PROVENANCE OF THE CLAY AND PREPARATION OF THE CLAY PASTE

This chapter is an attempt to understand the sources of clay and the preparation of clay paste used for making pottery by the Harappan potters of Gujarat. The following discussions are based on the results obtained from thin-section study and x-ray diffraction analysis of pottery specimens recovered from the stratified layers of excavations at Vagad, Nageswar and Ratanpura. The identification of the detrital particles in the pottery was done under the petrological microscope. The results were further confirmed by X-ray diffraction analysis. An understanding of the mineralogy of the detrital particles throws useful light on the sources of the clay that were exploited by the ancient potters for making pottery. Clay being a product of weathering of rocks, it contains many detrital particles which help towards tracing the parent rocks. Hence a study of the mineralogy of the detrital particles in the pottery and the lithology and drainage patterns of the related areas helps in identifying the sources of clay that the
ancient potters exploited.

Scholars in Europe and America have done extensive work in attempting to understand the sources of clay for pottery and terracotta objects by studying their mineralogy and chemical composition. Analysis of pottery specimens from Tepe Gawre by Harold Tomlison and Marian Welker (Tobler 1950) helped them to understand the nature of the inclusions (sand particles) present, the various processes involved in the making of pottery and the probable sources of the clay. An extensive survey of similar kind of works by Anna Shepard (1965) has revealed the potential as well as limitations of petrographic studies in provenance analysis. In recent years many attempts have been made to analyse archaeologically important ceramic samples using scientific methods like thin-section studies, x-ray diffraction, x-ray photoelectron microscopy, neutron activation analysis, atomic absorption spectrometry, scanning electron microscopy, x-ray fluorescence and chemical analysis. Various scholars have revealed different aspects of ancient ceramic technology using thin-section techniques and textural analysis (Blackman 1981, Williams 1982, Morris 1982, Freestone et al. 1982a, Mainman 1982), Kilmurry 1982, Hughes et al. 1982, Vince 1982, Freestone et al. 1982b, Edwards et al. 1984, Aronson 1984, Maggetti et al. 1984). It has been
found that when compared to the thin-section techniques, the neutron activation analysis has many advantages as this method provides better data for provenance determination. Simultaneous application of both the methods have also been attempted by a few scholars for locating the sources of clay (Fransworth et al. 1977, Blackman 1981 Davidson 1981, Neilson et al. 1981, Kilmurry 1982, Hughes et al. 1982, Krywonos et al. 1982, Matthers et al. 1983, Allen et al. 1984, Blackman 1984, Perlman 1984).


This brief survey of literature reveals the potentials of the application of various scientific techniques to the provenance analysis of ancient pottery.
Such provenance studies have not so far attracted much attention in India. This is the first work of its kind to be attempted in India. A similar work in India was the provenance determination of sand that was used in the preparation of ancient Indian lime plaster (Karanth et al. 1986).

The present study includes investigation of the pottery specimens collected from three different Harappan sites in Gujarat, viz., Vagad, Nageswar and Ratanpura.

5.1 Vagad

Thin-section studies and textural analysis of pottery specimens from Vagad have revealed the mineralogy and the relative abundance and grain size of the non-plastic inclusions (Table 4.1). X-ray diffraction studies confirm the thin-section data (Figure B.9, B.10 and B.13). Quartz appears to be the common component in most of the sections (Table 4.1). Feldspars, augite and mica form a part of the other major component. A few of the thin-sections contained rock fragments also. The rock fragments were of basalt showing basaltic texture with its principal component minerals as augite and plagioclase feldspar. Calcite encountered in the thin-sections were of cryptocrystalline nature. One of the thin-sections contained a few shell fragments also. Among the feldspar group of minerals, plagioclase and microcline were present. The
Fig. NO.C1 COMPOSITION OF THE NON-PLASTIC INCLUSIONS IN THE HARAPPAN POTTERY AT VAGAD
plagioclase feldspar was of the labradorite variety. This was determined by the extinction method.

Among the minerals, plagioclase feldspar and augite are the chief constituents of basalt rock. Mica is a common constituent of rocks like granite and certain metamorphic rocks like mica schist.

For the purpose of provenance analysis, quartz, augite, plagioclase feldspar, mica and rock fragments found in the thin-sections were taken into consideration. From table 4.1 it is clear that as the percentage of mica increases, the percentage of augite and plagioclase decreases and vice versa. Even though quartz is present in all the sections, it is not much affected by this fluctuation. The basalt rock fragments and its principal components augite and plagioclase are clubbed together and considered as a single factor, while quartz and mica are taken as the other factors. These three factors were then plotted in a triangular diagram (Figure C.1).

It is seen from this diagram that the sherds from Vagad fall in three distinct areas. Among these three areas one is extremely rich in basaltic components, the second contains almost equal amounts of basaltic components and mica while the third one has fewer basaltic components but more mica.
Geologically Gujarat State is characterised by four major formations, viz., Precambrian granites and metamorphics exposed to the northeast, Deccan Trap (Upper Cretaceous to Eocene) exposed in Saurashtra and the main land of Gujarat, sandstones (Mesozoic and Tertiary) mainly exposed in patches and the alluvial formations and miliolites (Pleistocene to Holocene) (Krishnan 1982) (Figure C.2). This alluvium is formed due to the detritals brought down by the rivers like the Tapi, Narmada, Mahi and Sabarmati and their innumerable tributaries. Besides these larger rivers there are several minor rivers like Bhadar, Bhogavo, Rupen, Saraswati and Banas which have also played an important role in the formation of this alluvium (Figure C.3).

Here we have to take into account the fact that when compared with the alluvial fans of the major rivers like the Sabarmati the role played by the minor rivers like the Bhadar is not large because their discharge is restricted to narrow zones along their courses. Often the alluvial fans of the larger river systems coalesce with one another.

Mineralogical composition of the alluvium varies with the geology of the area through which the rivers drain. Detrital particles derived from Sabarmati are restricted to Precambrian rocks (granites and metamorphics with mica schists). These rocks account for quartz and mica in the clay. Vagad falls partly in this alluvium
(Figure C.2). Since the site is located on the southern bank of the Bhadar river which flows from west to east in the Saurashtra area along the Deccan Trap Terrain (Basalt rocks), the alluvium that is seen in and around Vagad contains detritals brought by the Sabarmati and Bhadar.

From the thin-section studies it is observed that as the percentage of mica increases the percentage of augite and plagioclase decreases. Those which are fairly rich in augite and plagioclase are found to include basalt fragments as well. The shape of the grains varied from angular to subangular and subrounded to rounded. The former shape is always associated with those pottery specimens which are rich in augite and plagioclase while the latter ones with those rich in mica. The grain shape throws some light into the distance travelled by a grain. Hence it is possible to believe that the clay which is used to make the mica rich pottery is derived from the weathering of the distant Precambrian rocks and the clay that is rich in augite and plagioclase feldspar is derived from the Deccan Trap formations. Apparently two clay sources were exploited at Vagad.

Clay samples collected from the bank of the Bhadar river and the depressions forming lakes away from the river bank near the Harappan settlement were sieved and
studied under the microscope. This study revealed that the clay which is rich in augite and plagioclase was collected from the banks of the Bhadar river and the clay rich in mica with fewer basaltic components was obtained from the lake beds formed in depressions away from the river.

5.2 Nageswar

Thin-section studies and textural analysis carried out on the pottery specimens excavated from Nageswar have revealed the mineralogy, grain-size and the percentage of non-plastic inclusions (Table 4.5). This data is further confirmed by X-ray diffraction studies (Figure B.10, B.11 and B.12). Quartz is common in all the sections and it is the major component among the non-plastic inclusions (Table 4.5). The other major inclusions are feldspar, augite, biotite mica, muscovite mica and cryptocrystalline silica. Among the feldspars both plagioclase and microcline are present. Rock fragments that appear in a few sections are identified as sandstone and basalt. Calcite occurs in cryptocrystalline forms. Tourmaline and hornblende also appear but scantily and are encountered in very few sections (Table 4.5).

For the purpose of provenance analysis quartz, augite, plagioclase feldspar, mica, basalt fragments and
Fig. No. C-4 COMPOSITION OF THE NON-PLASTIC INCLUSIONS IN THE HARAPPAN POTTERY AT NAGESWAR
cryptocrystalline silica are taken into consideration. Quartz and cryptocrystalline silica are clubbed together to form one factor while basalt components augite and plagioclase feldspar make the second factor. The percentage of mica is taken as the third factor. These three factors were plotted on a triangular diagram (Figure C.4). But this diagram only shows the variation in the percentage of mica and quartz. From the table 4.5, it is clear that when the amount of quartz increases the amount of mica decreases and vice versa. The percentage of augite, feldspar and other minerals do not seem to be very important since their amount is negligibly small.

Nageswar (Figure C.2) in Okhamandal Taluka of Jamnagar district is situated in the Dwarka beds. The Dwarka beds consist of gypsiferous clays and sandy foraminiferal limestones which are believed to be Mio-Pliocene (Krishnan 1982). Besides these, the coastal deposits here consist of a mixture of different detritals of various origin. This mixed mineralogical nature of this coastal region is due to the deposition of alluvium derived in the Gulf of Kutch by wave action. There are small rivers flowing towards the Gulf of Kutch from Saurashtra peninsula and the main land of Kutch (Figure C.3). The Saurashtra peninsula is rich in Deccan Trap formations. The Kutch mainland also consists of patches of Deccan Trap, Tertiary and Mesozoic formations (Sand stones and Limestones). Thus:
all those rivers which flow into the Gulf of Kutch have discharged various detritals into the Gulf. These detritals were then slowly deposited on the Dwarka beds due to wave action. Thus this coastal deposit contains a mixture of various minerals of different origins.

The mineralogy of the detrital particles encountered in the pottery specimen from Nageswar shows this mixed nature of the source material. The thin-section analysis of the Harappan pottery excavated at Nageswar clearly shows that the source of the clay used for making this pottery was from within the vicinity of the site. The most important source of clay within the vicinity is the bed of Bhimgajao Talav on the edge of which the Harappan site is located. Clay samples collected from this lake were sieved and the detritals recovered were studied under the microscope. A good agreement in the mineralogy was found between the detritals in the clay samples and detritals in the pottery specimens. One of the clay samples was subjected to x-ray diffraction analysis. This further supported the above observation (Figure B.14). The presence of vitrified pottery among the cultural remains of Nageswar (Hegde et al 1985) also indicates that pottery was locally manufactured.
Fig. No.C-5 Composition of the Non-plastic Inclusions in the Harappan Pottery at Ratanpura
5.3 **Ratanpura**

Pottery specimens collected from Ratanpura was also subjected to thin-section studies and textural analysis. The mineralogy grain shape, grain size and percentage of non-plastic inclusions were studied in detail (Table 4.9).

Quartz and mica form the major components among the non-plastic inclusions in these thin-sections, it can also be observed that as the percentage of quartz increases, the percentage of mica decreases and vice versa (Table 4.9). Besides, minerals like augite, plagioclase feldspar, microcline feldspar and cryptocrystalline silica are the other common non-plastic inclusions. Rock fragments appear only in a few sections (Table 4.9). They are mostly fragments of mica schists. Stray appearance of zircon and epidote is also noticed in a few sections. Calcite appears in cryptocrystalline form and has often occupied pores.

As done for the previous sites a triangular diagram was drawn for the convenience of provenance analysis. Quartz and cryptocrystalline silica are clubbed together to form one factor. Plagioclase feldspar and augite form the second factor. Mica constitutes the third factor. It is found that in the diagram all these pottery samples fall in one area (Figure C.5).

Ratanpura (Figure C.2) is located on the bank of the Rupen river. This area falls in the alluvial and wind
blown deposits of north Gujarat. The description of the formation of this alluvium given in the earlier part of this chapter (discussed in 5.1 Vagad) holds good here also. The alluvial and wind blown deposits near Ratanpura area contain detrital particles derived from Precambrian formations. The Precambrian formations in this area include Aravalli/Delhi systems (phyllite, mica schist, quartzite, calc-silicate rocks) and their acid and basic intrusive like the granite, pegmatite and dolerite.

The mineralogy of the detrital particles present in the pottery specimens from Ratanpura (Table 4.9) agrees with the mineralogy of the detritals in the alluvial deposits of Ratanpura area. The mineralogy of the detritals present in the clay samples collected from the lake bed near the Harappan site at Ratanpura was found to be similar to that of the pottery specimens. Excavations at Ratanpura have yielded vitrified pottery (Indian Archaeology, 1984-85). This further indicates that pottery was locally manufactured at this site.

Thus thin-section analysis of pottery specimens from Vagad, Nageswar and Ratanpura have revealed that the Harappan potters at these settlements exploited the locally available clay deposits for manufacturing pottery.
5.4 Preparation of the Clay Paste

The size of the non-plastic inclusions (detrital particles) present in the pottery were found to be very small and hence it appeared that the potter did not add them deliberately, but they were present in the clay. The range of the grain size in the pottery specimens from each site is given in Table 5.1.

**Table 5.1**

Variation in the Average Grain-size of Non-plastic inclusions

<table>
<thead>
<tr>
<th>Name of the site</th>
<th>Size of the non-plastic inclusions</th>
<th>Minimum size mm</th>
<th>Maximum size mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vagad</td>
<td>0.018</td>
<td>0.018</td>
<td>1.21</td>
</tr>
<tr>
<td>Nageswar</td>
<td>0.02</td>
<td>0.02</td>
<td>0.85</td>
</tr>
<tr>
<td>Ratanpura</td>
<td>0.01</td>
<td>0.01</td>
<td>1.06</td>
</tr>
</tbody>
</table>

1.21 mm was found to be the size of the largest grain encountered in the thin-sections of pottery from all the sites. To deliberately eliminate such grains which were coarser than this grain the potter would have repeatedly elutriated the clay. The process of elutriation (Hodges 1964: 20) is that the clay collected from its source is suspended in water until the heavier particles subside.
The supernatant fluid is then decanted and the finer clay allowed to settle down. Clay is plastic when mixed with water. Since clay crystals are small, thin and platy they tend to remain in suspension in water for a long time. Fine material remains (non-plastic inclusions) present in the clay adhere to the crystals while the coarser ones subside. When the potter finally takes out the refined clay, the fine grains also accompany the clay. It is then thrown into a pot. When the pot is baked these non-plastic inclusions render the pot porous and prevents shrinkage and cracking.

The process of elutriation further helps to understand the techniques involved in the preparation of clay paste which was used for throwing coarse ware and fine ware. As the clay is elutriated for a large number of times, the heavier particles subside and simultaneously the amount of these detritals in the clay becomes less. This is evident from the ratio of the non-plastic inclusions against the clay matrix (Table 4.1, 4.5 and 4.9). In fine wares the amount of non-plastic inclusions was found to be smaller while in coarse ware it was relatively larger. Thus it appears that two types of clay pastes were prepared for throwing the wares (1) less elutriated clay paste which contained coarser particles for throwing coarser wares and (2) well elutriated clay paste which included fine grains for throwing fine wares.
Fig. No. C-6 HISTOGRAM SHOWING THE SIZE OF NON-PLASTIC INCLUSIONS IN THE HARAPPAN POTTERY AT NAGESWAR
Fig. No. C'7 HISTOGRAM SHOWING THE SIZE OF NON-PLASTIC INCLUSIONS IN THE HARAPPAN POTTERY AT VAGAD
Fig. No. C-8 Histogram showing the size of non-plastic inclusions in the Harappan pottery at Ratanpura
It is generally noticed that in the later phases of the Harappa Culture in Gujarat the pottery become coarser. This was found to be true in the case of the specimens analysed. The detritals present in the pottery from Vagad and Ratanpura were coarser than that of Nageswar (Figure C.6, C.7, and C.8). Similarly the percentage of coarse pottery also increased in the later phase. This is mainly due to the reduced number of elutriation in preparing the clay paste.
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