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The role of petrography in archaeology: ores, pots and stones

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IXER, R.A. (1994). The role of petrography in archaeology: ores, pots and stones. *Proceedings of the Shropshire Geological Society*, **10**, 10–13. An indication of what can be done with ordinary petrographic studies on thin sections to assist the archaeological study of pots and smelted metals, including attempts to provenance items.

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PETROGRAPHY AND POTS

The importance of the petrographer to the study of ancient pots is in describing the rock component without interpretation. Pots comprise a plastic component (clay) and a non-plastic component (sand or grit or anything over 15 µm diameter) mixed to give the clay stability in firing. Non-plastic components of ancient pots are studied in the hope of matching them to outcrops from which they were derived on the assumption that the factory is likely to have been near such outcrops, although this is not always the case.

Ancient pots have been studied from a very restricted environment north of Cusco, Peru. 50,000 shards of pots had been collected from the time of the Inca empire just before its destruction by the Spaniards in the 1530s. The author worked with an archaeologist, Dr. Sarah Lunt, who had recognised a series of stylistically different pots that were made for different uses. They originally tried to decide where each type of pot had been made by provenancing the non-plastic component.

The pots were all made in the high Andes, an area of high vulcanicity and intense plutonic activity. The lithologies and stratigraphy are so chaotic that it is very difficult to tie individual rocks to particular outcrops. There are few very distinctive rocks, one andesite looking more or less like another. Within the succession many andesites occur and are intruded by numerous granites and granodiorites.

However, thin sections revealed differences in the non-plastic component of Inca fineware compared with Inca utilitarian pots, cooking pots or Kilké ware. These groups were also different stylistically. The methods used to make the pots were also studied by trying to determine how much effort had gone into making the Inca pots.

There were four different types of pot. Inca fineware was the most prestigious. These pots were made to give to vassal states, exchanged between dignitaries or used in high class burials. They had no functional use, unlike the Inca utilitarian ware which was nicely made and used for storage. The third group, the Inca cookpots, is ordinary ware used for everyday purposes. Below the third group stratigraphically is the fourth type, the Kilké ware. Probably the most prestigious pot would have had the most care in its manufacture, and so the pots were studied for evidence of such care.

Grog, which is crushed pot, is sometimes added to improve the texture of a clay. It cannot get into the clay by chance, but must have been intentionally added, so its presence confirms that a material has been deliberately added to a clay.

Clay direct from source with some mica and quartz may by chance be suitable for potting. However, if some pots have lithologies not found in the local clays, then there are two possibilities: (i) the pot is not local, or (ii) it was made locally using imported material. The latter indicates positive intent for a particular purpose.

"Bottom of the garden" pots are those that look as if clay had been scooped directly from the river, coiled, made into a pot and fired. Such pots would be used a few times, broken and replaced. These local clays varied considerably, particularly in their grain size. However, if in a series of pots every shard looked identical, with the same grain size, the same exotics etc., it would indicate that these were controlled variables involving a high level of work.

Many of the pots had very variable non-plastics but the clays were similar - they were clean, indicating that bits of twigs and large clasts had been removed and that the clay had been washed. It is particularly necessary to wash clay to get the smooth flat surface to take the careful detailed decoration seen on the Inca fineware.

A restricted range at the fine end of the non-plastics indicates that the clay had been washed. A tight range at the coarse end, particularly if it was exotic, would indicate that the rock had been crushed and sieved before being added to the clay, thus indicating a high degree of work.

In the local geology there are granites, composed of feldspar, mica and quartz. Micas have very flat surfaces, feldspars cleave along good planes, and quartz gives conchoidal fracture, so a crushed granite gives a lot of particles with very flat surfaces which do not stick to clay very well and the pot does not last very long.

The Inca fineware pots which look elegant are very thin, can be 1.5 m tall, and are found up to 1500 km from their probable place of manufacture. These pots required a non-plastic component with very angular fragments to give strength to the clay. The best rock for this purpose is a vesicular lava.

For a cooking pot any temper will do, but a high-quality pot needs the optimum temper – a fine- to medium-grained angular rock which is fresh. It had been argued that some material was added for ceremonial reasons, but this seems unlikely.

The author and his colleagues collected clay from sources currently used by local Peruvians. They also collected modern fineware and modern utilitarian ware and asked how these were made. The modern day samples showed mixed lithologies, being material taken directly from the river, but it was difficult to identify grog which, after all, is anthropogenic mudstone and similar in appearance to natural mudstone. These modern cooking pots are made from local clays which are washed, then crushed 'slate' is added for strength. In fact the 'slate' was anything locally suitable.

The Inca plainware, which was made for immediate use and was not intended to travel far, did not have too much effort put into the making. Clay was tempered with any lithology. There was no consistency among the pots.

Modern fineware is still made in the Cusco locality and traded throughout the Andes, in a similar way to the Inca fineware. Specific clays are used and carefully washed. Lava (andesite) from local fields is crushed, sieved and added in specific amounts. This care is evident in the analysis of the clay which is fine-grained and very uniform in character and contained no grog. The Inca fineware is virtually the same as modern fineware and one of the modern sites is, by anecdotal evidence, the same as an Inca site.

The Kilké ware, which is older than Inca ware, was not cheap as it was found in high class burials, and it must have had careful preparation. Most Kilké ware was tempered with syenite or arkose trachyte – fine-grained felspathic rocks rather than vesicular basalt. However, the grain size is restricted, indicating that the temper was sieved, but the grains were quite variable and this ware had the most grog. The lithologies in this group were very variable but all contained feldspars with angular shapes. The binding properties of arkose are similar to trachyte. Kilké ware is now considered to be the precursor of the Inca ware because of petrographic studies. Previously it was thought that these different pots must have come from the coast.

One group in the Kilké ware was somewhat different and fell between the Kilké and the Inca ware. It is stratigraphically between the two and is petrographically a hybrid between them.

The author showed slides of a modern unwashed clay with quartz and mica giving lots of flat surfaces and a particle size variation from a few microns up to half a centimetre. The modern utilitarian ware is made from a cleaned clay. A temper of feldspars and quartz is added giving sharp angles but no embayments (as would be found in a vesicular basalt). The Inca utilitarian ware was also made from cleaned clay with a similar temper composed of any reasonable material.

The Kilké ware was made from cleaned clay but differed from the Inca utilitarian ware in that the temper was from lithologies similar to each other and the angular casts had a restricted grain size. This suggested that imported material had been used and in fact it was possible to identify the source andesite which has a restricted outcrop in the valley. The group studying these different pots came to the conclusion that the original potters chose the temper according to feel.

The author showed a slide of a magnificent Inca pot. These could be anything from 20 cm up to 1.5 m in size. They were very thin pots, beautifully decorated and taken long distances. This was the acme of pottery from excavations of the highest (i.e. latest) horizon. Thin sections show the uniform grain size which includes only biotite or pyroxene andesites and individual biotite flakes. In some pots there is a thin layer of mica on top of the pot. Each individual pot is consistent, so a single lump of rock must have been crushed to form the temper. In thin section there is no white line between the shard and the clay indicating a very good contact between the two. The clay had a large amount of temper packed into it which gave strength to the big pots. These pots are similar to modern fineware which is made from very clean clay with vesicular andesite lava as the temper. The vesicles might make the pot lighter. Modern pots have a lower temper to day ratio than Inca fineware but are not so big.

These studies indicate what can be done with ordinary petrographic studies on thin sections, without trying to provenance but applying petrography to a rather different problem. Ironically, it turned out, against expectations, that they could provenance some of the andesites as they had specific characteristics.

PETROGRAPHY AND ORES

Turning to ores, the author explained that about 500 minerals are opaque and therefore cannot be studied in thin section. Reflected light from a polished surface is used involving successively finer diamond pastes down to a quarter-micron paste to get a reflective surface better than any mirror. Properties studied include colour, reflectance, hardness, whether they are anisotropic or have reflection pleochroism, etc.

The main use of ore microscopy is in the metals business, but in archaeology gold or platinum artefacts can be studied and probable sources identified. The best and most common way of proving provenance is by chemical methods.

The author showed a grain mount of gold, iron and copper for identification. A firm rule about gold is that if one is uncertain about its identity it isn't gold. The gold/silver/copper/palladium ratios of gold artefacts can be studied and compared with likely sources.

Gold is classified according to its fineness. The fineness is the amount out of 1000 which is gold. Sterling silver is 975 ppt with the remaining 25 parts being copper. Natural gold is found in particular degrees of fineness, e.g. 860, 980.

In reflected light colour and reflectance vary. Silver has the highest reflectance (98%), gold about 70%. The grains in gold show a series of yellows according to the fineness of the gold and its combination with different elements.

There is a premium on natural gold, and even more on platinum, due to its use in provenancing. Amalgam is sometimes used, illegally, to extract gold (amalgam is, of course, poisonous). The author showed a slide of gold/mercury alloy in an oil mount in contrast with grain mounts. Osmium/iridium alloy looked very similar.

Gold can be found as nuggets which are probably formed at low temperatures in ordinary rivers but there is no consensus of opinion on this – the arguments depend on interpretation of texture. Some grains of gold have an enriched rim which shows as a brighter yellow. These may be formed as a result of silver being leached out as gold found in rocks is usually 965 ppt gold, 35 ppt silver. However, the author has found gold rims around a platinum/iridium alloy which must be due to later precipitation and not to leaching.

With quick reference to platinum, we learned that some of the richest in the world is on Unst but in an unknown quantity. It may be anything from 10 to 100 kilos but not enough to be commercially extracted. However, hand specimens of fabulous richness (e.g. 120 ppm) can be collected. 1 ppm is economic and 10 ppb can indicate a worthwhile source.

Turning to the study of bronzes, the author explained that early Bronze Age people used pure copper but most artefacts have 10% arsenic added to improve the quality. Attempts have been made to match artefacts with ores.

Often a combination of copper, antimony and arsenic is used to make artefacts, sometimes with additional silver or cobalt, etc. Sometimes these other metals are present in small amounts which do not change the characteristic of the copper and must have been inherited from the source material. These are characteristic of very early Bronze Age artefacts.

Copper sulphide deposits have a zone of supergene enrichment where copper ores without iron are found and above that are malachite, azurite, cuprite and native copper. Early miners were attracted by bright colours and extracted copper by smelting it with charcoal. The extraction of copper from sulphide ores is much more complex involving roasting the ores to remove the sulphur and then reducing the resultant ore. The presence of iron, as in chalcopyrite, makes the process even more difficult.

The author showed a slide of copper from Mount Gabriel, Co. Cork, which is said to be one of the earliest copper mines in Europe. Copper carbonate and copper-iron sulphide would be extracted to give only a copper signature. Other copper ores in Co. Cork have high arsenic and antimony in them. These ores are chemically very simple but mineralogically complex and very difficult to smelt. The resultant copper would leave traces of the elements in its signature.

A few other mines were discussed briefly, in particular Great Orme, which in 3000 BC must have been the dominant mine in Europe and controlled the distribution of copper in the same way that Parys Mountain did in the 1860s. In Great Orme there is no arsenic nor antimony, just ordinary copper.

Discussion ensued on a wide range of topics including relating known processes to resultant ores, the formation of gold nuggets, and materials used in pottery.

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