Dung by Preference: The Choice of Fuel as an Example of how Andean Pottery Production is Embedded within Wider Technical, Social, and Economic Practices

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1 author:

Bill Sillar
University College London

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DUNG BY PREFERENCE: THE CHOICE OF FUEL AS AN EXAMPLE OF HOW ANDEAN POTTERY PRODUCTION IS EMBEDDED WITHIN WIDER TECHNICAL, SOCIAL, AND ECONOMIC PRACTICES*

B. SILLAR

Institute of Archaeology, University College London, 31–34 Gordon Square, London, WC1H 0PY, UK

A discussion of how Andean potters acquire and use their fuels is used to demonstrate the 'embedded' nature of ceramic technology. The most common choice of fuel in the highlands of Peru and Bolivia is animal dung (mainly cow, sheep, and llama). This technological choice is related to wider social and economic practices (particularly in relation to animal husbandry) which has further repercussions that affect other technologies (such as agriculture practices). Such a succession of interrelated activities is not unique to pottery; it is fundamental to all technologies and should be considered within archaeological analysis.

KEYWORDS: SOUTH AMERICA, ANDES, BOLIVIA, PERU, ETHNOARCHAEOLOGY, ANIMAL DUNG, CERAMICS, FIRING, FUEL, TECHNOLOGICAL CHOICE

INTRODUCTION

The production of every pot requires the potter to make a series of 'choices' selecting from a range of possible raw materials, tools, energy sources, and techniques. Yet the potter is never aware of all the potential techniques s/he could use, and the specifics of a particular pottery-making tradition will depend on the wider social practices and technological traditions that the potter is a part of (Sillar and Tite this issue).

In this paper the 'embedded' nature of ceramic technology will be considered through a discussion of how various modern Andean potters acquire and use their fuel during pottery firings. The most common choice of fuel in the highlands of Peru and Bolivia is animal dung (mainly cow, sheep, and llama). This choice has influenced the structure of the pottery firing, the form and decoration of the pots, and the longer-term development of the region's ceramic technology. The technological choices involved in pottery firing arrangements are dependent on wider social and economic practices (particularly animal husbandry in this case) and the choice of firing techniques will have further repercussions that affect other technologies (such as agriculture practices). This interdependence between a range of different techniques and activities is not unique to pottery making, it is fundamental to all technologies. Archaeologists should be ideally placed to utilize this interconnection between different technologies to discuss the basis upon which technological choices were made and maintained in the past. This approach should help us to escape from the rather unsatisfactory distinction between the functional and the symbolic aspects of technological choices and to focus more upon the cultural background that informs the development of technological traditions.

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WHY DID I CHOOSE TO STUDY DUNG?

Why should I take such a passionate interest in an animal product that most people politely ignore? During my ethnographic fieldwork in the highlands of Peru and Bolivia I was confronted by animal dung on a daily basis, not just as a fuel and a fertiliser, but also as an ingredient in ritual drinking, a major influence in the use of space within the house compound, and a frequent topic of conversation. This made me aware of just how rich a resource dung is, and, more significantly for this paper, how the management of that resource impinges on many different areas of Andean life.

If archaeologists wish to understand 'technical choices' in the past we must consider how the particular materials and technologies we wish to study were related to (embedded within) the wider technical practices and cultural values of the society. I have chosen to look at fuel because it is one of the major areas where the interdependence of pottery technology with wider social, economic, and technical practices is most visible. Any analysis of Andean pottery firing technology would have to include a discussion of the physical properties of dung as a fuel. But, in order to understand the 'technical choices' involved in selecting dung as a fuel, we will need to widen our analysis in order to see how the production, procurement, and use of dung are embedded within many other activities.

POTTERY PRODUCTION IN THE ANDES

The Andean highlands are a rugged area with many communities at 4000 m and above. Pottery production in this area is surprisingly consistent both in terms of the techniques used as well as in the organization of production. The pottery production I have observed in the highlands of southern Peru and Bolivia is organized at the household level. Pottery forming usually involves the use of a flat slab of clay to form the base, and large thick coils that are further thinned by drawing the clay up to form the sides. Firings usually take place in the evening after the vessels have dried and warmed in the powerful Andean sun. Open firings normally involve placing the pots on a flat surface which has a low protective wall around the base of the firing and then covering the vessels with fuel, usually dried dung (see Table 1 and Figs. 1–4). This is not to say that alternative methods are not known about and used—two-, three-, and four-part moulds are used for slip casting in the Pucara area, the potter's wheel and kilns are used in both Pucara and Huayculi, kilns are also used in Paracay and were being introduced to Charamoray while I was there (see below). But the underlying grammar of pottery-making technology, described above, appears to be characteristic of the south-central Andes and is consistently reported by a number of authors (e.g., Tschopik 1950; Donnan 1971; O'Neale 1977; Ravines 1978; Hagstrum 1988; Ravines and Villiger 1989; D. E. Arnold 1993; Chávez and Mohr 1992; Sillar 1997).

FUEL—A QUESTION OF VALUES (CALORIFIC AND CULTURAL)

The large number of ethnographic reports on pottery production and firing allows us to appreciate the near infinite variety of materials and techniques that can be used in the craft, particularly when the restraints of large-scale mechanized production are not imposed. In the case of fuels used in non-kiln firings it is accepted that in many areas, where wood is not plentiful, potters will develop fuel resources that are often the waste product from an agricultural process or industry, such as prunings from vines and olive trees, cotton lint, or car tyres. There is,

Table 1 *Pottery firing techniques used in eleven communities in the southern central Andes*

Community	*Form of firing*	*Location of firing in relation to house compound*	*Main fuel*	*Extra-houshold fuel acquisition*	*Size of firing (radius in m)*	*No. of pots*	*No. of firings per year*	*Use of ash after firing*
Araypallpa	Open (sub-rect.)	Inside or outside	Dung (C. S.), *ichhu*	Not to my knowledge	0.50–3.50	5–45	1–6	
Charamoray/Urubamba	Open (circular)	Usually outside	Dung (C.)	Occasionally	0.50–2.00	20–150	5–20	
	Kiln	Usually inside	Cactus fronds	Occasionally	—	40–100	5–20	
Machaca	Open (rectangle)	Outside (exposed)	Turfs, dung (S. L.)	Not to my knowledge	1.00–2.50	50–200	5–25	Not used
Raqchi	Open (circular)	Inside	Dung (C. S.), *iru*, wood, cactus	Occasionally	0.75–5.00	50–600	1–5	Ash collected for fields
Seq'ueracay	Open (sub-rect.)	Outside, located in field	Dung (C.), *ichhu*	Not to my knowledge	1.00–3.00	40–150	1–5	Firing site is ploughed into field
Colcapirhua	Open (circular)	Inside	Dung (C.)	Frequently	2.00–7.00	20–100	1–3	
Huayculi	Kiln	Inside	Brushwood	Frequently	—	150–600	10–50	Not reused
Paracay	Kiln	Outside	Brushwood	Occasionally	—	20–80	4 –10	
Surumi Rancho	Open (circular)	Inside	Dung (C. S.)	Frequently	2.00–7.00	20–100	1–3	
Pumpuri (itinerant)	Open (rectangle)	Outside	Dung (C. S. L.), cactus, peat	Occasionally	1.50–7.00	30–150	1–3	Sometimes ash is collected by locals
Totorani (itinerant)	Open (rectangle)	Outside (exposed)	Dung (C. S. L.)	Occasionally	1.00–3.50	50–200	5–15	Sometimes ash is collected by locals

Dung: (C.) cattle; (S.) sheep; (L.) llama.

I think, a tendency to consider these fuel choices as inferior to that of wood, choices born of economic or environmental necessity, and it is perhaps for this reason that there has been little consideration of the effect that the choice of fuel has on the pottery technology or the wider society.

Meat consumption in most Andean communities is comparatively low (chickens or guinea pigs are the main meat for birthdays and festivals); most animals are utilized for their wool, draft power, and dung, and they are usually sold to traders for the urban market rather than slaughtered by the household that reared them. While we tend to think of livestock mainly as a source of meat and milk, in practice they produce more dung than anything else. In fact cows, sheep, and llamas drop about four times their body weight in dried dung each year, turning widely dispersed and bulky grasses into a 'compact and easily gathered source of energy and nutrients' (Winterhalder *et al.* 1974, 89). So it is not surprising that dung is one of the most widely used fuels for non-kiln firings—in India and Pakistan (Saraswati and Behura 1966; Rye and Evans 1976), Africa (Nicklin 1981; Tobert 1984), North America (Shepard 1985; Colton 1951), and Latin America (Reina and Hill 1978; D. E. Arnold 1985). It is worth noting at the outset that all of these locations have a significant dry season; the local environment, and the way it is understood and managed, is a major consideration in shaping many technological choices. In the Andes the use of dung as a fuel for pottery firing appears to be a long-standing practice, as is evidenced by recent excavations at Tiwanaku (Franke 1992; Melanie Wright pers. comm.). Father Bernabe Cobo writing *c.* 1653 (*Historia del Nuevo Mundo*, Book 3, chap. 6, cited in Ravines and Villiger 1989, 18) also states that dung and grasses were the fuel used for pottery firings, commenting that cow dung was quickly appropriated as a fuel by indigenous potters soon after the Spanish conquest.

All herbivore dung shares a few distinctive characteristics that make it particularly suitable for firing pottery: it has a compact, porous structure that, when dry, will burn steadily, and completely, without too vigorous a flame. The rate of fuel combustion is affected by the ratio of surface area to weight, as it is this which determines the availability of oxygen (Rice 1987, 157), which helps to explain why the porous structure of dry dung makes it such an efficient fuel. Because dry dung burns evenly, it does not, like wood, release a lot of free carbon that would smudge the pottery, and the porous structure means that even vessels surrounded by it will be oxidized rather than reduced. It is important to note that this will depend on the form of the dung and the firing arrangements used by the potters. For instance, Rice (1987, 158, quoting LeFree 1975) reports layering powdered manure on top of the pottery towards the end of an open firing to create a smudging effect where the oxygen supply is reduced and a layer of carbon is deposited on the surface of the pottery (I expect this would work most effectively if the manure was slightly damp). This example helps to remind us that it is not just the availability of raw materials which shapes a technology, but the way they are used within local technological practices.

One of the greatest problems for non-kiln firings is the fluctuating temperature, particularly at the edges of the firing structure, which can create great stress in the pottery and cause it to 'blow' or shatter. One of the advantages of dung is that the ash tends to retain its structure after combustion; thus, the ash acts as an insulator which protects the pottery from these fluctuations in temperature. This makes dung an exceptionally appropriate material for firing pottery without the use of any permanent structure. Open firings using dung as their fuel also have the significant advantage of all 'open firings' that the size of the firing can be easily adapted according to the amount of pottery being fired. Nonetheless, it is advantageous for the potter to build a sufficiently large firing so that s/he can achieve a good temperature for the pottery to fuel ratio. Larger firings also facilitate the potter's ability to achieve and maintain a stable firing temperature. I have never taken a pyrometer into the field, but temperatures up to 865 °C have been recorded for dung firings (Nicklin 1981) and the lead sulphide glaze used in Charamoray (see below) would suggest a temperature not much below 900 °C was achieved. I have also seen some wasters that have been heavily warped in the firing, suggesting that temperatures around 1000 °C do occasionally occur. Nonetheless, one of the remarkable features of the firings I have observed is the very low level of wasters produced. Most potters expect a success rate of about 95% from their firings and they frequently achieve 100%; they tend to be very disappointed if the success rate falls below 90%.

This has implications for how we use pottery vessels and sherds to interpret the firing techniques used in the past. The frequent assertion that kiln firings permit a greater control over the firing atmosphere and temperature has encouraged an overly dogmatic split between the properties of 'open firings' as opposed to 'kiln firings'. Whether the ceramic analysis is based on simple observation or more sophisticated techniques (e.g., Mössbauer spectroscopy), we should remember that it is possible to achieve a relatively stable high temperature and oxidizing condition within some open firings.

Several authors have referred to the deliberate oxidation or reduction of vessels that are intended for particular functions (Tobert 1984; Bryant and Brody 1986; Reina and Hill 1978). As I have described, the use of dung as a fuel tends to promote oxidation. However, at the base of the firing, the part of the vessel that is towards the ground will crush the dung as it burns and so lie in a bed of crushed ash that oxygen cannot enter, and this part of the vessel will be reduced. In Raqchi (Sillar 1997), Colcapirhua, Surumi Rancho, and Seq'ueracay (Fig. 1) care is taken to ensure that the vessels are raised above the ash by using large sherds to support them. In Machaca (Fig. 2) and Totorani (Fig. 3) many vessels are not raised above the ash so that part of each vessel on the bottom layer of the firing is reduced, but it is only pots that are intended for use on the hearth (mainly cooking pots) that are placed at the base of the firing and so subjected to reduction, all other vessels being lifted above it and so oxidized. The itinerant potters from Pumpuri place their large open-mouthed jars (*wirqis*) with their mouth to the ground so that the inside of these vessels is reduced to black, whereas the closed mouth jars (*p'uñus*) are fired with

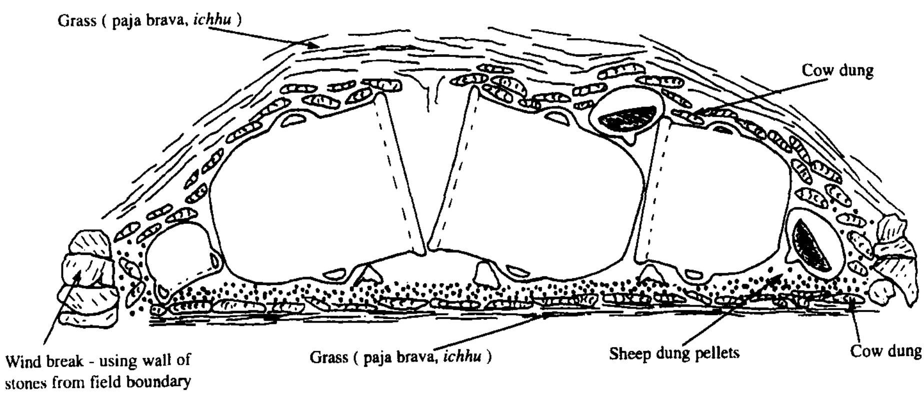

Figure 1 *Seq'ueracay, Department of Cuzco, Peru: cross-section showing the placement of pots and fuel in the pottery firing.*

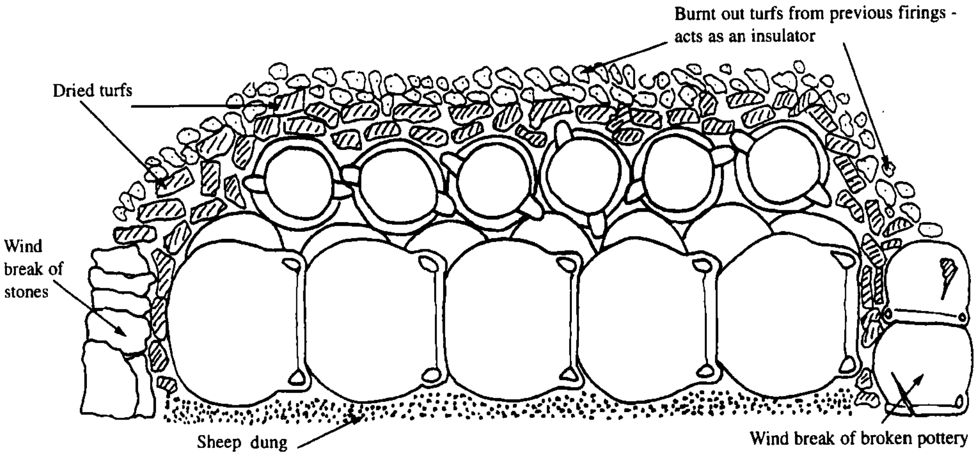

Figure 2 *Machaca, Department of Cuzco, Peru: cross-section showing the placement of pots and fuel in the pottery firing.*

their base in the ash so that only the base is reduced to black and the inside is fully oxidized (Fig. 4). Thus, the oxidizing properties of using dung within this firing arrangement are made significant, and the placement of the vessels in the firing relates to the practical and symbolic values of the pots.

TECHNICAL CHOICES IN ANIMAL HUSBANDRY AND THEIR EFFECT ON THE PROPERTIES AND AVAILABILITY OF DUNG AS A FUEL

The type of dung produced by different animals varies, according to the species, the size of the animal, environmental conditions, diet, age, and the health of the animal. The accessibility of the dung and its structural properties are also affected by animal husbandry practices, such as whether or not the animals (and their manure) are sheltered from the rain in a roofed barn,

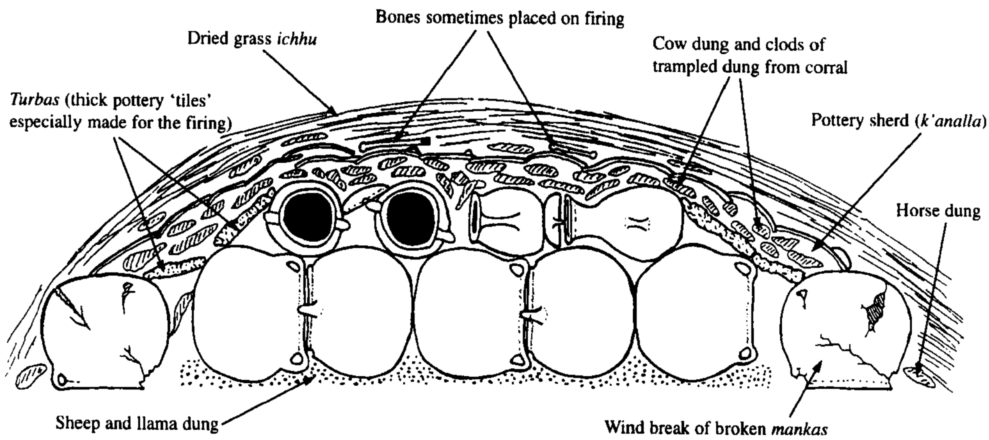

Figure 3 *Totorani, northern Potosi, Bolivia: cross-section showing the placement of pots and fuel in the pottery firing.*

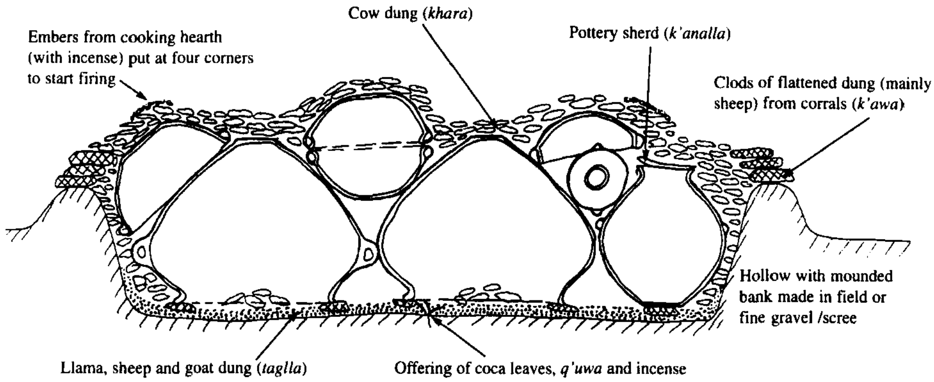

Figure 4 *Pumpuri, northern Potosi, Bolivia: cross-section showing the placement of pots and fuel in the pottery firing arrangement used by the itinerant potters from Pumpuri.*

whether or not the dung is mixed with other materials (such as straw bedding) or compacted by trampling, and how and when it can be collected (Anderson and Ertug-Yaras 1998). The specific combination of these natural and cultural factors has a significant effect on how easy it is to collect, store, and dry out the dung, as well as its nutritional and combustible properties. These 'technical choices' may be largely understood in terms of animal husbandry practices, but they will play a significant role in determining the availability and the properties of animal dung. For instance, cow dung 'pats' are very easy to collect and dry out and burn steadily for a long time. Although sheep dung pellets are more difficult to pick up, and they produce an acrid smoke when burnt in small quantities, they can achieve a hotter temperature than cattle dung, and are richer in nutrients (Winterhalder *et al.* 1974). Rice (1987, 157) has pointed out the inconsistencies in published description of the properties of dung as a fuel, inconsistencies which are not surprising when the differences in species, diet, and moisture content are considered along with variations in firing structure, wind velocity, and the observer's previous experiences in pottery firings. This is an area that would benefit from detailed experimentation to compare the properties of different fuels (cf. Winterhalder *et al.* 1974) and different firing structures (cf. Woods 1982).

Variations in animal behaviour and husbanding practices also affect the availability of their dung. Cattle are taken to many different fields to be pastured and to be used as draught animals, but, because of their large size, cow pats are relatively easy to collect, and this becomes an almost unconscious habit, particularly for children and the people who are pasturing the animals. Sheep pellets are more difficult to collect, but, by encouraging sheep to graze over fallow plots, they will be automatically fertilizing the soil, and, as, like many animals, they do much of their defecating in the evening or in the early morning, their produce can be centralized by penning them in at night. Collecting dung from animal pens highlights the fact that the animals have grazed over a wide area and, thus, concentrated a very dissipated resource into a compact form which they have conveniently transported back and 'down-loaded' in the animal pen. Llamas and alpacas are grazed in the higher areas of the altiplano above most arable land, their dung is collected by the shepherds that are guarding them, and many families make special trips towards the end of the dry season to collect 20 or more sacks of llama dung from the high puna. This is facilitated by the tendency of camelids to choose a restricted area, often near a water source, where they defecate in communal piles, making the collection of this resource very much easier. Cultural attitudes to the ownership of resources may vary widely—but in my experience there seems to be a relatively common understanding in the Andes that the dung which accumulates in an animal pen belongs to the animal herder, but when defecated on fields or pasture land it is considered to be available to any community member who is able to collect it.

While today cattle dung has become very important for pottery firing, in the past there was a larger population of llamas and alpacas that would have supplied a vast amount of dung for use as fuel and fertiliser. For example, 800 000 loads of llama dung were taken each year to the colonial silver mines at Potosi to be used as fuel in smelting the ore (Browman 1974, 194). Llama dung has a higher heat value and energy efficiency than cattle dung, burning with an even, hot fire that produces little smoke (Winterhalder *et al.* 1974, 98). The form of open pottery firings used in several present-day communities uses the greater heat of sheep and llama dung by placing this fuel at the base of the firings, whereas the large plate-like structure of cow dung allows for an easier covering of the firings (see Figs. 1–4). But, although the trampled dung from sheep and llama corrals is commonly dug up and used as a fertiliser, it can be used as a fuel for pottery firing. Where cow dung is not available the laminated layers of trampled dung from these corrals can be used. For instance, at Totorani dung from llama corrals was dug out in 'plates' some 3–5 cm thick, and 10–20 cm in diameter, and these were used to cover the firing (Fig. 3).

Like all fuels, dung is most effective when it is thoroughly dry. Cow pats are plastered onto the wall of many Andean animal corrals and houses so that they can be dried out thoroughly. Sheep, llama, and horse dung is usually collected dry from the pasture lands, but, if damp, it is spread out on the ground to dry in the sun, wind, and frost for two or three days. Although dung is produced all year, it is difficult to collect and dry during the rainy season, and I was told that this was a major reason for not firing at this time. But, dung is a very storable resource and in some areas of highland Peru and Bolivia stacks of dung (as large as $8 \times 4 \times 2$ m), often built on a stone platform to raise them above moist ground and promote air drying, are a common sight. In other areas many households have a separate outhouse that is used to store dung for use throughout the year, and a special effort is made to fill it during the dry season. The collection and storage of fuel, like so many aspects of society, is embedded within the social relations of the family, and the use of space in the house is organized to facilitate the management of dung and ash which are not seen as waste products but as valuable raw materials (Fig. 5). When Denise Y. Arnold (1988) reports that the house is sometimes perceived of as a giant dung-heap, this is not meant to be a disparaging term; it is a reference to the centrality of dung within the productive activities of the household.

It is clear that the use of dung in open firings depends very heavily on the interrelationship with other aspects of Andean production, particularly animal husbandry and agriculture, which in most cases is another facet of the pottery-making household's own activities. The fuel is collected on a daily basis by whoever is pasturing the animals, and by occasionally devoting a few hours or a day to collecting extra fuel. For instance, in Raqchi many family members collect fuel each morning, sometimes rising before sunrise in order to collect frozen cow pats from communal pasture lands. A few Raqchi potters are occasionally supplied with fuel through exchange relationships with other community residents who have more access to dung. In other areas, fuel can be given to the potters by non-community members; for instance, in Totorani some traders will bring sacks of llama dung which they exchange for some of the fired pots.

There is a sense in which the choice of dung as a fuel makes Andean pottery production a more stable and sustainable craft activity. It is difficult to overexploit the use of dung as a

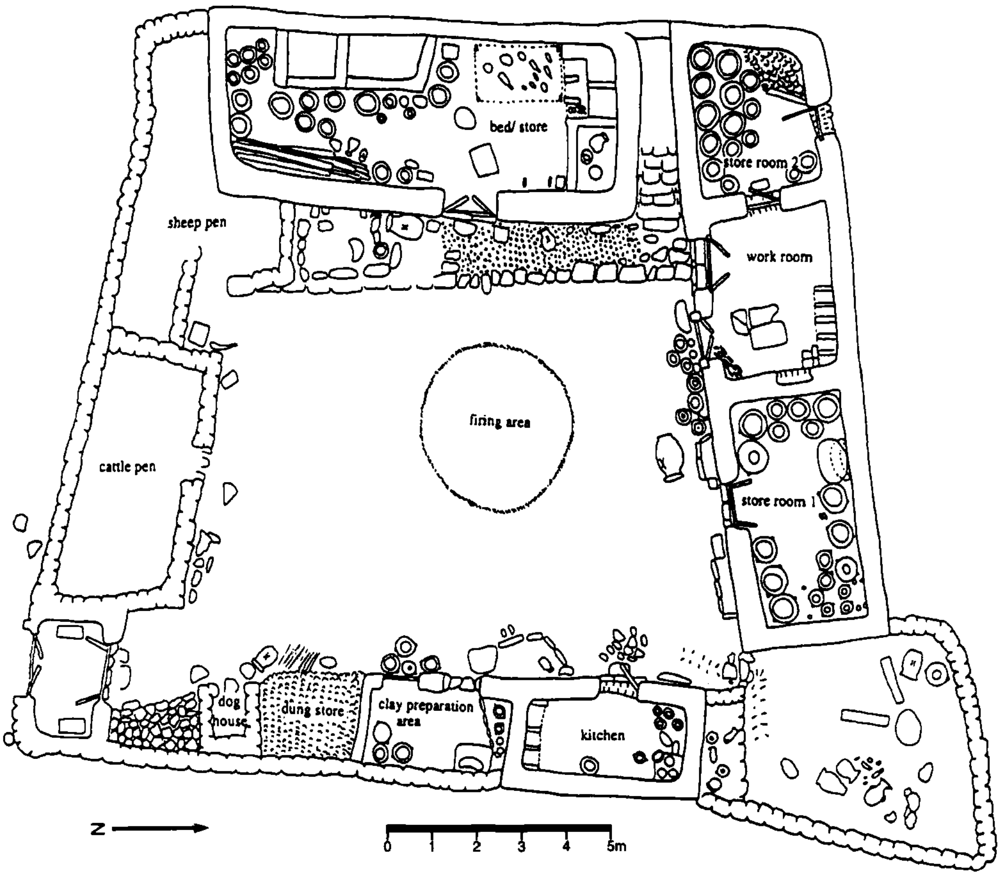

Figure 5 *Raqchi, Department of Cuzco, Peru: house plan showing location of pottery firing, animal pens, store of dung, kitchen, etc.*

resource because you can only use as much dung as the animal defecates, and, as long as you continue to look after the animals, they will continue to produce dung (although one should not underestimate the damage that overgrazing can cause). This can be contrasted with the use of wood as a fuel where the over-exploitation of the wood can kill off the plants. This has been a frequent problem in areas of intensive pottery production where potters are forced to acquire their fuel from greater and greater distances (D. E. Arnold 1985), which implies a significant change in the social relations involved in acquiring the fuel. This is the case in Huayculi (Department of Cochabamba, Bolivia) where the potters make wheel-made pottery which they fire in kilns. They have greatly depleted their local wood supply and now either go on trips to collect fuel from more distant trees or, more commonly, they depend on non-potters bringing in bundles of brushwood. In a sense the choice of dung from household or community animals may help to maintain stability, whereas the use of wood as a fuel can lead to increasing intensification and increasing dependence on pottery production as the major input to the household economy. We have very limited pollen studies from the Andes but one from the Department of Cuzco (Chepstow-Lusty *et al.* 1997) shows virtually no tree species from the start of the sequence *c.*

4000 years BP, and another from Columbia (Behling *et al.* 1998) demonstrates that tree cover had been removed before 2300 years BP. It is possible, therefore, that the use of dung as a major fuel in the Andes may itself be the result of an earlier period of land clearance and deforestation.

DUNG AS A FERTILISER

Perhaps one of the most forceful arguments that can be presented for the preferential choice of dung as a firing fuel is to illustrate that it is not an otherwise useless waste product. Dung is in fact a highly desirable resource which is used as a fuel for cooking and as manure for the fields. (I have not encountered the use of dung as a pottery temper as occurs in many other areas of the world: Tobert 1984; Miller 1985; Gaimster 1986; London 1981). Llama, sheep, and cow dung are commonly used as a fuel in Andean cooking hearths (*q'uncha*); these are very efficiently designed enclosed structures which help to maximize the value of the fuel. The smell of llama dung in the hearth is associated by many Andean people (and some anthropologists) with that feeling of comfort and security associated with home.

In pre-ICI societies, and places where the farmers can't afford sacks of chemical nitrates, dung is an essential element in the agricultural cycle that is laboriously collected and broadcast on the fields as a fertiliser. Dung provides the essential organic component to bind the soil matrix, reduce erosion, and fasten any available nutrients so that they are not leached out of the soil too rapidly, while at the same time the dung gradually releases its own vital plant nutrients as it decays. In Qaqachaka, Bolivia, dung is ritually referred to as *jakaña*, meaning placenta, as it is thought to wrap round the potato and nurture it (D. Y. Arnold 1988, 498), and this is a fairly accurate description of dung's role in maintaining agricultural fertility.

Today, many communities (particularly those that use dung for pottery firings) try to collect some brushwood, eucalyptus leaves, or agricultural by-products like corn cobs, bean stalks, and wheat chaff for use in their kitchen hearths, in order that some of their animal dung can be retained for use in the fields. In most pottery-making communities, the ash from firings is collected and stored to be put on to the fields as a fertiliser, and in Seq'ueracay the potters deliberately locate their firings in a field that is shortly to be planted. Using the ash as a fertiliser will return the potassium and phosphorus to the soil, but the nitrates go up in smoke and the physical properties of the organics in the dung are lost.

The use of dung as a fuel was a long-standing practice before the Spanish arrived in the Andes, and the agricultural system that had been developed accommodated the removal of a large proportion of this vital resource from the soil. Garcilaso de la Vega reported in 1612 (1989 edn., 246) that the Inkas 'fertilized the soil by manuring it, and in the valley of Cuzco and almost all the highland area they treated their maize fields with human manure, which they regarded as the best.' Human manure does not usually have the same fibrous structure that makes the dung of ruminants so attractive as a fuel. The Inkas also imported vast amounts of bird guano from the coast to produce a nutrient-rich soil. Andean agricultural technology is particularly good at compensating for the removal of this vital resource from the soil. Terracing reduced the problem of erosion, and by planting and irrigating crops before the heavy rains the problems of erosion and the leaching out of nutrients is further reduced.

THE SOCIAL AND RITUAL SIGNIFICANCE OF DUNG

The itinerant potter I met from Ticatica, who uses his llamas as pack animals when he goes down to the valleys to make and trade pottery during the dry season, stated that he was obliged to provide the dung dropped by his llamas for his *compadre*'s fields. It has also been reported that in the past the *colonos* who lived on the privately owned hacienda estates were required to pasture their animals on the *hacendado*'s fields and sometimes to provide the hacienda with dung manure from their own corrals (Deere 1990, 62–4). In Pumpuri, northern Potosi, the son-in-law is obliged to bring manure from his animal corrals to fertilize the field of his wife's family (cf. D. Y. Arnold 1988, 309). These very varied examples of 'relations of fertility'—the social obligations expressed through the exchange of dung as a fertiliser—are an important expression of Andean social values. It is entirely logical, then, that the word for manure (*wanu*) is also used to describe a debt. 'In the metaphorical association of debt and credit with manure we can detect a vision of circulation itself—or rather delayed circulation—as a fertilizing force' (Harris 1989, 248). In fact, the term *wanu* has a similar meaning to the word fertility (Meininger 1995) and it is used to describe the fertilizing effects of the winds that blow down to the crops from the pre-Colombian burial towers (Allen 1988, 56).

The ritual importance of dung as a fertiliser and fuel is recorded in many rituals. During the cattle markings I have attended in Lyncha, participants are given *chicha* (maize beer) to make libations requesting that the owner's herds will increase. This chicha is presented in two *turuwasus* (wooden bowls which have two yoked bulls carved in the centre), with three coca leaves and three bits of cow dung in each. In Qaqachaka, llamas and sheep are thanked for their dung during the *k'illp''a* marking ceremony, and songs celebrate their defecating as libations on the ground (D. Y. Arnold 1988, 468–71). Albó (1974, 171–2) reports offerings of animal dung and candles made from animal fat being made during Santa Vera Cruz at a pilgrimage site near Cochabamba; afterwards, the ash is taken home with a little bit of the earth from the pilgrimage site to be scattered in the animal corral. Each of these rituals shows a deep concern with the role of animals in maintaining Andean society and they acknowledge the vital role that the production of animal dung plays in maintaining the household economy and the community's fertility. Within this context it is perhaps less surprising that it is considered a compliment to say that the shining eyes of a lover are like small pieces of fresh moist llama dung (D. Y. Arnold 1988, 322).

ALTERNATIVE FUELS

Although dung appears to be the preferred fuel for most highland potters it is not the only fuel. *Ichhu*, a tough highland grass, is also used to cover many firings and, where large amounts of this grass are used, often in combination with manure from the corral, it has a similar effect to dung of insulating the firing with the layer of matted porous ash that is formed. In one village (Machaca) organic-rich turfs, with similar properties to peat, were dried and used to cover the firing in the same way as cow pats are used in the Pucara area where these potters' parents and grandparents came from over 50 years ago. In fact, these organic-rich turfs have very similar properties to those of dung in that they leave a porous structure which insulates the firing while allowing oxygen to pass through, resulting in well-oxidized vessels. Perhaps even more adaptable are the itinerant potters from the highlands who traditionally take their prepared clay down to the valleys where they make fire and exchange their vessels prior to returning home with valley produce (Sillar 1997). These itinerant potters use several criteria to decide where they will make and fire their pottery (accessibility, social acceptance, a house or shelter where they will be noticed by passers-by, a water supply, the quality and quantity of that year's harvest, etc.), but one of the most important is the availability of suitable fuel. All the itinerant potters I have talked to prefer to use dung, but, if suitable quantities of dung are not available, they can also use dried cactus plants and peat. They will occasionally use some brushwood, but I was told they never fire using only wood. Itinerant potters need to be exceedingly flexible in their choice of fuel because their distance from their home community means that they are neither able to guarantee access to dung through their own household activities nor through secure exchange partners. Potters can deliberately search for alternative fuels, and when they do so it is their perception of appropriate firing technologies that guides their choice and makes them search for materials which have similar properties to dung. Innovation in one aspect of the technology is always chosen through a knowledge and continuation of other aspects of the technological tradition (Sillar 1996).

CHANGE AND CONTINUITY—THE CASE OF CHARAMORAY

The two villages of Charamoray and Urubamba (Province of Chumbivilcas, Department of Cuzco, Peru, altitude 2970 m) are situated on opposite banks of the River Santo Tomas. Pottery making is a major activity in these villages between July and October. Some potters give their pottery two firings, the first using dried leaves and cactus fronds, the second using horse and cow dung in an open firing. I visited this community in September 1987 and accompanied members of a development project directed by Marco Villasante Llerena from the University of Cuzco and the Instituto de Investigacion UNSAAC-NUFFIC, which was working in the area. One of the development project's aims was to improve the local pottery production.

There is a frequently repeated rule of pottery technology that glazed pottery must be fired in a kiln; Charamoray provides at least one exception to this rule (see also Reina and Hill 1978, 89). Because pottery which is surrounded by dung in the firing can still come out 'clean' and well oxidized, the potters in Charamoray are able to produce lead glazed pottery out of an open firing. I assume that this innovation represents the incorporation of Spanish glazing practices into the indigenous firing technology. Locally mined lead is ground into a fine powder and mixed with a little water to form a watery paste that is wiped onto the pots in much the same way as red slip is painted onto pottery in many other communities. Water evaporating from the vessel during the firing could distort the glaze, and cause it to flake off before it melts into the pot's fabric. I presume that the initial firing (Fig. 6 (top)) (which I have not encountered in any other Andean communities) reduces this problem; however, I saw some glazed pots being fired without a first firing. During the open firing (Fig. 6 (middle)) the potter looks at the vessels occasionally to see when the surface of the vessels begins to reflect light, at which point the potter knows that the glaze has melted (this probably takes place at somewhere around 800–900 °C). This firing technology requires one significant variation to other open firings in the Andes because the glazed vessels have to be removed from the firing while still red-hot, presumably to prevent dung ash, as well as small stones embedded in the dung, adhering to the glaze. The pots are removed using a long wooden pole inserted in the mouth of the vessel; this must be done quickly after breaking the insulation of the dung covering as the vessels will cool rapidly and must be separated before they stick together; smaller vessels and plates are just rolled out of the ashes.

While I was in Charamoray the development project was introducing small up-draft kilns made out of adobe blocks (Fig. 6 (bottom)). These kilns used dried leaves of the Maguey (*paqpa*) cactus as fuel. This plant was introduced shortly after the Spanish Conquest and it is commonly

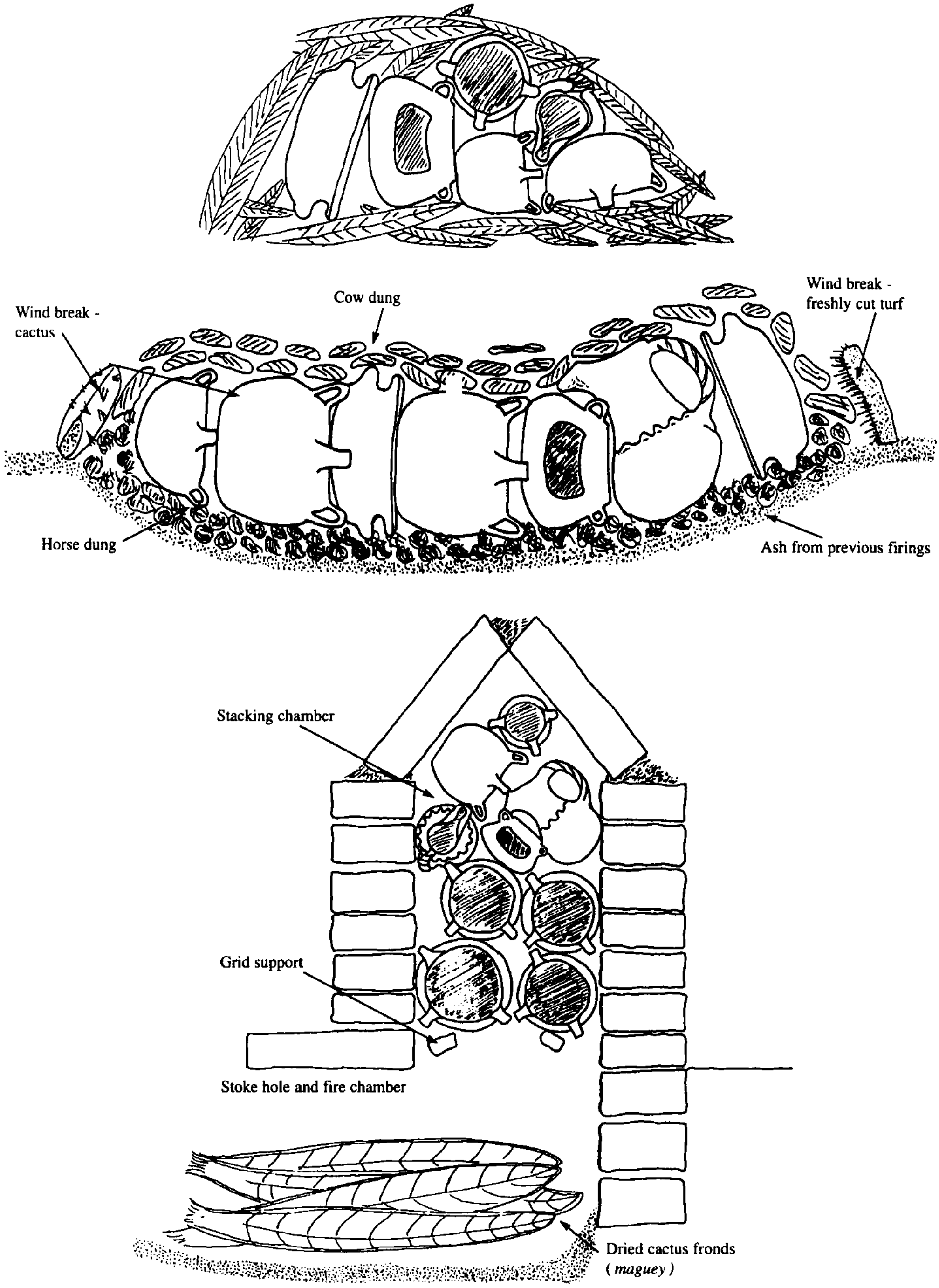

Figure 6 *Charamoray, Department of Cuzco, Peru: cross-sections showing the placement of pots and fuel in the pottery firings,* (top) *first firing prior to glazing, using Maguey cactus fronds as a fuel,* (middle) *traditional firing using animal dung as a fuel,* (bottom) *recently introduced kilns using Maguey cactus fronds as a fuel.*

used as a field boundary marker (Gade 1975, 148). Kiln firings take from an hour to an hour and a half to reach the desired temperature. As the glaze is painted over the entire vessel and no separators are used, these pots must also be removed immediately using the long wooden poles, but using a kiln means less material becomes attached to the glaze during the firing, resulting in a cleaner looking product.

In Charamoray community members reported that for them the major advantage of the kilns was the use of cactus fronds as the main fuel. In this area dung has become a scarce resource due to the practice, and the fear, of cattle rustling, and the use of cactus leaves for kiln firings was seen (at least in the short term) as an advantage. I think that it would be possible to use dung as a fuel for up-draft kiln firings, although most examples I know of where dung is used are 'pit kilns' using what Rye and Evans (1976, 164–6) called the 'mixed firing' method of placing the fuel around the pots (not using a separate fire chamber). During a kiln firing the tendency of dung to form an insulating layer of ash on top of the fuel would become its major disadvantage; this would require the potter to continually rake the fuel to achieve the maximum temperature. Thus, the very property which makes dung an ideal fuel for open firings would, I believe, make it a poor fuel choice for kiln firings. This may be relevant to changes in firing technology in other areas, where alternative fuels help to promote the adoption of a new technology. As Quilici-Pacaud (1993) has argued, the first technological choice which adequately solves a perceived technological problem frequently becomes 'frozen' in the minds of the innovators who perceive it as the only workable solution, reducing their willingness to consider alternative choices. For this reason, one might expect the initial choice of cactus fronds to affect later perceptions/representations of kiln technology in Charamoray and what fuels they considered it appropriate to use in the future.

When firing with a kiln, virtually the same amount of fuel is used for each kiln firing however many pots are inside. In contrast, it is easier to adjust the size of open firings according to the number of pots being fired or the amount of fuel available. In a kiln firing much of this fuel is used to heat up the kiln structure. When firing a large kiln this will be less significant than the insulating properties of the kiln, resulting in less fuel being used per pot. But, for small kilns, such as those introduced to Charamoray (and used by many small-scale pottery manufacturers), the fuel needed to heat up the kiln structure is no less, and frequently more, than what might be consumed in an open firing (e.g., P. J. Arnold III 1991). The few potters in Charamoray who had built and now owned their own kilns required payment (commonly in the form of fuel) if anyone else wished to use their kilns, and many kiln owners made further advantage of this by re-loading their kiln with their own pottery immediately after the previous firing so as to save fuel in reheating the kiln structure. The nature of the wasters had also begun to change with the more obvious firing faults of over-fired or 'slumped' vessels being produced. Some of the potters still using dung firings said they would like to use kilns. What held them back was their fear that pots would fail while they learnt how to use the kilns, and that they were conscious of losing two or so weeks production time to preparing the adobes and building the kiln. Thus, it seemed that it was short-term loss of production rather than long-term fears, or conservatism, that stopped them adopting this new technology. This conscious evaluation of the economic costs and benefits of adopting a new technology is in contrast to Foster's (1965) suggestion that peasants are inherently conservative and fearful of change due to their image of 'limited good' (cf. Papousek 1981). It tended to be the more secure potters (financially better-off, more productive agriculturally, with large families and older children that provided support), and perhaps those most interested in fostering links with the development project, who were prepared to try out the kilns. An interesting by-product of the development project was that kiln users stopped making the flat plates and shallow bowls which they were unable to lift out of the hot kiln with a pole. This prompted one potter in Urubamba, who was still using open firings, to increase his production of bowls and to start selling dung fired *moldes* (shallow bowls used as supports for pottery making) to other potters. These changes were stimulated by the activities of the development project, but each potter was evaluating the costs and benefits of adopting the new technology for themselves. The introduction of this new technology changed the potters' relationship with their fuel supply (indeed the adoption of kilns was partly due to changes in local animal husbandry practices), and it was also leading to changes in the social and economic relationships between the potters with new forms of dependence and new types of specialization emerging.

CONCLUSION: THE ARCHAEOLOGICAL SIGNIFICANCE OF EMBEDDED TECHNOLOGIES

We are all aware of the variety of fuels and firing arrangements that can be used to fire pottery successfully, yet we remain relatively ignorant of the particular characteristics of different fuels and firing arrangements, and the archaeological remains that will be left by them. In order to increase our understanding of fuels for firings we require a large series of analytical experiments comparing the potential calorific values of fuels and their actual performance in various conditions (cf. Woods 1982). But experimentation alone cannot provide an adequate basis for explaining 'technological choices'; our knowledge of material properties must be combined with a careful consideration of the wider technical, social, and economic context of each cultural setting which will have informed the 'technological choices' of firing structures and fuels. Fortunately, archaeobotanists are already working on the identification of different fuels and considering the implications of fuel choice in relation to landscape management. Where animal dung has been used as a fuel there is the possibility of using an analysis of the charred botanical materials inside the dung to identify the environments used by the animals—and at least some aspects of human interaction with them (Anderson and Ertug-Yaras 1998; Hastorf and Wright forthcoming).

In this paper the 'embedded' nature of ceramic technology was considered through a discussion of how various modern Andean potters acquire and use their fuel, and I have tried to show that this choice of fuel has repercussions on other technologies. Some pottery purists may feel that my discussion of animal husbandry, agricultural practices, and rituals has strayed rather a long way from pottery technology. But it is precisely by considering these related activities, which account for the availability of, and competing demands on, dung as a resource, that the technological choices in Andean firing arrangements, and the social and economic policies that account for the maintenance of this technology, can be explained. While an analyst may choose to study Andean pottery production as a particular area of technology, the potter is unavoidably involved in many other interrelated areas of production and consumption. This succession of interrelated technologies is not unique to pottery, it is fundamental to all technologies. This should be acknowledged and highlighted within our archaeological analysis. If we limit the study of the *chaîne opératoire* to the specific series of operations which transform a substance from a raw material into a manufactured product (Cresswell 1976 and 1990), we risk isolating the artefacts we study from the other technical and social aspects in which they were involved. It is by looking at the interconnections between many different *chaînes opératoires* that we will get a more social view of technology as an aspect of material practice which is

deeply embedded within people's cultural knowledge. Such interconnections can be looked for at various levels:
(1) how different technical acts may share the use of the same facilities (e.g., grinding stones are used to process both clay and food produce; sacks are used to carry clay, dung, maize, etc.; the house compound can be used for pottery production, drying, and firing, etc., as well as for sleeping, cooking, crop processing, etc.);
(2) the continuing cycle of technical acts, where the product of one activity becomes the raw material or tool for another (such as the use of dung as a fuel, ash as a fertiliser, or indeed the pots themselves as cookery tools);
(3) how technological understanding cross-cuts between different spheres of activity (Sillar 1996);
(4) how technology is socially defined (e.g., by age, gender, or community of origin) so that only certain people learn and perform particular activities and techniques.

This consideration of the embedded nature of technological choices should help us to avoid our having to make value judgements about the functional versus the symbolic significance of technological choices. Technological choices emerge out of wider cultural practices which account for the availability of materials, tools, energy sources, and technical knowledge, and this cultural setting informs peoples' perception of what is 'efficient' as well as the symbolic meaning of the practices.

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