scientific analysis into composition, manufacturing techniques and provenance studies, to name a few. Thus, the bead samples from Karanpura were studied for their manufacturing techniques using SEM at IIT Gandhinagar. Similarly, samples from copper were collected using ethylene diaminetetra acetic acid (EDTA) for lead isotope studies using ICP-MS to understand the provenance of copper raw materials. Law and Burton[49] have pioneered the sampling of copper, lead and silver samples using EDTA for a virtually non-destructive analysis of archaeological artefact.

The faunal remains were excavated with meticulous care using special tools, to prevent further damage (Figure 14). They were cleaned, documented and then packed for carrying out archaeozoological studies[50].

Ceramics form an important archaeological finding since the Neolithic period, and they diversify extensively with the introduction of pyrotechnology during the succeeding Chalcolithic period. The ceramic findings from each ‘locus’ or deposit from Karanpura were classified based diagnostic and non-diagnostic forms, then counted and weighed for quantification analysis. Sinopoli[51] has summarized the significance of quantification as: ‘recognition and quantification of variation within vessel classes may be significant in identifying chronological changes, interworkshop variation, or stylistic variations within broadly consistent categories of vessel’[51]. The indicators of manufacturing techniques like classification of core based on firing conditions (complete red, partly red, red and grey, grey at the centre and red at edges, which are indicators of different firing conditions), slip, texture and were also studied (Figure 15). Sampling was also carried out for undertaking starch grain and lipid analysis to understand the probable use of these ceramics. Further, experimentation in the manufacture of ceramics was also carried out in order to replicate various Harappan ceramic forms, and application of designs and motifs (Figure 16). This was followed by the construction of an updraft kiln similar to the Harappan technique, and the manufactured ceramics were fired to understand the fuel necessities and temperature required for complete firing. It was estimated that a continuous firing for 8 h with local firewood was sufficient to achieve complete firing.

Figure 15. ***a***, Example of early Harappan ceramic forms. ***b***, Harappan ceramic forms in Karanpura.

Figure 16. Experimental reproduction of Harappan ceramic forms using local clay, mineral colours and pigments with the help of pottery in Karanpura.

Post-excavation research

Excavation is followed by post-excavation research either at the excavation camp or in the laboratories to reconstruct technology, dietary practices, provenance studies, metallurgy, and a host of studies using various scientific disciplines. One such study is illustrated here. While in the field itself, impression of agate-carnelian bead holes found from the excavation using 3M polyxyloxene silicone impression material was taken, following the methodology well established by Kenoyer[52]. The bead impressions were studied in the SEM lab at IIT Gandhinagar to understand the manufacturing technology. The SEM analysis (Figure 17) indicated three distinct techniques: (i) pecking from both the sides for short bicone and barrel-shaped beads; (ii) pecking from one side and drilling with stone drill from the other side for long beads, and (iii) drilling with stone drills from both the sides. The polished surface of bead impressions of techniques (ii) and (iii) also indicates sophisticated drilling using ernestite drills, which is a hallmark of Harappan bead drilling technology, particularly followed at several sites located in Gujarat. As no evidence for craft activities was found at Karanpura, it may be concluded from the bead impression studies that the long beads were manufactured outside and traded here.

Conclusion

An attempt has been made here to understand the various methodologies and best practices used in Indian field archaeology. Even though it is impossible to compile all the

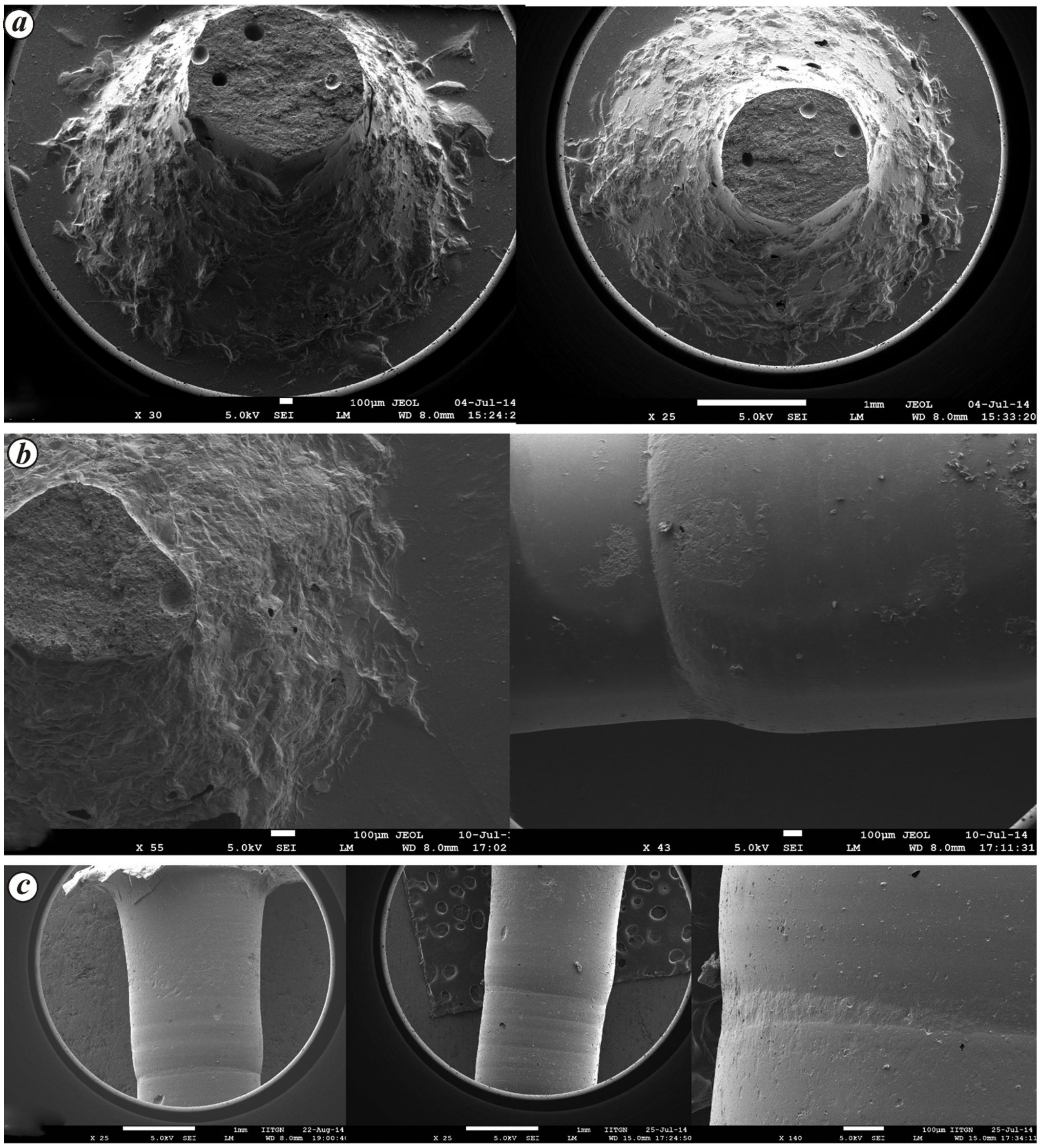

Figure. 17. SEM analysis of bead impressions of agate-carnelian beads from Karanpura. ***a***, Pecking from both the sides, ***b***, pecking on one side and drilling on the other. ***c***, Drilling from both the sides.

methodologies followed by archaeologists at present, and cite all the publications and research projects, those conducted during the last 15 years have been discussed here and mentioned in the references. As it has been understood well, excavation is a destructive process, which is irreversible, and hence maximum effort can be put into exploration of entire landscapes instead of single sites and monuments. Exploration of entire landscapes using various techniques and methodologies gives a holistic understanding of the archaeological site structures and monuments in the environmental setting and exploitation of various natural resources in the context. Systematic surveys at Anuradhapura and Sanchi that have been illustrated here are best examples of landscape survey. Similarly, post-systematic survey of landscapes, individual areas and sites can be selected for more detailed probing using various geophysical methods. The GPR surveys at Ahichchhatra present an excellent example of a survey followed by testing the anomalies through archaeological excavation. Similarly, at Dholavira, the GPR survey concentrated on the concept of 'known to unknown' by exploring areas to the east of the East Reservoir, the results of which were highly satisfactory. The excavations to check these anomalies are the next step in this regard and ideal for any GPR survey.

Excavation of select areas of an archaeological site is carried out either in the form of a problem-oriented research or subsequent to a well-conceived exploration programme. The excavation carried out Karanpura, Rajasthan is illustrated here as an example of both salvage archaeology to retrieve maximum information from a site under destruction and also to understand the expansion of Harappans into the Lower Drishadvati basin. A combination of grid-square and open area excavation methodology was followed at Karanpura, which helped in unearthing not only individual and complete house blocks, but also a part of the Harappan town along with fortification. The excavation also yielded various cultural elements, which were documented, sampled and studied, both in the field and laboratories. Some of the examples have been detailed above, the important ones being faunal analysis and bead impression studies.

Thus this article presents a synopsis of field archaeological research in India in response to advances in scientific field methods and techniques that are applied the world over.

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