4 POTTERY PASTE

CLAY

Generally speaking, ceramics consist of three main raw materials: *clay* – doughy fine-grained sediment which becomes plastic when wet; *non-plastic inclusions* – mineral and organic substances found naturally in clay or deliberately added to it to make it more workable (feldspar, calcium carbonate, sand, quartz, calcite); *water* – which is added to clay and its inclusions to make them more plastic. Other raw materials involved in pottery production include various colouring agents and the fuels used for firing (Sinopoli 1991: 9).

The most important of all the materials used for ceramic production is evidently clay. The meaning of the word *clay* differs according to the field of interest. In geology, clay denotes fine-grained minerals which formed as a result of the weathering of siliceous rocks. In chemical minerology, clay is an unconsolidated mineral that belongs to the group called clay minerals, while in soil science, the word *clay* is used to denote inorganic parts in soil, composed of very small particles. In archaeology, *clay* means a material which contains mineral particles, which when mixed with water becomes plastic, when dried off becomes solid, and when heated to a sufficient temperature acquires hardness, strength, and chemical and physical stability (Goffer 2007: 231).

Generally, clay is a complex material whose main characteristics are its very small particles (less than 0.002 mm in diameter) and a relatively high proportion of minerals (Orton et al. 1993: 114). This mineral sediment has been created by decomposition of various magmatic and silicate rocks caused by weathering and other factors (mechanical, chemical and organic decomposition). It consists of mineral particles (the so-called clay minerals) of aluminium silicates which contain water (kaolinites, montmorillonites, illites, halloysites, nontronites, allophanes etc.) and diverse other tempers such as quartz, iron hydroxide, carbonates, orthoclase and organic remains (Zlatunić 2005: 63). Clays (clay soils and clay rocks) make up 70% of all sedimentary rocks; they are classified into primary and secondary.

Primary clays are those deposits which have remained in more or less the same location as the original rocks they developed from. These clays have been made from various kinds of rock such as granite, basalt, diorite and some other volcanic rocks. For this reason, the natural composition of clay includes minerals – remains of the parent rock (Rice 1987: 31 –38). Primary clays are rather pure, uncontaminated with other materials; their structure is uniform and their particles very fine (less than 0.002 mm in diameter). In the majority of cases they are colourless or white, and a very small quantity of mineral such as quartz or iron oxides can make them yellow, brown or green. The presence of more than 20 different types of minerals in primary clay can be established by their chemical composition (kaolinite, illite, halloysite, montmorillonite, chlorite, sepiolite etc.) (Goffer 2007: 231–234).

Secondary clays (sedimentary or transported clays) have been moved from their original position by various natural processes such as erosions, waves, winds, ice etc. Such clays are much more frequent, and they are much more homogenous and fine-grained, as a result of sorting and sedimentation. In the majority of cases they contain 5–10% organic matter (Rice 1987: 31–38). Finer particles make wet secondary clays much more plastic and adaptable, making them more suitable for shaping and firing than primary clays. Another feature of secondary clays is a high proportion of non-clay particles (more than 50%), such as sand, limestone, iron oxides and organic substances, which is a result of their having been moved from their original positions. Iron oxides will make clay yellow, red, brown and sometimes green, while organic tempers will make any clay dark (Goffer 2007: 234–235). Many secondary clays become solid and hard when fired at relatively low temperatures, but they can, on the other hand, be too plastic to be shaped, and they can crack during drying and firing. Their properties can be improved by the inclusion of non-plastic tempers: materials which do not become plastic when mixed with water (Rye 1988: 31).

The choice of raw material can be conditioned by diverse factors, which will be discussed in greater detail in the following chapters. However, three main characteristics of clay are important for any potter: its formability, its plasticity, and controllability (Bronitsky 1986: 212–218). Usually these three characteristics are taken as the material's workability. Workability implies a link between clay, water and tempers, and their proportions depend on the potter's subjective estimate, acquired knowledge, experience and skill (Rye 1981: 20–21). Generally speaking, clay is less workable if more tempers have been added to it, but adding larger quantities of tempers will make ceramics more resistant to thermal stress. Clay properties, grain size and proportions of tempers are interrelated factors which influence the paste's workability.

TEMPERS

Rocks consist of minerals, and thus the natural composition of clay also includes many minerals. Another type of mineral found in clay is the secondary mineral, which has been included deliberately by the potter to improve its forming and firing properties. Various materials have been added to clay, ranging from organic substances to minerals and rocks. The choice of material was determined by geography, in that potters mostly used raw materials from their surroundings (Gibson & Woods 1997: 33).

Tempers are non-plastic materials the potter has deliberately added to the clay paste with the aim of preventing the vessel's shrinkage and cracking during its firing, increasing its resistance to thermal stress, and its hardness and strength after firing. Clay tempering is one of the oldest technological choices made in pottery production, and it can be divided into four categories:

1. ***Minerals*** - the most frequent tempers, predominantly consisting of quartz and calcite, whose properties will be discussed in the next chapter. Traditionally, sands have been used in pottery production due to their high content of quartz and feldspar (Albero 2014: 69). Experiments have shown that clay tempered with sand improves heat transfer to the vessel's contents, resulting in much better heating effectiveness of such vessels, and a shorter time needed to boil the water, than of vessels tempered with organic material (Skibo et al. 1989: 131–132).
2. ***Various metamorphic, sedimentary and eruptive rocks*** - such as granite, basalt, limestone, phyllite etc.
3. ***Organic material*** - which can make up as much as 17% of the natural composition of clay, but is mostly deliberately included in it. The amount of organic material in the paste will influence reduction firing because, due to the lack of oxygen necessary for oxidation, such material will turn into charcoal. Thus it will leave black traces in the pottery pores, resulting in a grey colour (with a small quantity of organic material) or a black colour (caused by soot, i.e. unburnt carbon) in reduction-fired ceramics. If burned at high temperatures, or-

ganic material will leave cracks which increase the vessels' porosity and permeability. The most frequent organic tempers have been grass, various plant fibres, straw, shells, chaff and dung. Shell-tempered vessels are stronger and more resistant to thermal stress (Skibo 2013: 44). A somewhat different tempering includes the addition of milk, blood and other liquid tempers, which has been evidenced in Egypt (Albero 2014: 70).

Vessels tempered with organic material have been explained primarily as a culturally conditioned phenomenon, which logically followed the transition from basketry containers, wooden vessels or animal skins; inclusion of grass in clay has been seen as a kind of link between the two technologies. The addition of dry dung to the paste used for making Early Neolithic pottery has been interpreted by some authors as a symbolic choice, rather than a technological one, marking the transition of economic activities from land cultivation to animal farming, while the inclusion of mineral temper would suggest that new lands had been occupied and cultivated (Gheorghiu 2008: 172–175). From a technological point of view, organic-tempered vessels have poorer heating effectiveness, which goes against their primary function, prompting many interpretations which have claimed that such vessels were not used for cooking over a fire, but rather for stone boiling (see Jordan & Zvelebil 2010a: 43–44; Skibo 2013: 41. However, as already mentioned in the previous chapter, traces of soot have been found on the external surfaces of some of the earliest vessels, undoubtedly pointing to their being used for cooking over a fire (Keally et al. 2004; Boaretto et al. 2009; Jordan & Zvelebil 2010; Wu et al. 2012), while analysis of organic remains has confirmed the presence of remains of the freshwater and marine foodstuffs which had been prepared in them (Craig et al. 2013). As has already been emphasized, the ability to use pottery for cooking over a fire was the main advantage of this technology over containers made of wood, animal skins or basketry (Skibo 2013: 43).

Various analyses and experiments have demonstrated that organic-tempered vessels share several techno-functional characteristics (Skibo et al. 1989):

a) they were resistant to breakage and mechanical impact if the organic temper was large-grained and sparse;

b) they were lighter than mineral-tempered vessels and, as such, more suitable for transportation;

c) experiments have shown that vessels tempered with both organic material and minerals were more resistant to thermal stress than those which were sand-tempered or untempered (Skibo et al. 1989; Schiffer et al. 1994). Furthermore, organic tempers provided higher strength, resulting from tight closure of pores (Schiffer et al. 1994);

d) they are more easily worked and shaped, because this temper is always available in the settlement and at the place of production. In addition, organic-tempered vessels dry more quickly (Skibo 2013: 41–43);

e) one of the shortcomings is their poorer heating effectiveness, so the surfaces of vessels with this type of temper have to be additionally treated (Skibo 2013: 43).

4. *Anthropogenic tempers* – grog (crushed ceramics) is the only temper which is manmade, rather than natural. In addition to organic material, grog is the most frequently used temper, and can be found in pottery ever since the Neolithic (Thomas 1991; Hamilton 2002; Spataro 2002; 2011; McClure et al. 2006; Arnăut & Ursu-Naniu 2008; Kreiter et al. 2009; Quin et al. 2010; Vuković 2010; Kreiter 2014). As we could see in the chapter on pottery origins, grog has been found even in the oldest pottery in China (Chi 2002). In later periods (especially in the Bronze Age), large grog particles – containing some even older particles – can often be observed in pastes (Mason & Coper 1999; Gherdán et al. 2007; Kreiter 2007; Kudelić 2015), suggesting that vessel recycling is a long tradition (*Fig. 80, p.*).

One of the reasons for its long technological record is its availability, given that such fragments of broken vessels could always be found in settlements. As a temper, grog appears in two forms: a) that which shares the same mineral properties as the 'host' vessel, and b) that which has different mineral properties (Whitbread 1986: 82). When pottery material is analysed under a polarizing microscope, sometimes it is difficult to distinguish included grog from clay pellets (Cuomo di Caprio & Vaughan 1993). They can be found in a paste, as deliberately added particles of dry clay or as natural inclusions which have formed within a depositional environment. Still, clay pellets can be identified by a high degree of roundness, a similarity of shape and their colour, which can be darker than that of the paste because of the concentration of oxides (Whitbread 1986).

Although it is made of clay, grog does not share the size of grain characteristic of clay, because its mineral properties were destroyed during its firing (Velde & Druc 1999: 83). However, its deliberate inclusion in the paste will make the vessel more resistant to thermal stress and diverse mechanical damage. Grog is also useful when the vessel is dried, because ceramic grains absorb moisture and thus contribute to an equal drying.

In general, tempering with grog is related to the vessel's functional properties, and is normally associated with cooking vessels, because of its low coefficient of thermal expansion. Nonetheless, some ethnographic studies have demonstrated that it is precisely in those vessels that the inclusion of grog is avoided. For example, the Yuma and Mohave communities of the American Southwest use grog in all vessels but those used for cooking. The Yumas temper clay with granite, and the Mohaves with sand. The Hopi community also adds sand to vessels used for cooking and storing, while they produce other types of vessels from untempered clay. In the Yucatan, limestone is added in vessels used for keeping water, and calcite in those used for cooking (Plog 1980: 85–86). On the other hand, ethnoarchaeological studies conducted on three traditional communities in Pakistan have shown that two different tempers, grog and sand, have been used in distinct parts of cooking vessels. A paste composed of 50% clay and 50% sand to facilitate forming has been used for making rims, whereas the vessels' bottoms have been made only from grog-tempered clay, because of its resistance to high temperatures (Spataro 2004: 173). Such examples reveal diverse technological traditions which use different recipes for particular vessel usage.

As a temper, grog is rarely found alone in a pottery paste; together with other tempers it can result in different qualities of paste. Its application is related to cultural traditions and changes in pottery technology which have yielded different recipes. Studies of the Hungarian Neolithic have shown that, in the Early Neolithic, potters tempered their clay only with organic material, while in the Middle Neolithic its use dropped, to be replaced by grog in the Late Neolithic (Kreiter 2014). An entirely different pottery practice has been documented during research on the Spanish Neolithic; there, grog was the predominant temper during the Early Neolithic; in the Middle Neolithic it gradually disappeared and was replaced by calcite; and in the Late Neolithic calcite was the only temper in the pottery paste (McClure et al. 2006).

Grog has more than recycling characteristics, as evidenced by some ethnographic studies. For example, in southeast Asia (Laos), potters produce grog themselves, by mixing clay and rice hulls, firing it and then deliberately crushing it into small fragments to be used in the production of vessels (Rice 1987: 412; Shippen 2005: 44). Clay balls are still fired at low temperatures in Thailand, and then crushed into small bits and used as grog (Velde & Druc 1999: 83). Ethnoarchaeological investigations in western Kenya have shown that, according to the estimates of local potters, one broken vessel can be used to produce three new ones of the same size (Dietler & Herbich 1989: 152).

Besides its functional properties and technological-traditional practices, tempering with grog is also related to a symbolic interpretation of the unbroken transformation of one vessel into another one, and inclusion of ancestral tempers into the next generation of vessels (Gamble 2007: 198). Ethnoarchaeological studies of various traditional practices testify to a symbolic use of grog, linking the person's life and death to the life of the vessel. One example comes from the Peruvian Andes, where all the vessels used by a person in life are deliberately crushed after his or her death, and some of the crushed fragments are set aside and used for the production of a new vessel (DeBoer 1974: 340). In western Africa, vessels are used to express the link between father and son. When the father dies, his son breaks away a part of the rim from the father's vessels, and incorporates it, as grog, into a new vessel (Sterner 1989 according to Kreiter 2007: 132). Grog temper has also been interpreted through a special meaning which the broken vessel, reproduced as grog in a new one, could have held for the community. On the other hand, the avoidance of grog tempering has been explained as deliberate avoidance of inclusion of old broken vessels because of the significance, or superstition, they would incorporate into the new vessel (For an overview, see Hamilton 2002). Continuity of life, reflected symbolically by the continuation of life in the same location, that is, by its social and material continuity, has been observed ever since the Neolithic in the form of deliberate burning of houses. Old houses were burned down and thus incorporated into new ones, which were built on the old foundations, thus establishing a symbolic continuity of the location in respect of a household (Whittle 1996; Stevanović 1997; Tringham 2000; Tripković 2009).

This short overview has demonstrated that the selection of temper is not guided only by its techno-functional properties, but can also be conditioned by its social, ideological, symbolic and traditional meanings, which should certainly be borne in mind.