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STUDIES IN ANCIENT MESOAMERICA, III

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OBSIDIAN DISTRIBUTION AND PROVENIENCE IN THE CENTRAL HIGHLANDS AND COAST OF PERU DURING THE PRECERAMIC PERIOD

Richard L. Burger and Frank Asaro

Introduction

High quality obsidian combines the qualities of chipping predictability and the sharpest known edge of any material. These features were known to the ancient inhabitants of the Old and New World who sought to gain direct access to obsidian or to acquire it indirectly through exchange. However, obsidian suitable for the production of projectile points and other fine edged tools, occurs only in rare instances of volcanic activity when magma of the requisite silica content and acidity cools rapidly enough to prevent the formation of crystals, but not so rapidly as to trap the volcanic gasses. The prime quality obsidian, born of the convergence of these complex factors of igneous tectonics, begins to decline in value as soon as its genesis is completed, due to its absorbtion of water and consequent devetrification. Thus the kind of obsidian valued for tools is often scarce in regions with a history of vulcanism and it is absent elsewhere. Other raw materials, such as basalt, chert, or quartzite, are more commonly encountered in the geological record and provide a convenient alternative for the toolmaker. Moreover, these other materials are harder and less brittle than obsidian.

For most ancient communities, the procurement of obsidian represents an extra expenditure of time and energy over and above minimum subsistence needs. Thus it is not surprising to find that obsidian use in most areas fluctuates throughout prehistory along with changes in political, social, and economic organization.

This article will discuss the patterns of obsidian exploitation in the Central Highlands and adjacent coast of Peru during the time period of approximately 10,000 B.C. to 2,000 B.C., that period preceding the introduction of ceramics. The domestication of the major Andean plants and animals and their spread into new ecological zones occurred during this time period. The diffusion of domesticated crops from valley to valley, and from the highlands to the coast implies extra-local communication and movement at a time when populations were small and societies were relatively simple. It has been hypothesized (Lynch 1971; 1973) that the hunting and gathering regimen of pre-agricultural highland populations included transhumance, a system of subsistence scheduling by which groups move from one ecological zone to another in accordance with seasonal climatic fluctuations and concurrent availability of resources. Such a model would partially explain the mechanism by which long distance and inter-zonal contacts were first established. However, recent research on the coastal lomas (Quilter, personal communication) and highlands (Rick, personal communication) does not support the model of preceramic transhumance. An alternative or complementary model for early contacts, is that inter-regional and inter-zonal travel occurred to procure raw materials. This article will deal only with obsidian, but other trade materials, such as salt, would create the same need to to beyond local boundaries; unfortunately, many of these other items are harder to detect in the archaeological record, and cannot be traced with the same precision.

Obsidian distribution at preceramic sites in central Peru [1]

Obsidian was commonly used during preceramic times to produce tools in the central highland area from Juaja-Huancayo to Ayacucho. The work of the Ayacucho Archaeological Botanical Project indicates that obsidian was used in a large number of preceramic sites in all of the defined micro-environments: dry thorn forest, tundra, desert, and humid scrub forest (MacNeish, personal communication). Importation of obsidian and manufacture of obsidian tools was already underway by 10,000 B.C. and continued throughout the Preceramic.

D. Browman, in his survey of archaeological sites in the Jauja-Huancayo area, found that the preceramic population of that area frequently used obsidian for projectile points during the middle and late Preceramic (Browman 1970: 89; MacNeish et al. 1975: 20).

The highlands north of the Huancayo-Jauja have recently been studied by the Proyecto de Investigaciones Arqueologicas Junin. A summary of their preliminary findings asserts that obsidian first appears in that area in the late Preceramic and even at this late date it is scarce. Obsidian is far less popular in this area than chalcedony, basalt or quartzite (Matos 1975: 55). Obsidian appeared in small quantities in the late Preceramic layers of Uchcumachay, in excavations directed by P. Kaulicke and R. Matos (Wheeler Pierres-Ferreira et al. 1976). At least one obsidian flake was recovered from levels tentatively cross-dated to the Piki/Jaywa phases of the Ayacucho sequence (Kaulicke, personal communication).

Sixty kilometers further north, John Rick excavated at the site of Pachamachay, near Lake Junin. In the preceramic layers he found no obsidian tools, and out of approximately six million flakes, only one was obsidian (Rick, personal communication).

This picture of obsidian scarcity in the highlands north of Jauja is supported by the research of Danielle Lavallee in the San Pedro de Cajas area. San Pedro de Cajas is located about 35 kms southeast of Pachamachay. In the excavations of preceramic components at four different sites, none of the artifacts were made from obsidian (Levallee and Julien 1975: 109). Further to the north, in the Huanuco drainage, teams from the University of Tokyo excavated extensive late preceramic deposits of the late Preceramic Mito culture at the sites of Kotosh and Shillacoto. No obsidian artifacts were found among the numerous lithics (Izumi and Sono 1963; Izumi and Terrada 1972; Izumi, Cuwliza, and Kano 1972). In the same area, Ravines discovered an earlier site, Ambo, at which he collected tools stylistically resembling middle Preceramic artifacts from Lauricocha and other sites. The artifacts are made of crypto-crystaline quartz; no mention is made of any obsidian (Ravines 1965). Further west in the puna zone, Cardich investigated preceramic remains at Ranracancha and Lauricocha. Apparently, no obsidian was used at these sites in the Preceramic (Cardich 1964; 1973).

The northernmost highland preceramic site for which there is good information is Quichqui Puncu in the Callejon de Huaylas (Lynch 1970). The site was occupied for the first time at approximately 7000 B.C. but abundant early ceramics were found mixed with the Preceramic materials (ibid.: 99). Less than a dozen flakes of obsidian were found there and no obsidian points or other tools were encountered (ibid.: 19). It is not clear whether or not the scarce obsidian predates the introduction of ceramics at Quichqui Puncu.

To the west of Huancayo, on the upper slopes of the Cordillera Occidental, T. Patterson and his students surveyed archaeological sites in the Huarochiri area. According to a recent summary, obsidian was used there at the end of the early Preceramic continuing in middle Preceramic and intensifying in the late Preceramic (MacNeish, et al. 1975)

Unfortunately, the sample of highland preceramic sites in the current archaeological literature, reaches only 20 kms. south of the city of Ayacucho (Ac351) and no information is available about the early occupations of the neighboring regions to the south, such as Andahuaylas or Abancay. Moreover, we are unaware of detailed published information on preceramic sites in the highlands west of the Ayacucho region (eg. Castrovirreyna). One exception to this vacuum of knowledge are the lithic scatters on the Pampas Galeras to the southwest of Ayacucho (Province of Ayacucho, Department of Ica). These assemblages, rich in obsidian artifacts, appear to be the products of hunting activities which, judging from the style of the projectile points, began during preceramic times (M. Neira, personal communication). A systematic survey of these materials has yet to appear, although several surface collections have been made.

Piecing together the fragmentary bits of information ennumerated here, a pattern of central highland obsidian distribution can be inferred and presented as a working hypothesis. The area of extensive obsidian use is the Huancayo/Ayacucho region and adjacent highland areas to the west. The neighboring southern region is not included due to the absence of investigation there. In the more northernly highland areas (northern Junin and beyond), obsidian plays a negligible role, appearing sporadically as an exotic material.

Obsidian has also been found at preceramic sites on the coast of Peru, particularly to the west and southwest of the highland region where obsidian was commonly used. At the preceramic shellmound of San Nicolas, located on the bay of the same name in the Province of Nasca, W. Strong discovered abundant obsidian flakes and an obsidian "flake knife" (Strong 1957: 10). While he was there he collected more than 400 waste flakes of obsidian along with obsdian cores and nodules "representing workshop debris." Later investigations by Vescelius and Engel confirmed the prevalence of obsidian at the site, and revealed two points and a scraper made of obsidian (Vescelius 1963). The presence of cotton at the site suggests that it was probably late Preceramic in date (Bonavia and Ravines 1972).

Surveys by Engel and Lanning also discovered obsidian at the preceramic shellmounds of Casavilca, at the mouth of the Ica Valley (Engel 1957: 61-62; Lanning 1960: 50; 1963: 368) and at Mound 12 at Otuma, slightly south of the Paracas Peninsula (Engel 1957b: 57-61; Lanning 1960: 49; 1963: 368). Otuma and Casavilca "are characterized by an abundance of small projectile points, neatly pressure flaked and made of obsidian..." (Lanning 1967: 72). Obsidian points were also discovered in preceramic graves at Asia, a site located in the lower Asia-Omas Valley. At this site there is evidence that hunting was done with spear-throwers using darts tipped with obsidian, worked bone, wood, or chipped quartz crystal (Lanning 1960: 49; Engel 1963: 56, 99, 111). Otuma, Casavilca, and Asia also appear to date to the late Preceramic (Bonavia and Ravines 1972).

In the next drainage, that of Chilca, Engel and his collaborators have conducted large scale excavations at several preceramic sites. Recent work by a team from CIZA and the University of Missouri, directed by R. Benfer and F. Engel, concentrated its efforts at the lomas site of Paloma. A surface area of over 2,000 m^2 was opened by Engel and Benfer,[2] a figure which suggests the extensiveness of the sample. Only four obsidian flakes and one obsidian point were found in the excavations; an additional obsidian point fragment was collected from the surface. Lithics are rare at the Paloma site. The dating of these is not definitively resolved but the Paloma site seems to have been occupied during the middle Preceramic. Two of the Paloma flakes were found in early levels of the site (Quilter, personal communication). Engel also excavated at the nearby preceramic site of Chilca 1, from which he illustrates an obsidian point (1966: fig. 12).

In the adjacent Rimac Valley, Engel reports "small leaf shape projectile points of obsidian" from the lowest layers of the Chira/Villa site; these apparently have preceramic associations (Engel 1957: 62-65).

Further north on the coast, obsidian is not generally found at preceramic sites. For example, none appeared in the preceramic layers at Ancon (Ravines and Mulle 1972), nor at Aspero (Willey and Corbett 1954: 151). It was not found by Wendt at Rio Seco (Wendt 1976: 31-33).

Despite the considerable amount of research at preceramic complexes north of Lima, the only evidence of obsidian is a single unique obsidian projectile point found by P. Ossa at La Cumbre in the Moche Valley. This site contains typologically early artifacts such as Paijan points and a fish tail point, as well as extinct megafauna. It has yielded an early C14 measurement of 8585 ± 280 B. P. 4,892 tools and waste flakes were collected, of which the unique obsidian point constituted .02%. Most of the tools at La Cumbre were made of fine grained grano-diorite or basalt, and less frequently, chert. The obsidian projectile point is not related typologically to the other artifacts (Ossa, personal communication). Since there is no indication of a later occupation at La Cumbre, the stylistic distinctiveness of the obsidian point is best explained as the result of non-local manufacture. The rarity of obsidian and complete absence of obsidian debitage at

La Cumbre are consistent with this hypothesis.

The exceptional find of obsidian at La Cumbre can be compared to the isolated but statistically insignificant appearance of obsidian at Pachamachay, and the rare obsidian pieces from Paloma may be comparable in importance to the rare fragments of obsidian found at Uchcumachay, Junin. It is unfortunate that quantitative data are not available on the raw materials of lithics at the coastal sites investigated by Engel and Lanning. The impression given in the publications is that obsidian is frequently found on the coast south of Chilca. Absence of quantitative data prevents comparison of the intensity of obsidian use in the highlands and coast. Imprecise chronological controls on most coastal sites makes diachronic discussion difficult. The extant evidence for obsidian exploitation on the coast is drawn primarily from late Preceramic occupations, but this may partially reflect the bias which exists in the archaeological literature. [3]

The sources of preceramic obsidian

Lanning, in 1967, speculated that obsidian found on the early sites of the south and south central coast had been imported from the southern highlands (1967: 72). R. Ravines later discovered an obsidian flow in the barren heights of San Genaro, Huancavelica (Petersen 1970: 50). This source, located near the snow line, is strategically located, being near the headwaters of the Pisco, Mantaro, and Pampas drainages. These river valleys provide natural routes of transportation of the obsidian to coastal and highland areas. Ravines speculated that this mine could be the source of the obsidian artifacts encountered on the coast and highlands.

Subsequently, the Ayacucho Archaeological Botanical Project located another natural obsidian deposit near Tukumachay, to the south of the city of Ayacucho. Although the samples recovered were of low quality obsidian, the possibility remained that there exists, or existed, a better outcrop of the same geological deposit which could have served as a source for early tool makers of Ayacucho and neighboring regions.

The source of obsidian artifacts can be determined by matching the trace element composition of source samples with the same measurements for the artifacts in question. The underlying assumptions of the technique are that 1) each source of obsidian has a unique, and therefore, diagnostic trace element composition; and 2) the trace element composition of a single source is relatively homogeneous. These assumptions have been rigorously tested and generally confirmed, with the amendation that in exceptional cases, homogeneity does not occur. However, the variation which does occur in the trace element composition of rare sources is patterned, and therefore recognizable, and equally diagnostic of the source (Bowman, Asaro, and Perlman 1973). Moreover, archaeological obsidian is usually more chemically homogeneous than the flow itself because only selected parts of most deposits were mined in antiquity. Since coincidental similarities do exist in the amounts of some trace elements in any two flows, the provenience analysis is most convincing when a large number of trace elements are measured. Since low precision measurements blur the compositional differences between different types of obsidian, a high level of measurement precision is desirable. When low precision techniques are used on a small number of trace elements, the result may be failure to distinguish between different sources.

In 1973, Burger began work on the trace element analysis of Andean obsidian using a method of rapid scan X ray fluorescence at the Department of Geology, University of California, Berkeley. This technique had been applied earlier to Mesoamerican and Californian obsidians (eg. Jack and Heizer 1968; Jack and Carmichael 1969). The technique provides semi-quantitative measurements for Sr. Rb, and Zr. This procedure proved inadequate in destinguishing between the different types of Peruvian obsidian (Burger and Asaro, in press). It was therefore decided to apply a technique which provided quantitative measurements for a larger number of trace elements. This goal led to the collaboration of the authors at the Lawrence Radiation Berkeley Laboratory.

The first step was to subject the two sets of source samples and a selected group of preceramic obsidian artifacts to a complete neutron activation analysis. This produced quantitative measurements for 26 trace elements. The analytical procedure is described elsewhere (Burger and Asaro, in press). The sample tested from the flow in Ayacucho (845 X) did not match any of the artifacts from preceramic or later archaeological sites. The three samples collected by Ravines from the Quispisisa mine, Huanacvelica (861 H, 861 J, and 861 K) had a homogeneous chemical composition which matched many of the archaeological samples tested from Ayacucho, the South Coast and other areas. It was demonstrated by neturon activation that ten samples from preceramic sites near Ayacucho, three samples from the preceramic site of San Nicolas (Nasca), and six samples from preceramic strata at Uchcumachay (Junin) came from the Quispisisa mine.

Many other samples were analyzed by neutron activation, including pieces from sites throughout Peru and northern Bolivia. An attempt was made to sample diachronically as well as geographically for each region (Burger and Asaro, in press). The neutron activation analysis of these samples initially characterized six of the most important sources of obsidian used in ancient Peru.

This work permitted us to design a method of X ray fluorescence which could successfully distinguish between these types of obsidian by providing quantitative measurements on the amounts of Ba, Ce, Rb, Sr, Zr and other trace elements. A detailed description of this procedure will soon be published (Burger and Asaro, in press). The X ray fluorescence technique has the advantage of being rapid, non-destructive, and inexpensive. Using this method, we analyzed a larger sample of obsidian artifacts in order to identify their sources. Any X ray fluorescence results which did not fit the established groupings were selected for further analysis by neutron activation. Through this process, we isolated a second type of obsidian used at preceramic sites in the Ayacucho area. The chemical composition of this type of obsidian differs from both the Quispisisa source material and the sample taken from the natural outcrop near Tukumachay, Ayacucho. This new type of obsidian must come from an unlocated flow. Since obsidian of this composition did not occur in our 1974/5 sample of over 900 pieces at archaeological sites outside of the Ayacucho area, we hypothesized that the obsidian source is in the Ayacucho region. We christened obsidian with this distinctive trace element composition as the Ayacucho Type obsidian, a term which will be replaced when the actual source of the obsidian is discovered.

More recent research (1977), in which an additional 90 obsidian samples were analyzed by X ray fluorescence, indicates that four of the five fragments tested from the Early Horizon site of Chupas, Ayacucho, are of the Ayacucho Type; the fifth fragment is from the Quispisisa mine. No obsidian artifacts tested from outside the Ayacucho area were of the Ayacucho Type. These new findings are in accord with the original hypothesis concerning the general source area of the Ayacucho Type obsidian.

In order to fully characterize the chemical composition of the Ayacucho Type obsidian, five samples were analyzed by neutron activation. These came from the sites of Puente (Ac158), Iomachay (Ac102), and Ac500. These results, as well as those for preceramic artifacts and source samples from the Quispisisa mine, are reproduced in Table 1. Also included in this table is the composition of a unique fragment found on the surface of Jaywamachay and that of the nonutilized outcrop near Tukumachay. The compositional differences between the Ayacucho Type obsidian and the obsidian from the Quispisisa source which are detected by X ray fluroescence are seen in Table 2. The provenience results of both the neutron activation and X ray fluroescence analysis for the preceramic artifacts tested are summarized in Tables 3 and 4.

The two types of obsidian just discussed constitute more than 99% of the materials of the preceramic artifacts tested. However, the single piece of obsidian recovered by Rick at Pachamachay in his preceramic layers is of a unique chemical composition. A second fragment, collected from the surface of Jaywamachay, has a different and equally rare composition. This sample may date to the Initial Period/Early Horizon occupation of the site. The occasional appearance of unique obsidians when large samples are tested is an interesting phenomenon which has received little attention in the literature. Such anomolies may be produced in the contact zones between the obsidian and the adjacent non-igneous geologic formations. Alternatively, they may come from igneous formations with small patches or inclusions of obsidian. Such flows might provide material for an occasional tool but not a reliable source for long-term tool production. A third alternative is that such rarities will prove to be long distance imports from unsampled regions. In the case of Pachamachay or Uchcumachay, the first two hypotheses are considered more probable than the latter.

Discussion

It has been shown that obsidian mined at two different natural deposits was used in central Peru during preceramic times and that the most popular source of obsidian was the Quispisisa quarry near Castrovirreyna, Huancavelica. This quarry was already being exploited by 10,000 B.C. and its obsidian transported to sites in Ayacucho, approximately 110 kms. to the east. Inportation of this obsidian apparently extended to highland areas in the northeast, more than 200 kms. from the Quispisisa quarry. The evidence for obsidian use in these regions has already been described. Although we have been unable to analyze preceramic artifacts from the Juaja-Huancyo area, obsidian from later occupations there have been shown to come from the Quispisisa source (Burger and Asaro, in press). The movement of Quispisisa obsidian to distant areas included the south and south central coast. Forty-nine samples tested from San Nicolas all were shown to be Quispisisa obsidian. The Quispisisa mine is located 270 kms. by air from San Nicolas. Also identified as Quispisisa obsidian were artifacts from Jaywamachay, Puente, Iomachay, Tukmachay, Ac500, Ac300, Pikimachay, Pampas Galeras, Uchcumachay, and La Cumbre (see Table 3).

Three alternative models can be presented to describe the mechanism by which Quispisisa obsidian reached preceramic archaeological sites outside the Castrovirreyna area. The first model is one of direct exploitation in which representatives of distant communities journey to the source area, mine the raw material themselves, and then return to their communities. A second model would be the existence of mobile non-specialized traders, possibly local pastoralists from near the mine, who would mine and transport the obsidian to the areas which utilized it. A third model would postulate multiple small exchanges from group to group as part of a larger exchange system, so that by the time the obsidian reached a distant site like La Cumbre, it would have passed through the hands of many communities. All three of these models have the advantage of not requiring complex economic organizations absent among small scale societies of hunter-gatherers, littoral collectors and fishermen, or incipient agriculturalists. Markets, ports of trade, self-sufficiency through archipellagos may have all played a role in trade in later times, but they are difficult to reconcile with the present understanding of the preceramic societies of Peru.

The first model, that of direct acquisition, could only function if there was unrestricted access to the source of obsidian. The neutrality and multi-ethnic exploitation of essential raw materials is a pattern which occurs in the Central Andes before and after the arrival of the Spaniards. For example, the salt deposits of the jungle and highlands were the destinations of long distance journeys by numerous outside groups (Conchas Contreras 1975: 74-76; Oberem 1974: 350). These groups arrived, camped, mined the salt, and then returned to their homes. Such trips are often so long that they imply some sort of trade and social contact during the journey, if only to procure food and drink and to avoid hostilities. Contact would have occurred even if these other groups do not play an active role in gaining the obsidian. For example, a trip to San Nicolas from the Quispisisa mine crosses numerous ecological boundaries and must have crossed many cultural boundaries as well. The trip to the mine and back must have taken over a month, if we use a figure of 15 to 20 kms per day as the average distance covered by a llama caravan (Flores 1968: 130). This is probably a very conservative estimate of trip length because it is based on distance by air rather than the actual distance than must be traversed along the winding paths of the convoluted central highlands. The trip from Chavin to Olleros, Ancash, for example, measures only 28 air kilometers, which would be a trip of two days using Flores' figure. But even the most fit resident cannot make the journey by foot in less than 14 hours; it would be even slower with cargo animals or humans carrying a heavy load. Thus, the time to reach the Quispisisa mine and to return to San Nicolas might actually take almost two months, especially if one includes several days for the mining activities. However, unlimited access to resources, even during the Preceramic, cannot be presumed. Recently Moseley has argued that jural rights over coastal resources began on the central Peruvian coast during the Preceramic (1975: 51-52).

The second model, that of long distance trading expeditions, is appealing since it is derived from the widespread tradition of lengthy trips by puna dwellers into the lower agricultural valleys of the sierra and coast in order to obtain products which cannot be produced within the puna environment. Such journeys are scheduled to coincide with the dry season when pastrues are reduced and the temperatures are the coldest on the puna. This same type of pattern may have existed even preceding the domestication of camelids since herds of wild camelids may have migrated naturally to lower zones in search of pasture. If this was the case, this model might apply to the early as well as the middle and late Preceramic.

In the second model the direction of movement would have been reversed, as compared with the first model. However, the overall result would have been quite similar: contact between peoples of different ecological zones and cultures, and the exchange of goods. Both systems would be capable of providing dependable supplies of quantities of obsidian. Either model would have been adequate to supply the inhabitants of San Nicolas, Otuma, or Jaywamachay with the large quantities of obsidian that they needed for their tools.

The third model, one of multiple exchanges, would have had a different impact since only people in adjacent communities would have been brought into contact. This model best accounts for the rare occurrence of obsidian in distant areas such as the North Coast. It may also apply to nearer areas, on the outer edge of the obsidian utilization sphere, such as northern Junin (Uchcumachay) or the area around Lima (Paloma).

Ayacucho Type obsidian has only been found at preceramic sites in the Ayacucho area, where it made up 12% of the preceramic artifacts tested. The earliest concrete evidence of its use is from Puente (Ac158), from a "zone" with an estimated age of 7100 B.C. Obsidian of this type was was found in later preceramic layers at Puente, Ac500, and Iomachay (Ac102). Its use apparently continued throughout the preceramic, Early Horizon, and possibly Early Intermediate Period. A relatively local source for this obsidian was hypothesized because of its apparent absence from archaeological sites elsewhere. Such an explanation, however, does not account for the greater popularity of the Quispisisa source obsidian at preceramic sites in Ayacucho (87% of the sample). Perhaps this unlocated source will be found in some of the yet unsampled and somewhat distant areas of Ayacucho, such as the Provinces of Cangallo or Victor Fajardo. Other considerations might include differences in the quality of the two obsidians or more limited access to the Ayacucho Type source as the result of jural restrictions. If the Ayacucho Type source is local or semi-local, it could have been distributed by either direct exploitation or by exchange.

During the Peruvian Preceramic, society underwent major social and economic transformations, and one would expect that the use and distribution of obsidian would reflect these radical changes. It may be, for example, that small quantities of obsidian reached the coast in early preceramic times through multiple exchanges, but its use intensified in late Preceramic times, at which time it was procured through mining expeditions or through trade with the members of pastoral caravans. The study of such diachronic shifts must await future archaeological investigation.

Conclusions

1. Long distance distribution of obsidian in the central highlands of Peru predates the advent of agriculture, and was underway by 10,000 B.C.

2. Direct contact between the coast and highlands is domonstrated by the presence of obsidian from the Quispisisa mine, over 4,600 meters above sea level, at preceramic sites on the south and south central coast. This situation existed by the late Preceramic (approximately 2500 B.C.) and probably earlier.

3. Journeys of one to two months were made during preceramic times in order to distribute Quispisisa obsidian to the coast and distant highland areas.

4. At least two obsidian flows were already being exploited in central Peru during the early Preceramic. One is the Quispisisa source near Castrovirreyna, Huancavelica and the other is an unlocated deposit probably in the Ayacucho region.

5. Beginning in the early Preceramic, small amounts of obsidian reached distant areas, up to 900 kms. away from the original source. This probably occurred through multiple exchanges.

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Footnotes

1. This article is confined to the Preceramic in central Peru because of the paucity of data for other regions. Work by M. Neira and others shows that obsidian is abundant at preceramic sites in Arequipa. Preliminary XRF results on samples from Sumbay, Arequipa and elsewhere indicate that neither Quispisisa nor Ayacucho Type obsidians were utilized.

2. Some of this work was begun by Engel and C.I.Z.A. before the collaboration of R. Benfer and the University of Missouri team.

3. At present, there is no adequate chronological framework for dealing with the Preceramic Period on a pan-Peruvian basis. The terms used in this paper are broad chronological divisions based on C14 measurements and the artifactual inventories of the sites. The coarseness of the divisions are appropriate to the vagaries of the current diachronic controls prior to the introduction of ceramics, and for this reason were preferred over the system utilized by Lanning and others. The terms used will be employed as follows:

	approx. absolute dates	Lanning (1967)
early Preceramic	? to 6000 B.C.	Preceramic I to III
middle Preceramic	6000 B.C. to 2500 B.C.	Preceramic IV to V
late Preceramic	2500 B.C. to 1800 B.C.	Preceramic VI

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Key to Figure 1

1. La Cumbre
2. Shillacoto
3. Kotosh
4. Ambo
5. Lauricocha
6. Ranracancha
7. Rio Seco
8. Aspero
9. Pachamachay
10. San Pedro de Cajas
11. Ushcumachay
12. Ancon
13. Huarochiri
14. Chiravilla
15. Huancayo preceramic sites
16. Chilca 1
17. Paloma
18. Asia
19. Quispisisa obsidian source
20. Ac 100 (Pikimachay); Ac 102 (Iomachay)
21. Ac 158 (Puente)
22. Ac 500, Ac 351 (Tukumachay)
23. Otuma
24. Pampas Galeras
25. Casavilca
26. San Nicolas

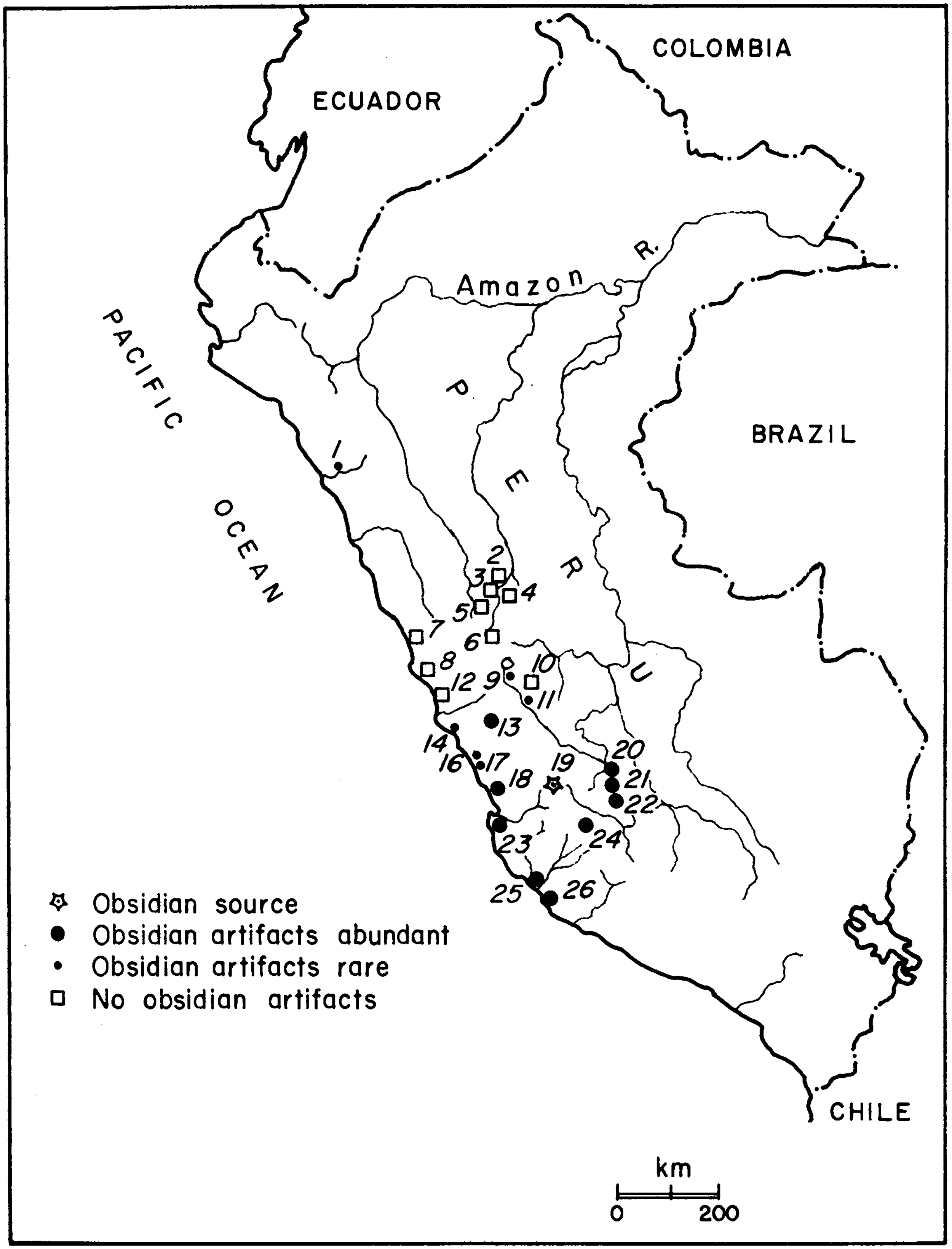

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Figure 1. Map of Peru indicating archaeological sites and geological deposits discussed in this article.

Table 1. Results of Neutron Activation Analysis

Element Abundances in Representative Peruvian Obsidians

(Values in ppm or percent if indicated by % after chemical symbol)

			Al%	Dy	Mn	Na%	K%	Sr
OBSIDIAN FROM QUISPISISA SOURCE								
SOURCE MATERIAL FROM QUISPISISA, HUANCAVELICA								
1	861 H	BURG-66	5.86 +/- .14	1.59 +/- .09	363 +/- 3	2.973 +/- .018	3.75 +/- .23	95 +/- 67
2	861 J	BURG-67	7.01 +/- .17	1.77 +/- .09	367 +/- 3	2.951 +/- .018	4.06 +/- .24	115 +/- 69
3	861 K	BURG-68	6.66 +/- .08	1.83 +/- .08	361 +/- 3	2.874 +/- .018	4.07 +/- .23	112 +/- 70
ARTIFACTS FROM SAN NICOLAS								
4	822 G	BURG-3	6.95 +/- .12	1.64 +/- .09	370 +/- 5	3.021 +/- .029	3.65 +/- .28	265 +/- 126
5	822 M	BURG-8	6.99 +/- .12	1.52 +/- .10	373 +/- 5	3.051 +/- .032	3.97 +/- .32	138 +/- 109
6	822 W	BURG-18	6.90 +/- .11	1.80 +/- .09	369 +/- 4	2.952 +/- .031	4.26 +/- .37	132 +/- 95
ARTIFACTS FROM JAYWAMACHAY								
7	861 R	BURG-74	6.96 +/- .18	1.69 +/- .08	366 +/- 3	2.897 +/- .018	3.88 +/- .23	130 +/- 62
8	871 J	BURG-92	6.86 +/- .20	1.69 +/- .09	359 +/- 2	3.000 +/- .018	3.78 +/- .22	149 +/- 68
9	890 O	BUR-129	7.06 +/- .16	1.70 +/- .09	364 +/- 3	2.652 +/- .017	4.45 +/- .23	102 +/- 72
10	890 P	BUR-130	7.08 +/- .20	1.82 +/- .10	364 +/- 3	2.859 +/- .018	4.32 +/- .23	9 +/- 75
11	893 F	BUR-108	6.97 +/- .14	1.84 +/- .08	360 +/- 2	2.709 +/- .017	4.01 +/- .22	96 +/- 68
12	893 G	BUR-109	6.80 +/- .16	1.68 +/- .09	364 +/- 3	3.011 +/- .018	4.00 +/- .22	110 +/- 71
13	893 H	BUR-110	6.45 +/- .21	1.63 +/- .09	358 +/- 3	2.905 +/- .018	3.67 +/- .21	239 +/- 74
ARTIFACTS FROM UCHCUMACHAY								
14	861 W	BURG-79	6.89 +/- .10	1.59 +/- .08	370 +/- 3	2.974 +/- .018	3.57 +/- .22	141 +/- 72
15	871 Z	BUR-106	6.94 +/- .21	1.71 +/- .09	358 +/- 3	3.005 +/- .018	3.66 +/- .22	140 +/- 72
16	890 E	BUR-120	5.97 +/- .12	1.77 +/- .08	365 +/- 2	3.037 +/- .018	3.67 +/- .22	56 +/- 63
17	890 G	BUR-123	5.88 +/- .16	1.67 +/- .08	363 +/- 2	3.037 +/- .018	3.64 +/- .22	110 +/- 66
18	890 U	BUR-135	6.71 +/- .17	1.59 +/- .10	363 +/- 3	2.992 +/- .018	4.14 +/- .22	111 +/- 73
19	893 D	BUR-115	5.93 +/- .14	1.55 +/- .09	365 +/- 3	2.990 +/- .018	3.77 +/- .22	95 +/- 72
ARTIFACT FROM IOMACHAY								
20	890 Q	BUR-131	6.73 +/- .08	1.68 +/- .08	363 +/- 3	2.577 +/- .016	4.76 +/- .23	160 +/- 65
ARTIFACT FROM PUENTE								
21	890 R	BUR-132	6.67 +/- .10	1.66 +/- .09	364 +/- 3	2.919 +/- .018	3.88 +/- .24	107 +/- 73
ARTIFACTS FROM AYACUCHO SITE AC300								
22	890 X	BUR-138	6.56 +/- .12	1.73 +/- .10	361 +/- 3	3.002 +/- .019	3.87 +/- .25	214 +/- 82
23	890 Z	BUR-140	5.90 +/- .17	1.64 +/- .09	363 +/- 3	2.344 +/- .015	5.06 +/- .22	237 +/- 72
AYACUCHO TYPE OBSIDIAN								
ARTIFACTS FROM IOMACHAY								
24	893 J	BUR-111	7.20 +/- .37	1.48 +/- .10	449 +/- 3	2.980 +/- .018	[illegible]	[illegible]
25	893 K	BUR-112	6.81 +/- .08	1.37 +/- .08	443 +/- 3	2.878 +/- .018	4.51 +/- .23	111 +/- 70
26	893 M	BUR-113	6.82 +/- .10	1.57 +/- .09	452 +/- 3	3.033 +/- .018	4.19 +/- .23	109 +/- 73
ARTIFACT FROM AYACUCHO SITE Ac 500								
27	893 N	BUR-114	6.97 +/- .12	1.34 +/- .09	453 +/- 3	3.414 +/- .020	3.78 +/- .23	38 +/- 76
ARTIFACT FROM PUENTE								
28	893 E	BUR-107	6.65 +/- .12	1.52 +/- .09	509 +/- 3	3.294 +/- .020	3.64 +/- .24	196 +/- 77
RARE TYPE 2 OBSIDIAN								
ARTIFACT FROM JAYWAMACHAY								
29	828 V	BURG-38	7.10 +/- .13	1.59 +/- .10	508 +/- 7	3.109 +/- .023	3.64 +/- .23	0 +/- 75
OBSIDIAN FROM AYACUCHO SOURCE (NEAR TUKUMACHAY)								
30	845 X	BURG-60	6.60 +/- .12	1.27 +/- .10	393 +/- 3	2.165 +/- .014	4.47 +/- .22	156 +/- 95

No.		Sample	As	U	Ba	Sm	La	Co
			OBSIDIAN FROM QUISPISISA SOURCE					
SOURCE MATERIAL FROM QUISPISISA, HUANCAVELICA								
1	861 H	BURG-66	13.7 +/- 1.8	8.376 +/- .102	689 +/- 22	2.382 +/- .015	26.88 +/- .92	.55 +/- .06
2	861 J	BURG-67	15.8 +/- 1.8	8.374 +/- .102	706 +/- 22	2.401 +/- .015	24.34 +/- .91	.53 +/- .06
3	861 K	BURG-68	13.9 +/- 1.8	8.269 +/- .101	675 +/- 22	2.402 +/- .015	26.21 +/- .92	.47 +/- .06
ARTIFACTS FROM SAN NICOLAS								
4	822 G	BURG-3	15.1 +/- 1.1	8.518 +/- .053	717 +/- 21	2.482 +/- .009	27.59 +/- .63	.61 +/- .05
5	822 M	BURG-8	14.5 +/- 1.1	8.374 +/- .052	731 +/- 21	2.440 +/- .009	26.89 +/- .62	.46 +/- .05
6	822 W	BURG-18	14.9 +/- 1.1	8.627 +/- .053	736 +/- 20	2.476 +/- .009	27.82 +/- .64	.48 +/- .05
ARTIFACTS FROM JAYWAMACHAY								
7	861 R	BURG-74	14.2 +/- 1.9	8.642 +/- .111	749 +/- 24	2.422 +/- .016	27.47 +/- .98	.40 +/- .06
8	871 J	BURG-92	17.3 +/- 1.7	8.879 +/- .072	748 +/- 19	2.520 +/- .013	28.05 +/- .80	.53 +/- .05
9	890 O	BUR-129	17.8 +/- 1.8	8.789 +/- .074	747 +/- 22	2.543 +/- .013	26.62 +/- .81	.56 +/- .06
10	890 P	BUR-130	1d.7 +/- 1.8	8.731 +/- .074	738 +/- 23	2.532 +/- .013	29.46 +/- .85	.54 +/- .06
11	893 F	BUR-108	15.2 +/- 1.4	8.723 +/- .062	737 +/- 21	2.479 +/- .010	26.49 +/- .70	.66 +/- .05
12	893 G	BUR-109	16.0 +/- 1.4	8.648 +/- .062	739 +/- 21	2.485 +/- .011	27.89 +/- .72	.65 +/- .05
13	893 H	BUR-110	15.6 +/- 1.4	8.642 +/- .062	750 +/- 21	2.477 +/- .011	28.23 +/- .71	.54 +/- .05
ARTIFACTS FROM UCHCUMACHAY								
14	861 W	BURG-79	15.4 +/- 2.0	8.627 +/- .111	696 +/- 23	2.420 +/- .016	26.33 +/- .99	.50 +/- .06
15	871 Z	BUR-106	19.7 +/- 2.0	8.753 +/- .069	749 +/- 18	2.522 +/- .013	28.79 +/- .82	.54 +/- .05
16	890 E	BUR-120	14.5 +/- 1.7	8.701 +/- .073	710 +/- 22	2.545 +/- .013	28.42 +/- .82	.69 +/- .06
17	890 G	BUR-123	17.0 +/- 1.8	8.741 +/- .073	730 +/- 23	2.513 +/- .013	27.66 +/- .83	.45 +/- .06
18	890 U	BUR-135	17.8 +/- 1.7	8.772 +/- .071	761 +/- 22	2.524 +/- .013	27.48 +/- .80	.47 +/- .06
19	893 O	BUR-115	15.6 +/- 1.4	8.729 +/- .063	774 +/- 20	2.484 +/- .011	26.44 +/- .71	.50 +/- .05
ARTIFACTS FROM IOMACHAY								
20	890 Q	BUR-131	14.7 +/- 1.6	8.797 +/- .071	748 +/- 21	2.525 +/- .012	27.10 +/- .79	.60 +/- .06
ARTIFACT FROM PUENTE								
21	890 R	BUR-132	d.6 +/- 6.0	8.649 +/- .101	686 +/- 19	2.528 +/- .025	26.75 +/-1.57	.56 +/- .07
ARTIFACTS FROM AYACUCHO SITE AC300								
22	890 X	BUR-138	16.2 +/- 1.9	8.956 +/- .077	735 +/- 23	2.585 +/- .015	28.63 +/- .91	.49 +/- .06
23	890 Z	BUR-140	14.4 +/- 1.6	8.884 +/- .072	743 +/- 21	2.546 +/- .013	27.76 +/- .78	.55 +/- .06
			AYACUCHO TYPE OBSIDIAN					
ARTIFACTS FROM IOMACHAY								
24	893 J	BUR-111	4.7 +/- 1.1	4.604 +/- .042	231 +/- 16	1.975 +/- .009	21.50 +/- .64	.20 +/- .04
25	893 K	BUR-112	3.0 +/- 1.1	4.663 +/- .042	259 +/- 16	1.956 +/- .009	22.54 +/- .64	.43 +/- .04
26	893 M	BUR-113	3.7 +/- 1.1	4.705 +/- .042	227 +/- 16	1.979 +/- .009	23.16 +/- .66	.28 +/- .04
ARTIFACT FROM AYACUCHO SITE Ac 500								
27	893 N	BUR-114	3.0 +/- 1.2	4.720 +/- .043	212 +/- 17	1.996 +/- .009	23.01 +/- .68	.26 +/- .04
ARTIFACT FROM PUENTE								
28	893 E	BUR-107	1.3 +/- 1.1	4.595 +/- .043	208 +/- 17	2.217 +/- .009	18.82 +/- .64	.48 +/- .05
			RARE TYPE 2 OBSIDIAN					
ARTIFACT FROM JAYWAMACHAY								
29	828 V	BURG-38	3.2 +/- 1.1	4.537 +/- .039	312 +/- 14	2.341 +/- .009	21.69 +/- .63	.19 +/- .03
			OBSIDIAN FROM AYACUCHO SOURCE (NEAR TUKUMACHAY)					
30	845 X	BURG-60	3.1 +/- 1.0	4.500 +/- .038	288 +/- 14	1.955 +/- .008	27.93 +/- .61	.16 +/- .03

			Sc	Fe%	Cs	Sb	Th
OBSIDIAN FROM QUISPISISA SOURCE							
SOURCE MATERIAL FROM QUISPISISA, HUANCAVELICA							
1	861 H	BURG-66	1.68 +/- .02	.55 +/- .02	11.55 +/- .31	1.25 +/- .14	20.93 +/- .18
2	861 J	BURG-67	1.47 +/- .02	.55 +/- .02	11.57 +/- .31	1.37 +/- .15	21.05 +/- .18
3	861 K	BURG-68	1.44 +/- .02	.55 +/- .02	11.64 +/- .31	1.38 +/- .15	20.96 +/- .18
ARTIFACTS FROM SAN NICOLAS							
4	822 G	BURG-3	1.52 +/- .02	.60 +/- .01	11.51 +/- .24	1.49 +/- .12	21.08 +/- .13
5	822 M	BURG-8	1.49 +/- .02	.57 +/- .01	11.27 +/- .23	1.24 +/- .11	20.87 +/- .13
6	822 W	BURG-18	1.50 +/- .02	.57 +/- .01	11.30 +/- .23	1.20 +/- .10	20.82 +/- .12
ARTIFACTS FROM JAYWAMACHAY							
7	861 R	BURG-74	1.51 +/- .02	.61 +/- .02	11.36 +/- .32	1.16 +/- .14	21.02 +/- .19
8	871 J	BURG-92	1.52 +/- .02	.58 +/- .02	10.96 +/- .23	1.45 +/- .15	21.26 +/- .18
9	890 D	BUR-129	1.52 +/- .02	.55 +/- .02	11.65 +/- .30	1.29 +/- .12	19.98 +/- .13
10	890 P	BUR-130	1.52 +/- .02	.58 +/- .02	11.74 +/- .30	1.22 +/- .12	20.08 +/- .13
11	893 F	BUR-108	1.55 +/- .02	.57 +/- .01	11.53 +/- .25	1.24 +/- .11	20.96 +/- .14
12	893 G	BUR-109	1.55 +/- .02	.59 +/- .01	11.24 +/- .25	1.30 +/- .12	20.74 +/- .14
13	893 H	BUR-110	1.53 +/- .02	.56 +/- .01	11.42 +/- .25	1.35 +/- .12	20.88 +/- .14
ARTIFACTS FROM UCHCUMACHAY							
14	861 W	BURG-79	1.48 +/- .02	.59 +/- .02	11.46 +/- .32	1.31 +/- .15	20.96 +/- .19
15	871 Z	BUR-106	1.51 +/- .02	.62 +/- .02	11.47 +/- .24	1.38 +/- .13	20.89 +/- .17
16	890 E	BUR-120	1.52 +/- .02	.57 +/- .02	11.61 +/- .29	1.35 +/- .12	19.86 +/- .13
17	890 G	BUR-123	1.51 +/- .02	.60 +/- .02	11.51 +/- .29	1.39 +/- .13	19.93 +/- .13
18	890 U	BUR-135	1.53 +/- .02	.56 +/- .01	11.33 +/- .27	1.15 +/- .11	20.00 +/- .13
19	893 D	BUR-115	1.50 +/- .02	.55 +/- .01	11.51 +/- .25	1.32 +/- .12	20.86 +/- .14
ARTIFACTS FROM IOMACHAY							
20	890 Q	BUR-131	1.47 +/- .02	.58 +/- .01	11.52 +/- .28	1.19 +/- .11	19.94 +/- .13
ARTIFACT FROM PUENTE							
21	890 R	BUR-132	1.49 +/- .02	.56 +/- .02	11.07 +/- .27	1.34 +/- .12	19.97 +/- .13
ARTIFACTS FROM AYACUCHO SITE AC300							
22	890 X	BUR-138	1.52 +/- .02	.56 +/- .02	11.29 +/- .28	1.30 +/- .13	19.91 +/- .13
23	890 Z	BUR-140	1.50 +/- .02	.56 +/- .01	11.28 +/- .27	1.22 +/- .11	20.00 +/- .13
AYACUCHO TYPE OBSIDIAN							
ARTIFACTS FROM IOMACHAY							
24	893 J	BUR-111	1.71 +/- .02	.51 +/- .01	4.07 +/- .12	.25 +/- .05	16.20 +/- .11
25	893 K	BUR-112	1.72 +/- .02	.48 +/- .01	3.86 +/- .12	.32 +/- .05	16.06 +/- .11
26	893 M	BUR-113	1.73 +/- .02	.49 +/- .01	4.00 +/- .12	.27 +/- .05	16.24 +/- .11
ARTIFACT FROM AYACUCHO SITE Ac 500							
27	893 N	BUR-114	1.72 +/- .02	.48 +/- .01	4.01 +/- .12	.24 +/- .05	16.62 +/- .12
ARTIFACT FROM PUENTE							
28	893 E	BUR-107	2.03 +/- .02	.49 +/- .01	3.89 +/- .13	.28 +/- .05	15.97 +/- .11
RARE TYPE 2 OBSIDIAN							
ARTIFACT FROM JAYWAMACHAY							
29	828 V	BURG-38	1.87 +/- .02	.54 +/- .02	3.80 +/- .11	.24 +/- .05	15.44 +/- .17
OBSIDIAN FROM AYACUCHO SOURCE (NEAR TUKUMACHAY)							
30	845 X	BURG-60	1.56 +/- .02	.48 +/- .01	4.89 +/- .13	.27 +/- .05	16.00 +/- .11

No.	Sample	ID	Eu	Ce	Hf	Ta	Yb
OBSIDIAN FROM QUISPISISA SOURCE							
SOURCE MATERIAL FROM QUISPISISA, HUANCAVELICA							
1	861 H	BURG-66	.422 +/- .009	52.48 +/- .81	3.39 +/- .08	1.104 +/-.008	1.129 +/- .028
2	861 J	BURG-67	.420 +/- .009	51.13 +/- .80	3.33 +/- .08	1.101 +/-.008	1.168 +/- .029
3	861 K	BURG-68	.415 +/- .009	50.77 +/- .80	3.31 +/- .08	1.098 +/-.008	1.121 +/- .028
ARTIFACTS FROM SAN NICOLAS							
4	822 G	BURG-3	.421 +/- .007	51.73 +/- .60	3.25 +/- .06	1.144 +/-.006	1.187 +/- .021
5	822 M	BURG-8	.424 +/- .007	52.32 +/- .61	3.39 +/- .06	1.134 +/-.006	1.156 +/- .021
6	822 W	BURG-18	.438 +/- .007	51.94 +/- .61	3.22 +/- .06	1.103 +/-.006	1.169 +/- .021
ARTIFACTS FROM JAYWAMACHAY							
7	861 R	BURG-74	.440 +/- .009	52.23 +/- .83	3.31 +/- .08	1.111 +/-.008	1.096 +/- .029
8	871 J	BURG-92	.442 +/- .008	51.06 +/- .81	3.27 +/- .08	1.124 +/-.007	1.144 +/- .030
9	890 D	BUR-129	.427 +/- .009	52.99 +/- .74	3.27 +/- .08	1.114 +/-.007	1.149 +/- .025
10	890 P	BUR-130	.431 +/- .009	53.26 +/- .74	3.32 +/- .08	1.122 +/-.007	1.154 +/- .025
11	893 F	BUR-108	.440 +/- .008	50.96 +/- .69	3.19 +/- .07	1.113 +/-.006	1.141 +/- .024
12	893 G	BUR-109	.416 +/- .008	51.05 +/- .68	3.30 +/- .07	1.104 +/-.006	1.156 +/- .024
13	893 H	BUR-110	.426 +/- .008	51.89 +/- .69	3.24 +/- .07	1.116 +/-.006	1.140 +/- .024
ARTIFACTS FROM UCHCUMACHAY							
14	861 W	BURG-79	.431 +/- .009	52.01 +/- .83	3.23 +/- .09	1.112 +/-.008	1.213 +/- .031
15	871 Z	BUR-106	.440 +/- .007	53.46 +/- .83	3.31 +/- .08	1.135 +/-.007	1.192 +/- .029
16	890·E	BUR-120	.434 +/- .009	52.78 +/- .73	3.20 +/- .08	1.117 +/-.007	1.170 +/- .025
17	890 G	BUR-123	.426 +/- .009	52.33 +/- .73	3.34 +/- .08	1.119 +/-.007	1.123 +/- .025
18	890 U	BUR-135	.445 +/- .009	51.53 +/- .71	3.20 +/- .08	1.098 +/-.007	1.118 +/- .025
19	893 D	BUR-115	.431 +/- .008	52.03 +/- .69	3.24 +/- .07	1.119 +/-.006	1.160 +/- .024
ARTIFACTS FROM IOMACHAY							
20	890 Q	BUR-131	.415 +/- .009	50.78 +/- .71	3.19 +/- .08	1.106 +/-.007	1.154 +/- .025
ARTIFACT FROM PUENTE							
21	890 R	BUR-132	.428 +/- .009	51.83 +/- .76	3.36 +/- .08	1.106 +/-.007	1.162 +/- .027
ARTIFACTS FROM AYACUCHO SITE AC300							
22	890 X	BUR-138	.417 +/- .010	52.92 +/- .81	3.28 +/- .09	1.121 +/-.008	1.135 +/- .028
23	890 Z	BUR-140	.436 +/- .009	51.58 +/- .72	3.28 +/- .08	1.114 +/-.007	1.176 +/- .025
AYACUCHO TYPE OBSIDIAN							
ARTIFACTS FROM IOMACHAY							
24	893 J	BUR-111	.287 +/- .006	40.49 +/- .59	3.79 +/- .07	1.770 +/-.008	.847 +/- .022
25	893 K	BUR-112	.291 +/- .006	40.73 +/- .59	3.84 +/- .07	1.781 +/-.008	.876 +/- .022
26	893 M	BUR-113	.300 +/- .006	40.97 +/- .60	3.67 +/- .07	1.780 +/-.008	.826 +/- .022
ARTIFACT FROM AYACUCHO SITE Ac 500							
27	893 N	BUR-114	.288 +/- .006	40.70 +/- .59	3.76 +/- .07	1.791 +/-.008	.815 +/- .023
ARTIFACT FROM PUENTE							
28	893 E	BUR-107	.332 +/- .007	38.96 +/- .58	3.85 +/- .07	1.951 +/-.009	.968 +/- .023
RARE TYPE 2 OBSIDIAN							
29	828 V	BURG-38	.344 +/- .006	42.92 +/- .82	3.86 +/- .09	1.936 +/-.011	.953 +/- .032
OBSIDIAN FROM AYACUCHO SOURCE (NEAR TUKUMACHAY)							
30	845 X	BURG-60	.307 +/- .006	46.25 +/- .60	3.71 +/- .07	1.641 +/-.007	.744 +/- .020

Table 2. Selected trace element composition of Andean obsidian: x-ray fluorescence analysis made at Lawrence Berkeley Laboratory (in parts-per-million)

obsidian type	Ba	Ce	Rb	Sr	Zr
Quispisisa	735	52	195	139	99
Ayacucho	220	43	138	56	85
Rare 9 (Pachamachay)	844	-	150	171	60

Table 3. Summary of source identifications of preceramic obsidian artifacts analyzed by neutron activation (NAA) and x-ray fluorescence (XRF)

Archaeological Site	Quispisisa Source	Ayacucho Type	Rare	Method
San Nicolas, Dept. Ica	49			NAA 3 XRF 46
Ac335, Dept. Ayacucho (Jaywamachay)	30		1	NAA 8 XRF 23
Ac158, Dept. Ayacucho (Puente)	9	3		NAA2 XRF 10
Ac351, Dept. Ayacucho (Tukumachay)	3			XRF 3
Ac500, Dept. Ayacucho	4	2		NAA 1 XRF 6
Ac300, Dept. Ayacucho	10			NAA 2 XRF 10
Ac100, Dept. Ayacucho (Pikimachay)	1			XRF 1
Pampas Galeras, Dept. Ica	5			XRF 5
Uchcumachay, Dept. Junin	8			NAA 6 XRF 2
Pachamachay, Dept. Junin			1	XRF 1
La Cumbre, Dept. La Libertad	1			XRF 1

Table 4. Analysis of obsidian from the excavations of the Ayacucho Archaeological-Botanical Project

Sites Sampled	Microenvironmental Zone*
Ac100 (Pikimachay)	dry thorn forest
Ac102 (Iomachay)	dry thorn forest
Ac158 (Puente)	desert
Ac300	tundra
Ac335 (Jaywamachay)	humid scrub forest
Ac351 (Tukumachay)	tundra
Ac500	humid scrub forest

Site	Zone	Phase*	Tentative dates*	Quispisisa Source	Ayacucho Type
Ac100	f-2	Puente	7000 BC	1	
Ac102	8	Puente	7300 BC	1	
	7	Jaywa	5600 BC	2	
	6	Chihua	3600 BC		3
Ac158	XIII	Puente	7100 BC		1
	XII	Puente	6900 BC		1
	XI	Jaywa	5900 BC	2	
	IX	Piki	5300 BC	1	
	VIII	Piki	5200 BC	1	
	VII	Piki	4900 BC	2	1
	VI	Piki	4720 BC	1	
	V	Piki	4520 BC	1	
	I	Chihua	4000 BC	1	
AC300	C-north	Jaywa	5500 BC	6	
	C-south	Chihua	3100 BC	4	
Ac335	M-N	Ayacucho	10000 BC	1	
	K		9020 BC	3	
	J-2	Huanta	7940 BC	3	
	I	Puente	7610 BC	2	
	H	Puente	7030 BC	2	
	G	Puente	6850 BC	2	
	F	Jaywa	6550 BC	5	
	E	Jaywa	6490 BC	1	
	D	Jaywa	6410 BC	5	
	C	Jaywa	6300 BC	4	
Ac351	C-2	Cachi	2500 BC	2	
	C-1	Cachi	1800 BC	1	
Ac500	F	Puente	7300 BC	2	
	E	Piki	4600 BC	1	
	D-1	Chihua	3000 BC	1	2

* data from MacNeish et al. 1970; and MacNeish, personal communication.