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Saluvankuppam coastal temple – excavation and application of soil micromorphology

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The 26 December 2004 tsunami exposed an inscription of the 10th century engraved on a rock boulder at Saluvankuppam, 6 km north of Mamallapuram. The inscription indicates the existence of a Subramanya temple. The temple and the mound around the granite inselberg were excavated by the Archaeological Survey of India, Chennai Circle. The excavation exposed the entire Subramanya temple complex constructed over a period of time (4th/5th CE to 12th/13th CE). The temple complex and the litho sections reveal phases of temple building activity. The cement and lime used for the temple complex contain fragments of shells. Soil micromorphology technique was applied to understand the type of textures and fabric in soil sediments, bricks, potsherds, well rims, bone fragments, etc., using a polarized microscope. Thin sections of the laterite bricks which formed the foundation indicate high content of hematite, magnetite, kaolinite patches and the porosity of the laterite brick varies from 5% to 10% only, whereas thin sections of potsherds indicate that the firing temperature was fairly low and that the pots were well fired. Geoarcheology study of this temple complex indicates that a number of naturally occurring raw materials have been used for constructing this temple that were locally available.

Keywords: Coastal temple, excavation, soil micromorphology.

THE 26 December 2004 tsunami caused a colossal damage towards loss of life and property along the east coast of Tamil Nadu. It was a catastrophic flood event but opened up new vistas of research for the geoarchaeologists. An inscription of the 10th century engraved on a rock boulder at Saluvankuppam, 6 km north of Mamallapuram (Figure 1) was exposed consequent to the tsunami. This donatives inscription mentioned the existence of a temple for Subramanya. The mound around the granite inselberg was excavated and the entire Subramanya

Figure 1. Study area.

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temple complex constructed over a period of time (4th/5th CE to 12th/13th CE), was unravelled. The area in and around Mamallapuram is well known for its cave temples, monoliths, bass relief and stone structural temples. The discovery and excavation of a brick temple of the Pallava period links the early brick structure to the later stone edifices. The excavation revealed that the temple structure was rectangular and was built abutting the granite rock boulder. In due course, the temple was developed from brick into stone. The excavation brought to light many aspects of temple construction techniques that were followed by the Pallavas. The temple complex has been dated to the Pallava period based on architectural and epigraphical evidences as follows.

Phase I – Simple, rectangular structure comprising one layer of man-made bricks overlain by four layers of laterite bricks, subsequently followed by four layers of man-made bricks; dated to 4th/5th CE.

Phase II A – The height of the temple was increased by adding another 10 courses of man-made bricks. This structure and the rock boulders were enclosed by a cloister mandapa with a mukha mandapa in the north. A bali peeta and a stone spear (place where the dwaja stambha is usually situated) have also been added in this phase; dated from 6th to 8th CE.

Phase II B – The level of the temple was further raised to 23 courses (nine added) and the corresponding level of the cloister mandapa was also raised and a new mukha mandapa was constructed in the north; dated from 8th to 10th CE.

Phase III – The main temple complex was retained and an ardha, maha and mukha mandapa were added in granite rock, dated between 10 and 13 CE.

In order to understand the nuances of the measures adopted, and where and how the present excavated brick structures fit into this architectural landscape, a geo-archaeological perspective was adopted. This coastal site was excavated from 2005 to 2008 to understand the conscious choices made by the builders of this coastal temple. A previous work[1] explains the radiocarbon dates derived from charcoal pieces dating to 405–1091 AD. The study also suggested that short, but hard-striking storm surges caused the submergence and destruction of the coastal temple structures. Moreover, the phase of temple activity was suggested by them[1], when the excavation was still in progress. Since the excavation has been completed and a systematic study of the structures has been made, a clearer picture has emerged. An alternative theory[2] explained the occurrence of long-term sea-level rise and severe coastal erosive phases as the main cause of submergence and destruction of temples off the coast of Mamallapuram about 1000 years ago.

Our study aims at understanding the construction of this particular temple at Saluvankuppam and its unique features. The application of soil micromorphology technique, i.e. studying soil sediments, bricks, potsherds, bone fragments, etc. using a polarized microscope of historical sites can help in understanding pedo or soil turbation, leaching, humification, illuviation, eluviation, soil and sediment texture, digenesis, distribution of micro artifacts, source and provenance of material and microstratigraphy. Soil micromorphology also allows the study of three-dimensional context and it deals with a microscopic study of undisturbed soil and sediment layers using less than 30 μm thin sections on glass slides and studying them under a polarizing microscope[3].

During the excavation, it was observed that the main temple complex was built on a cushion of alluvium (~ excavated for 30 cm; river). Over this was laid a layer of man-made bricks, followed by four layers of laterite and finally four layers of man-made bricks. The exposed laterite bricks and man-made bricks were plastered with fine lime plaster. The lime plaster was prepared at the site with the shells as corroborated with lime kilns (four) and mortars (Figure 2) and saddle querns (three) found at the site.

The excavated litho sections (Figure 3) reveal that during each phase of temple-building activity, the ground level of the temple was raised with brick bats, earth, fragments of pottery and stucco. This was overlain by a thick layer of shell and shell fragments in the northwestern side of the temple complex, which might have served as store for the shells as lime kilns have been unearthed at the site. Shells were identified as *meretrix*, *mytilus*, *ostrea*, *unio*, *vnericardia*, *tellina*, *laternula*, *arca*, *nucula*, *pteriacea*, *inoceramus*, *cardium*, *pectin*, *venus* and oyster shells, of which *arca* is about 42% of the collection. These shells are characteristically bottom-dwellers, adapted to life in brackish and normal marine waters. The shells are thick and aragonite in composition. They occur abundantly in the shell beds at Muttukadu and probably, Muttukadu was a major source of shells and lime mortar for plastering the structure at this site.

Two sets of bricks (Figure 4 *a* and *b*) are used in the construction of the Saluvankuppam temple. Large-sized

Figure 2. Mortar exposed during the excavation.

bricks have been used since phase I; they measure $41 \times 20 \times 7$ cm and $38 \times 20 \times 7$ cm approximately. Thin-section study of the laterite bricks which formed the foundation indicated high hematite and magnetite content as well as kaolinite patches, and the porosity of the laterite brick varied from 5% to 10% only. The laterite could have been brought from a source exposed nearby.

Thin-section study of the laterite bricks indicates sources from: (a) Ferrugenized sandstone bedrock; (b) Fe impregnated and indurated sediments, including clays and sandy sediments; (c) Laterite bricks of complex sedimentary and pedogenic origin (like the pisoliths).

Type (a) and (b) laterite bricks have simple fabric and iron-oxide mineralogy dominated by hematite, magnetite and gibbsite ($Al(OH)_3$). Iron oxides have variously replaced mica and feldspar. In bedrock ferricrete samples, it is common to observe the physical disintegration of primary micas due to infiltration of iron-bearing solutions along cleavages, fractures and subsequent crystallization of Fe oxide minerals. Thin-section studies reveal that the laterite bricks are made of multiple phases of iron-oxide mobilization and precipitation textures cementing iron-oxide pisoliths.

During the excavation, red ware and coarse red ware were encountered. The types of pottery included storage jars, water pitchers, shallow bowls, vases, spouted vessels and lamps. Potsherds were present below 45 cm in the northwestern sector, disturbed by human activity, trenching and filling with debris. Potsherds were collected from a depth of 30–80 cm down to the base level, which represents the litho section ~ 1 m thick facing west and north. Dimension of potsherds ranged from 0.5 to 6 cm in length, with a mean thickness of 0.3–0.5 cm. However, the well rim was around 2.2 cm. The colour of the potsherds varied from reddish-yellow on the surface to brown, and they were largely coarse red ware. The coarse red ware pottery showed surface features indicating that it was handmade, whereas the finer red ware sherds were probably manufactured using a combination of wheel and handmade technique. Representative 10 potsherds and 11 brick thin sections were studied for petrological analysis. Small pieces measuring $\sim 2 \times 2$ cm were cut from each potsherd and the bricks were subjected to a test to determine porosity, mineral composition and texture. The thin-section study of the potsherds revealed the following:

Figure 3. Litho section facing west, exposed during the excavation. Note the layer of shell and shell fragments at the surface as resource material for the preparation of lime plaster.

The grain size ranged from 40 to 110 μm. Coarse grain-size frequency was bimodal, sub-angular to sub-rounded, frosted and stained by iron (Figure 5). Coarse grains comprised of 15–16% rock fragments. They were fractured and stained with iron. Orientation of fine grains along with mica indicates that the pottery was wheel-made.

Orthoclase feldspar, garnet and muscovite were present and varied from about 2–4% in the upper layer to 5% in the lower layer. Some of the muscovite flakes were altered. Coarse quartzite grains occurred as rock fragments (12–14%).

It is known that the crystal structure of kaolin is destroyed at about 600°C. The absence of the kaolin group of minerals in the potsherds examined so far indicates that firing temperature would have reached this level.

The occurrence of diffused illite (micaceous clay minerals) suggests that the temperatures at which firing took place may not have been less than 600°C.

The crystalline form of quartz undergoes a change at 573°C. The fact that the quartz grain in the samples described above is unaltered makes it clear that, on the whole, maximum temperature could not have exceeded 600–700°C.

As pointed out earlier, traces of orthoclase feldspar occurred throughout sequence. Although feldspar has inversion point of 900°C, effects of this alteration have not been detected in the pottery.

Two types of matrix can be identified in the potsherds, one of which is composed of iron oxide which may be a mixture of hematite and goethite. Minerals of the iron-oxide group in fine-grained clay form pseudo grains which are sub-angular to well-rounded. The ratio of clay matrix to the coarse and fine fraction varied from 7 : 3 to 4 : 6. In places, the matrix exhibited micro fracture and flow structure, and traces of cellular structure represent vegetal materials (well rim) which have been burnt during firing. Pores were in the form of voids – regular to irregular in shape and many times lined with greyish, fine silt components or black soot (Figure 6).

The thin-section analysis indicated that the firing temperature of the pottery was fairly low and well-fired.

Magnetite (M), hematite (H), goethite (G) and metahalloysite were the dominant iron oxides and clay minerals.

Figure 4. (***a***) Laterite bricks used as a foundation material for the temple. Note the subsequent layers of thin, tabular bricks of a younger period (***a*** and ***b***).

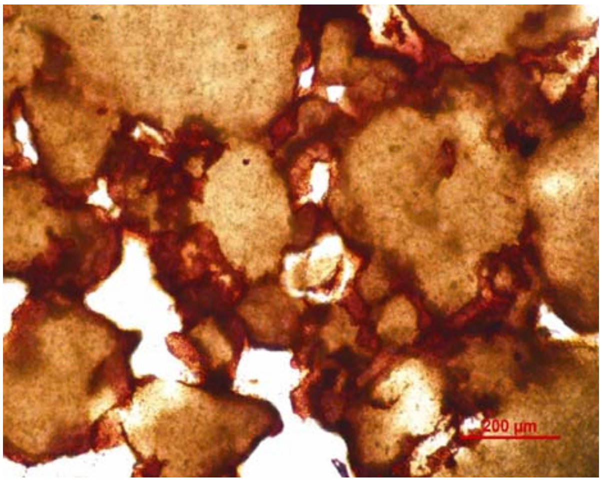

Figure 5. Photomicrograph showing thin section of laterite bricks that contain iron-oxide clay.

Hematite and magnetite represent iron oxide cementing the detritus grains of quartz and feldspar. Iron segregation produced a great variability of colours, degree of opacification and of forms. Both external and internal colours ranged from dark red to black, ochreous and brown. Opacification is directly related to the abundance of iron oxides and MnO_2. An optical microscope was used for the approximate estimation of this abundance (G/M + H ratio). This ratio varied from 6 : 4 to 2 : 8. Voids, fractures and channels exhibited laminated clay deposition of hematite and gibbsite, and some pores were completely filled with limonite or hematite. These fillings have subsequently imparted an overall reddish colour to certain parts of the thin sections (Figure 5). Some of the channels and fractures were also lined with black manganese oxide representing the final depositional phase.

Corrosion of primary minerals such as quartz and feldspar (microcline, orthoclase and a few grains of plagioclase) was observed to be intense in the laterite bricks cut from Gondwana sandstone and shale. Colloform structures were commonly observed in the matrix, with iron oxides in the intergranular spaces. Some of the coarse quartz grains (170–190 μm) had hematite coating. Bleached zone material contained kaolinite and fine-grained quartz with mica and feldspar. Quartz is the most resistant mineral to weathering. It exists as relic mineral in the weathered charnockites and ferricrete/red soil. Quartz grains of varying shapes were found embedded in the iron oxide–kaolinite matrix. The primary mineral composition showed only few easily weathered minerals: around 5% feldspar and 5% phyllosilicate, which are mostly muscovite. In the heavy minerals separation, the minerals identified were tourmaline, zircon, rutile and garnet. The laterite bricks had not been burnt. They were cut into bricks from the laterite rock exposures near the source.

The well rims (Figure 7) were thick (~ 2–2.3 cm); paddy husk was mixed with clay in the inner side of the well rim and carbonized. The strongly carbonized inner layer has been dated to 880 ± 55 ^{14}C yrs BP. Micromorphology of the well rim revealed highly carbonized matrix with coarse quartz grains and quartzite as rock fragment. The margins of the grains were well discerned in the matrix, indicating very low temperature heating. Pottery and the rim of the well did not contain shells. Adding paddy husk to clay for making pottery had retained heat for a longer period of time, ensuring less use of fuel.

The sediments were coarse-grained, ill-sorted, subangular, negatively skewed with less percentage of mafics and no salt or clay coating around the grain margins. The

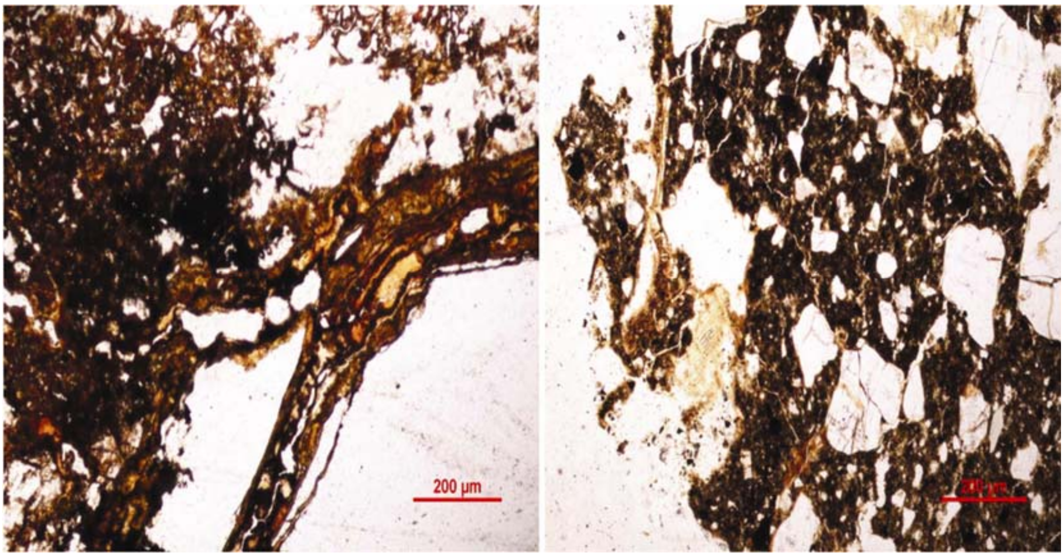

Figure 6. Photomicrograph showing thin section of pottery sherd with angular to subrounded detritus grains in a burnt iron-oxide matrix.

Figure 7. Thick well rim. Note the carbonized layer with coarse paddy grains and husk marks.

alluvium can be traced to the Palar River (they match well when compared with the present-day Palar River bed sediments).

Tafoni on the rock boulder also indicated the prevailing wind direction towards north-northeast, ensuring site preservation and survival of the temple facing north. Cave temples in a similar type rock at Saluvankuppam facing east were weathered by salt spray alteration.

In summary, several naturally occurring raw materials such as shells from the inlet of the sea, alluvium from the river bed, laterite from the weathered sandstone and shale and granite rock have been used for construction purpose at the study site, that were locally available. The Pallava architectural history is a period of experimentation and this coastal temple site indicates that experimentation was carried out even in raw materials. Based on the excavation data from 2005 to 2008, epigraphy, temple architecture, sedimentology, soil micromorphology, radiocarbon dates including those published by Rajendran *et al.*[1], it can be surmised that there has been a systematic resource management of the local materials available. Proper site planning and care was taken to ensure that this temple continued to exist over a period of ~ 800 years.

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