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FORMATIVE PERIOD OBSIDIAN EXCHANGE ALONG THE PACIFIC COAST OF MESOAMERICA*

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*Long-distance networks for the transport of exotic goods and the beginnings of specialized craft production first appear in Mesoamerica during the Formative Period. The results of portable X-ray fluorescence (pXRF) analysis of 456 obsidian artefacts imported to the Pacific coast site of La Zanja (Guerrero, Mexico) indicate that long-distance exchange of finished obsidian blades along the coast began during the Early Formative (*c.*1400–1000 cal* BC*) and remained constant into the Middle Formative Period (*c.*800–550 cal* BC*). Comparisons with sourcing studies from elsewhere in Mesoamerica indicate the development of a major Pacific coast trade network during the Formative Period that linked coastal Guerrero to the central Mexican highlands and the Valley of Oaxaca. Weaker connections existed with Gulf coast obsidian trade networks that traversed the Isthmus of Tehuantepec. As the first obsidian sourcing study from coastal Guerrero, these data contribute to a greater understanding of the development of exchange networks in Mesoamerica during the Formative Period.*

KEYWORDS: OBSIDIAN, PORTABLE XRF, FORMATIVE PERIOD, GUERRERO, MESOAMERICA, TRADE AND EXCHANGE

INTRODUCTION

The Pacific coast provided a natural pathway for the movement of people, ideas and specialized craft items, including finished obsidian blades, during the Formative Period in Mesoamerica. In this paper, we examine social and economic interactions between coastal and highland populations in Mesoamerica north of the Isthmus of Tehuantepec during the Early and Middle Formative Periods (*c*.1400–500 cal BC) based on obsidian source assignments of artefacts from La Zanja, an early agricultural village located along the Pacific coast of Guerrero, Mexico. Before the widespread adoption of obsidian blade technology (*c*.1500 cal BC), Mesoamericans largely produced simple, expedient flaked tools made from local materials (Boksenbaum *et al*. 1987; Clark 1987, 260). Communities on the Gulf coast and in Oaxaca imported low-quality obsidian from the Guadalupe Victoria source in the highlands of Puebla, Mexico during the Late Archaic and Early Formative Periods for percussion flake tool production (Cobean *et al*. 1971; Blomster and Glascock 2011, 29; Hirth *et al*. 2013). The percussion flake tradition was gradually supplanted by prismatic pressure blade technology during the Early and Middle Formative as more hierarchically organized groups developed along with an expansive trade in finished obsidian blades from multiple sources in the highlands of Mexico and Guatemala (Clark 1987; Awe and Healy 1994; Clark and Blake 1994; Blanton *et al*. 1999; Joyce 2010; Moholy-Nagy *et al*. 2013).

Two major obsidian trade networks developed during the Formative Period as complex socio-economic institutions were established throughout Mesoamerica. Gulf coast Olmec populations

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became connected with the Soconusco region along the Pacific via the Isthmus of Tehuantepec (Cobean *et al*. 1971). The presence of obsidian from Guatemalan sources at sites in the Soconusco, San Lorenzo and the Maya lowlands indicates long-distance networks that crossed the isthmus into southern Mesoamerica (Cobean *et al*. 1971; Hirth *et al*. 2013; Moholy-Nagy *et al*. 2013). Fragments of imported ceramics from San Lorenzo, identified using instrumental neutron activation analysis (INAA), have been found at some Pacific coast sites both north and south of the isthmus, suggesting that a wide variety of other craft items also moved along this route (Neff and Glascock 2002; Blomster *et al*. 2005; Neff *et al*. 2006; Gomez *et al*. 2011).

A second obsidian trade route extended across the central Mexican highlands and connected this region to coastal Guerrero and Oaxaca, with the Pacific coast acting a conduit supporting the movement of people, goods and ideas (Joyce 1991, 1993; Joyce *et al*. 1995; Niederberger 1996). Archaeological research at some sites in Guerrero (e.g., Teopantecuanitlán—Martinez Donjuan 1994; Niederberger 1996, 101) suggest that obsidian also travelled overland from central Mexico into the region, although no obsidian artefacts have been sourced geochemically. Potentially important sources of obsidian for inland and coastal sites in Guerrero included Otumba (Estado de Méxcio), Ucareo–Zinapecuaro (Michoacán), Paredon (Puebla), Pachuca (Hidalgo) and Zaragoza (Puebla) (Fig. 1; see also Niederberger 1996; Kennett *et al*. 2002). Identifying the specific sources of obsidian recovered at the site of La Zanja in coastal Guerrero serves as the

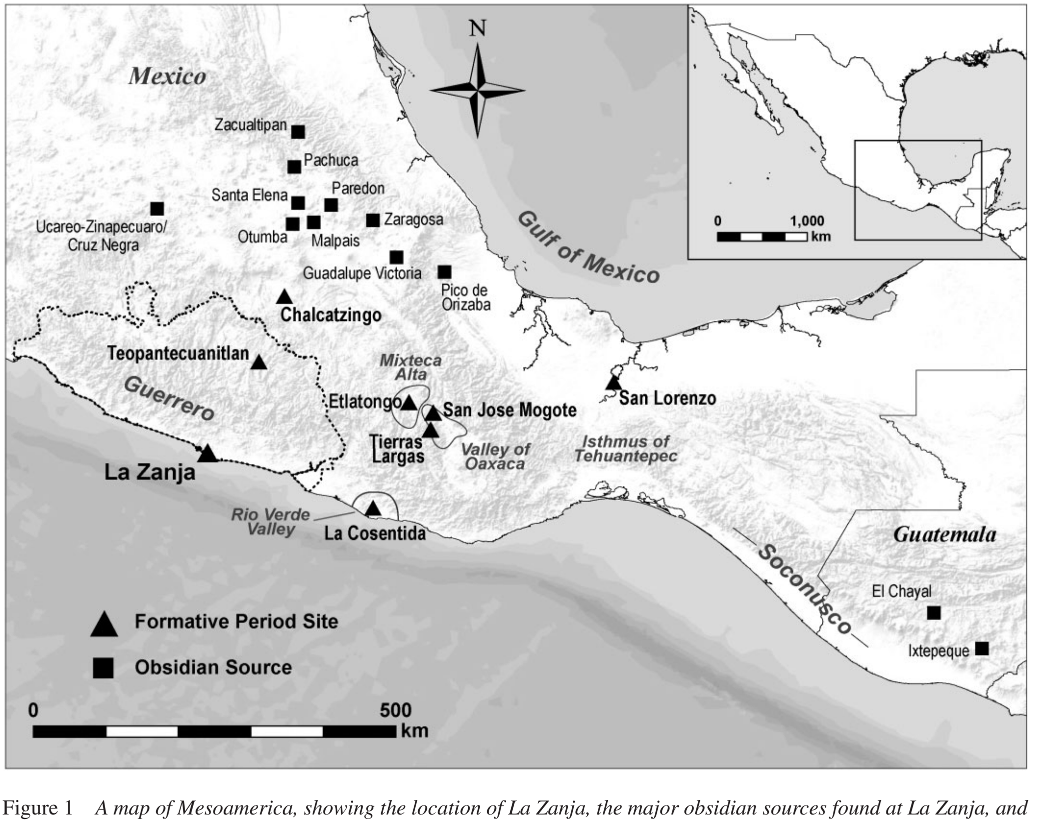

Figure 1 *A map of Mesoamerica, showing the location of La Zanja, the major obsidian sources found at La Zanja, and the Formative Period sites mentioned in the text.*

basis for interpretations of procurement, production, exchange and consumption of obsidian tools, and for inferring economic and social connections with other parts of Mesoamerica during the Formative Period.

In this study a total of 456 obsidian artefacts from the site of La Zanja were technologically analysed and geochemically sourced using portable X-ray fluorescence (pXRF) to examine how this early agricultural village articulated with developing Pacific coast trade networks in the Early and Middle Formative Periods. Geochemical sourcing data are compared to attribute analysis for obsidian artefacts to examine changes in technology (percussion flaking versus pressure blade production) over time. The results suggest that people at La Zanja engaged in low-level expedient obsidian flake-stone tool production, but relied primarily on prismatic blades manufactured elsewhere. Obsidian was procured from three primary sources (Ucareo–Zinapecuaro, Paredon and Otumba), and technological analysis suggests that these obsidian sources were used to produce both flakes and blades throughout the Formative Period. Ucareo–Zinapecuaro (referred to as Ucareo in the remainder of the paper) is the closest obsidian source, located in highland Michoacán, and was the dominant material used throughout the Formative Period. Assemblages begin to diversify to include more artefacts from the Otumba and Pachuca sources in the Middle Formative Period. Comparisons to published obsidian sourcing studies from other parts of Mesoamerica (Pires-Ferreira 1975, 1976; Blomster and Glascock 2011; Hirth *et al*. 2013) suggest that La Zanja was strongly linked to the Valley of Oaxaca through exchange networks along the Pacific coast. Weaker connections existed with the Isthmus of Tehuantepec trade networks dominated by the Olmec sites of the Gulf coast lowlands. This is the first obsidian sourcing study from coastal Guerrero, and the data presented contribute to a greater understanding of the development of exchange networks in Mesoamerica during the Formative Period.

BACKGROUND

Archaeological work in Guerrero documents interaction with neighbouring regions on the Pacific coast, including the Soconusco, central Mexico and Oaxaca, during the Formative Period (Evans 2001, 311–21; Niederberger and Reyna-Robles 2002). More distant complex groups in the Olmec heartland of the Gulf coast were also socially and economically connected to Guerrero (Paradis 1981, 1990; Martinez Donjuan 1994; Reyna-Robles 1996; Evans 2001). The site of La Zanja is located just south of Acapulco Bay, at the north-eastern edge of the Costa Chica, between the Sierra Madre del Sur and the Pacific Ocean. The site is composed of a low earthen mound approximately 40 000 m^2 in size that is situated 2 km from the Pacific coast at the confluence of the Sabana River and Tres Palos Lagoon (Fig. 2). The nearby site of Puerto Marqués is the earliest site documented in the area, with initial components dating to the Late Archaic Period (*c*.2500 cal BC) (Brush 1969; Manzanilla Lopez *et al*. 1991; Manzanilla Lopez 2000; Kennett *et al*. 2008). Archaic occupational levels contain a limited range of stone tool types and assemblages consist primarily of expedient flakes and associated debitage manufactured from locally available quartz, chert and chalcedony. Only a small number of obsidian flakes were identified in these deposits (Kennett *et al*. 2008).

La Zanja was established as a permanent settlement in the Early Formative Period, with persistent aggregated settlement extending throughout the Late Formative and Classic Periods (Brush 1969). Based on chronological modelling of stratified archaeological deposits at La Zanja, the bulk of occupation is placed during the Early (*c*.1400–1000 cal BC) and Middle Formative (*c*.800–550 cal BC) periods, with both phases of occupation spanning roughly equal lengths of

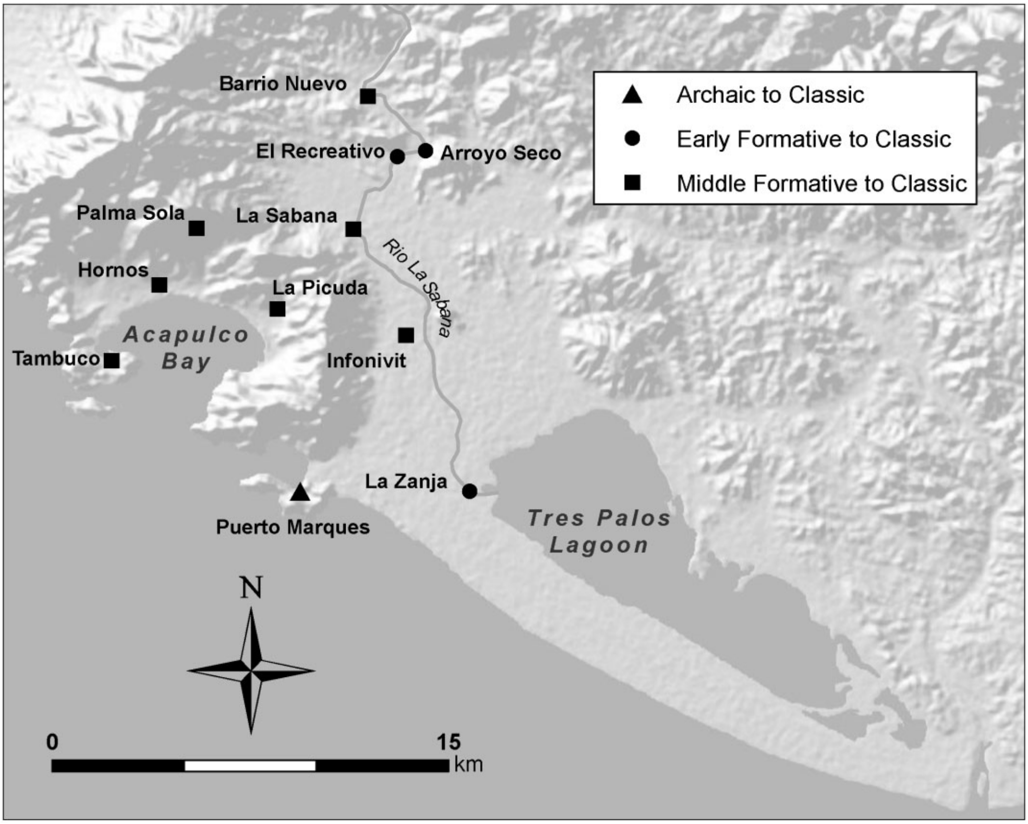

Figure 2 *A map of the north-eastern edge of the Costa Chica (Guerrero, Mexico), showing the location of La Zanja relative to contemporary Formative sites in the Acapulco Bay region.*

time (*c*.450 years; Smith *et al*. in press). The presence of tools associated with agricultural production and a diverse array of shellfish remains suggest year-round occupation and subsistence strategies based on fishing and farming (Kennett *et al*. 2002, 2008; Smith *et al*. 2007, in press; Gomez *et al*. 2011). Stone tool assemblages from the Early and Middle Formative include formal or specialized tools, the majority of which are imported obsidian prismatic blades. Obsidian flakes and cores dating to the Early Formative were also recovered and represent a comparatively simple bipolar flake industry compared to later assemblages dominated by blade technology (Kennett *et al*. 2002).

Obsidian provenance in Mesoamerica and XRF

The acquisition, exchange and use of obsidian in prehistoric Mesoamerica has been the focus of extensive geochemical investigations for decades (Cobean *et al*. 1971, 1991; Pires-Ferreira 1975, 1976; Boksenbaum *et al*. 1987; Glascock *et al*. 1988; Joyce *et al*. 1995; Hirth *et al*. 2013). The highlands of Mexico and Guatemala possess most of the obsidian sources in Mesoamerica, and their chemical characterization has been well defined through several extensive studies using INAA and ICP–MS methods (Cobean *et al*. 1991; Glascock *et al*. 1988, 1998, 1994; Cobean

2002). Sourcing studies from sites in the Gulf coast (Cobean *et al*. 1991; Hirth *et al*. 2013), Oaxaca (Joyce 1991; Joyce *et al*. 1995) and the Maya lowlands (Golitko *et al*. 2012; Moholy-Nagy *et al*. 2013) demonstrate that long-distance trade of obsidian formed an essential part of inter-regional Formative Period Mesoamerican economies, starting at least by 1800 cal BC.

Obsidian provenance data provide a valuable proxy for reconstructing prehistoric exchange networks for several reasons. First, stone tools were the most effective cutting implements in Mesoamerica during prehistoric times, and high-quality material such as obsidian was geographically restricted. The control of access to obsidian may have been a critical component in the development of social and economic complexity (Spence 1981; Santley 1984; Clark 1987, 275; Clark and Byant 1997, 133). Second, the chemical composition of each source can be distinguished from other sources geochemically through trace element characterization. Third, obsidian is well preserved in most archaeological contexts and is ubiquitous throughout most sites in Mesoamerica. Finally, the technological components of obsidian assemblages can be traced through time because the production/reduction sequences used to create these tools are well known (Sheets *et al*. 1975; Collins 1993; Clark and Byant 1997; Hirth 2003, 2006).

The complete obsidian artefact assemblage from La Zanja ($n = 470$) was characterized geochemically using pXRF. A small number of artefacts ($n = 18$) produced low valid counts during pXRF analysis due to their extremely small size or thinness (<2 mm), and are therefore not included in the results presented here. Although several other geochemical methods are available for sourcing, including INAA and ICP–MS, pXRF technology allows archaeologists to analyse a large number of samples at relatively high precision in a variety of field and laboratory settings (Shackley 2005, 90). Geochemical analysis with pXRF, in particular, is relatively cost-effective, requires little sample preparation and no sample destruction (Moens *et al*. 2000; Craig *et al*. 2007; Nazaroff *et al*. 2010; Shackley 2011), and is becoming the dominant method for sourcing obsidian in Mesoamerica (e.g., Glascock *et al*. 1998; Cecil *et al*. 2007; Nazaroff *et al*. 2010; Millhauser *et al*. 2011; Moholy-Nagy *et al*. 2013). A small subset of obsidian artefacts ($n = 49$) from La Zanja was additionally analysed using a bench-top XRF as a quality control measure to evaluate the accuracy of pXRF analyses. Sourcing studies of Mesoamerican (Nazaroff *et al*., 2010; Moholy-Nagy *et al*. 2013) and Andean obsidian (for recent publications, see Burger *et al*. 2000; Craig *et al*. 2007), among others, suggest that pXRF analyses distinguish geochemical sources as reliably as bench-top XRF (Craig *et al*. 2007; Speakman and Shackley 2013).

METHODS

The obsidian assemblage excavated from La Zanja was technologically analysed and subjected to geochemical sourcing via pXRF. A single 2 × 2 m unit was excavated into primary midden deposits (not construction fill) in the centre of the site to a depth of 3.6 m in 20 cm arbitrary levels. Stratigraphy within the unit was horizontal, with two major cultural components represented by unique artefact assemblages dating to the Early (360–240 cm below datum, *c*.1400–1100 cal BC) and Middle Formative (200–280 cm below datum, *c*.900–550 cal BC) Periods. The results of radiocarbon dating for the Early and Middle Formative deposits suggest occupations of comparable duration (423 and 420 years, respectively; Smith *et al*. in press). Pumps removed water during excavation of the cultural deposits below the water table (~180 cm below surface). All sediment recovered was water-screened through a 5 mm mesh, with additional one-litre samples from each level passed through a 3 mm screen (Kennett *et al*. 2004). Although the excavations were exploratory due to budgetary constraints, obsidian was abundant throughout the excavation at La Zanja, and the sample analysed came from primary deposits likely to be representative of Early and Middle Formative Period obsidian use at the site.

Technological assemblage: analysis and results

Technological lithic analysis focused on a total of 470 obsidian artefacts (Table 1; see also Supplementary Material 1). The majority of the stone tool assemblage collected from excavations at La Zanja is composed of prismatic blades from obsidian, a pattern noted at other sites in Guerrero (e.g., Teopantecuanitlán; Niederberger 1976, 1986, 1996). Most of the artefacts come from the Early (*n* = 346) and Middle Formative Period levels (*n* = 91). An additional 33 obsidian artefacts were recovered from mixed contexts that postdate the excavated Formative Period levels (see Supplementary Material 1).

Early Formative Period deposits at La Zanja contain both chert and obsidian flakes (*n* = 243). Obsidian prismatic blades were recovered from the deepest parts of the Early Formative levels (280–360 cm). The concentration of blades increased dramatically in the upper portion of the Early Formative Period deposit (220–280 cm), closer to the boundary between the Early and Middle Formative Period deposits (*c*.1100–800 BC). In the Early Formative deposits, more than half of the blade segments (54%, *n* = 131) were reduced using two bipolar percussion techniques. The first, bipolar splitting, was used to break blade segments lengthwise, creating two pieces using bipolar force. Splitting removes the lateral facets of the blade and creates a flat surface and narrow cutting edges (Clark 1981). The second, bipolar thinning, was used to split the dorsal and ventral surfaces of blades, or to remove flakes to create a thinner blade. Bipolar techniques have been described for assemblages in Oaxaca and Guatemala, where obsidian was imported as small pieces that were later reduced (Clark and Lee 1984; Nance and Kirk 1991; Joyce *et al*. 1995).

A smaller number of stone tools were recovered from Middle Formative Period levels at La Zanja (60–200 cm; *n* = 163). The bulk of the assemblage consists of obsidian blades or blade fragments. Blades were the most common formal artefacts recovered in these upper levels. Bipolar reduction of blade segments was less frequent during the Middle Formative Period (41%; *n* = 28). Lithic debitage increases substantially in the Middle Formative compared to earlier in time, but a majority of this material is quartz rather than obsidian. This suggests local acquisition and expedient lithic tool production during this time at La Zanja. Twenty per cent (*n* = 92) of the total obsidian assemblage from both periods is composed of expedient percussion flake artefacts and a small number of cores suggest that some artefacts were produced locally.

Table 1 *Results of lithic analysis divided by pressure blade and percussion flake traditions and shatter*

	Early Formative	*Middle Formative*	*Mixed Upper*
Pressure blades	243	68	17
with bipolar reduction	131	28	7
Percussion artefacts	53	10	8
with bipolar reduction	15	3	3
Shatter	35	10	4
Total artefacts	346	91	33

XRF provenance analysis

The La Zanja obsidian assemblage was first sorted visually using colour and texture as a proxy for source. Twelve distinct groups were defined, but only four groups were identified with any confidence. Seven very small (<1 mm) artefacts were not categorized visually. The most notable were artefacts from the southern Hidalgo source of Pachuca, with obsidian objects characterized by their bright translucent green colour (Cobean 2002). Grey banded obsidian was consistent with descriptions of the Otumba obsidian source. Clear obsidian (transparent with some grey streaks) was consistent with descriptions of material originating from the Paredon source in central Mexico (Cobean *et al*. 1971; Boksenbaum *et al*. 1987, 69). Most of the assemblage could not be assigned to a specific source visually. While some studies have found that visually defined categories may be consistent with particular sources (e.g., Braswell *et al*. 2000), variations within geological sources make confident associations unlikely.

A sample of 49 obsidian artefacts was analysed with a bench-top Spectrace 5000 EDXRF spectrometer at the Northwest Research Obsidian Studies Laboratory. Initial visual sourcing identified these samples as possibly representative of larger groups from a specific source. Samples were also selected based on size (a minimum of 10 mm in diameter and 1.5 mm thick) as specified by laboratory guidelines. Artefacts at least >2 mm thick are optimal for XRF analyses, with reduced levels of accuracy noted with decreasing size (Lundblad *et al*. 2008; Davis *et al*. 2011; Shackley 2012). Diagnostic trace element values and ratios used to characterize the samples were compared directly to those of known obsidian sources in Mesoamerica (Cobean *et al*. 1991; Glascock *et al*. 1998, 29; Cobean 2002) and unpublished trace element data collected through analysis of geological source samples. Artefacts were assigned to an obsidian source or chemical source group if diagnostic trace element values fell within two standard deviations of the analytical uncertainty of the known upper and lower limits of chemical variability recorded for the source (Northwest Research Obsidian Studies Laboratory unpubl.).

A total of 452 obsidian artefacts were subjected to chemical characterization at the Pennsylvania State University using a Bruker Tracer III-V+ SD handheld XRF spectrometer with X-rays emitted from a rhodium tube. These included the samples sourced using the bench-top EDXRF as a quality control measure. All samples analysed with the pXRF were measured at 40 kV and 12.0 μA from an external power source, with a 12 mil Al, 1 mil Ti and 6 mil Cu (i.e., green for obsidian) filter placed in the X-ray path. Samples were analysed for 200 s. The flattest surface on the artefact was targeted to ensure that analysis of each sample included the bulk of the X-ray produced. Irregularly shaped samples were placed with the smoothest side positioned for analysis. Peak intensities for 10 elements (Mn, Fe, Zn, Ga, Th, Rb, Sr, Y, Zr and Nb) were converted to parts per million (ppm) concentrations by normalizing intensities to the Compton peak of rhodium and using Bruker's factory calibration for obsidian based on MURR standards (Glascock and Ferguson 2012; Speakman 2012). Trace element values were compared to the same standards as those for bench-top results. The bench-top XRF and pXRF analyses of select La Zanja obsidian confirm this observation and demonstrate that pXRF technology is able to effectively distinguish between geochemical source groups in the larger sample (see Supplementary Material 2).

RESULTS OF pXRF ANALYSIS

Cluster analysis of pXRF data identified five primary sources that compose the La Zanja obsidian artefact assemblage: Ucareo, Paredon, Otumba, Guadalupe Victoria and Pachuca (Table 2; see

Table 2 *Elemental concentrations for obsidian artefacts analysed by pXRF in parts per million; values are rounded to the first whole number, and the relative standard deviation (%rsd) is reported as a percentage*

Source		*Mn*	*Fe*	*Zn*	*Ga*	*Th*	*Rb*	*Y*	*Sr*	*Zr*	*Nb*
Otumba	mean	441	10 248	67	19	12	137	26	137	148	15
n = 59	std	58	1 037	29	2	2	10	2	14	8	2
	%rsd	13	10	44	8	17	7	9	10	6	12
Ucareo	mean	180	9 413	65	19	16	173	27	15	132	16
n = 287	std	50	1 098	30	2	3	13	3	4	8	2
	%rsd	28	12	46	9	17	8	9	23	6	11
Paredon	mean	421	10 253	86	20	18	187	53	6	218	44
n = 92	std	60	1 235	32	2	3	15	4	2	14	3
	%rsd	14	12	37	8	14	8	7	26	6	7
Guadalupe Victoria	mean	550	5 061	38	18	7	106	14	68	81	11
n = 8	std	48	250	17	1	1	5	1	4	4	1
	%rsd	9	5	45	6	19	5	7	5	5	9
Pachuca	mean	1 184	17 159	234	26	22	203	113	3	903	91
n = 4	std	101	1 076	35	2	3	7	3	1	38	4
	%rsd	9	6	15	9	13	4	3	39	4	5
Zaragoza	mean	242	10 601	53	17	20	153	34	34	199	19
n = 2	std	6	1 216	0	2	1	19	3	3	18	2
	%rsd	2	11	0	13	6	12	8	7	9	11

also Supplementary Material 3). Two artefacts were assigned to a sixth source located at Zaragoza. Four artefacts could not be assigned to an archaeologically known source despite producing valid results from pXRF measurements. Figure 3 presents bivariate plots of source material compared to the La Zanja obsidian artefacts. The large spread of clusters may result from a minor variation within the sample itself, or the small size and thinness of artefacts, which can skew trace element values (Lundblad *et al*. 2008; Davis *et al*. 2011; Shackley 2012).

Table 3 presents data on diachronic changes in obsidian used at La Zanja, with temporal trends divided into categories based on lithic technology (e.g., flakes or blades). The Early Formative assemblage is composed of obsidian from five distinct sources, including one artefact from an unknown source. Over half the assemblage (*n* = 224; 66%) was manufactured using obsidian from the Ucareo source located in the highlands of Michoacán. Ucareo obsidian artefacts include 196 prismatic blades, and of these 107 were reduced using bipolar reduction techniques. A smaller number of pressure blade artefacts come from the Paredon source (*n* = 31) and only 17 of these were reduced using bipolar techniques. Rather, Paredon obsidian was used to produce most of the bipolar flaked assemblage during the Early Formative Period. A smaller number of artefacts were assigned to the Otumba source, with more percussion flakes than blades present. Four percussion flake artefacts were assigned to the Guadalupe Victoria source. No artefacts from the Early Formative Period deposits were assigned to the Pachuca source.

The Middle Formative Period obsidian assemblage is composed of obsidian from six central highland Mexican sources, and is dominated by prismatic blades from Ucareo. Artefacts from Otumba become more prevalent compared with the preceding Early Formative Period. Blades from the Pachuca (*n* = 2) and Zaragoza (*n* = 2) sources were also introduced during the Middle Formative. The remainder of the obsidian assemblage, recovered from mixed upper contexts, is assigned primarily to Ucareo, Paredon and Otumba sources.

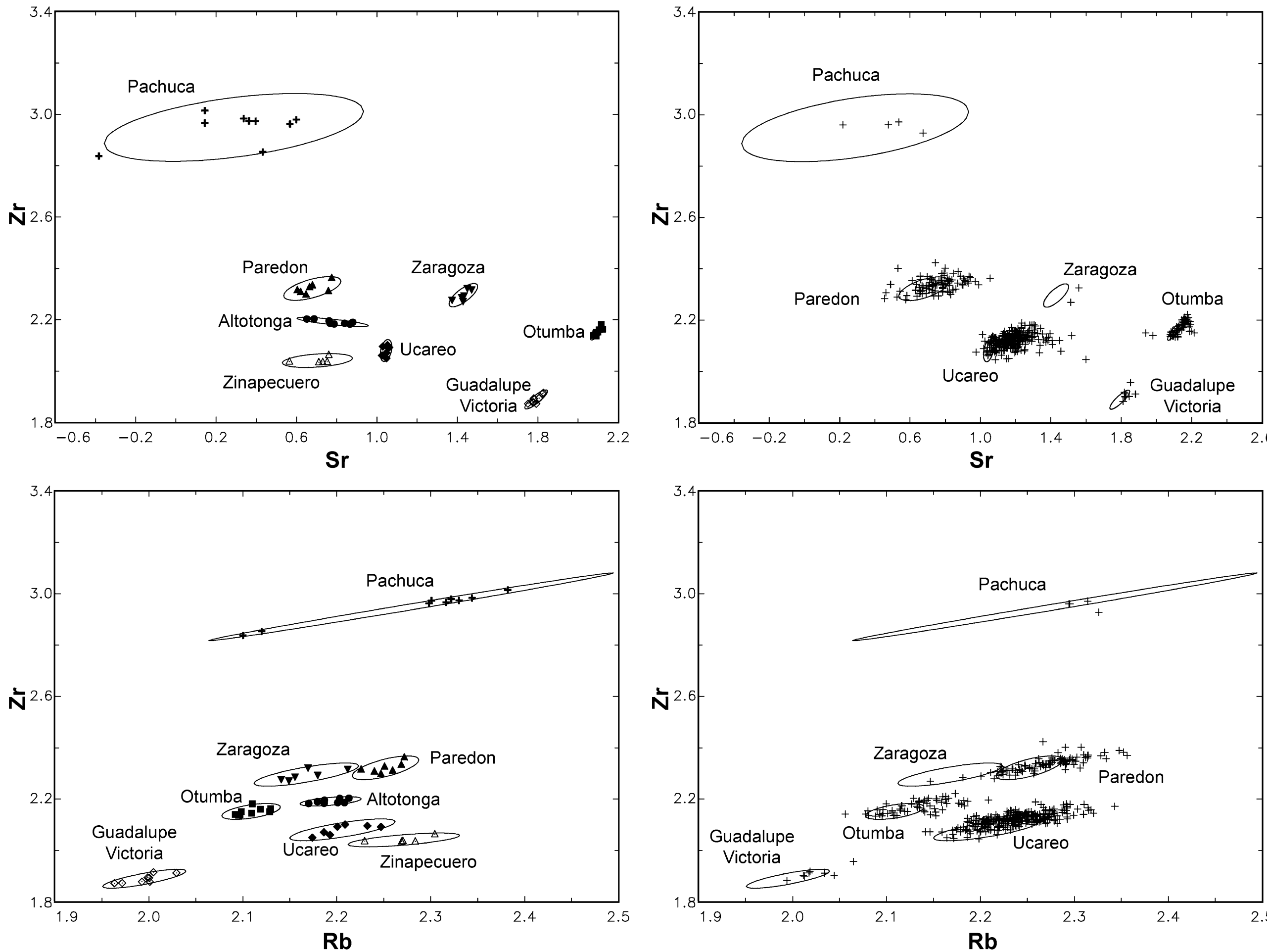

Figure 3 *The bivariate Zr/Sr and Zr/Rb plot of the $\log_{10}$ transformed elemental concentrations. The plots on the left are for samples with known proveniences. The plots on the right show source assignments for La Zanja artefacts. Ellipses represent 90% confidence intervals for group membership.*

Table 3 *A comparison of lithic technology and obsidian sources for Early and Middle Formative and Mixed Upper contexts excavated at La Zanja*

Phase	*Lithic technology*	*Guadalupe Victoria*	*Otumba*	*Pachuca*	*Paredon*	*Ucareo*	*Zaragoza*	*Unknown*	*Total Technological Type*
Early Formative		4	28		76	224		2	334
	Percussion sequence	4	17		45	28		2	96
	with bipolar reduction		2		12	4		1	19
	Pressure blade		11		31	196			238
	with bipolar reduction		1		17	107			125
Middle Formative		4	21	2	11	41	2	2	83
	Percussion sequence	3	7		5	2		1	18
	with bipolar reduction		3		1	1			5
	Pressure blade	1	14	2	6	39	2	1	65
	with bipolar reduction	1	7	1	3	11	2		25
Mixed Upper			10	2	5	13			30
	Percussion sequence		6		2	6			14
	with bipolar reduction		2		1				3
	Pressure blade		5	2	3	7			17
	with bipolar reduction		1		1	4			6
Total from source		8	59	4	92	278	2	4	447

DISCUSSION

Identification of the geological source of obsidian tools used at different sites across Mesoamerica provides one method for reconstructing exchange networks and how they changed through time (Cobean *et al*. 1971, 1991; Pires-Ferreira 1975; Boksenbaum *et al*. 1987; Glascock *et al*. 1998; Freund 2013; Hirth *et al*. 2013). The results of this study expand upon the body of knowledge concerning the role of coastal Guerrero in these exchange networks during the Early and Middle Formative Periods. The ancient inhabitants of La Zanja were active participants in an exchange system that connected the central Mexican highlands with the Pacific coast as far south as Oaxaca (Pires-Ferreira 1975, 1976; Joyce *et al*. 1995), the Gulf coast (Cobean *et al*. 1971; Hirth *et al*. 2013) and the Isthmus of Tehuantepec (Zeitlin 1978).

Most of the obsidian artefacts at La Zanja come from the upper levels of the Early Formative deposits (240–280 cm) that date to *c*.1130–1100 cal BC. These levels are dominated by fragmented late-series pressure blades. Medial segments are the most common portion of these blades, suggesting that they arrived at the site in finished form (De León *et al*. 2009). The prevalence of blade technology in Early Formative levels is not surprising, since blade exchange proliferated in many parts of Mesoamerica during the latter part of the Early Formative (*c*.1200–800 BC—Clark and Lee 1984, 225; Clark 1987; Awe and Healy 1994). Obsidian blade cores and manufacturing debris are not common in the assemblage, providing further evidence that finished blades were imported, a pattern consistent with whole-blade trade or processed-blade trade described by De León *et al*. (2009).

The results from pXRF analysis indicate that the people living at La Zanja used at least six different sources of obsidian from the central Mexican highlands. The primary source of obsidian during the Early and Middle Formative was the Ucareo source (~62%) in nearby Michoacán. Paredon (~21%) and Otumba (~13%) were also relatively common sources of material. A Shannon–Weaver diversity index was calculated for each time period represented at La Zanja (Early Formative, Middle Formative and Mixed upper) to reflect the number of different sources of obsidian from each period (richness) while taking into account how evenly artefacts are distributed among sources (equitability; Fig. 4). In this case, an obsidian assemblage with an even distribution of abundance between sources has a higher diversity than assemblages with the same number of sources, but a disproportionately high abundance of a few types. Equitability independent of richness was also calculated to measure the heterogeneity of assemblages. Equitability values range from 0 to 1.0, with values approaching 1.0 indicating an even distribution of obsidian types in the complete assemblage for each time period. The diversity of obsidian sources used at La Zanja increases from the Early to Middle Formative Periods, concurrent economic changes including exploitation of a greater variety of marine resources (Smith *et al*. 2007, in press). Equitability in the assemblages also increases through time. The equitability values for the Mixed Upper contexts are also higher compared with the Early Formative assemblages, although this is probably due to increased time of accumulation and other taphonomic processes impacting the site through time. The increase in prismatic blades relative to bipolar flakes through the Formative Period, together with increasing diversity and equitability indices, is comparable to the trend visible at the nearby site of Puerto Marqués (Kennett *et al*. 2008), suggesting that greater economic and social interactions impacted people along the entire coast.

Obsidian source data from La Zanja indicate that it was positioned along a coastal exchange route connecting this region with the central Mexican highlands and parts of Oaxaca (Pires-Ferreira 1975; Joyce *et al*. 1995). At the Isthmus of Tehuantepec, this trade route connected with one of the primary conduits that linked the Soconusco region and sites such as San

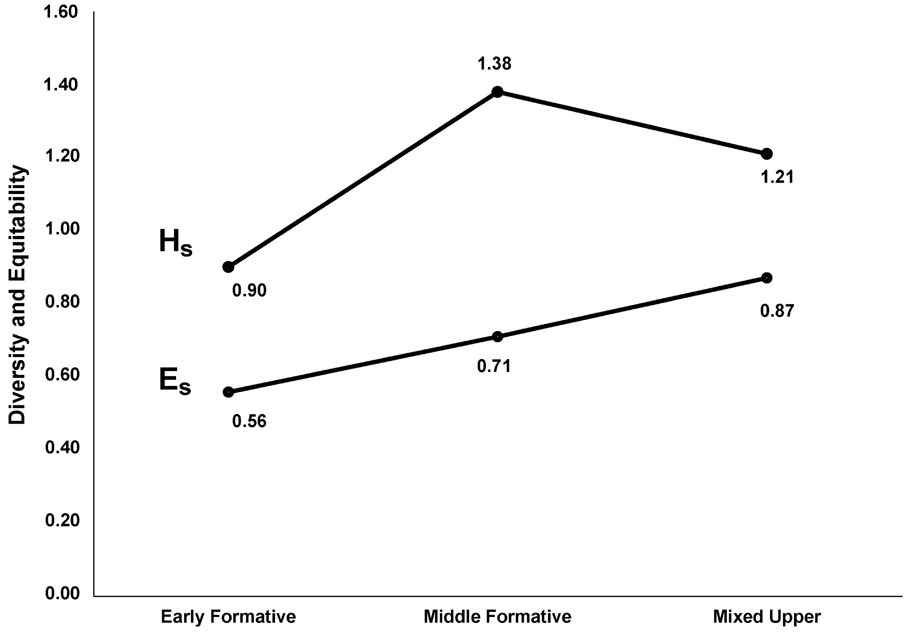

Figure 4 *Diversity and equitability values of obsidian assemblages from La Zanja from the Early to Middle Formative Periods and Mixed Upper contexts.*

Lorenzo in the Gulf coast heartland. Two neighbouring sources on the eastern sides of the Mexican highlands, Guadalupe Victoria and Pico de Orizaba, were particularly important in the Gulf coast and parts of Oaxaca during the Formative Period (Cobean *et al.* 1971; Hirth *et al.* 2013). Percussion flakes and cores recovered from the earliest phases of occupation at San Lorenzo (*c.*1800–1400 cal BC) are composed primarily of Guadalupe Victoria obsidian (70–77%; Table 4 and Fig. 5). The earliest evidence for finished blades at San Lorenzo dates slightly later, to *c.*1500–1400 BC, and there is no evidence of on-site production at this time (De León *et al.* 2009; Hirth *et al.* 2013). Blades in this early assemblage at San Lorenzo were sourced via bench-top XRF to Paredon ($n = 3$), Otumba ($n = 1$) and Zaragoza ($n = 1$) in the central Mexican highlands, and to El Chayal ($n = 2$) in the highlands of Guatemala.

During the San Lorenzo A and B phases (1400–1000 cal BC), roughly contemporaneous with the Early Formative levels at La Zanja, San Lorenzo grew to be the largest and most complex site in Mesoamerica (Cyphers 1996; Hirth *et al.* 2013). At this time, an increasing number of prismatic pressure blades were consumed in roughly equal proportions from the Ucareo, Paredon and Otumba sources, perhaps indicating increasing contact with people as far away as the Basin of Mexico (Hirth *et al.* 2013). The shift in procurement to sources of obsidian in and around the Basin of Mexico corresponds to an increasing investment in prismatic blade production (Blomster and Glascock 2011, 192). Obsidian from the Guadalupe Victoria source, however, remained the primary material imported to San Lorenzo to produce percussion flake tools that composed the bulk of the obsidian assemblage. The presence of some obsidian from Guatemala during the Early Formative at San Lorenzo indicates that the site was connected to Guatemalan obsidian exchange networks (Cobean *et al.* 1971; Hirth *et al.* 2013). The types and proportions of sources represented in roughly contemporaneous obsidian assemblages from La Zanja and San Lorenzo may indicate different connections to highland Mexican obsidian procurement networks.

Table 4 *A comparison of Early Formative obsidian sources (in %) from La Zanja, San Lorenzo (Hirth* et al. *2013), Etlatongo (Blomster and Glascock 2011), and San Jose Mogote and Tierras Largas (Pires-Ferreira 1975, 1976): the assemblage is broken down by percussion versus pressure blade technology where data is available. All percentages have been rounded off to whole numbers unless >1%; totals may not equal 100%*

Obsidian source	*La Zanja*			*San Lorenzo*			*Etlatongo*	*San Jose Mogote*	*Tierras Largas*
	Percussion, n = 97	*Blades, n = 240*	*Total assemblage, n = 337*	*Percussion, n = 333*	*Blades, n = 191*	*Total assemblage, n = 524*	*Total assemblage, n = 216*	*Total assemblage, n = 44*	*Total assemblage, n = 39*
Ucareo, Michoacán	29	82	67	5	35	16	2	32	38
Paredon, Puebla	47	14	23	8	27	15	65		
Otumba, Mexico	18	18	8	0.3	17	7	18	43	31
Guadalupe Victoria, Puebla	4		1	65	2	42	7	11	23
Zaragoza, Puebla				0.9	9	4	6	4	5
Pachuca, Hidalgo					0.5	0.2			
Pico de Orizaba, Vera Cruz				2		1	1		
El Chayal, Guatemala				19	6	14	1		
Ixtepeque, Guatemala				1	3	2	0.5		
Cruz Negra, Michoacan							0.5		
Zacualtipan, Hidalgo				0.6	1	0.8			
Unknown	2		0.6		0.5	0.2		7	3
Total sources	5	3	5	9	10	11	9	5	5

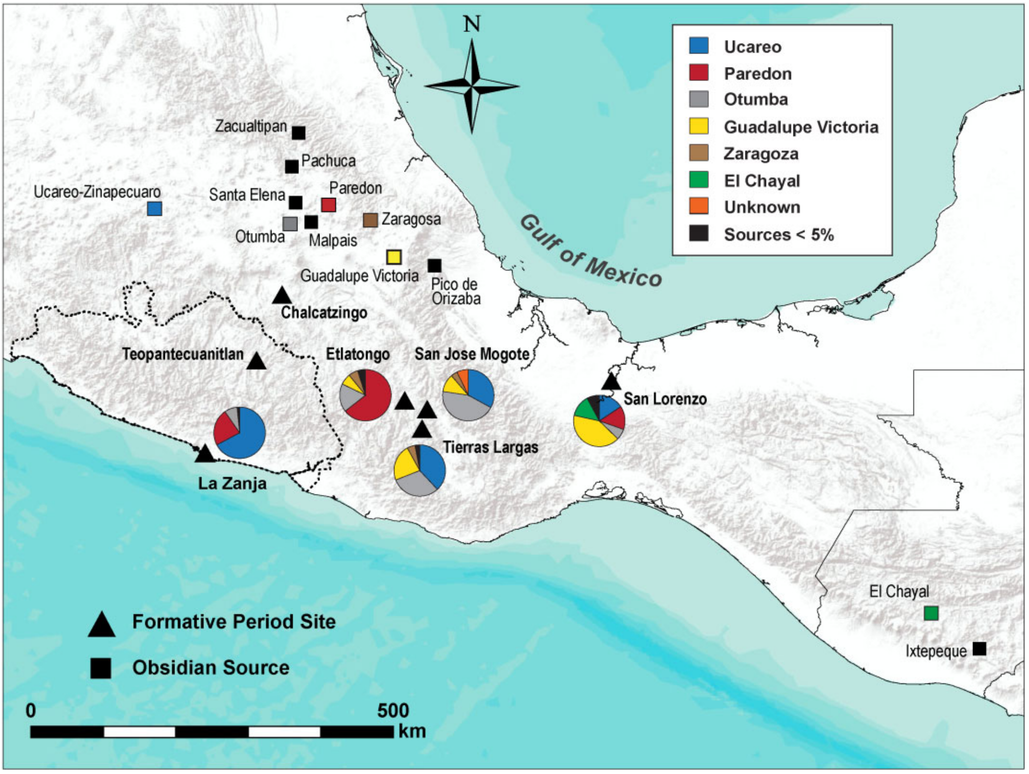

Figure 5 *A map of the Early Formative obsidian sources from La Zanja, San Lorenzo, Etlatongo and San Jose Mogote, and Tierras Largas. Sources that compose less than 5% of the total assemblage are combined (for colour, see the online version).*

The types of obsidian found in other parts of Mesoamerica during the Early Formative Period link those areas with La Zanja and the exchange networks associated with the Pacific coast. At Early and Middle Formative Period sites in and near Basin of Mexico (e.g., Chalcatzingo; Grove 1987), between 50 and 80% of obsidian was procured from the Otumba and Paredon sources that were relatively close (Charlton 1984, 24; Boksenbaum *et al*. 1987). However, networks of trade and interaction were complex during the Formative Period and site location alone cannot be used to determine obsidian source. Formative Period sites in Oaxaca, for example, may have developed different methods to procure obsidian from the Mexican highlands. The Early Formative Period site of La Cosentida, located near the Pacific coast in the lower Río Verde Valley, for example, used obsidian from the Pico de Orizaba source (>50%) in combination with smaller quantities from five other sources (Guadalupe Victoria, Otumba, Paredon, Zaragoza and Malpais; Hepp 2011) that may have crossed the Isthmus of Tehuantepec into the Río Verde area (Workinger 2013, 208). Pachuca and Ucareo obsidians, the latter of which was the most abundant type of obsidian at La Zanja, appear at other sites in the region later in time during the Classic Period (Joyce *et al*. 1995, 10–11; Joyce 2013; Workinger 2013). Blomster and Glascock (2011) described results of an obsidian sourcing study using INAA and XRF from Cruz B (*c*.1200/1150–850 BC) levels at the site of Etlatongo, located inland in the Mixteca Alta region of Oaxaca. Cruz B households at Etlatongo relied primarily on obsidian from the Paredon source, imported via an overland route. Samples sourced to Ucareo, the majority of the La Zanja obsidian, comprise only 6.5% of the Etlatongo assemblage.

Different quantities of obsidian from other sources have been recorded at the contemporaneous San Jose Phase (*c*.1450–850 BC) sites of San Jose Mogote and Tierras Largas, both located in the Valley of Oaxaca. Sourcing studies by Pires-Ferreira (1975, 1976) indicate that the inhabitants of San Jose Mogote used obsidian from five sources, but primarily from Ucareo. The assemblage at Tierras Largas contains Ucareo and Otumba artefacts in roughly equal quantities (Pires-Ferreira 1975). The types of obsidian consumed at San Jose Mogote and Tierras Largas are not evenly distributed between households, however, suggesting that individual households used different methods of procurement that were linked to specific obsidian sources (Winter and Pires-Ferreira 1976). While the exact routes of travel for different types of obsidian into Oaxaca is unknown, the differences in assemblages between Early Formative Etlatongo and contemporaneous Valley of Oaxaca sites suggest alternate obsidian procurement networks, and some of these appear to be associated with La Zanja. In particular, the high percentage of Ucareo obsidian in both blade and percussion flake form at San Jose Mogote (~32%) and Tierras Largas (~38%) is suggestive of linkages between Valley of Oaxaca and coastal Guerrero obsidian procurement networks.

In the Middle Formative, the number of obsidian sources documented at San Jose Mogote and Tierras Largas was reduced from six to four, with a shift to Ucareo as a primary source (Winter and Pires-Ferreira 1976). During this time, San Jose Mogote grew from a large site into a regionally prominent community surrounded by approximately 40 smaller settlements. Elite domestic structures also appear for the first time at San Jose Mogote (Marcus and Flannery 1996). While fewer sources of obsidian were used in the Valley of Oaxaca, they were found more uniformly distributed between households. Winter and Pires-Ferreira (1976) proposed that this pattern represented the 'pooling' and subsequent redistribution of obsidian that came into the village, perhaps by important families or emergent elites (Blanton *et al*. 1999; Joyce 2010, 110–14). As the demand for finished blades developed, individuals or families began to control, pool and redistribute obsidian to kin and dependents in the village and to surrounding hamlets (Winter and Pires-Ferreira 1976). As they grew in size and prominence, San Jose Mogote and other large sites such as Tierras Largas may have relied more heavily on the Pacific coast as a trade network that probably used both overland pedestrian transportation of goods (White and Barber 2012) and watercraft to move items along the coast (Gomez *et al*. 2011).

The diversity of obsidian sources found at La Zanja in the Early and Middle Formative Periods presents a record of economic interactions in Mesoamerica during the Early and Middle Formative. Since the site was located along the Pacific coast, the inhabitants of La Zanja were participants in social interaction and the growth of economic networks during the Formative Period. The types of sources represented in the La Zanja obsidian assemblage suggest that the site was not directly connected to the Gulf coast through obsidian consumption. This is not to say, however, that other items or ideas were not exchanged between the Acapulco region of Guerrero and the Gulf coast. Examples of Olmec-style figurines come from several sites in Guerrero dating to the Early Formative *c*.1500–1200 BC (Paradis 1990). Olmec-like artistic representations on architecture and stone sculpture occur at the Formative Period (*c*.1200–600 BC) civic-ceremonial site of Teopantecuanitlán, the earliest site in Guerrero with clear evidence for well-developed status hierarchies (Paradis 1981; Martinez Donjuan 1994; Niederberger 1996; Reyna-Robles 1996). These items and ideas may have travelled via the Isthmus of Tehuantepec or other overland routes. The presence of certain types of obsidian found in large quantities (Ucareo and Paredon) at La Zanja, however, suggests that people living along the Pacific coast of Guerrero had access to different obsidian exchange networks compared to Gulf coast populations, perhaps due to the proximity of the site to specific highland Mexican sources or trade routes.

CONCLUSIONS

Major societal transformations occurred across Mesoamerica during the Early and Middle Formative Periods and the exchange of exotic products and ideas tied people together into multiple overlapping trade networks. This study highlights the diachronic patterns of obsidian procurement and consumption at the site of La Zanja, linking Guerrero to the Basin of Mexico, Oaxaca and the Gulf coast. During this time, the foundations of complex society were emerging at sites such as San Lorenzo in the Gulf coast lowlands and San Jose Mogote in Oaxaca. Obsidian arrived at La Zanja as finished pressure blades and a total of six different obsidian sources provisioned the site during the Early and Middle Formative Period occupation. Both obsidian percussion flakes and prismatic pressure blades occur within the assemblage and the frequency of blades increased over time. The high percentage of blades at the site may represent the early development of craft specialization and trade in finished blades with the central highlands of Mexico, particularly people mining obsidian from the Ucareo source in nearby Michoacán (Boksenbaum *et al*. 1987; De León *et al*. 2009).

Portable XRF analysis provides one of several geochemical sourcing techniques that will continue to help define the extent and complexity of economic and social interaction in Mesoamerica during the Formative Period. The results of this study suggest that the Pacific coast may have been a major route along which people, products and ideas travelled. Connections with the central Mexican highlands via the Pacific coast facilitated the exchange of goods such as finished obsidian prismatic blades that required specialized production. Further analysis of the broader patterns of distribution of obsidian at both the regional and the site level are crucial for understanding the evolving relationships between source areas and points of consumption both within Guerrero itself and elsewhere in Mesoamerica. Future work will focus on characterizing obsidian assemblages from other sites located in the Acapulco region near La Zanja, and elsewhere in Guerrero, to better understand the paths of movement and distribution of different types of obsidian between local communities. Variation in site assemblages may reveal differences in access to specific sources over time, with increasing diversity perhaps indicative of independent and overlapping economic connections between local and regional groups.

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SUPPLEMENTARY MATERIAL

Additional Supplementary material may be found in the online version of this paper on the publisher's website:

Supplementary Material 1: Results of Lithic Analysis
Supplementary Material 2: Comparison between EDXRF and pXRF Results
Supplementary Material 3: Portable XRF Results