9 What Contact Did They Have?

Trade and Exchange

The study of exchange and trade in early societies has been one of the growth areas of archaeology in recent years. It was realized that the materials of which artifacts are made can be a far better guide than their style to the place of origin of such artifacts. Whole exchange systems can be reconstructed, or at least the movements of the goods can be investigated, if the materials in question are sufficiently distinctive for their source to be identified. Numerous chemical and other methods now exist for the precise characterization of these materials – that is, the determination of characteristics of specific sources that allow their products to be recognized.

These techniques allow us to tackle the whole question of the production and distribution of traded goods. It is a more ambitious task to try to reconstruct the organization of the trading system as a whole. It is a particularly difficult one if there are no written records to tell us what commodities were traded in exchange for the ones we find in the archaeological record.

Raw materials were not the only items traded, or offered as gifts. Manufactured goods were just as important. Certain prestige goods had symbolic values, with precise meanings that are not always clear to us today, such as the jadeite axes of Neolithic Europe. But some prestige goods were highly significant, and this provides us with another line of investigation to be followed up.

Finds of the actual goods exchanged are the most concrete evidence that the archaeologist can hope to have for determining the contact between different areas, and different societies. But the communication of information, of ideas, may in many ways be more significant. Earlier generations of scholars were too willing to accept similarities between different cultures as a proof of contact, of the flow of ideas, or "diffusion" between the two. Partly in reaction against this tendency, the independent origins of things have been stressed, and the significance of interactions between neighbors somewhat understated. The time is now ripe for a reconsideration of such contacts.

All this relates closely to the social questions discussed in Chapter 5, and no clear separation is possible. Social structure itself may be defined as the pattern of repeated contacts between people, and social organization and exchange are simply different aspects of the same processes.

THE STUDY OF INTERACTION

Exchange is a central concept in archaeology. When referring to material goods, to commodities, it means much the same as trade. But exchange can have a wider meaning, being used by sociologists to describe all interpersonal contacts, so that all social behavior can be viewed as an exchange of goods, non-material as well as material. Exchange in this broader sense includes the exchange of information.

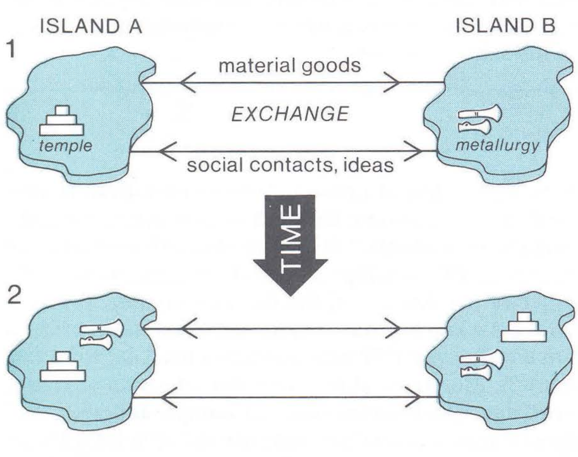
It is necessary, therefore, to consider the exchange transaction in rather more detail. In many exchanges the relationship is more important than what is exchanged. In the Christian tradition, for instance, when presents are exchanged within a family at Christmas, the giving of presents between relatives is generally more important than the actual objects: "it is the thought that counts." There are also different kinds of exchange relationship: some where generosity is the order of the day (as in the family Christmas); others where the aim is profit, and the personal relationship is not emphasized ("Would you buy a used car from this man?"). Moreover, there are different kinds of goods: everyday commodities that are bought and sold, and special goods, valuables, that are suitable for gifts. In all of this we have to consider how exchange works in a non-monetary economy where not only coinage may be lacking, but any medium of exchange.

In the next section we shall consider the ways in which artifacts (traded objects) found by archaeologists can be made to yield information about early trade and exchange. But, first, we must consider further the nature of exchange.

Exchange and Information Flow

Let us imagine two societies, living on islands some tens of miles away from each other. If there was no contact between them they would lie in complete isolation, exploiting their island resources. They may, however, have had boats, and so been in contact with each other. In that case, the archaeologist of the future, in studying the settlements and the artifacts found in them, will recognize on island A objects made from materials that were only available on island B, and will thus be able to document the existence of such contact: there must have been travel between the islands. But what may have been of much more importance to the islanders was the possibility of social contacts, the exchange of ideas, and the possibility of arranging marriage links. These, too, the archaeologist must consider, together with the material goods that were exchanged.

When there is exchange between island A and island B there is a flow of information. Ideas are exchanged, inventions are transmitted, and so are ambitions and aspirations. If the people of island A decide to build a temple of a new kind, those of island B may decide to follow suit. If those of island B develop the techniques of metallurgy, those of island A will not be far behind. There is thus a real equivalence between the



Contact between two islands has the effect that innovations on one (e.g. the building of a temple; metallurgy) may lead to similar developments on the other.

interaction seen as a communications system, and the interaction as a system for the exchange of material goods.

For most of this chapter we shall be dealing with economic aspects of exchange, and with material things. But, at the end, we shall return to this theme of interaction as information exchange: in the long run, it is often more important.

Scale and "World System"

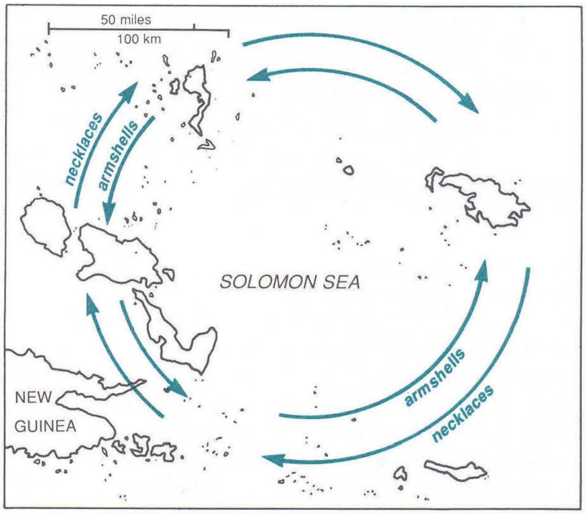
For some purposes it is convenient to distinguish between *internal exchange*, taking place within the specific society we are considering, and *external trade* or *exchange*, where goods are traded over much greater distances, moving from one social unit to another. In using the term "trade," we generally mean external trade – something that takes place with the outside world. But when we consider the interactions within a society, whether involving information or goods, we tend to use the terminology of social organization not of trade. The emphasis in this chapter is on external trade; relations internal to the social unit were dealt with in Chapter 5, where we considered questions of scale and organization of society. But the distinction between the two levels of exchange is not always clear.

Trading systems often have what is almost a life of their own. By definition, they extend widely, over the boundaries of many politically independent societies. But sometimes the different parts of a widespread trading system of this kind can become so dependent on each other commercially that one can no longer think of them as independent entities. This point has been stressed by the American historian Immanuel Wallerstein. He used the term "world system" or "world economy" to designate an economic unit, articulated by trade networks extending far beyond the boundaries of individual political units (e.g. nation states), and linking them together in a larger functioning unit.

Wallerstein's initial example was the relationship that developed between the West Indies and Europe in the 16th century AD, when the economy of the West Indies was indissolubly linked with that of the European parent countries of which they were colonies. (It should be clearly understood that Wallerstein's rather odd term "world system" is not meant to refer to the entire world. He imagines a collection of several world systems, each of which might be conceived as a separate entity: one world system might involve Europe and the West Indies, another China and its Pacific neighbors.)

Wallerstein sees the emergence of the present world system, based on capitalism, as taking place during the Great Transformation of the 16th century AD. But archaeologists and ancient historians have applied the terminology to earlier periods. So that just as Wallerstein speaks of the "core" and the "periphery" of modern world systems, so these historians would like to use this terminology for earlier ages.

In the last section of this chapter we shall see that to adopt this terminology unthinkingly can lead to very dangerous archaeological assumptions. For the moment, it is enough to note that Wallerstein's approach helps us to pose a very important question: What was the scale of the effective functioning economic system in the past? In Chapter 5, we discussed the different approaches that the archaeologist may take to define the scale of the effective social unit. Here, we need to discuss how we can define the scale of the economic system if it is larger than the social system, embracing several politically independent units.



The kula network of Melanesia, in which necklaces were exchanged for armshells and armshells for necklaces in a cycle that cemented relations among the islanders.

Gift Exchange and Reciprocity

One of the most fundamental advances of anthropological theory was the revelation by the French sociologist, Marcel Mauss, of the nature of gift exchange. He saw that in a range of societies, especially in those lacking a monetary economy, the fabric of social relations was bound by a series of gift exchanges. Individual X would establish or reinforce a relationship with individual Y by means of a gift, a valuable object, which would pass from the hands of X to those of Y. This gift was not a payment: it transcended mere monetary considerations. It was a gesture and a bond, imposing obligations on both parties, especially, of course, on the recipient. For acceptance of the gift implied the obligation of repayment by another, equally munificent presentation.

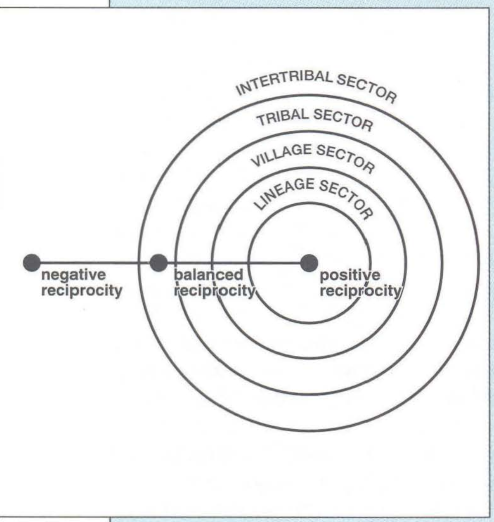
The anthropologist Bronislaw Malinowski, in his celebrated and influential work *Argonauts of the Western Pacific* (1922), described an exchange network, the *kula*, in which a series of exchange relationships between the inhabitants of some islands in Melanesia was cemented by the exchange of valuable gifts of objects, often of shell. The entire overseas contacts of these islanders centered on the ceremonial exchange with their exchange partners within the *kula*, although within this framework other exchanges of more everyday commodities, such as foodstuffs, took place.

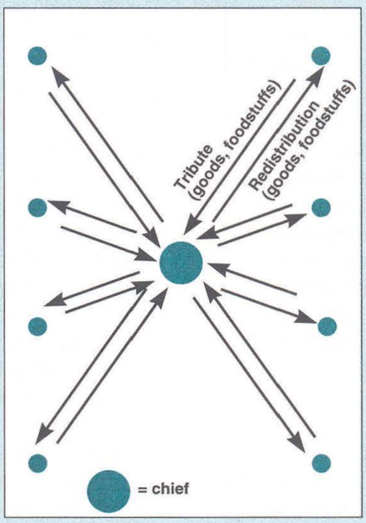
Exchanges such as these, where the transfer of specific objects as gifts is only one part of a relationship with other obligations (including friendship) and with other activities (including feasting), are said to take place within a framework of reciprocity. The donor gains in status through the generosity of the scale of the gift. Gifts are often given with maximum publicity and ostentation. Indeed, in some New Guinea societies the position of "Big Man" is achieved by the munificent giving of gifts (often pigs) to exchange partners, and by the accumulation thereby not only of credit (i.e. the obligation of exchange partners to repay), but also what one may term kudos, the immense prestige that comes from being in the creditor position as donor.

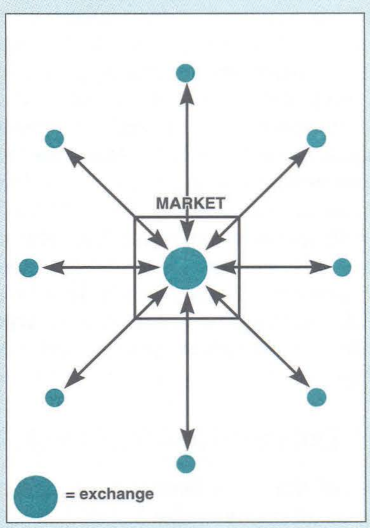
The notion of reciprocal exchange of valuables, derived from anthropological studies, including Malinowski's work on the *kula* exchange cycle of Melanesia, has been very influential in shaping the thinking of many archaeologists about trade. For instance, in Britain during the Neolithic period there was clearly an extensive network of trade in stone axes. The methods by which this exchange has been documented, including the petrographic study of thin sections, are discussed below. The long-distance exchange networks that such characterization studies document led the British archaeologist Grahame Clark to suggest that a system of gift exchange was in operation in the British Neolithic. He likened this to the system of exchanging stone axes that operated in Australia into the present century (see boxes p. 369 and 376).

MODES OF EXCHANGE

Exchange, or trade, implies that goods change hands, and that this is a two-way transaction. The American anthropologist Karl Polanyi established that there are three different types or modes of exchange: reciprocity, redistribution, and market exchange.







Reciprocity refers to exchanges that take place between individuals who are symmetrically placed: that is, they are exchanging more or less as equals. Neither is in a dominant position. In effect, it is the same as gift exchange. One gift does not have to be followed by another at once, but a personal obligation is created that a reciprocal gift will later take place. The American anthropologist Marshall Sahlins has suggested that the generosity or altruism associated with such exchange can be illustrated as positive reciprocity (i.e. generosity) and takes place among close kin. Balanced reciprocity takes place among those well known to each other in a definite social context. And negative reciprocity (i.e. exchange where you try to do better out of it than your exchange partner) operates between strangers or those socially distant from one another.

Redistribution implies the operation of some central organization. Goods are sent to this organizing center, or at least are appropriated by it, and are then redistributed. Sahlins suggested that many chiefdoms in Polynesia operate in this way: the chief redistributes produce, and geographical diversity can thus be overcome. The fisherman receives fruit, and the worker in the plantation gets fish. Such exchange can be much more highly ordered than a series of relatively unstructured reciprocal exchanges between individuals, and it is a feature of more centrally organized societies, such as chiefdoms or states (see Chapter 5). Since it implies the existence of a coherent political organization within which it works, redistribution is a form of internal exchange.

Market exchange implies both a specific central location for exchange transactions to occur (the marketplace) and the sort of social relationship where bargaining can occur. It involves a system of price-making through negotiation. Polanyi argued that this kind of bargaining first became the basis of a true market system in ancient Greece, when coinage based on a well-defined monetary system also made its appearance. But other workers have argued that there were markets also in the ancient Near East, as there certainly were in Mesoamerica and China.

Markets are often internal in the socio-political unit – for example, the rural markets of China, or the Greek marketplace (agora). But they do not have to be. The port-of-trade is a place where traders of different nationalities (i.e. belonging to different political units) can freely meet, and where free bargaining and hence price-fixing can take place.

Another instance, perhaps even more comparable to the Melanesian *kula* system, is the exchange of bracelets and other ornaments made of the marine shell *Spondylus gaederopus*, which is a native of the Mediterranean. Such ornaments were distributed right across the Balkans and into central Europe around 4000 BC, and it is clear that a long-distance trade network was in operation then. Just as in the case of the *kula*, handsome marine shells were one of the most conspicuous features of the exchange. But in this case, the exchange was a land-based one. The archaeologist today sees the shell ornaments of that period as fulfilling the role of valuables. Once again, the extent of the trade has to be established through a careful characterization study (to determine the place of origin) before such explanations in terms of reciprocity between exchange partners can be proposed.

When exchange takes place outside close personal relationships, it takes on a different character: the positive reciprocity of the profit motive (see box). And when the symmetrical one-to-one relationship of gift exchange or direct barter gives way to the trader/buyer relationship of the marketplace or to the demands of the tax collector, a different kind of economic relationship is implied (see box, under redistribution and market exchange).

These ideas have become part of the mental toolkit of the student of early trade. In some cases, they can be extended by reference to early documents, such as the inscribed clay tablets from the Assyrian trading colony at Kültepe in Anatolia, dating from the 18th century BC. Here most of the trade was controlled by private merchants in the Assyrian capital of Assur, while the merchants at Kültepe were acting as agents: that may be regarded as redistribution. But in some cases they do seem to have been trading on their own account, for personal gain.

Ethnographic work offers a rich repertoire of examples of trading systems: the markets of West Africa, and those of pre-industrial China have been studied by anthropologists and geographers and provide valuable insights to the archaeologist as to the ways in which exchange can take place.

Valuables and Commodities

In gift exchanges, as observed by anthropologists, the high-prestige gifts that are the focus of attention in any ceremonial exchange are of a special kind. They are valuables, and they are to be distinguished from the commonplace commodities – such as foodstuffs and pots – that may well be exchanged through a more mundane system of barter at the same time.

There are two important concepts here. The first is what the American anthropologist George Dalton has termed ***primitive valuables***: the tokens of wealth and prestige, often of specially valued materials (see box overleaf), used in the ceremonial exchanges of non-state societies. Examples include the shell necklaces and bracelets of the *kula* system, and pigs and pearl-shells, and, on the Northwest Coast of America in pre-European times, slaves and fur robes.

Exotic animals were often thought appropriate for royal gifts. Thus, the Near Eastern potentate Haroun al-Rashid presented Charlemagne, the 8th- to 9th-century AD ruler of much of north-central Europe, with an elephant, while a 13th-century Icelandic tale tells how the Icelander Authin presented the King of Denmark with a polar bear from Greenland. Traces of such gifts are sometimes recoverable – for example, the remains of falcons from Greenland have been found on several medieval sites in western Europe.

It should be noted, as Dalton remarks (1977), that "to acquire and disburse valuables in political or social transactions was usually the exclusive prerogative of leaders; or else the valuables were permissibly acquired by leaders in greater quantity or in superior quality than permissibly acquired by small men."

The second important concept is that of the ***sphere of exchange:*** valuables and ordinary commodities were exchanged quite separately. Valuables were exchanged against valuables in the prestige transactions already noted. Commodities were exchanged against commodities, with much less fuss, in mutually profitable barter transactions.

George Dalton has pointed out that ceremonial exchanges in non-state societies were of two different sorts. The first were ceremonial exchanges to establish and reinforce alliances, such as the *kula* system. The second were competitive exchanges, used to settle rivalries, in which the path to success was to outshine rivals in the richness of one's gifts and the conspicuous nature of public consumption. The potlatch, the ceremonial of the Northwest American Indians, was of this kind. These exchanges involved not only the making of conspicuous gifts of valuables, but also sometimes the actual destruction of valuables in a display of conspicuous wealth.

It is only through an awareness of the social roles that material goods can have, and of the way material exchange can either mask or represent a whole range of social relationships, that we can understand the significance of the exchange of goods. The study of early exchange thus offers many insights not only into the commerce, but also into the structure of early societies.

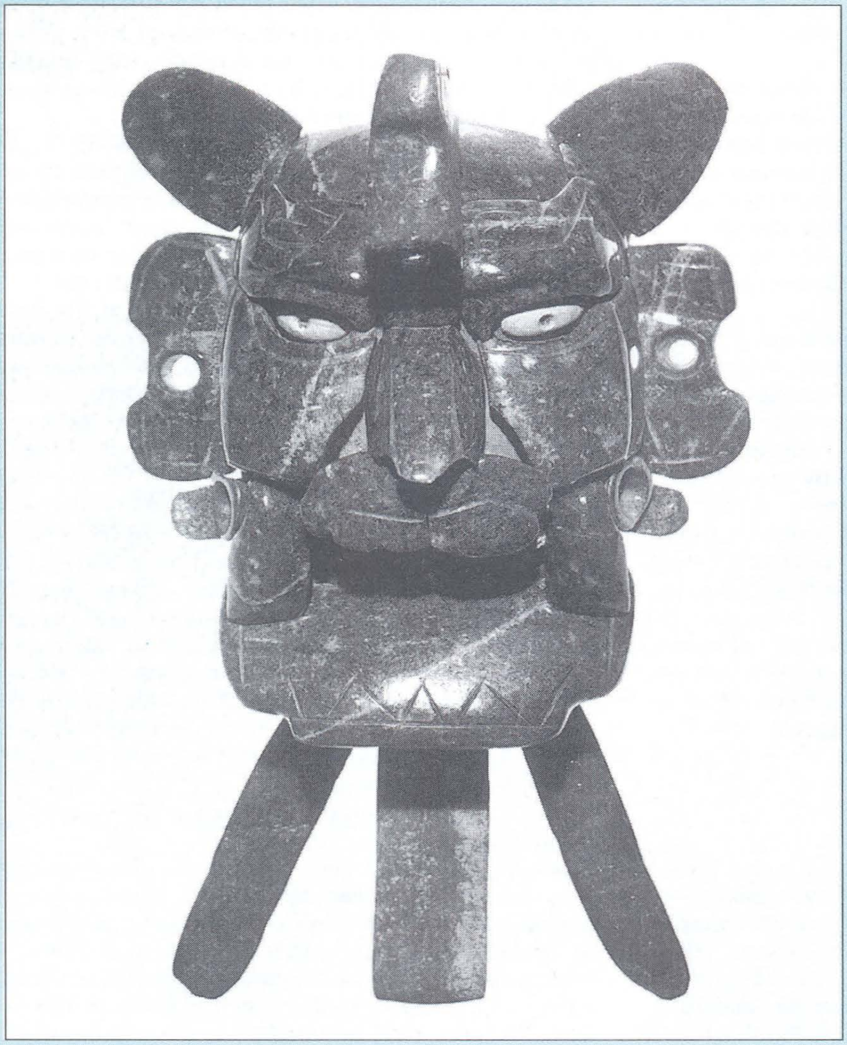
MATERIALS OF PRESTIGE VALUE

Nearly all cultures have valuables. Although some of these are useful (e.g. pigs in Melanesia, which can be eaten) most of them have no use at all, other than display. They are simply prestige objects.

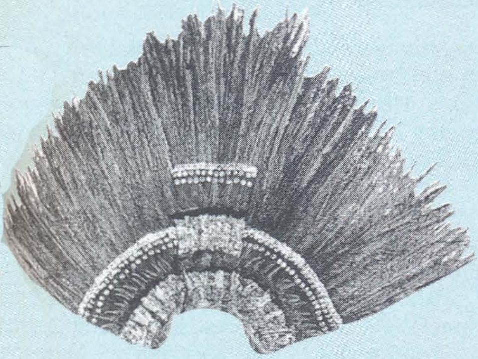
Valuables tend to be in a limited range of materials to which a particular society ascribes a high value. For instance, in our own society gold is so highly valued as to be a standard against which all other values are measured. We tend to forget that this valuation is an entirely arbitrary one, and we speak of gold's *intrinsic* value, as if in some way it were inherent. But gold is not a very useful material (although it is bright, and does not tarnish), nor is it the product of any special skills of the craftsperson. Intrinsic value is a misnomer: the Aztecs valued feathers more highly, unlike the Conquistadors who craved gold; both were following subjective systems of value.

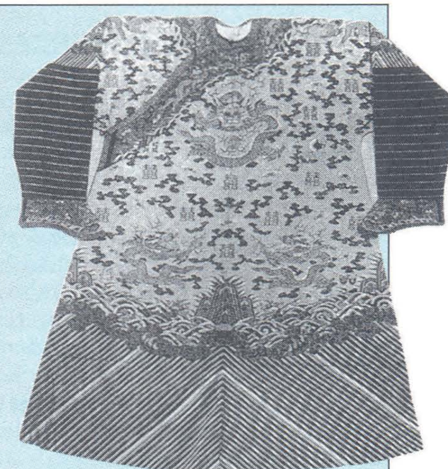
When we survey the range of materials to which different societies have ascribed intrinsic value we can see that many of them had the qualities of rarity, of durability, and of being visually conspicuous:

- The bright **feathers** favored by the Aztecs and by tribes of New Guinea fulfill two of these qualities.
- **Ivory:** elephant and walrus tusks have been valued since Upper Paleolithic times.
- **Shell**, especially of large marine molluscs, has been highly prized in many cultures for millennia.
- That very special organic material **amber** was valued in Upper Paleolithic times in northern Europe.
- **Jade** is a favored material in many cultures, from China to Mesoamerica, and was valued as long ago as 4000 BC in Neolithic Europe.
- Other naturally hard and **colorful stones** (e.g. rock crystal, lapis lazuli, obsidian, quartz, and onyx) have always been valued.
- **Gemstones** have taken on a special value in recent centuries, when the technique of cutting them to a faceted, light-catching shape was developed.
- **Gold** has perhaps pride of place (certainly in European eyes) among "intrinsically" valuable commodities, followed by **silver**.
- **Copper** and other metals have taken a comparable role: in North America copper objects had a special value.
- With the development of pyrotechnology (Chapter 8) artificial materials such as **faience** (glazed terracotta) and **glass** came into full prominence.
- The finest **textiles** and other clothing materials (e.g. *tapa* in Polynesia) have also always been highly valued, for prestige often means personal display.



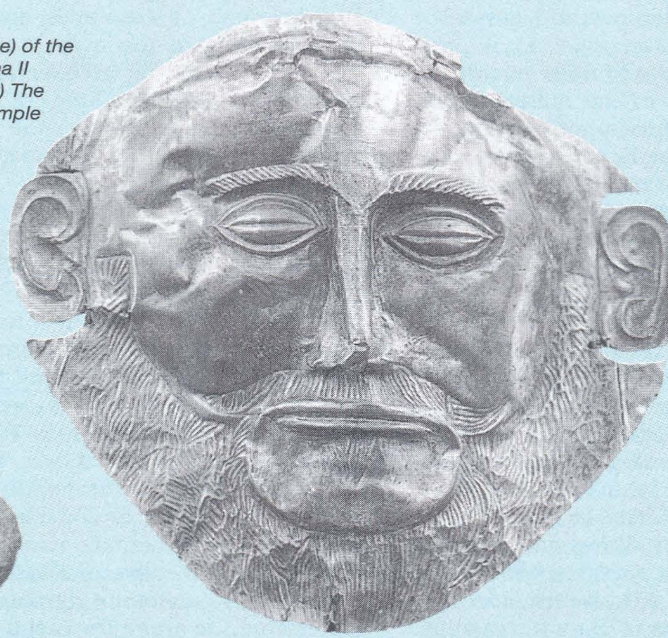
***Zapotec mask** from Monte Albãn, Mexico, made of jade, the eyes of shell.*

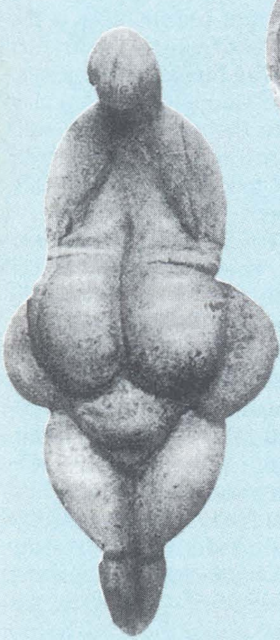




Feathered headdress *(above) of the Aztec emperor Motecuhzoma II (Moctezuma). (Above center) The Portland vase, a superb example of 1st-century* AD *Roman glassworking.*

Woven silk *robe (above) from the reign of the Chinese emperor Yung Cheng (1723–35), bearing the Imperial dragon.*





Upper Paleolithic *ivory female figurine (cast) from Lespugue, France (ht. 14.7 cm) (above). (Above center) Gold mask thought by Schliemann to represent King Agamemnon, from a shaft grave at Mycenae, late 16th century* BC.

Prestige objects *of North America's Mississippian culture (c.* AD *900–1450). (Above) Embossed copper face, with typical forked eye motif. (Left) Shell pendant (c. 14 cm) from Texas, showing a panther and bird of prey.*

DISCOVERING THE SOURCES OF TRADED GOODS: CHARACTERIZATION

Artifact forms can be imitated, or can resemble each other by chance. So it is not always safe to recognize an import in an archaeological context just because it resembles objects that are known to have been made elsewhere. Much more reliable evidence for trade can be provided if the raw material of which the object is made can be reliably shown to have originated elsewhere. Characterization refers to those techniques of examination by which characteristic properties of the constituent material may be identified, and so allow the source of that material to be determined. Some of the main methods for sourcing of materials by characterization (e.g. petrographic thin section) are described below.

For characterization to work, there must obviously be something about the source of the material that distinguishes its products from those of other sources. Of course, sometimes a material is so unusual and distinctive in itself that it can at once be recognized as deriving from a given source. That used to be thought to be the case with the attractive blue stone called lapis lazuli, for which, in the Old World, only one major source in Afghanistan was known. Now, however, other sources of lapis lazuli in the Indian subcontinent are known, so such claims must be treated with care.

In practice, there are very few materials for which the different sources can be distinguished by eye. Usually, it is necessary to use petrological, physical, or chemical techniques of analysis, which allow a much more precise description of the material. During the past 40 years there have been striking advances in the ability to analyze very small samples with accuracy. A successful characterization, however, does not just depend on analytical precision. The nature of the various sources for the material in question must also be considered carefully. If the sources are very different from each other in terms of the aspects being analyzed, that is fine. But if they are very similar, and so cannot be distinguished, then there is a real problem. For some materials (e.g. obsidian), the sources can be distinguished quite easily; for others (e.g. flint, or some metals), there are real difficulties in detecting consistent differences between sources.

Some materials are not well suited to characterization, because samples from different areas are difficult to distinguish. For example, organic remains, whether of plants or of animals, can present a problem. Of course, if a species is found far from its natural habitat – for instance, shells from the Red Sea in prehistoric Europe – then we have evidence for trade. But when the species has a widespread distribution, there can be genuine difficulties. However, as we shall see below, even here there may be techniques available, such as oxygen or strontium isotope analysis, to resolve the matter.

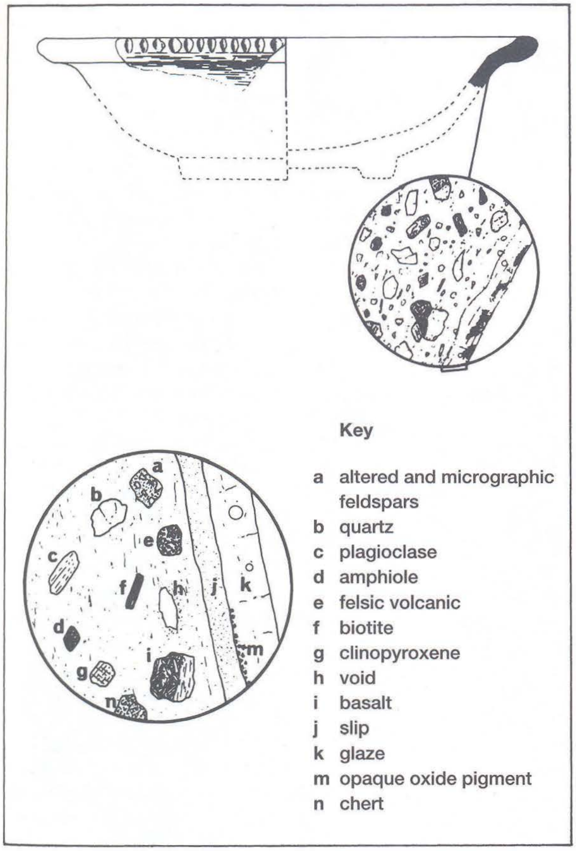
An important point to note is that the sourcing of materials by characterization studies depends crucially on our knowledge of the distribution of the raw materials in nature. This derives mainly from the fieldwork of such specialists as geologists. For example, one might have a good series of thin sections cut from a whole range of stone axes, and many of these might be distinctive in the eyes of a petrologist. But this would not help the archaeologist unless one could match those particular kinds of rock with their specific occurrences in nature (i.e. the quarries). Thus, good geological mapping is a necessary basis for a sound sourcing study.

There are two further important points. One is the extent to which the raw material of which the artifact is made may have changed during burial: for instance, some soluble and therefore mobile elements in a clay pot may have leached out into the surrounding soil; or indeed they may leach from the soil into the pot; fortunately this problem is not too severe as it mainly affects poorly fired coarse wares.

A more crucial factor is the extent to which the raw material was changed during the production of the artifact. For objects of stone, this is not a problem. For pottery, one needs to consider the effect of refining the clay, and of adding various possible tempering materials. For metals, however, the problem is serious because there are many significant changes in composition from the ore to the metal artifact. During smelting (Chapter 8), a proportion of the more volatile impurities (e.g. arsenic or bismuth) will be lost. And in the Old World, from the later part of the Bronze Age onward, there is the problem of the reuse of scrap copper and bronze that could have come from more than one source.

Analytical Methods

Visual Examination. Just looking at the material is often the best way to start, whether we are dealing with pottery or a stone object. But while appearance makes an excellent starting-point – it always pays to make a preliminary separation by appearance – it can never be a reliable or authoritative guide.



Examination of pottery thin section under the microscope: inclusions in the fabric have been used to characterize medieval ceramics from the Yemen, such as this example.

Microscopic Examination of Thin Section. Since the middle of the 19th century techniques have existed for cutting a ***thin section*** of a sample taken from a stone object or a potsherd to determine the source of the material. It is made thin enough to transmit light and then, by means of petrological examination (studying the rock or mineral structure) with a light microscope, it is usually possible to recognize specific minerals that may be characteristic of a specific source. This part of the work has to be done by someone with petrological training.

This method has been applied to ***stone*** objects in different parts of the world – to building stones (e.g. the special colored stones used by the ancient Greeks and Romans), monuments (e.g. Olmec heads, Stonehenge), and portable artifacts, such as stone axes (e.g. in Australia, New Guinea, and in Britain). Indeed, the elucidation of the trade in stone axes in Neolithic times in Britain, which started before 3000 BC, is one of the success stories of characterization studies. It is further discussed in the section on the study of distribution below (box p. 369).

Difficulties are encountered when the stones are insufficiently distinctive: for instance, different kinds of flint are usually difficult to characterize by thin section, and the white marble used for building or statues is so pure and homogeneous that it also does not give good results with this method (see also p. 366).

With ***pottery***, the clay itself may be distinctive, but more often it is the inclusions – particles of minerals or rock fragments – that are characteristic. Sometimes the inclusions are naturally present in the clay. In other cases, the inclusions are deliberately added as temper to improve drying and firing qualities, and this can complicate characterization studies, since the pottery fabric may then consist of material from two or more separate sources. Fossil constituents, such as diatoms (Chapter 6) can also be an aid to identification of the source of the raw materials.

Studies of ***grain sizes*** in the clay itself have also proved useful. In much pottery, the only inclusions present are common minerals such as quartz sand, flint, and calcite/limestone/shell and these are of little help in identifying the sources. In such circumstances, study of the grain size of the quartz, etc. (but not the clay) has also proved useful. ***Heavy mineral analysis*** is a closely related petrological technique. For this, the body of the pottery sample is broken down using a chemical reagent, and the heavy mineral component (materials such as zircon and tourmaline) is separated from the lighter clay in a centrifuge. These constituent minerals can then be identified under the microscope. Those characteristic of a particular source area may help to identify the place of origin of the clay.

The picture of the prehistoric trade in pottery in Britain that such analyses have documented is quite surprising. Until the thin-section work of David Peacock and his associates it was simply not realized that pottery bowls and other vessels might be traded over quite long distances (of the order of 100 km (62 miles)) in Neolithic times, before 3000 BC. Now that we know the extent of this exchange of pottery, and that of stone axes discussed above, it is clear that many individuals and settlements were linked by quite far-flung exchange systems.

These characterization studies reveal clear evidence of widespread distribution of materials from their geological sources, but the interpretation of this evidence in human terms demands special techniques of spatial analysis and often the use of models based on ethnographic (or ethnoarchaeological) research.

ANALYSIS OF ARTIFACT COMPOSITION

A range of scientific techniques can be used in artifact characterization studies, but they differ in their possibilities, cost, and sample requirements. None of the methods listed below is universal. The archaeologist must carefully match objectives and requirements against the cost and potential of the different techniques. All accurate quantitative analytical methods require the use of standards, that is, specimens of known chemical composition. Some of the methods listed below can detect simultaneously most elements present in the sample and therefore give its qualitative or semi-quantitative composition without the necessity of standardization (XRF and NAA for example, though for quantitative results standards are needed); others (like AAS) need separate tests for each required element.

Modern analytical techniques use the physical properties of atoms for identification and quantification. The methods discussed are listed in groups relying on the same physical principles, but varying in the methods of excitation of the atom, or the detection of the information (energy or wavelength) obtained as a result of excitation.

Optical emission spectrometry (OES) is based on the principle that the outer electrons of the atoms of every chemical element, when excited (e.g. by heating to a high temperature), emit light of a particular wavelength (and hence color) when a sample is burned in a carbon arc. The light given off is composed of different wavelengths, which can be separated into a spectrum when passed through a prism or diffraction grating. The presence or absence of the various elements can be established by looking for the appropriate spectral line of their characteristic wavelengths. The results, expressed as percentages for the commoner elements and in parts per million (ppm) for trace elements, are read off and expressed in tabular form. Generally the method gives an accuracy of only about 25 percent. OES has been more-or-less superseded by **inductively coupled plasma atomic emission spectrometry (ICP-AES)**. This follows the same basic principles, but the sample in solution is atomized and excited in a stream of argon plasma rather than in a carbon arc. Very high temperatures can be reached, which reduces problems of interference between elements. It is suitable for analysis of major and trace elements in most inorganic materials. The sample size needed for elemental analysis is about 10 mg and accuracy is about ±5 percent. ICP-AES is not excessively expensive and a very high rate of sampling can be achieved.

More expensive, but also much more sensitive (many elements can be detected in concentrations in the parts per billion range) is another version of this method – **inductively coupled plasma mass spectrometry (ICP-MS)**. In ICP-MS the sample in solution is again atomized and ionized in a stream of argon plasma, but then the ions are injected into a mass spectrometer where they are divided into their isotopes which can be detected separately and counted, giving the concentration of the elements present.

Atomic absorption spectrometry (AAS) is based on a principle similar to OES – the measurement of energy in the form of visible light. The sample to be analyzed (between 10 mg and 1 g) is dissolved in acid, diluted, and then heated by spraying it onto a flame. Light of a wavelength which is absorbed by the element of interest – and only that element – is directed through the solution. The intensity of the emergent light beam, after it has passed through the solution, is measured with a photomultiplier. The concentration of the particular element is related to the intensity of the beam.

By using different wavelengths of light over 40 elements can be measured, with an accuracy of ±1 percent for major elements and ±15 percent for trace elements. The method has the disadvantage of being slow and it is also destructive. It does, however, have a particular advantage over other methods in detecting metals such as lithium and sodium which have low atomic numbers. AAS has been used archaeologically for analysis of non-ferrous metals (e.g. copper and bronze), flint artifacts, and other materials.

X-ray fluorescence analysis (XRF) is based on the excitation of the inner electrons of the atom. The sample is irradiated with a beam of X-rays which excite electrons in the inner shells (K, L, and M) of all atoms present in the surface layer of a sample. The X-rays bombarding the sample cause the electrons to move up to a higher shell. They instantly revert, however, to their initial positions, and in the process emit specific amounts of energy equal to the difference in energy between the appropriate inner electron shells of the atoms of each element present in the sample (they are called characteristic X-rays). These fluorescent X-ray energies can be measured and their values compared with figures known for each element. In this way the elements present in the sample can be identified. The energy of electromagnetic radiation is directly related to its wavelength. There are two methods of measuring the energy of the characteristic X-rays: the wavelength dispersive XRF method and the energy dispersive XRF method (sometimes also called non-dispersive). The first technique (WD XRF) relies on a measurement of the wavelengths of the X-rays by diffracting them in a crystal of known parameters; the second (ED XRF) relies on the direct measurement of X-ray energy using a semi-conductor detector. In both methods the intensity of the radiation is also measured and can be used to quantify the amount of an element in the sample by comparing the unknown sample with standards.

The measurement geometry of the WD XRF instruments usually requires that the sample is in the form of a pressed powder or glass pellet, and so for many archaeological artifacts this method is not suitable. In contrast, the ED XRF instruments can be constructed in such a way that it is possible to analyze a small area (as small as 1 mm in diameter) on the surface of an object of any size and shape. Also, it is possible to make quantitative and qualitative analyses of small samples taken either from the surface or the interior of the artifact. The effective depth of the XRF analysis is in the range of a millimeter for light materials like glass and pottery, but decreases dramatically for metals. For the analysis of metal artifacts it is advisable either to clean the surface or to take a drilled sample of the unaltered metal from the interior. Detection and measurement of elements present in concentrations below 0.1 percent can be problematic. The accuracy of this technique depends on many factors: it can be as good as 2 percent, but 5–10 percent is more usual. ED XRF is ideal for identifying types of alloys and major components of the fabric of pottery, faience, glass, and glazes, as well as pigments used to color them. There is no need for specific sample preparation for ED XRF (except surface cleaning) and the analysis takes only a few minutes.

Electron probe microanalysis (or **scanning electron microprobe analysis – SEM**) is based on the same physical principle as XRF, but the excitation of the electrons in the atoms is achieved by focusing an energetic beam of electrons from an "electron gun" on to the surface of the sample in a vacuum. The samples for quantitative SEM have to be specially prepared either as thin polished sections or as perfectly flat, carbon- or gold-coated, mounted specimens. The beam can be focused to a spot of a size below 1000th of a millimeter and different layers of a sample (e.g. glaze, underglaze, fabric of a pot) can be analyzed separately, or the chemical composition of inclusions in the material can be identified one by one. Scanning electron microscopes are present in many archaeological laboratories and this method has been in the last decade a basic tool for the study of metal and ceramic technology.

Proton-induced X-ray emission (PIXE) is a further method based on the emission of characteristic X-rays. PIXE relies on their excitation using a beam of protons from a particle accelerator. The range of analytical possibilities is similar to that of SEM, but PIXE is much better for analyses of very small areas of light materials like layers of pigments, or paper and the soldering of alloys in making jewelry. This method is very good at producing "maps" of elemental concentrations in the samples on the sub-micron scale. PIXE belongs to a group of methods known as **ion beam analysis** (IBA). The same facility (based on an accelerator producing a high energy beam of protons) can be used for analysis based on **particle induced gamma-ray emission (PIGME** or **PIGE)** and **Rutherford backscattering (RBS).** PIGE relies on excitation of the nucleus rather than the electrons in atomic shells, and on measuring gamma-rays emitted as the nuclei return to their ground-state (unexcited) levels. PIGE is used mostly for the analysis of light elements (below sodium) and employed together with PIXE can provide analysis over the entire periodic table. The facility at the Lucas Heights, Australia, was used for analysis of obsidian artifacts adopting this approach. RBS is based on the recoil of particles in the beam from the nuclei of the atoms in the sample and can be used for major element characterization of the composition of the material (including carbon, oxygen, and nitrogen) and measurement of thickness of layers and diffusion profiles without the necessity of preparing cross-sectional profiles.

There are some laboratories in Europe and North America where PIXE is routinely used for analyses in art and archaeology, notably the facility AGLAE in the Louvre, Paris. The IBA facility in Oxford has been used for projects using simultaneous PIXE/ PIGME/RBS for the non-destructive analysis of, for example, gemstones (the Ashmolean "Alexander gem"), gilded metal artifacts, and glazed ceramics.

Neutron activation analysis (NAA) – depends on the transmutation of the nuclei of the atoms of a sample's various elements by bombarding them with slow (thermal) neutrons. This process leads to the production of radioactive isotopes of most of the elements present in the sample. The radioactive isotopes, which have characteristic half-lives, decay into stable ones by emitting radiation, often gamma radiation. The energies of these gamma rays are characteristic of the radioactive isotopes, and are measured to identify the elements present. The intensity of radiation of a given energy can be compared with that emitted by a standard which was irradiated together with the sample; hence the quantity of the element in the sample can be calculated. Nuclear reactors are the most efficient source of thermal neutrons, but to some extent other sources of neutrons can also be used for NAA. It is usual to analyze samples of 10–50 mg in the form of powder or drillings, but in the past whole artifacts (mostly coins) were irradiated to provide information about total composition. Unfortunately, all samples and artifacts remain radioactive for many years. Some elements, such as lead and bismuth, cannot be analyzed by NAA, because the isotopes produced by their interaction with thermal neutrons are too long- or short-lived or do not emit detectable gamma rays.

Until recently NAA was the most frequently used method of analysis for trace elements in pottery and metal. It is accurate to about ±5 percent, it can measure concentrations ranging from 0.1ppm to 100 percent, and it can be automated. Because it involves the use of a nuclear reactor it can be used only in certain laboratories, which are becoming rarer as research reactors are being closed down.

Trace-Element Analysis. The basic composition of many materials is very consistent. Obsidian, a volcanic glass used in the manufacture of chipped stone tools in the same manner as flint, is a good example of this. The concentration of the main elements of which obsidian is formed (silicon, oxygen, calcium, etc.) is broadly similar whatever the source of the material. However, the ***trace elements*** (elements present only in very small quantities, measured in just a few parts per million) do vary according to the source, and there are several useful methods for measuring their concentration.

Optical emission spectrometry, or OES (see box, previous pages), was the first of such methods to be applied to archaeological material. The Austrian archaeologist R. Pittioni and his scientific collaborators used it in the late 1930s in pioneering studies on early metallurgy in the Alpine region. In the 1950s and 1960s, it was used in further studies on early European metallurgy, in the study of faience beads in early Europe, and for the characterization of obsidian. It has now largely been replaced by inductively coupled plasma emission spectrometry (ICPS), as well as by atomic absorption spectrometry (see below).

Neutron activation analysis, or NAA (see box, previous pages), was developed later and came into widespread use in the 1970s. It has been widely used for obsidian, pottery, metals, and other materials. It is particularly useful for coins and other small objects, because it is entirely non-destructive.

Other methods for trace-element analysis include ***atomic absorption spectrometry*** (AAS), ***X-ray fluorescence spectrometry*** (XRF), and ***PIXE*** and ***PIGME*** (see box, previous pages). The PIXE and PIGME method has recently been automated, and applied to obsidian from the Admiralty Islands in the Pacific, indicating a trade from the Bismarck Archipelago to Vanuatu (for-

Archaeological Material	*Means of Characterization*	*Analytical Techniques*
Pottery	Major and trace elemental composition, mineral inclusions distribution patterns	SEM, NAA, AAS, XRF, ICPS/MS, thin section petrology, PIXE&PIGME&RBS
Homogeneous/glassy stone (inc. obsidian and flint)	Major and trace elemental strontium isotope composition	SEM, NAA, AAS, XRF, ICPS/MS, PIXE&PIGME&RBS, TIMS
Gemstones	Major and trace elemental composition, distribution pattern of elements	SEM, NAA, AAS, XRF, ICPS/MS, PIXE&PIGME&RBS
Stone with mineral and biological inclusions	Identification and characterization of inclusions, major and trace elemental composition	Optical microscopy, thin section petrology, SEM, NAA, AAS, XRF, ICPS/MS, PIXE&PIGME&RBS
Marble	Major and trace elemental, oxygen, carbon, and strontium isotope composition	ICPS/MS, NAA, PIXE&PIGME&RBS, Gas MS, TIMS
Marine shell	Oxygen, carbon, and strontium isotope, trace elemental composition	Gas MS, PIXE, NAA, ICP MS, TIMS
Amber	Identification and quantification of organic compounds	Infrared absorption spectroscopy, gas chromatography (GC/MS)
All metals and alloys	Major and trace element, lead isotope composition	SEM, NAA, AAS, XRF, ICPS/MS, PIXE&RBS, TIMS, ICP-MMS
Metal slags	Identification of inclusions, major and trace elements, lead isotope composition	SEM, NAA, AAS, XRF, ICPS/MS, PIXE&RBS, TIMS, ICP-MMS
Ore minerals and pigments	Identification of minerals, major and trace element, lead isotope composition	X-ray diffraction, SEM, NAA, AAS, XRF, ICPS/MS, PIXE&RBS, TIMS, ICP-MMS
Glasses and glazes	Major and trace element, lead (if present) isotope composition	SEM, NAA, AAS, XRF, ICPS/MS, PIXE&RBS, TIMS, ICP-MMS
Pottery decoration	Identification of minerals and technology	X-ray diffraction, Mössbauer spectroscopy, XRF, PIXE&PIGME&RBS

Table summarizing the most appropriate characterization methods for various archaeological materials.

merly the New Hebrides), a distance of 3000 km (1860 miles), over 3000 years ago. Similarly the XRF method has recently demonstrated that finds of Rouletted Ware (first identified at Arikamedu in India by Sir Mortimer Wheeler) from the Indonesian island of Bali share the same geological source as examples found in Sri Lanka and southern India, suggesting the presence of substantial trade networks linking the two areas by the 1st century AD.

These various methods simply produce a table giving the analyses, usually expressed in parts per million (ppm), for each artifact or sample, taking each element in turn. Some of the chemical elements are well-known ones, such as lead or tin, others are less common, such as vanadium or scandium. The problem then arises as to how to interpret them. Obviously, the aim is to match the compositions of the artifacts under examination with those of specific sources. But that can present problems. In the case of pottery, potters' clays are common, so there is little chance of matching specific pots with specific clay beds. Different sources can have similar compositions, thus giving misleading results. For this reason, the trace-element analysis of pottery, or indeed of metal, is not necessarily the best procedure for characterization. In the case of pottery, petrological methods (see above) can be more satisfactory. However, trace-element analysis is more effective than petrology for distinguishing between clay sources near, and therefore similar petrologically, to one another, provided that as many trace elements as possible are considered. (Certainly, if sources are different petrologically it would be most unusual for them to be similar in terms of trace-element analysis.)

In general, rather than considering each sample in turn, with all its constituent elements, it is more satisfactory to group samples according to the concentration of just two or three elements in them. When samples are available from the sources, and the number of sources is limited (as with obsidian), clear results can emerge.

The trace-element analysis of obsidian from sources in Anatolia during the Neolithic period, undertaken by a British team, is a good example. It is described in more detail in the section on the Study of Distribution below. Several methods were employed including NAA, XRF, OES, and fission-track analysis. The results allowed the grouping of samples from the various sources and of artifacts from different excavations.

For any chemical analysis, it is essential to have an interpretive strategy, and to understand the logic underlying the arguments. One of the least successful characterization projects of recent years involved the analysis (by OES) of thousands of copper and bronze objects from the Early Bronze Age of Europe. These were classed into groups on the basis of their composition, without recognizing clearly that very different source areas might produce copper with similar trace-element composition and, furthermore, that changes in the concentration of trace elements had occurred during smelting. From the standpoint of sourcing, the groups were more or less meaningless. The isotopic methods described below have proved much more effective for metal characterization.

Isotopic Analysis. All chemical elements consist of atoms specific for a given element. The mass of an atom is defined by the number of protons and neutrons in the

Element	*Isotopes*	*Archaeological Materials*	*Information*
O – oxygen	^{16}O, ^{17}O, ^{18}O	Bone Marble, shells	Diet Provenience
N – nitrogen	^{14}N, ^{15}N	Bone Ivory	Diet Provenience
C – carbon	^{12}C, ^{13}C	Bone Marble, shells	Diet Provenience
	^{14}C – radioactive	Wood, plants, seeds, charcoal, bone, teeth, shells (pottery, linen fabric)	Dating
Sr – strontium	^{88}Sr, ^{86}Sr, ^{84}Sr ^{87}Sr – radiogenic	Stone (gypsum, marble, obsidian) Bone (ivory)	Provenience
Pb – lead	^{208}Pb, ^{207}Pb, ^{206}Pb – all three radiogenic ^{204}Pb	Ore minerals, pigments in glass, glaze and lead-based paint, metals (silver, copper, lead, and iron)	Provenience
Nd – neodymium	^{142}Nd, ^{143}Nd, ^{144}Nd, ^{145}Nd, ^{146}Nd, ^{148}Nd, ^{150}Nd ^{143}Nd – radiogenic	Rocks, minerals, pottery?, ivory?, marble?	Provenience
U – uranium	^{238}U, ^{235}U, ^{234}U	Calcite materials (speleothems), bone, corals, foraminifera	Dating
Th – thorium	^{232}Th, ^{230}Th	Calcite materials, bone, corals, foraminifera	Dating

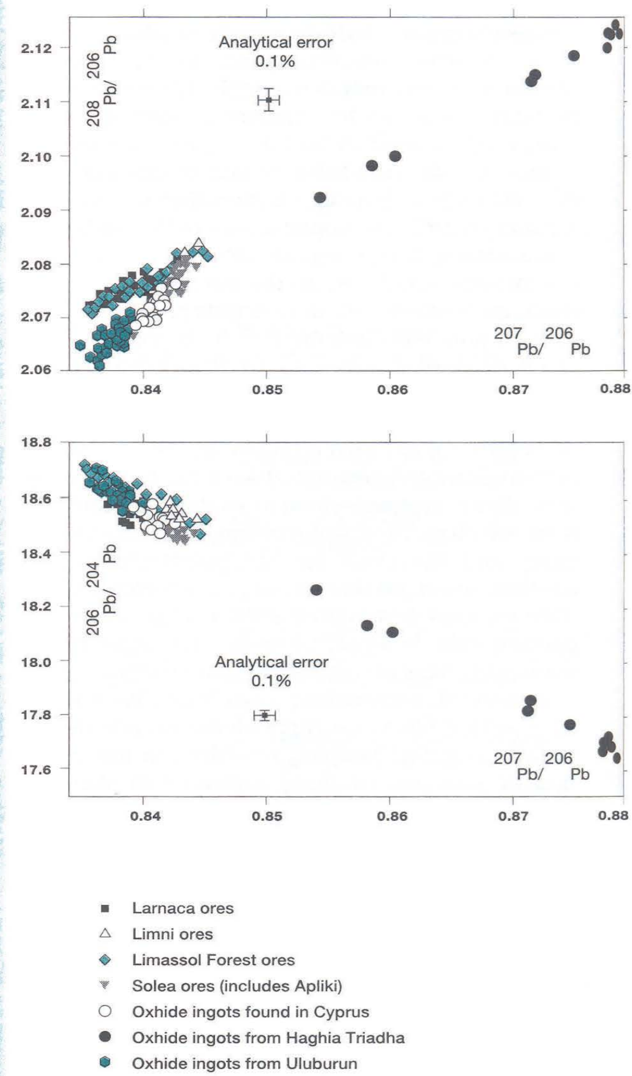
Table of isotopes of various elements that are useful in archaeological research.

nucleus. The chemical identity of an element depends on the number of protons in the nucleus, but the number of neutrons can vary. Atoms of the same element, but of different masses (different number of neutrons in the nucleus) are called isotopes. Most elements occurring in nature consist of a number of isotopes. For the great majority of elements the relative proportion of their isotopes (the isotopic composition) is fixed. However, there is a group of elements which due to chemical or biochemical processes are of variable natural isotopic composition (nitrogen, sulphur, oxygen, and carbon). Another group is formed by elements which contain stable (that is non-radioactive) but radiogenic isotopes, formed in part due to radioactive decay of another element (lead, neodymium, and strontium). All isotopic compositions are measured by mass spectrometry. (See table, p. 363, and Chapter 4 for isotopes of carbon, and also some other elements.) The isotopic composition of light elements listed in the first four rows of the table p. 363 can be measured using Gas Source Mass Spectrometers (a ^{14}C accelerator is also a kind of mass spectrometer).

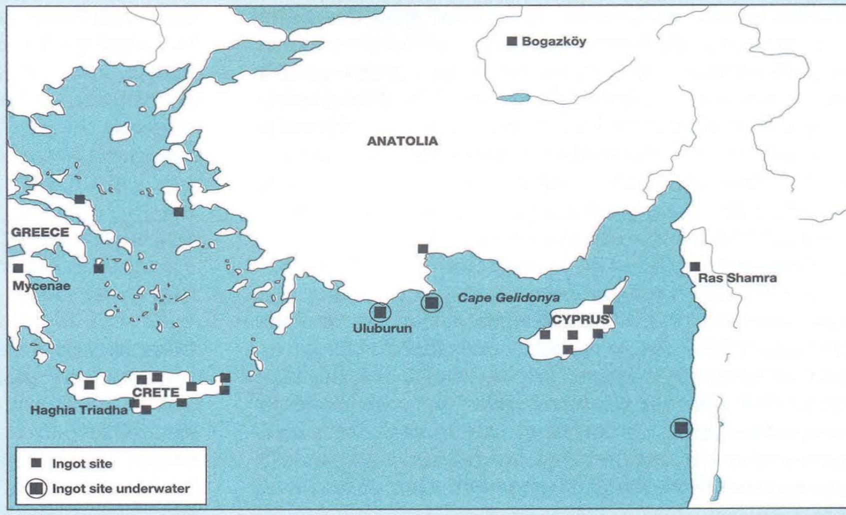
The isotopic compositions of all elements above calcium (mass 20) can in principle be measured by Thermal Ionization Mass Spectrometry (TIMS). The isotope compositions are measured as isotopic ratios and these ratios are used as unique parameters for the isotopic characterization of the samples. High accuracy measurements are necessary for sensitive differentiation. The introduction of multicollector TIMS machines in the late 1980s allows very high accuracy of the TIMS measurements of lead isotopes (overall error less than 0.1 percent). All TIMS measurements are standardized against Pb isotope standard and there are no problems with inter-laboratory comparisons. However, only a small number of elements can be ionized thermally with good efficiency: for example, lead, strontium, and neodymium are very well suited for TIMS, while tin and copper isotopes can be measured by this technique only with difficulty. A recently developed instrument for isotope measurements consists of a plasma source and a multicollector mass spectrometer (ICP-MMS). There are only a few of these machines working at present, but they have the capability for much faster and more accurate isotopic analysis of all elements, combined with far less time-consuming sample preparation procedures. The much more widely available ICP-MS instruments with a quadrupole magnet do not give sufficiently high accuracy of measurements of isotopic ratios for provenance studies.

Isotope geochemistry is now frequently used to investigate metal sources. Analysis of the lead isotopes in metal artifacts and their relation to ore bodies

LEAD ISOTOPE ANALYSIS



Lead isotope compositions *of Cypriot copper ores from different regions and oxhide ingots from Cyprus, the Uluburun shipwreck and the Minoan palace of Haghia Triadha, Crete. The diagrams show that the Cretan ingots could not have been made from the copper from any of the known Cypriot sources.*



Map showing finds of copper ingots in the eastern Mediterranean.

The great majority of the chemical elements occurring in nature have fixed isotopic compositions. There are some, however, whose isotopic composition differs, reflecting the geochemical or biological history of raw materials. One such element is lead which has four isotopes: ^{204}Pb, ^{206}Pb, ^{207}Pb, and ^{208}Pb. The three last isotopes owe their formation in part to the radioactive decay of uranium and thorium, and so the isotopic composition of ore deposits depends on the age of their formation, the initial amount of uranium and thorium, and the subsequent history of the ore deposit. Different lead, silver, and copper sources yield ores containing different proportions of the isotopes of lead. A large analytical program of lead isotope analyses at Oxford of numerous ores from deposits in the British Isles, the Mediterranean, and the Balkans has resulted in a substantial database (published in consecutive issues of *Archaeometry* 1995–8). This shows that ores from these regions have strictly limited and often different lead isotope ratios for each geographic region.

Any metals smelted from these ores retain their isotopic composition unaltered. Thus, in a given region, provided that one has located the main sources of these minerals, and identified their distinctive lead isotope ratios, it is possible to demonstrate that, say, a particular ancient metal artifact or pigment originated from a specific source in this region. Conversely, it can be proved that artifacts excavated on certain sites were made of raw materials not originating from the local sources.

Neither smelting of copper and lead, nor fire refining, nor silver production by cupellation, alters the isotopic composition of lead in the resulting metal. However, errors of interpretation might arise if objects were made of scrap metal originating from several ore sources. Also, some ore deposits, geographically distant or quite close, can have very similar lead isotope compositions and therefore the method is at its best when the isotope characterization of the ore source is based on multiple measurements of different sample ores from each mine, so that statistical evaluation of the data can be applied.

Metal Sources in the Mediterranean

Lead isotope analysis has been extensively applied to the characterization of metal sources in the Mediterranean. Coins of the Classical period made with silver from the mines of Laurion in Attica, Greece, can easily be distinguished from those made of silver from the island of Siphnos or other sources.

Hundreds of Bronze Age metal artifacts from the Aegean have been analyzed in order to discover the main sources of metals used at that time and their movement in this region. This method has been applied by the Oxford-based scientists Noel Gale and Zofia Stos-Gale to the Late Bronze Age copper ingots of the "oxhide" shape from Cyprus and Crete.

Their work has shown that a large group of post-1250 BC oxhide ingots found in regions geographically far apart (e.g. Central Anatolia, Cyprus, Italy) have unique lead isotopic characteristics identical with ore from one Cypriot mining area of Apliki in the Solea region (northern Troodos). However, they argue that a group of ingots found in the Late Minoan I palace of Haghia Triadha, very similar in appearance and metal composition but from a context some 300 years earlier, could not have been made from Cypriot copper (see diagrams: left), and the origin of their copper remains unknown. (Their copper isotope ratios are significantly different from the ingots consistent with an origin from the Apliki mine.)

The cargo of over 350 oxhide ingots carried on the Uluburun shipwreck (see p. 374–75) also appears to have a different origin. Their lead isotope ratios show consistency with copper ores mined in one location which the Gales suggest is most likely a mine neighboring Apliki in Cyprus. This particular lead isotope composition is very rare among many hundreds of other Late Bronze Age artifacts from the Mediterranean, suggesting that this particular mine was not commonly used and that the Uluburun ingots were the main products from it which have come to light.

exploited in antiquity has become an important characterization technique. The four lead isotopes (giving three independent isotope ratios), together with precise methods of analysis and a reasonable range of variation, afford rather good discrimination between different metal sources. The method relies very much on comparisons between the lead isotope characteristics of different ore deposits and their products and so the construction of an "isotope map" of the relevant ore sources, after systematic sampling, is very important. Ambiguities of interpretation occasionally arise as sometimes lead isotope ratios define more than one possible source, but usually these can be resolved by consideration of relevant trace element data.

Lead isotope analysis is of direct use not only for lead artifacts, but also for those of silver, in which lead is usually present as an impurity. Copper sources also contain at least a trace of lead, and it has been shown by experimentation that a large proportion of that lead passes into the copper metal produced during smelting. Here, then, is a characterization method applicable to lead, silver, and copper artifacts. It has been used successfully for the determination of mineral sources of Classical and medieval silver coins, Bronze Age copper and bronze tools, lead weights, as well as lead in pigments of glasses and glazes, and lead-based white paint. The sample of an artifact needed for Thermal Ionization Mass Spectrometry (TIMS) of lead varies from under 1 milligram to about 50 mg, depending on the concentration of lead in the material.

Strontium isotope ratios have been used in the characterization of obsidian artifacts and gypsum and can provide a simple method of distinguishing between marine and elephant ivory. Carbon and oxygen isotopes are widely used in sourcing marble. For a long time, the sourcing of marble had proved very difficult: it was well known that in the Mediterranean in the Classical period, good-quality white marbles were widely exported for sculpture or for building purposes Many of the most important quarries (e.g. on Mount Pendeli and Mount Hymettos near Athens, and on the Aegean islands of Paros and Naxos) had been identified. But attempts at matching the quarry source to a particular building or sculpture using either appearance or petrological methods (for instance, heavy mineral and trace-element analyses) were disappointing.

Analyses using two oxygen isotopes ($^{18}O/^{16}O$) and two carbon isotopes ($^{13}C/^{12}C$) can discriminate between several quarries, albeit with a certain degree of overlap. It is becoming increasingly clear that full characterization of marble sources will require the combined data from three analytical techniques: stable isotope studies, trace-element analysis, and cathodoluminescence.

Oxygen isotope ratios have also proved useful for the characterization of marine shell. As mentioned above, the shell of *Spondylus gaederopus* was widely traded in the form of bracelets and decorations during the Neolithic in southeast Europe. The question at issue was whether it came from the Aegean, or possibly from the Black Sea. As discussed in the section on deep-sea cores in Chapter 4, the oxygen isotopic composition of marine shell is dependent on the temperature of the sea where the organism lives. The Black Sea is much colder than the Mediterranean, and analysis confirmed that the shells in question came from the Aegean.

Other Analytical Methods. Many other analytical methods have been employed for characterization purposes.

X-ray diffraction analysis, used in determining the crystalline structure of minerals, from the angle at which X-rays are reflected, has proved helpful in defining the composition of Neolithic jade and jadeite axes that have been found at several British sites: it seems that the stone may have come from as far away as the Alps. It has also been used extensively in the characterization of pottery.

Infrared absorption spectroscopy has proved the most appropriate method for distinguishing between ambers from different sources: the organic compounds in the amber absorb different wavelengths of infrared radiation passed through them.

Cathodoluminescence segregates white marbles on the basis of colored luminescence emitted after electron bombardment. Calcitic marbles can be divided into two groups: one with an orange luminescence and one with a blue. Dolomitic marbles show a red luminescence. The different colors are caused by impurities or lattice defects within the crystals.

Mössbauer spectroscopy is used in the study of iron compounds, notably in pottery. It involves measuring the gamma radiation absorbed by the iron nuclei, which gives information about the particular iron compounds in the pottery sample and on the conditions of firing when the pottery was made. This was the analytical technique used in the characterization of mirrors made out of different kinds of iron ore (magnetite, ilmenite, and hematite) and widely traded in the Formative period in Oaxaca in Mesoamerica (see p. 378).

Fission-track analysis is mainly a dating method (Chapter 4), but has also been used to distinguish between obsidians from different sources, on the basis of their uranium content and the date of formation of the deposits.

Other dating methods have also been used to discriminate between geological materials of similar composition but different age.

Laser fusion argon-argon dating was successful in showing that a rhyolitic tuff used for making an axe, a fragment of which was found near Stonehenge, came originally from a volcanic source of Lower Carboniferous date in Scotland, not from older formations in South Wales, as had originally been thought. In Japan ESR has been used to differentiate between jasper implements of different sources.

These various analytical methods described enable archaeologists in many cases to identify the sources of the raw materials used in the manufacture of particular artifacts with some precision. How the subsequent movements of these artifacts are to be interpreted in terms of exchange presents a series of other, equally interesting problems, which we shall discuss in the next section.

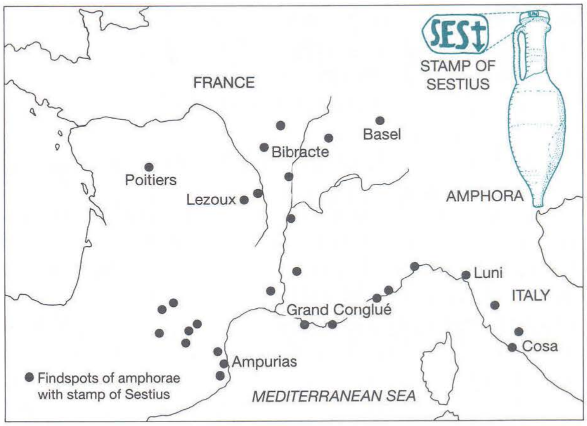
THE STUDY OF DISTRIBUTION

The study of the traded goods themselves, and the identification of their sources by means of characterization, are the most important procedures in the investigation of exchange. As we shall see below, the investigation of production methods in the source area can also be informative, and so can a consideration of consumption, which completes the story. But it is the study of distribution, or goods on the move, that allows us to get to the heart of the matter.

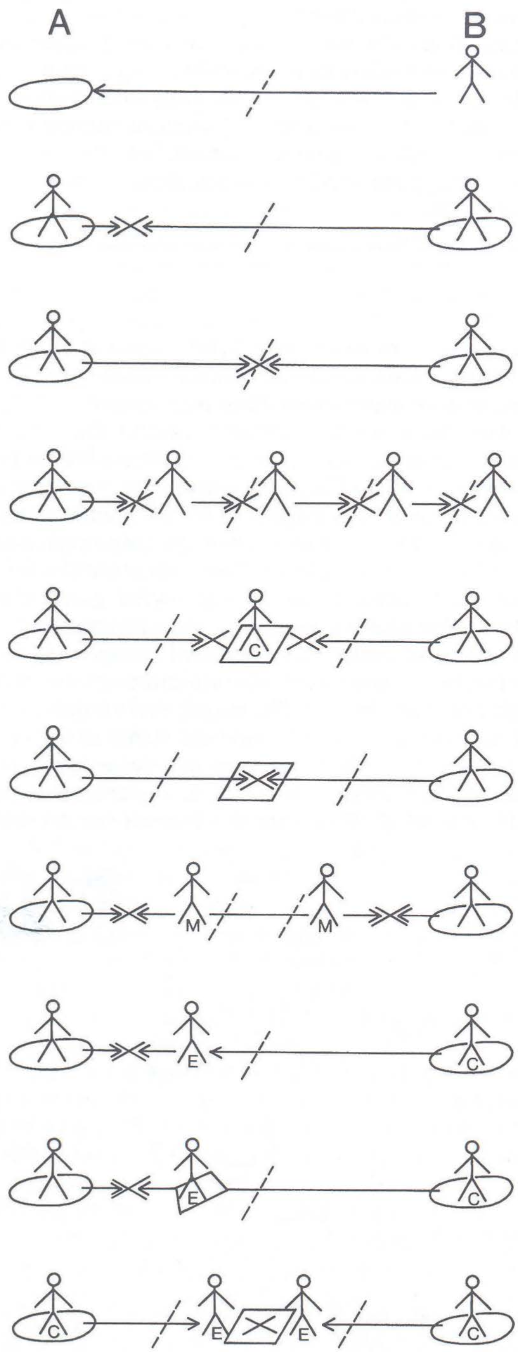
In the absence of written records it is not easy to determine what were the mechanisms of distribution, or what was the nature of the exchange relationship. However, where such records exist, they can be most informative. The Minoan Linear B tablets from the palace at Knossos in Crete and from Pylos in Mycenaean Greece give a clear picture of the palace economy. They show inventories of material coming in to the palace, and they record outgoings, indicating the existence of a redistributive system. Comparable records of account from centrally administered societies have offered similar insights – for instance, in the Near East. This precise sort of information is, of course, rarely available. Most of what the tablets record relates to internal trade – the production and distribution of goods within the society. But some Egyptian and Near Eastern records, notably in the archive dating to the 15th century BC found at Tell el-Amarna in Egypt, talk of gifts between the pharaoh and other Near Eastern potentates: this was gift exchange between the rulers of early state societies. Examples of such princely gifts survive: one of the treasures of Vienna is the ceremonial headdress of feathers given by the Aztec ruler Motecuhzoma II (Moctezuma) to Cortés as a gift for the King of Spain at the time of the Spanish Conquest of Mexico in the 16th century AD (see box, pp. 356–57).

Earlier evidence from preliterate societies – societies without written records – can, however, give some clear idea of ownership and of the managed distribution of goods. For example, clay sealings, used to stopper jars, to secure boxes, and to seal the doors of storehouses, and distinguished by the impression of a carved seal, are widely found in the preliterate phases in the Near East, and in the Aegean Bronze Age. In the past, these sealstones and their impressions have been studied more for their artistic content than for the light that they might throw on exchange mechanisms. However, if looked for, information about exchange is there, although, once again, it relates mainly to internal exchange. The impressions are only occasionally found at any great distance from their place of origin.

In some cases, however, the traded goods themselves were marked by their owner or producer. For instance, the potters who produced storage containers for liquids (amphorae) in Roman times used to stamp their name on the rim. The map below shows the distribution of amphorae bearing the stamp of the potter Sestius, whose kilns, although not yet located, were probably in the Cosa area of Italy. The general pattern of the export of oil or wine or whatever the amphorae



A distribution study. Roman storage containers (amphorae) bearing the stamp of the potter Sestius have been found in northern Italy and widely throughout central and southern France. They and their contents (no doubt wine) were probably made on an estate near Cosa. The distribution map thus indicates the general pattern of the export from the Cosa area of this commodity.



DIRECT ACCESS **B** has direct access to the source of the material without reference to **A**. If a territorial boundary exists, it can be crossed with impunity. There is no exchange transaction.

RECIPROCITY (HOME BASE) **B** visits **A** at **A**'s home base, and they exchange the special product each of them controls.

RECIPROCITY (BOUNDARY) **A** and **B** meet at their common boundary for exchange purposes.

DOWN-THE-LINE-TRADE Reduplicated home-base or boundary reciprocity (shown here for clarity as one-way only), so that a commodity travels across successive territories through successive exchanges.

CENTRAL PLACE REDISTRIBUTION **A** takes produce to the central place as tribute for the central person (no doubt receiving something in exchange, then or subsequently). **B** likewise takes produce to the central place and receives some of **A**'s produce.

CENTRAL PLACE MARKET EXCHANGE **A** takes produce to the central place and there exchanges it directly with **B** for **B**'s produce. The central person is not immediately active in this transaction.

FREELANCE (MIDDLEMAN) TRADING The middleman exchanges with **A** and with **B**, but is not under the control of **A** or **B**.

EMISSARY TRADING **B** sends an emissary, who is under **B**'s control, to exchange goods with **A**.

COLONIAL ENCLAVE **B** sends emissaries to establish a colonial enclave near **A**, in order to exchange with **A**.

PORT OF TRADE Both **A** and **B** send their emissaries to a central place (port of trade) which is outside the jurisdiction of either.

Source of material
Central place
Colonial enclave
Exchange transaction
Territorial boundary
Person involved in transaction
Controlling person
Middleman
Emissary

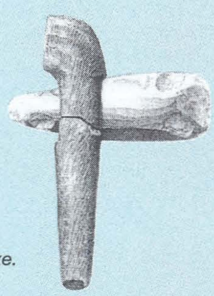
TREND SURFACE ANALYSIS

The aim of trend surface analysis is to highlight the main features of a distribution by smoothing over some of the local irregularities. In this way the important trends can be isolated from the background "noise" more clearly.

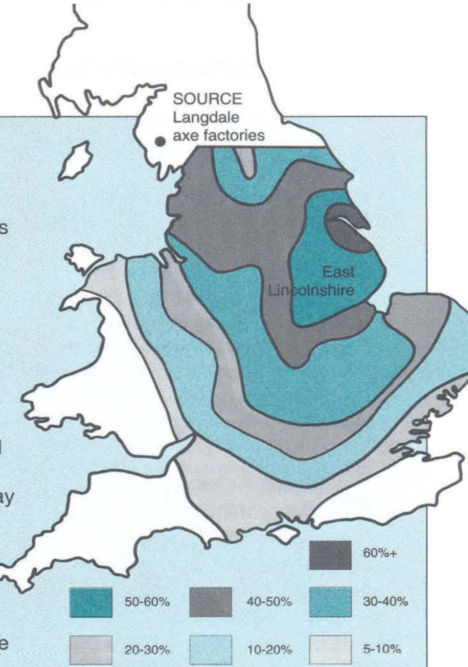
The first step is to divide the map into small, uniform areas or "cells." The number of finds within each cell is then noted. The patterning can be smoothed to reduce local irregularities by using not the actual figure of finds per cell but an average calculated from finds for each individual cell plus all its neighbors. In this way a moving average is produced from which a contour map may be drawn.

The example here shows the distribution density in Britain of so-called Group VI Neolithic stone axes, all of which came ultimately from the Langdale axe factories in northern England. This source was established for each axe by the petrological analysis of thin sections. But to display the distribution in this form may not reveal the mechanism underlying it. Grahame Clark suggested that gift exchange was involved for the British Neolithic axes, analogous to that among the Aborigines in Australia (see box, p. 376).

In a full trend surface analysis the principal trends would be defined by mathematics. This would allow the deviations from the trends (known as residuals) to be isolated and quantified.



Langdale axe.



Relative frequency distribution *of findspots of Group VI Neolithic axes, deriving ultimately from the Langdale axe factories. Out of some 500 axes, well over 50 percent were found in East Lincolnshire.*

contained (a question that can be decided by analysis of residues in the amphorae: see Chapter 7) can be made clear by the production of a distribution map. But a distribution map must be interpreted if we are to understand the processes that lay behind it, and at this point it is useful to distinguish again between reciprocity, redistribution, and market exchange, and to consider how the spatial distribution of finds may depend on the exchange mechanism.

"Direct access" refers to the situation where the user goes directly to the source of the material, without the intervention of any exchange mechanism. "Down-the-line" exchange refers to repeated exchanges of a reciprocal nature, and is further discussed below. "Freelance (middleman)" trading refers to the activities of traders who operate independently, and for gain: usually the traders work by bargaining (as in market exchange) but instead of a fixed marketplace they are travelers who take the goods to the consumer. "Emissary" trading refers to the situation where the "trader" is a representative of a central organization based in the home country.

Not all of these types of transaction can be expected to leave clear and unequivocal indications in the archaeological record, although, as we shall see, down-the-line trading apparently does. And a former port of trade ought to be recognizable if the materials found there come from a wide range of sources, and it is clear that the site was not pre-eminent as an administrative center, but specialized in trading activities.

Spatial Analysis of Distribution

Several formal techniques are available for the study of distribution. The first and most obvious technique is naturally that of plotting the distribution map for finds, as in the case of the stamped Roman amphorae mentioned above. Quantitative studies of distributions are also helpful; the size of the dot or some other feature can be used as a simple device to indicate the number of finds on the map. This kind of map can give a good indication of important centers of consumption and of redistribution. The distribution of finds on the map can be further investigated by the technique of trend surface analysis (see box above) to obtain valuable insights into the structure of the data.

Direct use of distribution maps, even when aided by quantitative plotting, may not, however, be the best

FALL-OFF ANALYSIS

The quantity of a traded material usually declines as the distance from the source increases. This is not surprising, because one would expect abundance to decrease with distance. But in some cases there are regularities in the way in which the decrease occurs, and this pattern can inform us about the *mechanism* by which a material reached its destination.

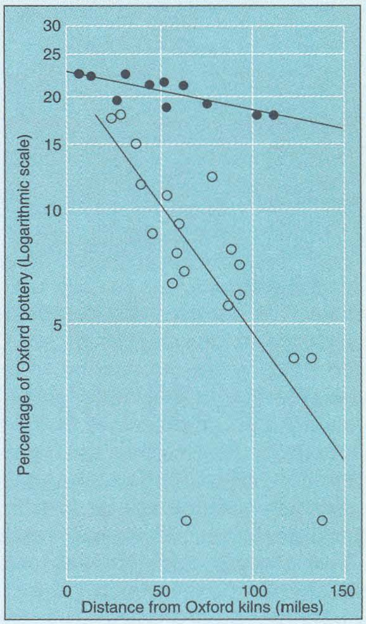
The now-standard way to investigate this is to plot a fall-off curve, in which the quantities of material (on the *y* axis) are plotted against distance from source (on the *x* axis). The first question is precisely what to measure. Simply plotting the number of finds at a site does not take into account the different conditions of preservation and recovery. Some kind of *proportional* method, measuring one class of find against another, can overcome this difficulty. For example, the percentage of obsidian in a total chipped stone industry is a convenient parameter to measure (although it is affected by the availability of other lithic materials).

In the study of Anatolian obsidian discussed in the main text, a plot of the quantity (i.e. percentage) on a *logarithmic scale* against distance (on an ordinary linear scale) produced a fall-off that followed an approximately straight line. That is the equivalent of a fall-off declining exponentially with distance, and it can be shown mathematically to be the equivalent of a "down-the-line" exchange mechanism, explained in the main text. A different exchange mechanism – for example involving central place redistribution – will produce a different fall-off curve (see main text).

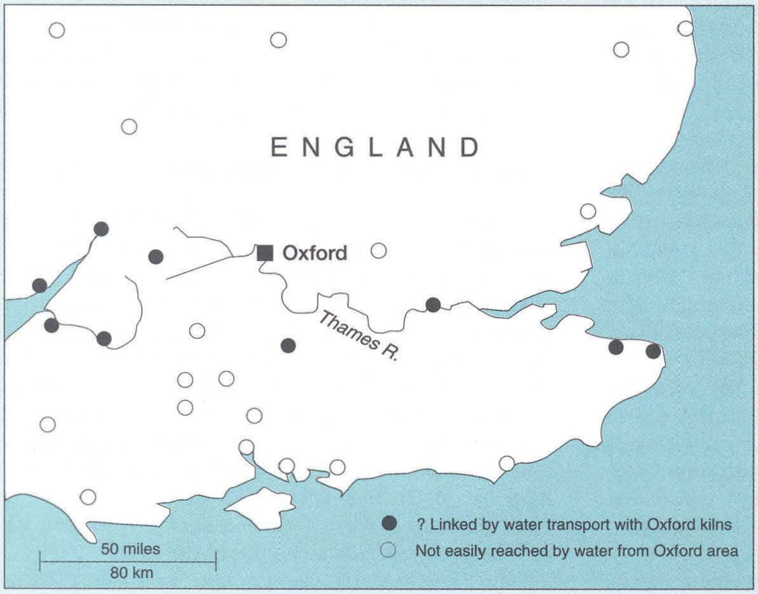
Various interesting results come from fall-off analysis. For instance, when a plot was done of the decrease in quantity with distance of Roman pottery made at kilns in the Oxford region in Britain, and when sites that could be reached by water transport were distinguished from those that could not, a clear distinction was visible. Evidently, water transport was a much more efficient distribution method than land transport for this commodity.

In principle, the fact that different models for the mechanism of distribution give different fall-off curves should allow an accurate plotting of the data to reveal which mechanism of distribution was operating. But there are two difficulties. The first is that the quality of the data does not always allow one to decide reliably which fall-off curve is the appropriate one. And the more serious difficulty is that, in some cases, different models for distribution produce the same curve.

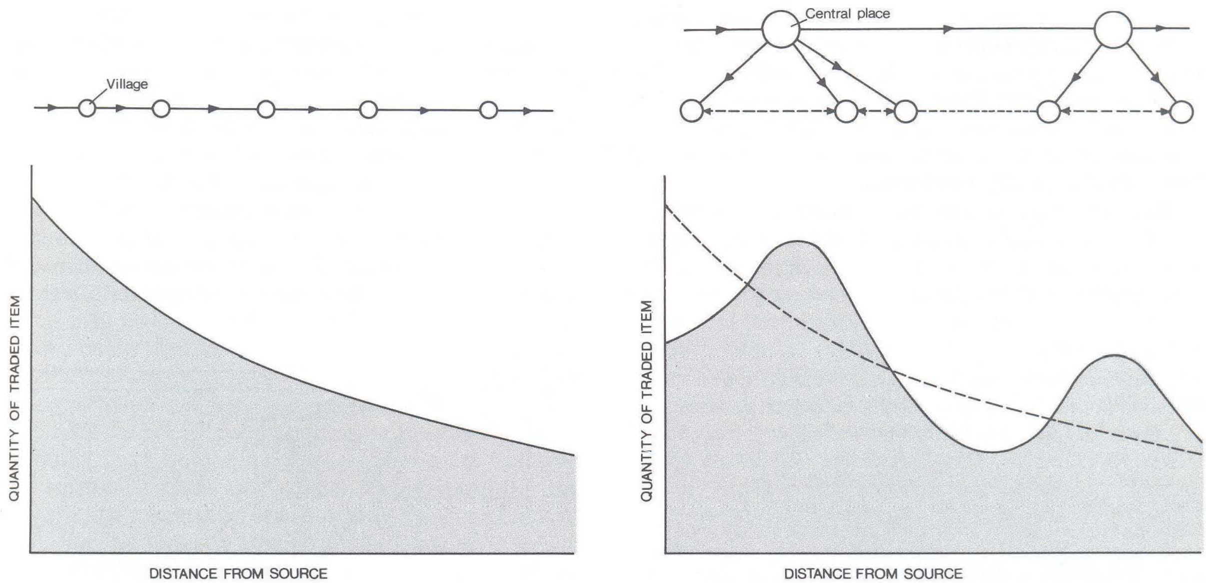
Fall-off analysis can be very informative, but these two limitations restrict its usefulness.



***The fall-off** in Oxford pottery with increasing distance from the Oxford kilns during the Roman period. Sites with good access to the kilns by water (filled circles) show a much less steep fall-off gradient than those without such easy access, indicating the importance of water transport as a method of distribution at this time.*



***Distribution map** showing the location of sites where Roman pottery from the Oxford kilns has been found.*



Relationship between settlement organization, type of exchange, and supply, for a commodity traded on land. (Left) Village settlement served by down-the-line exchange (on a basis of reciprocity) leads, in the archaeological record, to an exponential fall-off in abundance. (Right) Central place settlement with directional exchange between centers (and with either redistribution or central market exchange at local regional level) leads to a multi-modal fall-off curve. Note the tendency for lower-order settlements to exchange with the higher-order center, even if the latter lies further from the source than an accessible lower-order settlement.

way of studying the data, and more thorough analysis may be useful. Recently, there has been a considerable focus of interest on fall-off analysis (see box opposite). Although different mechanisms of distribution sometimes produce comparable end-results, the pattern of exponential fall-off is produced only by a down-the-line trading system. For instance, if one village receives its supplies of a raw material down a linear trading network from its neighbor up the line, retains a given proportion of the material (e.g. one-third) for its own use, and trades the remainder to its neighbor down the line, and if each village does the same, an exponential fall-off curve will result. When quantity is plotted on a logarithmic scale, the plot takes the form of a straight line. But a different distribution system, through major and minor centers, would produce a different fall-off pattern. There are many examples where patterns of trade have been investigated using a characterization technique together with a spatial analysis of the distribution of finds. It must be remembered, however, that such techniques rarely reveal the complete trading system, only one component of it.

Distribution Studies of Obsidian. A good example is the obsidian found at Early Neolithic sites in the Near East (see map p. 372). Characterization studies by Colin Renfrew and colleagues pinpointed two sources in central Anatolia and two in eastern Anatolia. Samples were obtained from most of the known Early Neolithic sites in the Near East, dating from the 7th and 6th millennia BC. A rather clear picture emerged with the central Anatolian obsidians being traded in the Levant area (down to Palestine), while those of eastern Anatolia were mostly traded down the Zagros Mountain range to sites in Iran such as Ali Kosh.

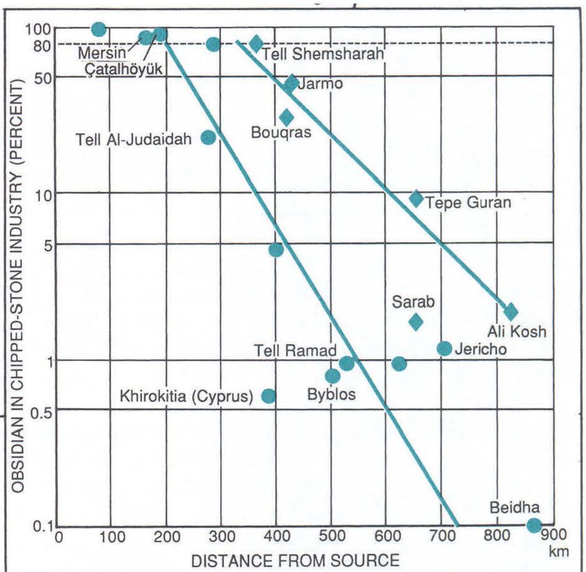
A quantitative distributional study (see box opposite) revealed a pattern of exponential fall-off, which as we have seen is an indicator of down-the-line trade. It could therefore be concluded that obsidian was being handed on down from village settlement to village settlement. Only in the area close to the sources (within 320 km (200 miles) of the sources) – termed the ***supply zone*** – was there evidence that people were going direct to the source to collect their own obsidian. Outside that area – within what has been termed the ***contact zone*** – the fall-off indicates a down-the-line system. There is no indication of specialist middleman traders at this time, nor does it seem that there were central places which had a dominant role in the supply of obsidian.

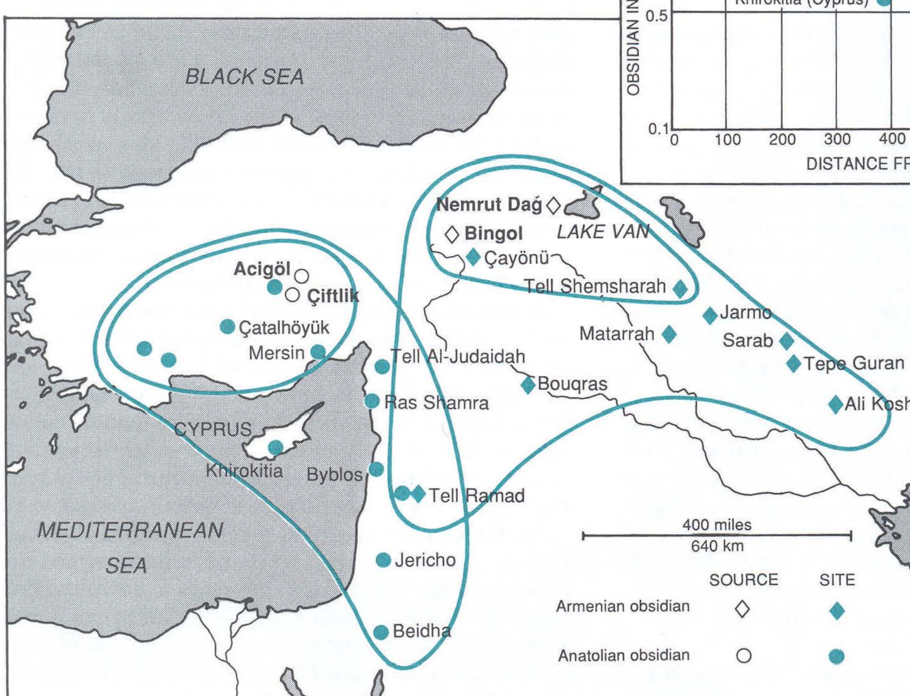
In the early period, the position was as seen on the map below. In the later period, from 5000 to 3000 BC, the situation changed somewhat, with a new obsidian source in eastern Anatolia coming into use. Obsidian was also then traded over rather greater distances. This is a case where it is possible to study the development of the obsidian trade over time.

Obsidian makes a very good material for a characterization and distribution study for several reasons. First, there are relatively few sources of obsidian in the world, because the material is found only at volcanic outcrops of relatively recent geological age. Secondly, it transpires that the different sources are chemically different, so that they can be distinguished by such methods as neutron activation analysis. Thirdly, obsidian was greatly prized in prehistoric times and was used to make chipped stone tools in the same manner as flint, so that it is found at many prehistoric sites.

In the Aegean, obsidian was being collected from the Cycladic island of Melos as early as 10,000 years ago, as finds in the Franchthi Cave on the Greek mainland show. This is the earliest secure evidence for seafaring

The obsidian trade in the Near East. Characterization studies revealed that Early Neolithic villages in Cyprus, Anatolia, and the Levant obtained their obsidian from two sources in central Anatolia, while villages such as Jarmo and Ali Kosh depended on two sources in Armenia (eastern Anatolia). At sites relatively close to the sources (e.g. Çatalhöyük, Tell Shemsharah), obsidian formed 80 percent of the chipped stone tools, suggesting that within this "supply zone" (inner lines on the distribution map) people collected obsidian directly from the source. Beyond this zone there was an exponential fall-off in obsidian abundance (right), indicative of down-the-line trade.





in the Mediterranean. The early trade of obsidian in the Pacific, for instance within the early Lapita culture (Chapter 12), has been documented by similar means. And in Central and North America, several investigations have been conducted of obsidian exchange systems – for example, in the Oaxaca region of Mexico in the Early Formative period (see p. 378).

Trade in Silver and Copper. In the Aegean again the technique of lead isotope analysis (see above) has allowed the sources to be determined for the silver and copper artifacts in use in the 3rd millennium BC. The analyses have shown the operation of the silver mines at Laurion in Greece at a very early date, and have also unexpectedly revealed the importance during the 3rd millennium of a copper source on the island of Kythnos. Lead isotope analyses also appear to indicate the surprising result that copper from Cyprus (in the eastern Mediterranean) was reaching the island of Sardinia (in the western Mediterranean) before 1200 BC. Sardinia has copper sources of its own, so the need for Cypriot imports is puzzling.

Shipwrecks and Hoards: Trade by Sea and Land. A different approach to distribution questions is afforded by the study of transport. Travel by water was often much safer, quicker, and less expensive than travel by land. The best source of information, both for questions of transport and for the crucial question of what commodity was traded against what, and on which scale, is afforded by shipwrecks from prehistoric as well as later times. Probably the best known of these are the wrecks of the treasure ships of the Spanish Main; the artifacts in them give valuable insights into the organization of trade. From earlier times, complete cargoes of the Roman amphorae referred to above have been recovered. Our knowledge of marine trade several centuries before has been greatly extended by George Bass' investigations of two important Bronze Age shipwrecks off the south coast of Turkey, at Cape Gelidonya and Uluburun (see box overleaf).

The terrestrial equivalent of the shipwreck is the trader's cache or hoard. When substantial assemblages of goods are found in archaeological deposits, it is not easy to be clear about the intentions of those who left them there: some hoards evidently had a votive character, but those with materials for recycling, such as scrap metal, may well have been buried by itinerant smiths.

In such cases, particularly with a well-preserved shipwreck, we come as close as we shall ever do to understanding the nature of distribution. Just occasionally, we are lucky enough to see a depiction of traders, together with their exotic goods. Several Egyptian tomb paintings show the arrival of overseas traders: in some cases, for instance in the tomb of Senenmut at Thebes (*c.* 1492 BC), they can be recognized as Minoans, with characteristic Cretan goods.

THE STUDY OF PRODUCTION

One of the best ways of understanding what was going on in a system involving production, distribution (usually with exchange), and consumption, is to start at the place of production. Whether we are speaking of the place of origin of the raw material, the location where the material was turned into finished products, or the place of manufacture of an artificial material, such a location has much to teach us. We need to know how production was organized. Were craft specialists at work, or did people travel freely to the sources to collect what they wanted? If there were craft specialists, how were they organized, and what was the scale of production? In precisely what form was the product transported and exchanged?

The investigation of quarries and mines is now a well-developed field of archaeology. Detailed mapping of the source area, both in terms of the geological formation and of the distribution of discarded material, is a first step for quarries. The work of Robin Torrence at the obsidian quarries on the Aegean island of Melos offers a good example. The main question that she posed there was whether craft specialists resident on Melos were exploiting this resource, or whether it was utilized by travelers who came in their boats and collected the material when they wanted to do so. Her sophisticated analysis showed that the latter was the case, and that craft specialists had not worked there: this was a direct-access resource.

One of the most interesting techniques for studying production is reconstituting the debris from the production of tool forms. C.A. Singer has done this at felsite quarries in the Colorado Desert of southern California, which have a long history of exploitation from the beginning of the Holocene. He was able to refit flakes and artifacts from one of the quarries (Riverton 1819) with those from an occupation site 63 km (39 miles) away, thus illustrating the movement of the raw material from its source.

This is an area where ethnographic studies, notably at quarries in Australia and Papua New Guinea, have

DISTRIBUTION: THE ULUBURUN WRECK

It is difficult for the archaeologist to learn what commodity was traded against what other commodity, and to understand the mechanics of trade. The discovery of the shipwreck of a trading vessel, complete with cargo, is thus of particular value.

In 1982, just such a wreck, dating from close to 1300 BC, was found at Uluburun, near Kaş, off the south Turkish coast in 43 m (141 ft) to 60 m (198 ft) of water. It was excavated between 1984 and 1994 by George F. Bass and Cemal Pulak of the Institute of Nautical Archaeology in Texas.

The ship's cargo contained about 10 tons of copper in the form of over 350 of the so-called "oxhide" ingots (i.e. shaped like an oxhide) already known from wall paintings in Egypt and from finds in Cyprus, Crete, and elsewhere. The copper for these ingots was almost certainly mined on the island of Cyprus (as suggested by lead-isotope analysis, and trace-element analysis). Also of particular importance are nearly a ton of ingots and other objects of tin found on the sea floor in the remains of the cargo. The source of the tin used in the Mediterranean at this time is not yet clear. It seems evident that at the time of the shipwreck, the vessel was sailing westwards from the east Mediterranean coast, and taking with it tin, from some eastern source, as well as copper from Cyprus.

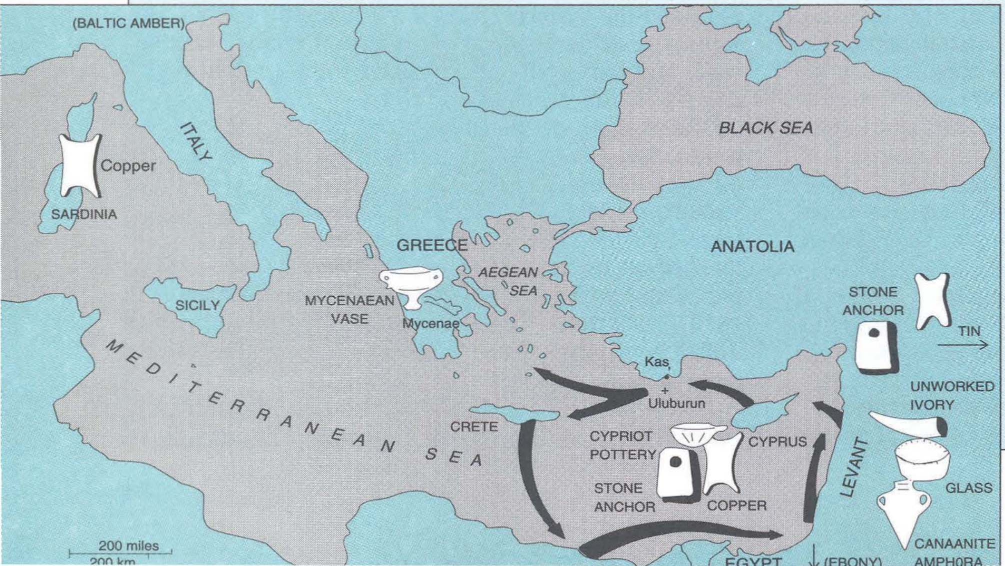
***Three striking** objects from the wreck: (clockwise, from top) impression of a hematite seal, cut in Mesopotamia c. 1750 BC, with a new scene carved over it some 400 years later; a gold scarab, the first ever found bearing the name of the famous Egyptian queen Nefertiti, who reigned with her consort Akhenaten during the 14th century BC; and gold pendant showing an unknown goddess with a gazelle in each upraised hand.*

The pottery included jars of the type known as Canaanite amphorae, because they were made in Palestine or Syria (the Land of Canaan). Most held turpentine-like resin from the terebinth tree, but several contained olives, and another glass beads.

Similar jars have been found in Greece, Egypt, and especially along the Levantine coast.

The exotic goods in the wreck included lengths of a wood resembling ebony, which grew in Africa south of Egypt. Then there were Baltic amber beads, which came originally from northern Europe (and which probably reached the Mediterranean overland). There was also ivory in the form of elephant and hippopotamus tusks, possibly from the eastern Mediterranean, and ostrich eggshells that probably came from North Africa or Syria. Bronze tools and weapons from the wreck show a mixture of types that include Egyptian, Levantine, and Mycenaean forms. Among other important finds were several cylinder seals of Syrian and Mesopotamian types, ingots of glass (at that time a special and costly material), and a chalice of gold.

This staggering treasure from the sea bed gives a glimpse into Bronze Age trade in the Mediterranean. Bass and Pulak consider it likely that the trader started his final voyage on the Levantine coast. His usual circuit probably involved sailing across to Cyprus, then along the Turkish coast, past Kaş and west to Crete, or, more likely, to one of the major Mycenaean sites on the Greek mainland, or even further north, as hinted by the discovery on the wreck of spears and a ceremonial scepter/mace from the Danube region of the Black Sea. Then, profiting from seasonal winds, he would head south across the open sea to the coast of North Africa, east to the mouth of the Nile and Egypt, and, finally, home again to Phoenicia. On this occasion, however, he lost his ship, his cargo, and possibly his life at Uluburun.

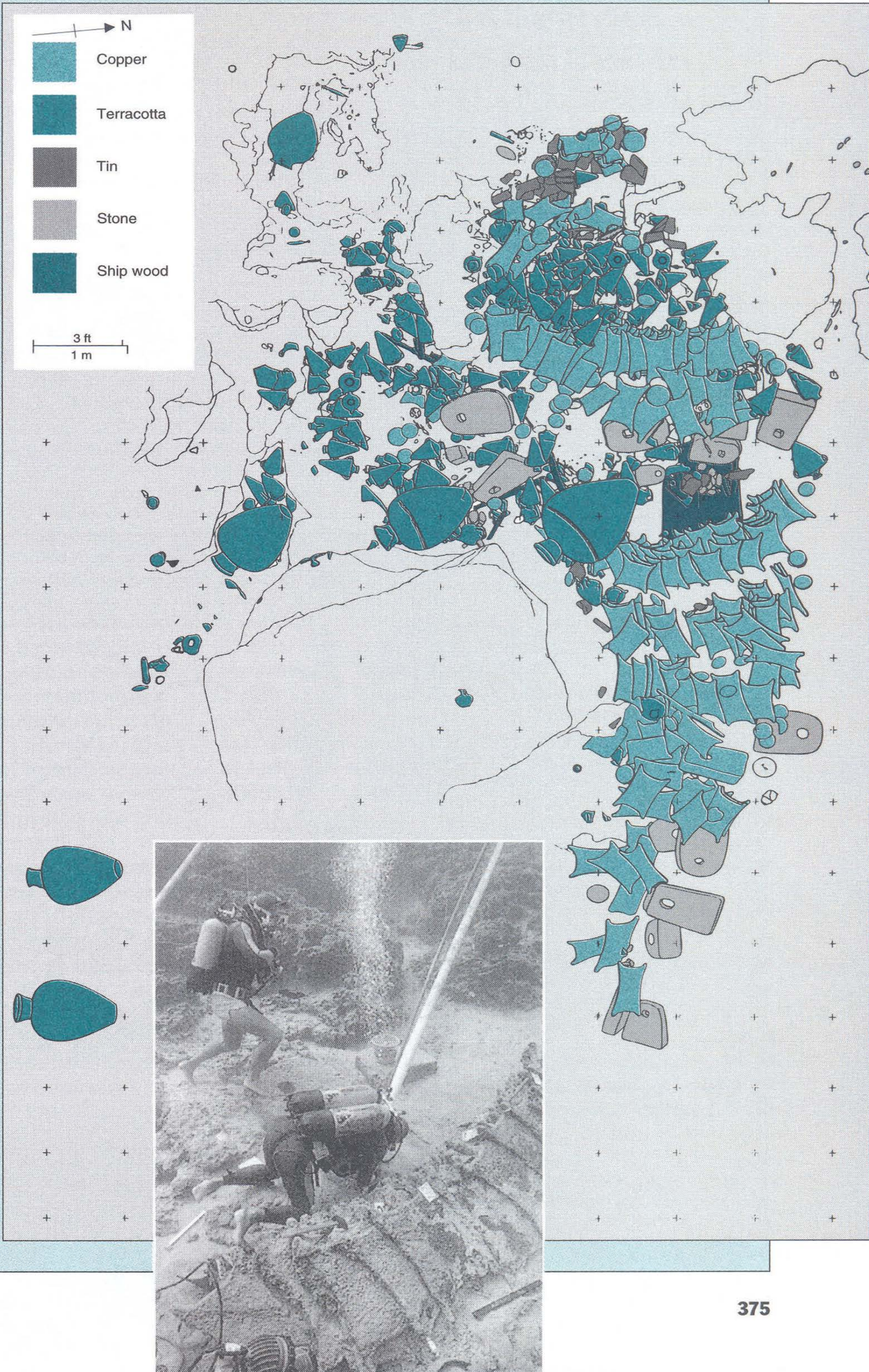


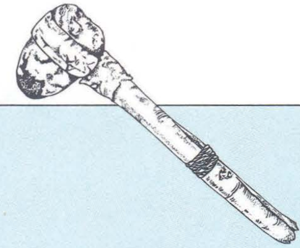
***The map** shows the probable route of the ill-fated ship found at Uluburun. Also indicated are likely sources of materials for the various artifacts found on board the wreck.*

The thousands of objects from the wreck were drawn on the site plan before the painstaking work of recovery began. (Below) Divers working on the oxhide ingots.

FINDS FROM THE WRECK

Gold 37 pieces: 9 pendants (Canaanite and Syrian?) • 4 medallions with star/ray design • Scarab of Nefertiti • Conical, collared chalice • Ring • Scrap **Silver** 2 bracelets (Canaanite?) • 4 bracelet fragments (scrap) • 3 rings (1 Egyptian) • Bowl fragment and other scrap pieces **Copper** Over 350 oxhide-shaped ingots (c.27kg/60 lb each) • Over 120 complete or partial plano-convex or "bun" ingots • Other ingots **Bronze** Statuette of a female deity partly clad in gold foil • Tools and weapons (Canaanite, Mycenaean, Cypriot, and Egyptian designs): daggers, swords, spearheads, arrowheads, axes, adzes, hoe, sickle blades, chisels, knives, razors, tongs, drill bits, awls, saw • 1 pair finger cymbals • Zoomorphic weights: 2 frogs, 5 bulls, sphinx, duck, waterfowl, calf, fly, lion and lioness, canine (?) head • Balance pans and weights • Figurines of man and 3 calves on lead-filled disk • Bowl and caldron fragments • Rings • Pins • Fishhooks, trident, harpoon **Tin** Over 100 tin ingots and fragments (round bun, oxhide, slab, and sections of large disk shapes) • Mug, pilgrim flask, plate **Lead** Over 1000 fish-net weights • Fish-line weights • Balance-pan weights **Faience** 4 rhyta (ram's head form) • Goblet in shape of woman's head • Tiny discoid beads • Biconical fluted beads • Other bead types **Glass** Over 150 cobalt-blue and light blue disk ingots (Canaanite?) • Beads (many stored in a Canaanite amphora) **Sealstones etc.** 2 quartz cylinder seals (1 with gold caps) • Hematite seal (Mesopotamian) • Gold-framed ?steatite scarab • 8 other scarabs (Egyptian and ?Syrian) • 2 lentoid Mycenaean sealstones • 6 other cylinder seals • Amber beads from Baltic • Small stone plaque with hieroglyphs "Ptah, Lord of Truth" on obverse **Stone** 24 weight-anchors • Ballast stones • Balance-pan weights • Mace heads • Nearly 700 agate beads • Mortar and trays • Whetstones **Pottery** 10 large pithoi (1 with 18 pieces Cypriot pottery inside) • About 150 amphorae (Canaanite) • Mycenaean kylix (Rhodian?), stirrup jars, cup, jugs, dipper, flask • Pilgrim flasks • Syrian jugs • Wide variety of Cypriot pottery **Ivory** 13 hippopotamus teeth • Complete and segment of sawn elephant tusk • 2 duck-shaped cosmetics containers • Ram's-horn shaped trumpet carved from hippopotamus tooth • Scepters, handles, decorative inlay pieces **Wood** Ship's hull (cedar planks fastened to cedar keel by mortise-and-tenon joints pinned with hardwood pegs) • Logs of African blackwood (Egyptian ebony) • 2 wooden diptychs (writing tablets): 2 wooden leaves joined by 3-piece ivory hinge **Other Organic Materials** Thorny burnet (shrub used as packing around cargo) • Olives stored in amphorae • Pomegranates stored in a pithos • Grapes, figs, nuts, spices • Yellow terebinth resin (?ingredient of perfume or incense) stored in over 100 amphorae • Orpiment (yellow arsenic) stored in amphorae • 1000s of marine mollusc opercula (?ingredient of incense) • Bone astragals • Ostrich eggshells and eggshell beads • 28 sea-shell rings • Over 6 tortoise-shell fragments (?part of soundbox for lute)





PRODUCTION: GREENSTONE ARTIFACTS IN AUSTRALIA

One of the most thorough studies of the circumstances of production and distribution yet undertaken is that conducted by Isabel McBryde at the quarry outcrops on Mount William in the ranges north of Melbourne, in southeastern Australia. McBryde started with a large quarry site known from ethnographic accounts to have been an important source for the greenstone used in the manufacture of tomahawks, a basic and universal tool among the Australian Aborigines. She then followed up the quarry's products in museum collections, identifying them in collaboration with petrologist Alan Watchman. Similar-looking greenstone from other quarries could be distinguished by thin-section analysis, supplemented by major- and trace-element analyses.

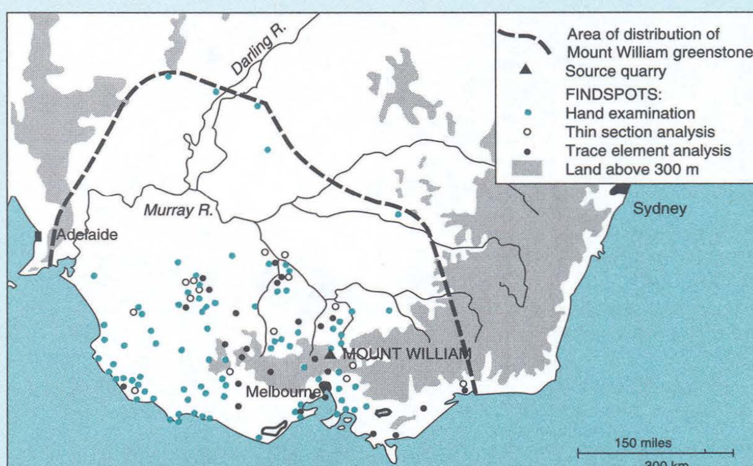
McBryde mapped and sampled the worked outcrops at the quarry. On the top of the ridge at Mount William, where the outcrop of greenstone is buried, there are strings of quarry pits where the unweathered stone was mined. There are scree slopes of quarried waste around the worked outcrops, and isolated flaking floors indicate the location of the areas where cores and preforms were shaped.

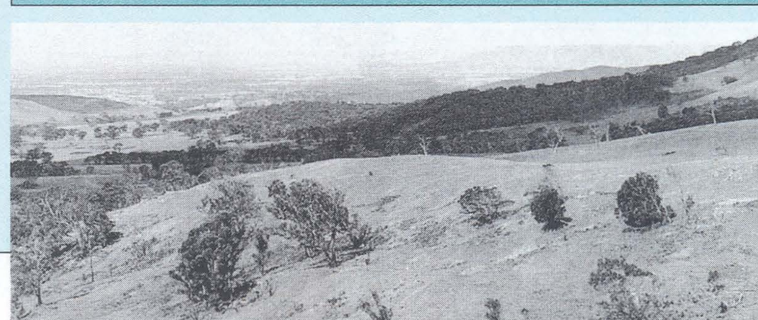
The work also involved the study of the distribution of the artifacts derived from the quarry site. McBryde, drawing on the ethnographic evidence, discovered that access to the quarry was strictly limited, and its stone was available only through those with the kinship or ceremonial affiliations to the "owners" of the site.

In the words of McBryde: "The quarry was still in use when Melbourne was first settled in the 1830s, its operation controlled by strict conventions. The outcrops were owned by a group of Woiwurrung speakers, and only members of a certain family were permitted to work them. The last man responsible for working the quarry, Billi-billeri, died in 1846."

Reed spears were brought from the Goulburn and Murray rivers in exchange. It is recorded that three pieces of Mount William stone would be exchanged for one possum skin cloak, "itself a considerable labor investment in hunting, skin preparation, sewing and decoration, when the skins of many animals might be needed for one garment." Thus the initial exchanges took the axes only to a fairly limited area around the quarry. The wider distribution – up to 500 km – was the result of successive further exchanges with neighboring groups.

Petrologist Alan Watchman takes a rock sample from a greenstone outcrop at the Mount William quarry. Comparison of the rock's composition with that of greenstone axes found elsewhere made it possible to match the artifacts to their quarry source.





Mount William, with its quarried outcrops along the ridge (right), and a map (above right) to show the distribution of artifacts made from the quarry's greenstone.

proved very informative: insights are gained not only into the problems of working those and similar production systems, but also into the solutions available to overcome them (see box, left).

The excavation of mines offers special opportunities. For instance, at the Neolithic flint mines at Grimes Graves in Norfolk, eastern England (see p. 315), it was possible for Roger Mercer to calculate the total flint obtained from each mine shaft, and to estimate the amount of work involved in digging the shaft, thus achieving a sort of time and motion study for the actual extraction process.

Studies of the specialist working of raw materials have been undertaken for several materials. One of these is Philip Kohl's study of the production and distribution of elaborately decorated stone bowls, made of green chlorite, in the Sumerian period (2900–2350 BC). He studied two sites in eastern Iran, Tepe Yahya and Shahr-i-Sokhta, and compared the production methods used with modern soft-stone workshops in Meshed. The rapid mass-production of vessels in Meshed, using modern tools such as lathes, contrasts markedly with the much slower production methods employed at Yahya. The distribution of the products also differs, with the ancient chlorite vessels restricted to the upper ruling strata of early urban centers, while the Meshed vessels were sold to a wider range of people. Such comparisons with modern situations can highlight important features of archaeological artifact distributions. The study of village craft specialization in present-day farming societies is another way of learning about techniques of production in the past.

The location of specialist workshops in urban sites is one of the main objectives of survey on such sites. But only the excavation of workshops and special facilities can give adequate insights into the scale of production and its organization. The workshops most commonly found are pottery kilns.

The scale of the installation is sometimes sufficient to imply the nature of the production, and sometimes the products; for instance, bricks referring to the *Classis Britannica*, the fleet of Roman Britain, indicate production under official auspices, as part of the official organization.

THE STUDY OF CONSUMPTION

Consumption is the third component of the sequence that begins with production and is mediated by distribution or exchange. There have been only a few serious studies of the consumption of traded commodities. But such studies are necessary if the nature and scale of the exchange process are to be well understood. The issues soon return to a consideration of formation processes (Chapter 2), because there is no reason to suppose that the quantities of material recovered at a site represent accurately the quantities once traded.

It is necessary to ask first how the materials recovered came to be discarded or lost. Valued objects, carefully curated, are found in excavations less often than less-esteemed everyday ones. Secondly, it is necessary to consider how discarded or lost objects or debris found their way into the archaeological record. On a domestic site, questions of cleanliness and rubbish disposal are important. The study cannot proceed properly without a consideration of both these aspects of formation processes, and also of the timespans involved.

The quantities of material will need estimating very carefully. This means explicit procedures for sampling the site, and standardized recovery procedures. On most excavations it is now standard practice to take samples of the excavated soil, and to sieve or screen it through a fine mesh, often with the aid of water (water sieving). The technique of flotation (Chapter 6) is also used for the recovery of plant residues. A mesh of 3 or 4 mm (0.1–0.15 in) is usually appropriate for the recovery of beads, flint chips, etc., but for pottery a mesh of a larger size is more suitable, so that only pieces above a given length (of say 1 or 2 cm (0.4–0.8 in)) are recovered. (It often makes sense to discard, or at least not to include in the counts, pieces less than about 1 or 2 cm (0.4–0.8 in) long.)

The American archaeologist Raymond Sidrys has attempted to study the pattern of consumption of a specific commodity: obsidian. He set out to see whether consumption of obsidian from source areas in Guatemala and El Salvador during ancient Maya times varied according to different types of site. In the Maya area, as in the Near East (see map, p. 372), the frequency of obsidian finds declines exponentially as the distance from source increases. But, allowing for this decay pattern, was there a marked difference in the amount of obsidian used at different types of site? Sidrys set out to answer this question with two measures of obsidian abundance. First he used a measure of obsidian density (OD), defined as:

$$\mathrm{OD} = \frac{\text{Mass of obsidian}}{\text{Excavated volume of earth}}$$

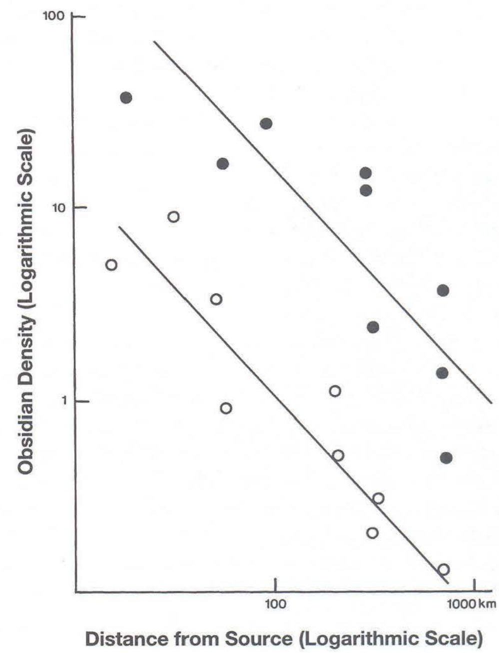
for each site. This measure involved estimating the quantity of soil excavated and weighing the total quantity of obsidian recovered (finished artifacts and waste material) as the soil was passed through the sieve.

The second measure was of obsidian scarcity (OS), defined as:

$$OS = \frac{\text{Number of obsidian artifacts}}{\text{Number of potsherds}}$$

Sidrys' calculations showed clearly that obsidian was less abundant at the minor centers than at the major ceremonial centers.

It is a matter for discussion as to whether this difference between the centers should be attributed to a difference in consumption patterns or to a difference in distribution, but with the major centers acting as the preferential recipients of supplies. The project is in any case a pioneering attempt to consider questions of consumption.



Consumption of Maya obsidian. In this analysis by Sidrys two separate fall-off patterns were revealed, one for minor centers (open circles) and the other for major centers (filled circles).

EXCHANGE AND INTERACTION: THE COMPLETE SYSTEM

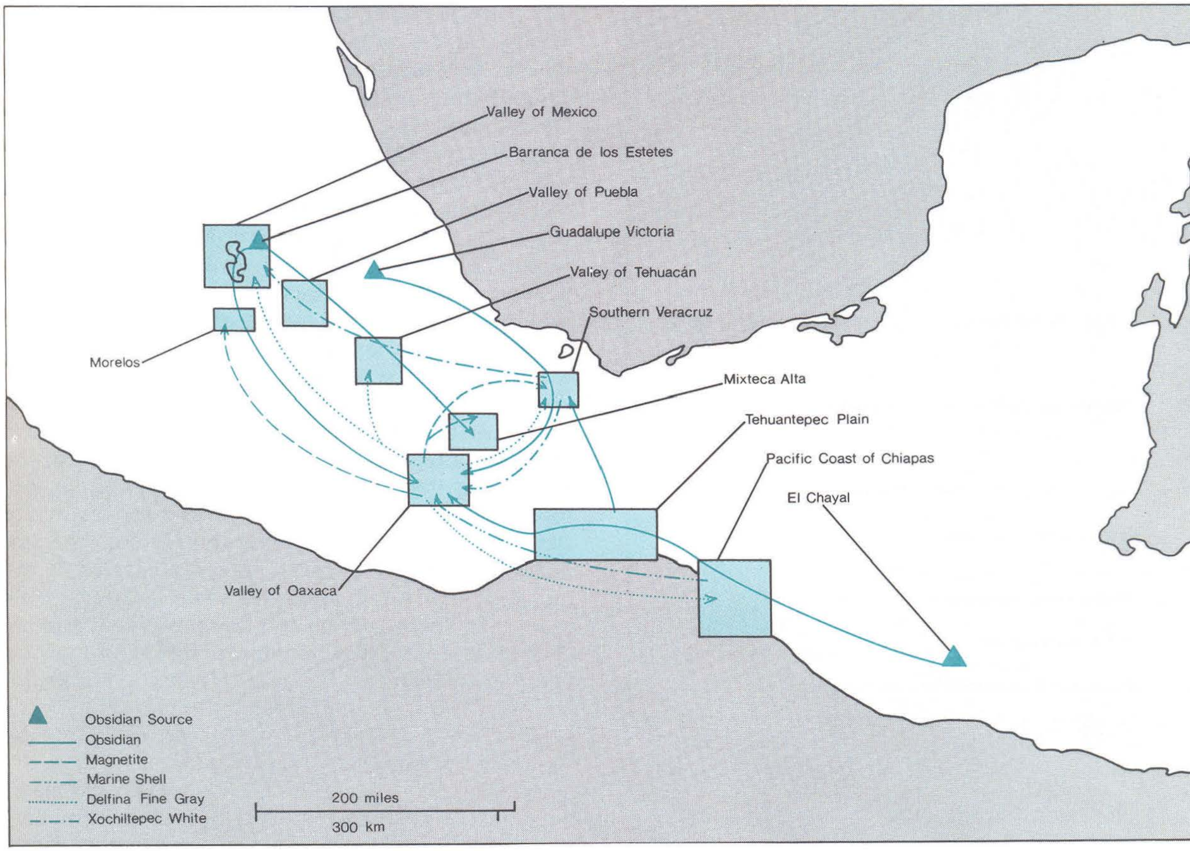
The archaeological evidence is rarely sufficient to permit the reconstruction of a complete exchange system. It is extremely difficult, for example, to establish without written records what was traded against what, and which particular values were ascribed to each commodity. Furthermore, exchange in perishable materials will have left little or no trace in the archaeological record. In most cases, all one can hope to do is to fit together the evidence about sources and distribution afforded archaeologically. A good example of such a project is the work of Jane Pires-Ferreira in Oaxaca, Mexico.

An Exchange System in Ancient Mexico. Jane Pires-Ferreira studied five materials used in Oaxaca during the Early and Middle Formative periods (1450–500 BC). The first was ***obsidian***, of which some nine sources were relevant. These were characterized by means of neutron activation analysis, and relevant networks were established. She then proceeded to consider exchange networks for ***mother-of-pearl shell***, and concluded that two different networks were in operation, one bringing marine material from the Pacific Coast, the other material from freshwater sources in the rivers draining into the Atlantic.

For her next study she considered the ***iron ore*** (magnetite, ilmenite, and hematite) used to manufacture mirrors in the Formative period. Here the appropriate characterization technique was Mössbauer spectroscopy. Finally, she was able to bring into consideration two classes of ***pottery*** whose area of manufacture (in Oaxaca and in Veracruz, respectively) could be determined stylistically.

These results were then fitted together onto a single map, showing some of the commodities that linked regions of Mesoamerica in the Early Formative period into several exchange networks. The picture is evidently incomplete, and it does not offer any notion of relative values. But it does make excellent use of the available characterization data, and undertakes a preliminary synthesis that is securely based on the archaeological evidence.

Further Insights into the Exchange System. In a money economy, it may be possible to go further in our analysis, because some measure of the total turnover of the economy may be possible once there is a single, unified measure of value. In the case of coined money, various steps in the economic system can be reconstructed: the circumstances of minting may be examined, and some-



The complete system: Pires-Ferreira's map to show some of the commodities that linked regions of Early Formative Mesoamerica.

thing of the taxation system is sometimes known from other sources.

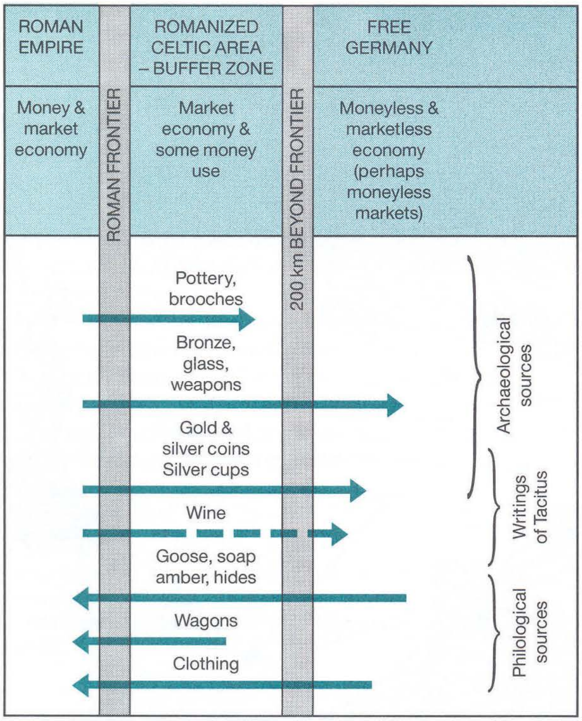
At a more specific level, coins can often give an accurate indication of the intensity of interactions in space and time because they can usually be dated and because the place of issue is frequently indicated. This is exemplified in the study by the American archaeologist J.R. Clark of the coinage of the Roman period from the site of Dura Europus in Syria. He examined a sample of 10,712 coins found there. These had been minted at 16 different Greek cities in the Near East, and by dividing the coins into four time periods he was able to show how Dura's commercial links with other cities had changed during the period 27 BC–AD 256, with an expansion of trade in the period up to AD 180, and a sharp decrease in the period AD 180–256.

In general, however, the exchange data in themselves are insufficient to document the functioning of the entire exchange system. It is necessary, then, to think of alternative models for describing the system, as advocated in Chapter 12. The use of such hypothetical models is entirely appropriate provided that the distinction between what has been documented and what is hypothesized is kept clearly in view.

A good example is the Danish archaeologist Lotte Hedeager's study of the "buffer zone" in northern Europe between the frontiers of the Roman empire and the more remote lands of "Free Germany." She drew on literary and philological sources as well as archaeological ones to construct a hypothetical view of the whole system (see illus. p. 380).

Trade as a Cause of Cultural Change

The possible role of trade in the development of a nation state or an empire from the trade interaction of smaller, initially independent units is seen in the illustration p. 381. The city states or other independent units (early state modules, ESMs) trade both at local level and through their capital centers. There are



Lotte Hedeager studied the exchange system between the Roman empire and "Free Germany." Using archaeological, literary, and philological sources, she concluded that Roman-Germanic trade incorporated three economic systems: (1) the Roman empire, with money and market economy; (2) a "buffer zone," extending c. 200 km (120 miles) beyond the frontier, which lacked independent coinage but maintained a limited money economy, perhaps including markets; and (3) Free Germany, with a moneyless and marketless economy, or perhaps with moneyless markets. Archaeological evidence indicated that the Germanic tribes mainly imported Roman luxury articles (bronze and glass; gold and silver in the form of coins) as prestige items (see Chapter 10). Philological and other evidence suggested that in exchange the Romans imported useful commodities such as soap, hides, wagons, and clothing.

circumstances when these flows of goods can lay the basis for a larger economic unification.

This notion is related to that of the "world system" of Immanuel Wallerstein (see above), which some archaeologists have sought to apply to the pre-capitalist world in a manner that Wallerstein himself did not propose. But there are dangers here of definition being mistaken for explanation. To propose that certain areas were united in an economic "world system" does not of itself prove anything, and it may easily lead the analyst to exaggerate the effects of quite modest trading links. For it readily casts the discussion in terms of dominance (for the supposed core area) and dependency (for the supposed periphery). Indeed, it can easily lead to the rather unthinking explanation of changes by "dominance" (i.e. diffusion) that processual archaeology has worked hard to overcome.

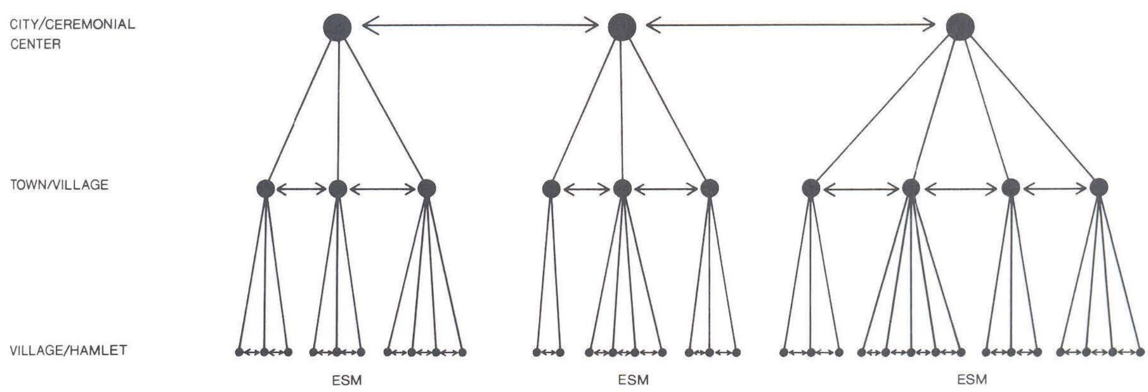
If exchange systems are to have a central role in explanation, then the model needs to be framed explicitly, and it should show the role of exchange within the system as a whole, and the relationship between the flow of goods and the exercise of power within the system. One good example of such a model is the one offered by Susan Frankenstein and Michael Rowlands for the transition toward a highly ranked society in Early Iron Age France and Germany. They argued that it was the control of the supply of prestige goods from the Mediterranean world exercised by the local chiefs that allowed these individuals to enhance their status. They did so both by using and displaying the finest of these valuables themselves (the use including burial in princely graves, recovered by the archaeologist) and in allocating some of them to their followers. The transition to more prominent ranking was in large measure produced by control of the exchange network by the elite. William L. Rathje has presented a comparable model for the rise of a prominent elite in the Maya lowlands, and hence for the emergence of Classic Maya civilization.

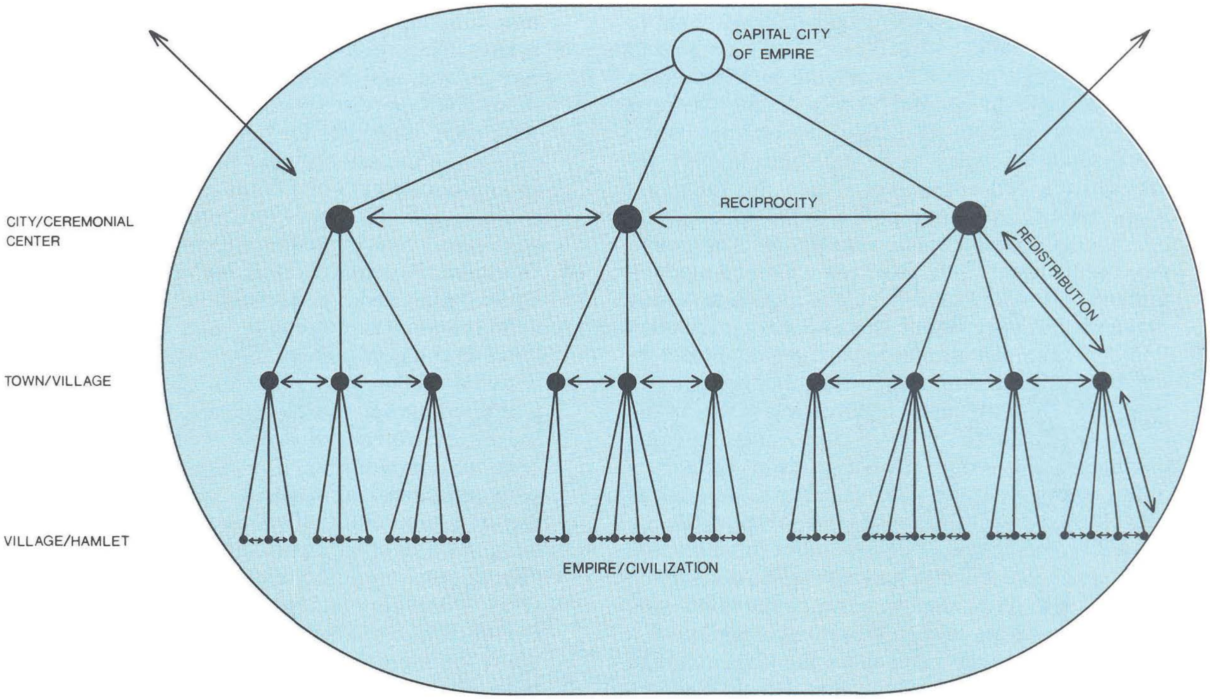
These are models put forward to explain change in the cultural system, and a discussion of their implications belongs in Chapter 12, where the nature of explanation in archaeology is considered. It is appropriate to mention them here, however, as external trade and exchange play integral parts in many explanations proposed for cultural change.

Symbolic Exchange and Interaction

At the beginning of this chapter it was stressed that interaction involves the exchange not only of material goods but of information, which includes ideas, symbols, inventions, aspirations, and values. Modern archaeology has learnt to cope tolerably well with material exchanges, using characterization studies and spatial analyses, but it has been less effective with symbolic aspects of interaction.

As noted above and as further reviewed in Chapter 12, there has been a tendency to label interactions between neighboring areas as simply "diffusion," with one area dominant over another. One response to such dominance models is to think in terms of autonomy: of complete independence of one area from another. But it seems unrealistic to exclude the possibility of





Trade and the development of an empire. (Top) Individual city states or other independent units (early state modules, ESMs) trade both at the local level, within each ESM, and at the higher level through their capital centers. (Above) In certain circumstances these higher-level interactions can lead to the integration of the ESMs within a larger-scale unit, the empire or civilization-state.

significant interactions. The alternative solution is to seek ways of analyzing interactions, including their symbolic components, that do not assume dominance and subordination, core and periphery, but consider different areas as on a more or less equal footing. When discussing such interactions between polities (independent societies) of equal status – known as *peer polities* – it has been found useful to speak of *interaction spheres*, a term first applied to the interaction sphere of the Hopewell people of the eastern United States (see box, opposite) by the late Joseph Caldwell.

Peer-polity interaction takes many forms, some of which have been distinguished:

1 *Competition.* Neighboring areas compete with one another in various ways, judging their own success against that of their neighbors. This often takes a symbolic form in periodic meetings at some major ceremonial centers where representatives of the various areas meet, celebrate ritual, and sometimes compete in games and other enterprises. Such behavior is seen among hunter-gatherer bands, which meet periodically in larger units (at what in Australia are called *corroborees*). It is seen also in the pilgrimages and rituals of state societies, most conspicuously in ancient Greece at the Olympic Games and the other Panhellenic assemblies, when representatives of all the city states would meet.

2 *Competitive emulation.* Related to the foregoing is the tendency for one polity to try to outdo its neighbors in conspicuous consumption. The expensive public feasts of the Northwest Coast American Indians – the institution of the potlatch – was noted earlier. Very similar in some ways is the erection of magnificent monuments at regional ceremonial centers, each outdoing its neighbor in scale and grandeur. One can suspect something of this in the ceremonial centers of Maya cities, and the same phenomenon is seen in the magnificent cathedrals in the capital cities of medieval Europe. The same is also true for the temples of the Greek city states.

   A more subtle effect of this kind of interaction is that, although these monuments seek to outdo each other, they end up doing so in much the same way. These different polities in a particular region, at a particular period, come to share the same mode of expression, without its being exactly clear where the precise form originates. Thus it is that in a certain sense all Maya ceremonial centers look the same, just as all Greek temples of the 6th century BC look the same. At a detailed level they are very different, of course, but they undeniably share a common form of expression. This is usually a product of peer-polity interaction: in most cases, one need not postulate a single innovatory core center, to which other areas are peripheral.

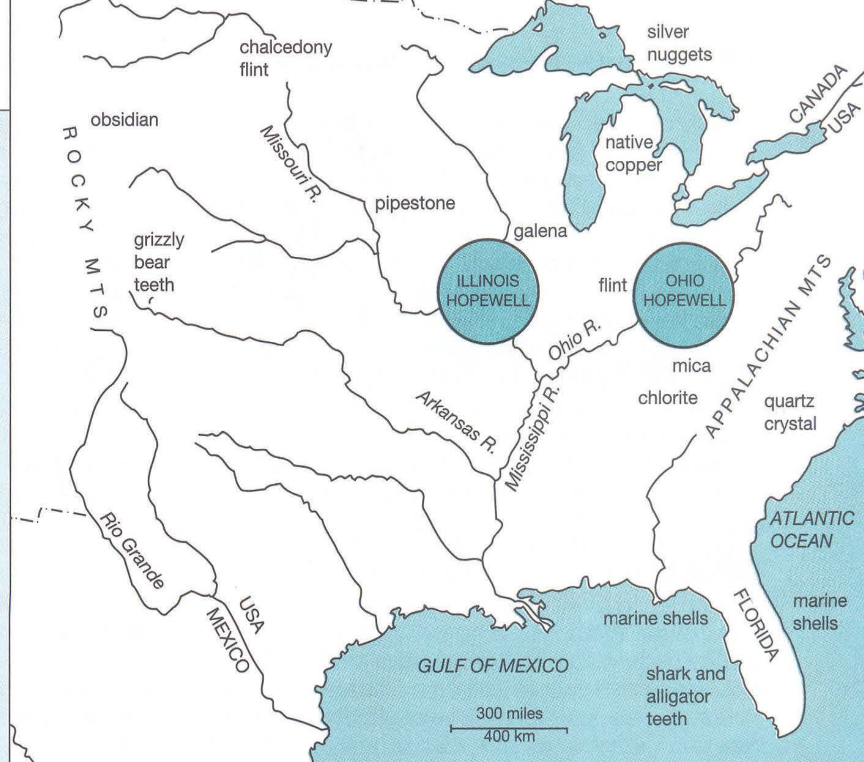
3 *Warfare.* Warfare is, of course, an obvious form of competition. But the object of the competition is not necessarily to gain territory. In Chapter 5 we saw that it might also be used to capture prisoners for sacrifice. It operated under well-understood rules, and was as much a form of interaction as the others listed here.

4 *Transmission of innovation.* Naturally a technical advance made in one area will soon spread to other areas. Most interaction spheres participate in a developing technology, to which all the local centers, the peer polities, make their own contributions.

5 *Symbolic entrainment.* Within a given interaction sphere, there is a tendency for the symbolic systems in use to converge. For instance, the iconography of the prevailing religion has much in common from center to center. Indeed, so does the form of the religion itself: each center may have its own patron deities, but the deities of the different centers somehow function together within a coherent religious system. Thus, in the early Near East, each city state had its own patron deity, and the different deities themselves were sometimes believed to go to war with each other. But the deities were conceived as inhabiting the same divine world, just as mortals occupied different areas of the everyday world. The same comments may be made for the civilizations of Mesoamerica, or ancient Greece.

6 *Ceremonial exchange of valuables.* Although we have emphasized non-material (i.e. symbolic) interactions here, it is certainly the case that between the elites of the peer polities there was also a series of material exchanges, including the kinds already described earlier in this chapter – the transfer of marriage partners and of valuable gifts.

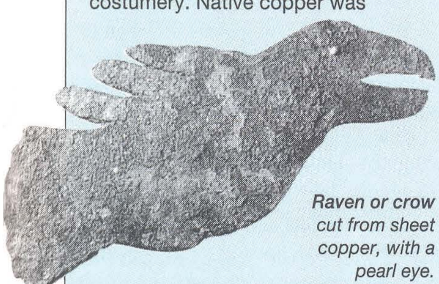
7 *Flow of commodities.* The large-scale exchanges between participating polities of everyday commodities should not, of course, be overlooked. The economies in some cases became linked together. This is precisely what Wallerstein intended by his term "world system." However, it should be noted that in this case there need be no core and periphery, as there is in Wallerstein's colonial case of the 16th century AD, or indeed as there was in the ancient empires. Those, too, are valid cases, but although it is frequently appropriate both to the colonial world and to the ancient empires, these dominance relations should not be made a paradigm for the whole study of interactions in early societies.



INTERACTION SPHERES: HOPEWELL

Among many societies the exchange of valuables far outweighed in importance the exchange of ordinary commodities. Few commodities moved between regions because each region was relatively self-sufficient and bulky goods were hard to transport. One interaction sphere, the Hopewell, operated on a very large scale in what is now the eastern United States during the first two centuries AD.

A number of regions participated in the exchange of valuables, two of which were more central in this exchange – the Scioto region of the Upper Ohio valley and the Havana region of Illinois. Items of marine shell, shark teeth, mica, and other rocks and minerals came from the south; objects of native copper, silver, and pipestone came from the north. Several flints from different regions were commonly used in exchange, and obsidian was obtained far to the west in Wyoming. These materials were made into highly distinctive objects for ritual and costumery. Native copper was



***Raven or crow** cut from sheet copper, with a pearl eye. Length 38 cm.*

hammered into various shapes, including axe and adze heads, large breastplates, headdresses, bicymbal earspools, and jackets for pan pipes. Sheets of mica were cut into geometric figures and naturalistic outlines. Flints, obsidian, and quartz crystal were chipped into large bifaces. Marine shells were made into large cups and beads. Soft carvable stone was used to create distinctively styled pipes for smoking.

The widespread exchange of prestige goods was accompanied by a symbolic system that was adopted in each of the independent regions. Locally made items, including pottery, ornaments, and ritually significant items, conformed to the pan-regional style. Exchange goods were consumed in patterns of mortuary treatment and destruction by fire that are remarkably similar from one region to another. Thus, in a commonality of artifact form and consumptive pattern a veneer of cultural unity was created over the entire interaction area where none had existed before. Nevertheless, at the material level there were significant regional variations. The largest and richest burials are found where the most impressive earthworks were erected. Those in south-central Ohio are the largest and richest of all.

The American archaeologist David Braun has spoken of peer-polity interaction within the Hopewell sphere (while emphasizing that these were relatively simple societies, not states), and has pointed out that competitive emulation and symbolic entrainment may be observed in Hopewell as in the case of other comparable interaction spheres.

***Mica ornament** in the shape of a human face, found in Ohio.*

8 *Language and ethnicity*. The most effective mode of interaction is a common language. This point is an obvious one, but it is often not explicitly stated by archaeologists. The development of a shared language, even when initially there was greater linguistic diversity, is one of the features that may be associated with peer-polity interaction. The development of a common ethnicity, and explicit awareness of being one people, is often related to linguistic factors. But archaeologists are only slowly coming to recognize that ethnicity is not something that always existed in the past: rather it came about over time as a result of interactions, which ethnicity itself further influenced.

Such concepts, where as much emphasis is laid on symbolic aspects as on the physical exchange of material goods, can profitably be used to analyze interactions in most early societies and cultures. Systematic analysis of this kind has, however, so far been rare in archaeology.

In Chapter 12, where similar issues are raised in the context of a discussion of explanation in archaeology, it is argued that a new synthesis in archaeological method is emerging, which one may term cognitive-processual archaeology (see p. 491). The analysis of interactions, including those of a symbolic nature, will have a significant role among the methods of that new synthesis.

SUMMARY

The study of exchange has been a growth area in modern archaeology. Scientific techniques of characterization – primarily microscopic examination of thin sections, trace-element analysis, and isotope analysis – now allow us to identify the distinctive characteristics of many materials, such as pottery, stone, and certain metals. Where the sources of raw materials in nature have likewise been identified – as for obsidian – one can then successfully plot on a map the distribution of such materials from source to archaeological findspot. Using techniques of spatial analysis (trend-surface analysis; fall-off analysis), the researcher goes on to investigate this exchange network further. Greater understanding of the network comes from studies of production (mines, quarries, craft workshops) and consumption, leading to as full a reconstruction of the complete exchange system as is possible without the benefit of written records.

Interpretation of exchange systems requires consideration of what the likely mechanism may have been: whether reciprocal exchange, redistribution, or market exchange. Nor should one forget that societies exchanged ideas and other information as well as material goods within a complete interaction sphere.

FURTHER READING

The following works provide a good introduction to the methods and approaches used by archaeologists in the study of trade and exchange:

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