A geochemical investigation of the origin of Rouletted and other related South Asian fine wares

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*Pottery of the Rouletted ware family belongs to India's Early Historic period (*c. *500 BC to* c. *AD 200) and has been found as far east as Bali in Indonesia and as far west as Berenike in Egypt. Although they appear similar to Mediterranean products, scientific tests by the authors show that Rouletted ware Arikamedu Type 10 and Sri Lankan Grey ware had a common geological origin in India. Since Grey ware at least pre-dates the arrival of Roman pottery in India, all these related wares were probably the products of indigenous communities.*

Keywords: South Asia, India, Sri Lanka, Arikamedu, Anuradhapura, ceramics, Rouletted ware, Grey ware, Arikamedu Type 10, ICP-AES, ICP-MS, REE

Method

Introduction

The origin and distribution of Rouletted ware (Figure 1) and related fine wares (Sri Lankan Grey ware and Arikamedu Type 10) have been debated since Syme (1955) and Lal (1960) reviewed Wheeler's publications of *Rome Beyond the Imperial Frontiers* (Wheeler 1954) and *Early India and Pakistan* (Wheeler 1959). In 1985, Silva reported the presence of Rouletted ware at Mantai in Sri Lanka, and showed the importance of this site for regional and international trade (Silva 1985: 46). In recent years, the problem has been illuminated through chemical examination of the pottery fabric. Reporting the discovery of Rouletted ware and Arikamedu Type 10 sherds from Bali and Indonesia, Ardika & Bellwood (1991: 224) proposed a geological source in India. Subsequently, Ardika *et al.* (1997) indicated a 'trading/warehousing' activity area at Sembiran and also the identification of a number of sherds of assumed South Asian origin, including Arikamedu Type 10 and Arikamedu Type 18. Roberta Tomber's research at Berenike, Egypt, highlighted the presence of Rouletted ware and Arikamedu Type 10, suggesting that they were the personal possessions of Indian merchants or sailors (Tomber 2000: 630) (Figure 2).

Rouletted ware and Arikamedu Type 10 are both fine wares found predominantly in Sri Lanka, notably at the site of Anuradhapura (Coningham 1999), and on the eastern coast of India, particularly, Arikamedu (Wheeler *et al.* 1946). They are thought to be tablewares and display distinct decorations, which allow them to be easily identified. They are both

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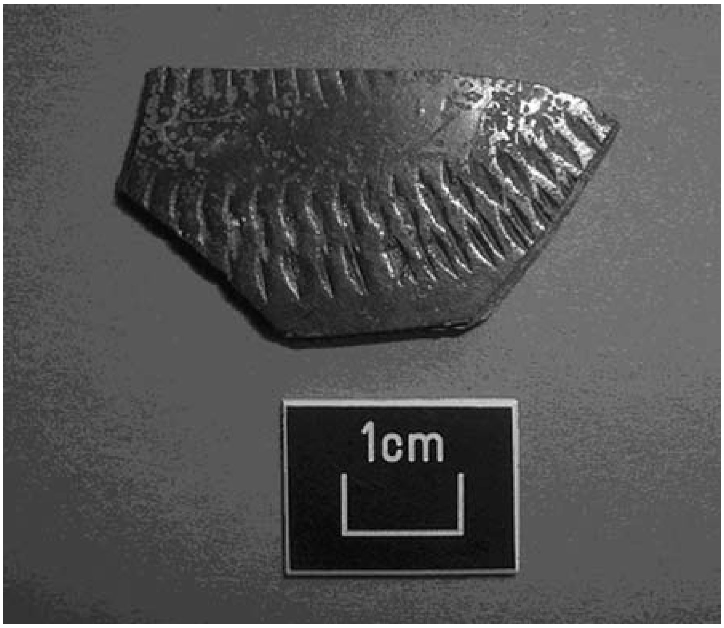

*Figure 1. Rouletted ware (S.f. 15199) from Anuradhapura displaying rouletted decoration from period G (*c*. 200 BC–AD 130).*

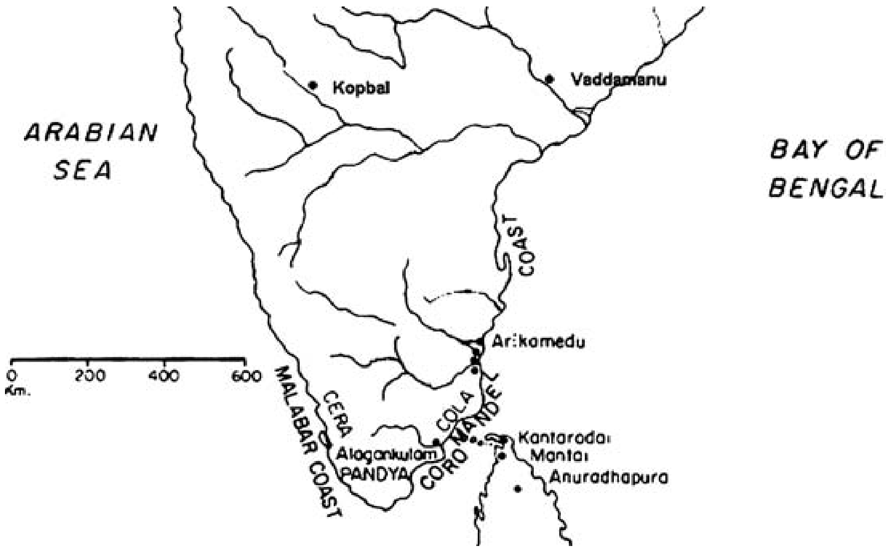

Figure 2. Map of the discussed sites (after Begley 1991: 177).

slipped and well-fired and show a variety of colours ranging from red to grey to black (Wheeler *et al.* 1946). Rouletted ware is dish-shaped and contains bands of indentations on the interior base, which include a variety of shapes, such as parallel lines, triangles, diamonds, and dots, and were possibly produced using a roulette (Begley 1988) (Figure 1). Rouletted ware is a key ceramic in South Asia, widely used to date Early Historic sites

(Wheeler *et al.* 1946). Recent research at Anuradhapura has extended its chronology from 400 BC to AD 300 (Coningham 1999). Wheeler proposed a Roman origin for these wares due to the presence of Arretine ware and amphorae in the same levels. However, further research has indicated that the Rouletted ware actually preceded the Roman layers, which later led Vimala Begley to postulate a Mediterranean origin for the decoration, although she did suggest an indigenous provenance for the actual form of Rouletted ware (Begley 1988).

Arikamedu Type 10 is cup-shaped and displays stamped decoration of birds, notably peacocks, on the interior placed in between incised lines (Wheeler *et al.* 1946). It dates from 200 BC to AD 300, based on radiocarbon dates from Anuradhapura (Coningham 1999). Unfortunately, little work has been done on Arikamedu Type 10 and a Mediterranean origin has been postulated (Nagaswamy 1991: 251).

Grey ware is found at both Anuradhapura (Coningham 1999) and Arikamedu (Wheeler *et al.* 1946), although only the samples from Anuradhapura have been analysed here. It displays a similar form and fabric to Rouletted ware, although it is not slipped. It dates from 500 BC to 300 BC (Coningham 1999) and therefore pre-dates both Rouletted ware and Arikamedu Type 10 and also coincides with Rouletted ware. By including an analysis of Grey ware with Rouletted ware and Arikamedu Type 10, it is possible to compare the fabrics directly. If a similarity is indicated, then it will provide useful information about any temporal changes and would be strong support for the theory of an indigenous origin for these wares as Grey ware was produced prior to any external contact.

Despite its importance, no chemical analysis of Rouletted ware was carried out until the 1990s, when two separate publications reported analyses by neutron activation analysis (NAA) and X-ray diffraction (XRD) (Ardika *et al.* 1993), or by XRD alone (Gogte 1997). Both suggested an indigenous origin for Rouletted ware utilising a single geological source. However, these studies need further investigation because XRD is not likely to be conclusive in assigning geological source, and the NAA result is based on only 10 samples. Nor did these studies include Grey ware and are hence lacking a temporal perspective. Debate has therefore continued on whether single or multiple geological sources were exploited. Thin-section analysis by Krishnan & Coningham (1997) has demonstrated clear relationships between Rouletted ware and Grey ware at Anuradhapura and also between Rouletted ware from Anuradhapura and Arikamedu, therefore, indicating both temporal and spatial similarities.

The aim of this article is to investigate, using chemical analyses of the fabric, whether Rouletted ware, Arikamedu Type 10 and Grey ware were produced from a single geological source.

Methods

The chemical composition of samples of Rouletted ware, Arikamedu Type 10 and Grey ware, were characterised by inductively coupled plasma–atomic emission spectroscopy (ICP-AES). This demonstrated significant similarities over a period of centuries. Because Grey ware pre-dates Mediterranean contact, this can be interpreted as demonstrating an indigenous common origin for all these wares. In an attempt to locate this source, rare earth element (REE) analysis by inductively coupled plasma–mass spectrometry (ICP-MS) was carried out, which, although not conclusive, points to an Indian rather than Sri Lankan origin for this

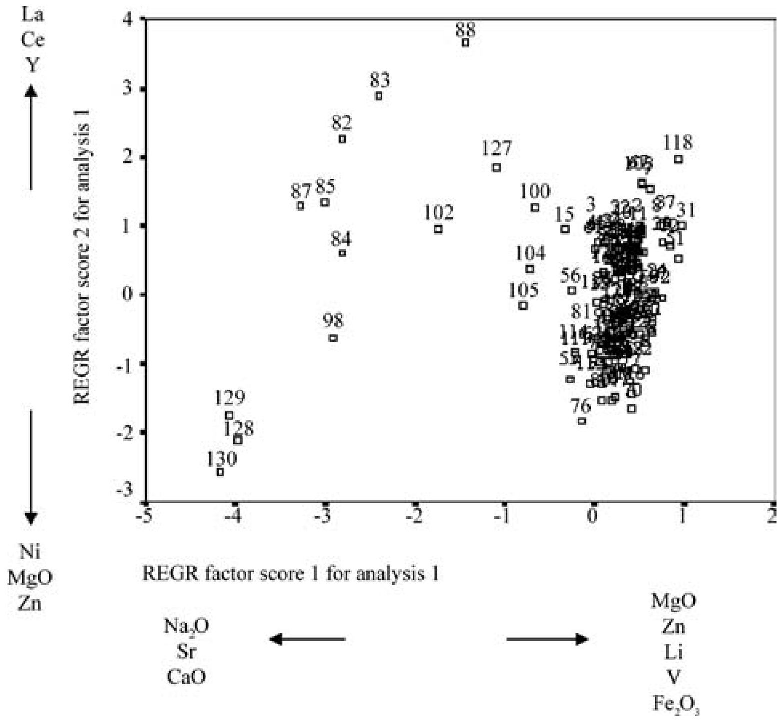

Figure 3. Principal-components analysis of all 127 samples analysed.

production centre. The chemical compositions of the samples were grouped and their degree of similarity or difference assessed using statistical analysis from the SPSS package. Details of the method are given in a Technical Note (see http://www.antiquity.ac.uk/projgall/ford/).

The samples of fine wares came from a variety of sites, including Anuradhapura (Rouletted ware [RW], Grey ware [GW], Arikamedu Type 10, Arikamedu Type 18 and Omphalos), Kantarodai (RW and Type 10), Mantai (RW), Arikamedu (RW, Type 10), Alagankulam (RW) and Vaddamanu (RW). Other samples include modern clay and modern pottery collected at Anuradhapura by one of the authors (RAEC), and coarse wares (CW) from Anuradhapura, Kantarodai, Mantai (all in Sri Lanka), Arikamedu and Kopbal (in India). A complete list of the 127 ceramic sherds used in this study is included in Appendix 2 on the Web (http://www.antiquity.ac.uk/projgall/ford/).

Results

The analyses demonstrated, to a high level of significance, that the fine wares were manufactured from materials deriving from the same source. Figure 3 shows the first two components resulting from a principal-components analysis (PCA) of the entire data set. PC1 (41 per cent of total variance) is constructed primarily from MgO (0.937), Zn (0.864), Li (0.860), V (0.856) and Fe_2O_3 (0.813) increasing to the right, with Na_2O (−0.902), Sr (−0.875) and CaO (−0.767) to the left. This strong initial separation on the basis of CaO and MgO is interesting and might suggest a more dolomitic source of limestone in the main

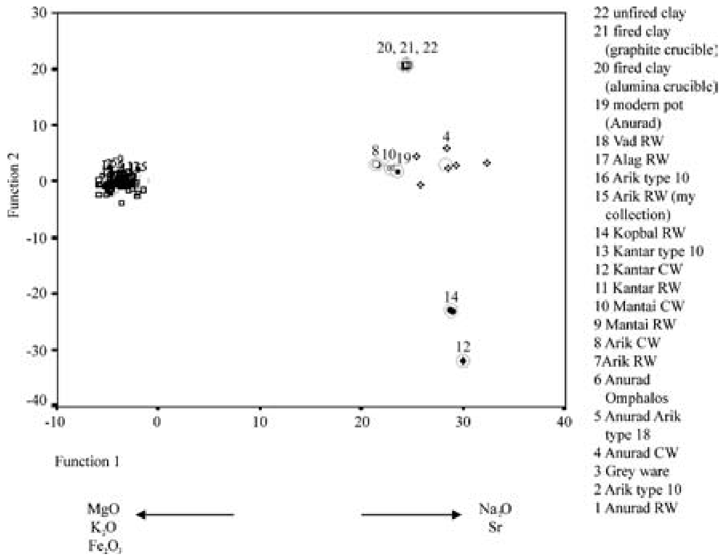

Figure 4. Discriminant analysis of all 127 samples classified into 22 groups.

group on the right-hand side of the figure, or possibly the influence of seawater, which has a higher Mg/Ca ratio. However, it may also point towards post-depositional influences on the sherds, especially the surface sherds found at the coastal sites of Arikamedu, Alagankulam, Vaddamanu, Kantarodai and Mantai. PC2 (17 per cent) reflects increasing rare earth concentrations (La [0.939], Ce [0.907] and Y [0.882]) towards the top, and increasing Ni (−0.081), MgO (−0.080) and Zn (−0.077) towards the bottom. The usefulness of the rare earth data is discussed in more detail below. The main group on the right-hand side of Figure 3 consists of all the fine wares, including most of the Rouletted ware, Arikamedu Type 10, Arikamedu Type 18, Omphalos ware and Grey ware. The samples which lie towards the left include the three modern clay samples from Anuradhapura (samples 128–130), the sample of modern pottery from Anuradhapura (127) and the coarse wares from Anuradhapura (numbers 82–85, 87, 88), Arikamedu (98), Mantai (100) and Kantarodai (102). The only Rouletted ware sherds which lie outside this main group are those from Kopbal (104, 105). This preliminary analysis suggests that the vast majority of the archaeological fine ware and Grey ware samples are all from a similar provenance, and that this source is distinct from that used for either modern pottery from Anuradhapura, or any of the ancient coarse wares.

This separation is confirmed and demonstrated more clearly using stepwise discriminant analysis (Figure 4), with the 127 samples classified into 22 groups according to pottery type and find-site. Function 1 provides by far the most significant discrimination, and is controlled primarily by Na_2O and Sr in the positive direction and MgO, K_2O and Fe_2O_3 in the negative. In this figure, the majority of the samples are superimposed in the tight cluster to the left, which consists of the Rouletted ware from Anuradhapura (Group 1), Arikamedu (Groups 7 + 15), Mantai (9), Kantarodai (11), Alagankulam (17) and Vaddamanu (18); Arikamedu Type 10 from Anuradhapura (2), Kantarodai (13) and Arikamedu (16); and

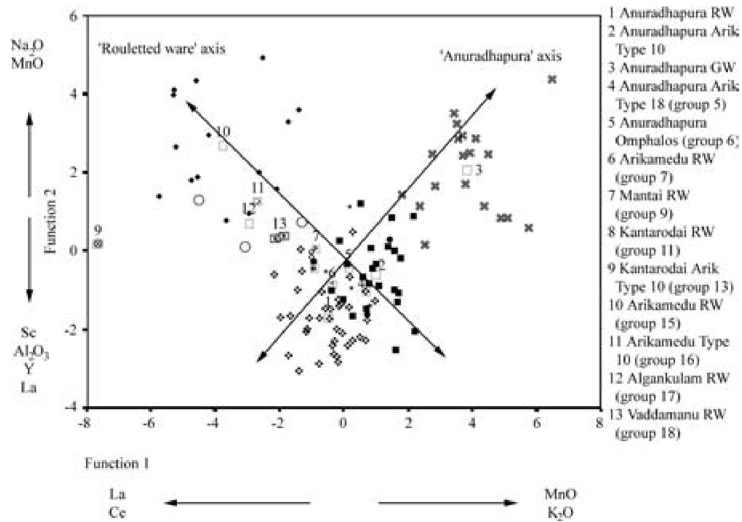

Figure 5. Discriminant function analysis of fine wares; 112 samples in 13 groups with added trend lines.

Grey ware (3), Omphalos (6) and Arikamedu Type 18 (5) from Anuradhapura. This strong superposition is sufficient to suggest that all of these wares come from a similar provenance.

To study further the relationships within this overlapping group, a discriminant analysis was undertaken after removing the samples not listed above, leaving 112 samples classified into 13 groups. Figure 5 shows some separation of these groups on the basis of Function 1 (MnO, K_2O in the positive direction; Ce, La in the negative) and Function 2 ($+Na_2O$, MnO; $-Al_2O_3$, Y, La). The Anuradhapura Grey ware (Group 3) are pulled out towards the top right-hand corner, at one end of an 'Anuradhapura' axis lying north-east–south-west, which includes the Arikamedu Type 10 (Group 2), Type 18 (5) and Omphalos (6) wares found at Anuradhapura and the Anuradhapura Rouletted ware (1). The other axis seen in the diagram is that of 'Rouletted ware', lying north-west–south-east, starting with the Anuradhapura Rouletted ware (1) at the bottom, through the Arikamedu Rouletted ware (7), Kantarodai RW (11), Mantai RW (9), Vaddamanu RW (18), Alagankulam RW (17), Arikamedu Type 10 (16) and ending with the Arikamedu RW (15). The only sample not on either axis is the single example of Arikamedu Type 10 found at Kantarodai (13).

It is fair to say that, although the discriminant analysis has had some success in separating these groups, it is not as much as would be expected if they were from completely separate provenances. In light of the similarity suggested in Figures 3 and 4, the most likely explanation of Figure 5 is that these wares come from a similar provenance. The small variation between the wares is just the sort of variation that might be expected if a single source is exploited over a long period of time. This view is supported by one further discriminant analysis, classifying archaeological samples (123) by ceramic type (6 groups) irrespective of find-spot (Figure 6). This demonstrates that all the coarse wares (Group 4) are similar, and that the Grey ware (Group 3) are close to but distinct from the main group of fine wares. This main group, essentially indistinguishable, contains all the Rouletted ware (1), Arikamedu Type 10 (2), Arikamedu Type 18 (5) and Omphalos (6), irrespective of find-site.

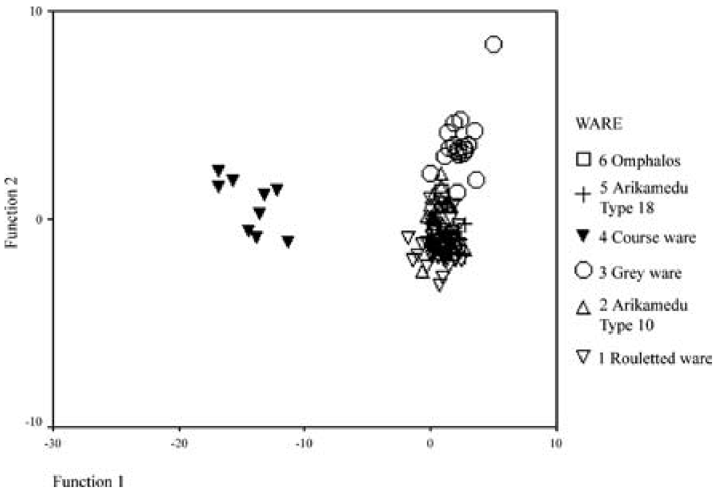

Figure 6. Discriminant analysis of samples classified by ceramic type (6 groups), irrespective of archaeological find-spot.

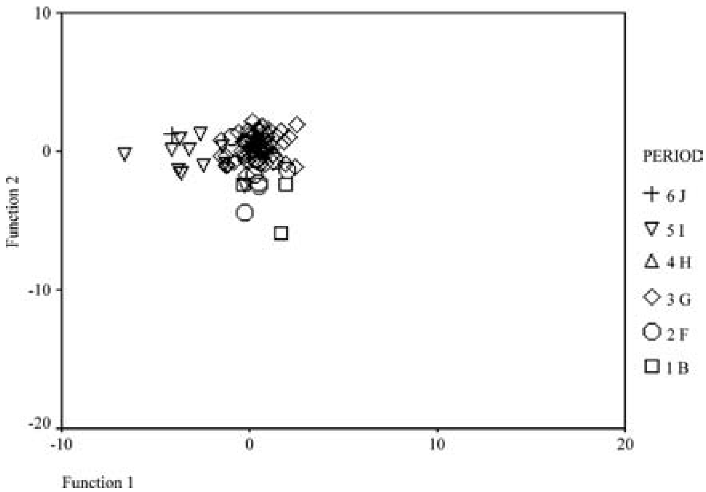

Figure 7. All samples from Anuradhapura (n = 93), classified by period code.

In view of the fact that 93 of the sherds analysed were recovered from Anuradhapura, from well-dated contexts, the opportunity was also taken to analyse these samples by date, to discern any temporal trends. The data listed in Appendix 1 were therefore classified by period code (column 6), resulting in six groups (periods B, F, G. H, I and J). Discriminant analysis (Figure 7) shows little variation by these codes – possibly periods B (to the right) and I and J (to the left) are slightly removed, indicating a chronological progression, but the majority of the samples representing periods F, G and H are indistinguishable. Period J is the oldest phase, dating from *c*. 510 BC to 340 BC, whilst period B is the youngest, dating from *c*. AD 600 to AD 1100 (Coningham 1999: xix).

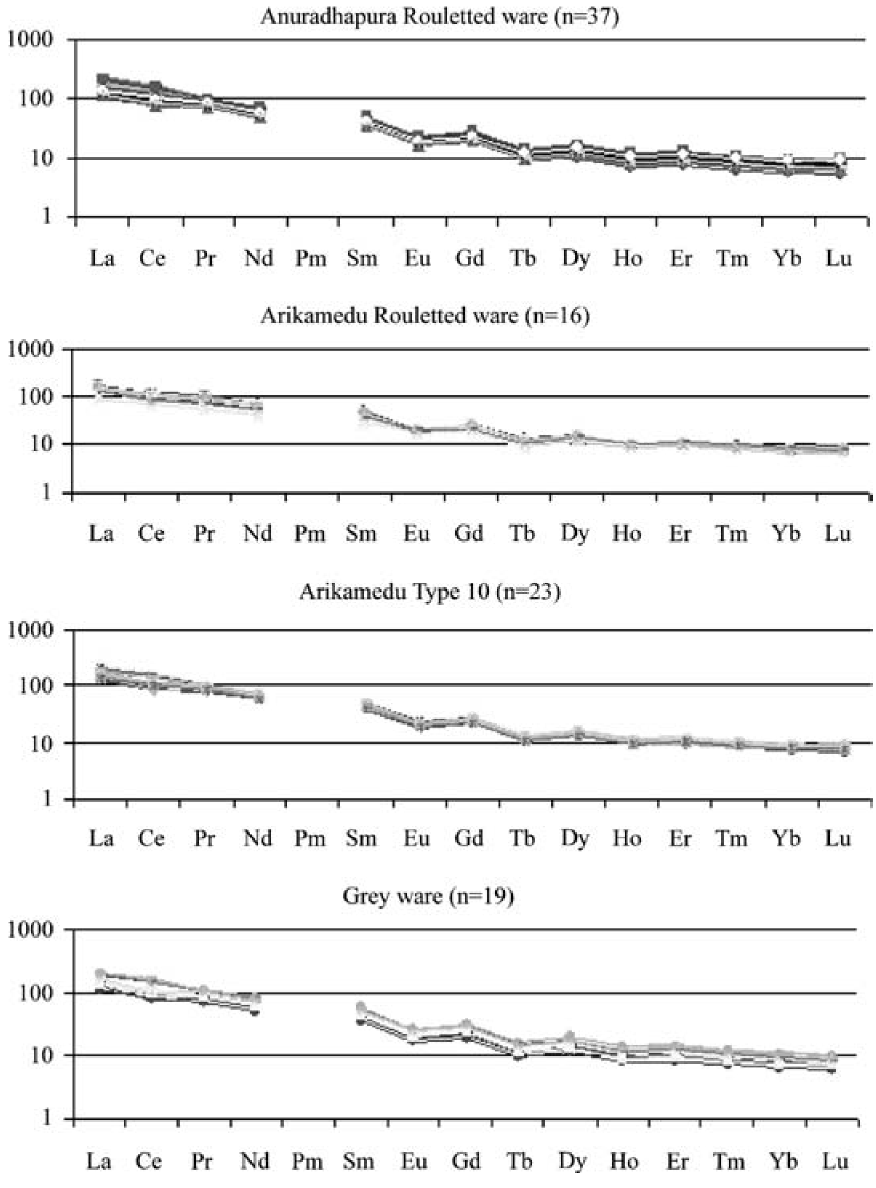

Figure 8. Comparison of chondrite-normalised REE profiles on selected samples.

A plot of the REE profiles normalised against chondrite values is shown in Figure 8 and the rare earth data are presented in Appendix 2 (Web file). The Rouletted ware from Anuradhapura and Arikamedu are seen to be identical (apart from one sample from Arikamedu). The Arikamedu Type 10 and the Grey ware from Anuradhapura are also very similar, confirming the outcome of the previous discussion: Rouletted ware, Arikamedu Type 10 and Grey ware were produced from material with a similar provenance. The REE profiles from the coarse wares (Figure 9), however, exhibit a small but significant difference.

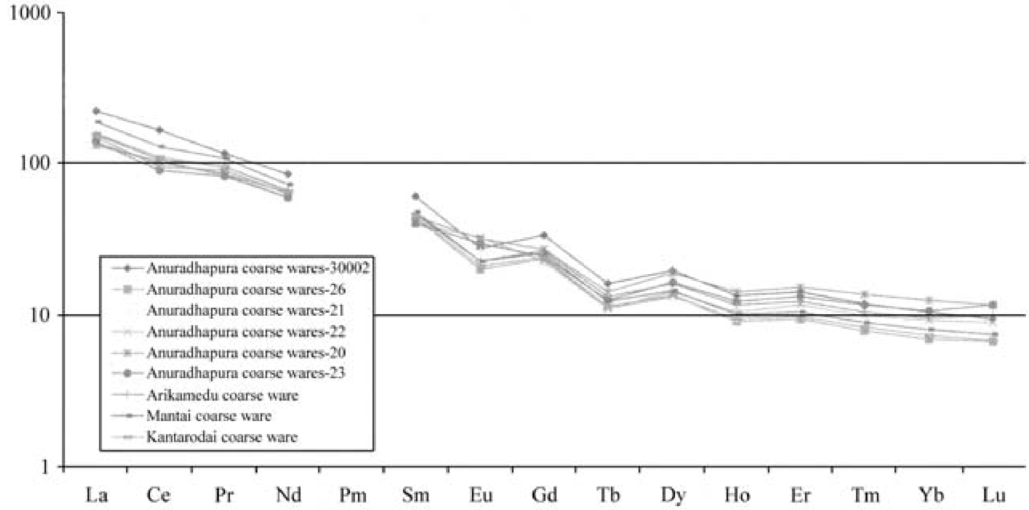

Figure 9. Chrondrite-normalised REE data of the coarse wares.

The element europium (Eu) is particularly diagnostic in REE profiles because it can exist in two oxidation states, and its abundance is therefore controlled by the redox conditions in the depositional environment. All the REE profiles discussed above display a significant negative europium anomaly (i.e. there is less europium in the sample than would be predicted from the other REE abundances). Four of the six coarse wares analysed from Anuradhapura do not demonstrate a negative europium anomaly, whereas the single samples of coarse wares from Arikamedu, Kantarodai and Mantai do show a negative anomaly (as do two of the six from Anuradhapura, of course). The evidence is equivocal, but suggests on balance that Anuradhapura is not the source of the clay used to manufacture the fine wares discussed in this article.

To investigate this problem further, it is necessary to identify areas of geological suitability within India as a possible source of production. The coastal sites of Arikamedu, Alagankulam and Vaddamanu comprise the same geology, which is recent alluvium and extends along the east coast of India (Krishnan 1982). Although this suggests that the production of these wares could be located anywhere along this strip, archaeological evidence indicates greater quantities of sherds of Rouletted ware and associated wares in southeast India and the presence of more sites containing these wares than in the northeast. The Grey ware, which appears to be an ancestral form of Rouletted ware, has only been identified at Arikamedu (south-east India) (Wheeler *et al.* 1946: 51), Anuradhapura and Kantarodai (Sri Lanka) (Coningham & Allchin 1995: 167, 171), thus supporting a south-east Indian origin.

The coarse wares were analysed in an attempt to identify the geographical location of this complex. As a group they are shown to be distinctly different chemically from the fine wares (Figure 6), as might be expected. There are well-known problems in attempting to compare coarse wares and fine wares chemically due to the inclusions present in the coarse wares. To overcome this, we have analysed a sub-set of the samples by solution ICP-MS. On the basis of the REE profiles, these analyses point to an Indian rather than Sri Lankan origin, but the exact source remains as yet unknown.

Conclusion

The chemical analyses reported here suggest that the clay of the majority of the fine wares analysed (Grey ware, Rouletted ware, Arikamedu Types 10 and 18 and Omphalos) came from the same or a set of closely related geological sources. This could be a discrete geographical location, or it could be an extended source such as a major river valley or estuary. A most important result is that Grey ware is sufficiently similar to the other fine wares to suggest a similar provenance. Grey ware is found at both Anuradhapura and Arikamedu and pre-dates the other fine wares, and, most important, pre-dates any Greek or Roman trade. That the Grey ware must be indigenous strongly suggests, because of the chemical similarity, that the later fine wares are also indigenous to South Asia. All of the later fine wares appear to be chemically indistinguishable, with the exception of two sherds of Rouletted ware from Kopbal. This was to be expected, as the samples from Kopbal visually differ significantly from typical Rouletted ware, suggesting that these were produced locally at Kopbal.

It appears that all the fine wares were not only made from the same geological material, but also produced in consistent fabric over a long period of time (*c*. 500 BC–AD 200), as well as being traded over large distances, from Berenike in the west (Begley & Tomber 1999) to Bali in the east (Ardika *et al.* 1993). This points to a single long-running major ceramic production centre. Such a major craft complex has yet to be found, and it is possible that the social organisation of production was dispersed and decentralised, despite a high level of ceramic standardisation: a network of individual potters operating in a single geological zone, utilising similar techniques for the preparation of the clay paste and the forming and firing of vessels. Such communities are known from ethnoarchaeological studies in Mexico, where a community of potters exploit a single resource area (Arnold *et al.* 2000: 314). However, no excavations have been conducted outside any south Asian urban centres to confirm the existence of such a pattern. Excavations within urban centres have yielded no evidence of pottery production during the Early Historic period, despite the presence of other craft activities. For example, at Anuradhapura, there is evidence of metal, bone, antler and shell working (Coningham 1997: 358). Although there is clear evidence of local craft production at Anuradhapura, there is also evidence of other influences in the form of trade, with the presence of carnelian from Gujarat and lapis lazuli from Afghanistan (Coningham 2002). They are represented by beads, with the former dating from *c*. 510 BC to 340 BC associated with structural period J, whilst the latter dates from *c*. 360 BC to 190 BC from structural period I (Coningham 2002).

Only intensive survey in the coastal regions of south-east India with a view to recovering evidence of production sites, such as wasters and kilns, will shed light on the exact provenance of Rouletted ware pottery and its related fine wares. Future research should also include the analysis of coarser varieties of Rouletted ware to identify the production and distribution patterns. This will be informative of the level of standardisation of the coarser wares in comparison with the fine wares. Scientific comparisons may also be made with other contemporaneous wares, such as Northern Black Polished ware, in order to build up a broader picture of ceramic production during the Early Historic period.

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