The Organization of Obsidian Exchange at Middle Postclassic Sauce and Its Hinterland in Veracruz, Mexico

Alanna Ossa

To describe the structure of production and the organization of exchange of obsidian chipped stone during the Middle Postclassic period (AD 1200–1350) in south-central Veracruz, Mexico, I analyzed 65 residential inventories from the center of Sauce and its hinterland. Previous research on obsidian production found a spatial association with Sauce, which could support the political administration of exchange, or alternatively, identify market exchange nearby. I argue that reliance on spatially based models alone for identifying exchange mechanisms is not advisable because of potential equifinality, in which different forms of exchange appear alike. Local obsidian artifacts have additional interpretive complications: they come from a single geological source, there was universal access to them, and they were employed in potentially specialized activities. I used the articulation of production combined with spatial distribution and residential contextual information to distinguish between redistribution and market exchange. Results indicate that market exchange is the main mechanism. The largest concentrations of primary production indicators and the highest quantities of blade segments were found near the Sauce center, which suggest that political elites at Sauce encouraged market exchange, although they did not direct it to the extent that they were controlling significant amounts of obsidian.

Keywords: Postclassic Mesoamerica, Veracruz, obsidian, craft production, exchange systems

Este artículo examina los artefactos de obsidiana de 65 colecciones residenciales del centro de Sauce y su hinterland en combinación con patrones de asentamiento para describir la estructura de producción y la organización del intercambio de obsidiana durante el Posclásico Medio (1200-1350 dC) en el centro-sur de Veracruz, México. Investigaciones previas identificaron una asociación espacial entre Sauce y la producción de obsidiana que podría sugerir la administración política del intercambio o, alternativamente, identificar un mercado en el área cercana. Sostengo que no se puede solo usar modelos espaciales para identificar los mecanismos de intercambio por el problema de la equifinalidad. Otros factores como fuente geológica única, acceso universal, y posibles actividades especializadas pueden complicar las interpretaciones sobre los artefactos de obsidiana. Este estudio utiliza la articulación de la producción en combinación con su distribución espacial y la información contextual para distinguir entre la redistribución y el intercambio de mercado. Los resultados indican que el mercado es el mecanismo principal. Las mayores concentraciones de indicadores de producción primaria se encontraron cerca del centro de Sauce, junto con las mayores cantidades de navajas prismáticas. Lo anterior sugiere que las élites de Sauce fomentaron el intercambio mercantil, aunque no lo dirigieron.

Palabras claves: Postclassic Mesoamerica, Veracruz, obsidian, produccíon, sistemas de intercambio

Centers in Mesoamerican settlements typically served as key places for economic activities, with the best surviving evidence provided by the production and dissemination of pottery and obsidian. There has been increased research attention to precisely how these everyday materials were acquired by households, with recent studies arguing that open market exchange is common and occurred much earlier in the Late Postclassic period (AD 1350–1521) than was originally recognized (Garraty and Stark 2010; King 2015). Even for the Maya region, where the presence of large commercial marketplaces prior to the Postclassic period has been questioned, recent studies have identified marketplaces within and adjacent to

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many Classic Maya centers, both big and small (King 2015; Masson and Freidel 2012). Market exchange and the central place function of Mesoamerican centers within their settlements are now widely recognized as features of Classic era centers (Hirth and Pillsbury 2013). Yet questions remain about how exchange networks operated for particular items; for instance, how were exchange systems for obsidian—a material often acquired via long-distance exchange—articulated within settlements (Garraty 2009; Stark and Ossa 2010). New approaches for characterizing exchange networks use artifact distributions among user groups, in combination with the production information of obsidian, to identify both the exchange mechanism and the social and political structure of exchange (De León et al. 2009; Marino et al. 2020; Stark and Ossa 2010).

This article focuses on the Middle Postclassic center of Sauce (AD 1200–1350) in the Western Lower Papaloapan Basin in south-central Veracruz. I analyzed the articulation of its production and distribution activities to determine how obsidian was acquired (Figure 1). The impetus for this current work was previous research that identified a change in local obsidian sourcing for the Middle Postclassic era based on obsidian compositional analyses and the identification of specialized production near the center of Sauce (Heller 2000; Heller and Stark 1998). This change coincided with larger regional economic changes related to political shifts between the Classic to Postclassic periods in the acquisition of obsidian (Millhauser 2005:297; Stark et al. 2016). The Middle Postclassic period was a critical time because it immediately preceded the consolidation of the powerful political and economic forces of the Aztec imperial state that eventually conquered many areas of the Gulf Lowlands (Curet et al. 1994).

Located between two regions—the Central Mexican highlands and the Maya Lowlands—and able to produce agricultural products in demand, the Gulf Lowlands were a focal point for migration and trade (Daneels 1997; Stark and Arnold 1997). Veracruz's importance to understanding broader trends in Mesoamerica is often overlooked, despite its lengthy occupation with impressive monumental constructions, long-lasting polities, distinctive material tradition, local script, and economic importance in producing key resources such as cotton (Stark et al. 1997). Because of its lingering colonial legacy and its reduced political power in Mexico from the Aztec period onward, Veracruz has attracted little archaeological interest, and its intermittent occupation through multiple political and social vicissitudes makes it less attractive as a "lost" civilization (Pool 2006:190). This study reframes the economic development of regional markets in Postclassic Mesoamerica from the perspective of a small community in a lesser-known area in Veracruz; thus, it has much to contribute to our understanding of Postclassic era changes outside what was to become the Aztec imperial core.

Many obsidian studies in Mesoamerica have focused on the site level or higher, evaluating exchange based on site-level obsidian inventories to answer basic questions about regional acquisition patterns. Establishing interregional exchange patterns, however, is essential, particularly considering that obsidian cores are often acquired outside the immediate vicinity of the sites where people use them; exactly how this production was organized at quarries has been the subject of research in Veracruz (Pastrana 1986), Puebla, and elsewhere (Knight 2017).

In this article, I argue that intrasite analyses, which are not common in obsidian studies, are also important in that they can show how these items were acquired by households and deployed (or not) by elites at the end of the process. Hirth's (2008) study using excavation data from Xochicalco outlined multiple models of localized obsidian production (and exchange) using household units of analysis, which made feasible inferences about how obsidian exchange was organized. Likewise, in their study of the Classic period Tuxtlas in southern Veracruz, Wilson and Arnold (2017) leveraged distinct (and below site-level) survey units, combined with excavation information, to identify two obsidian exchange networks.

This study, which uses household-level inventories in combination with broader survey-based information from two closely associated projects, can likewise provide a more holistic view of household obsidian acquisition. Using

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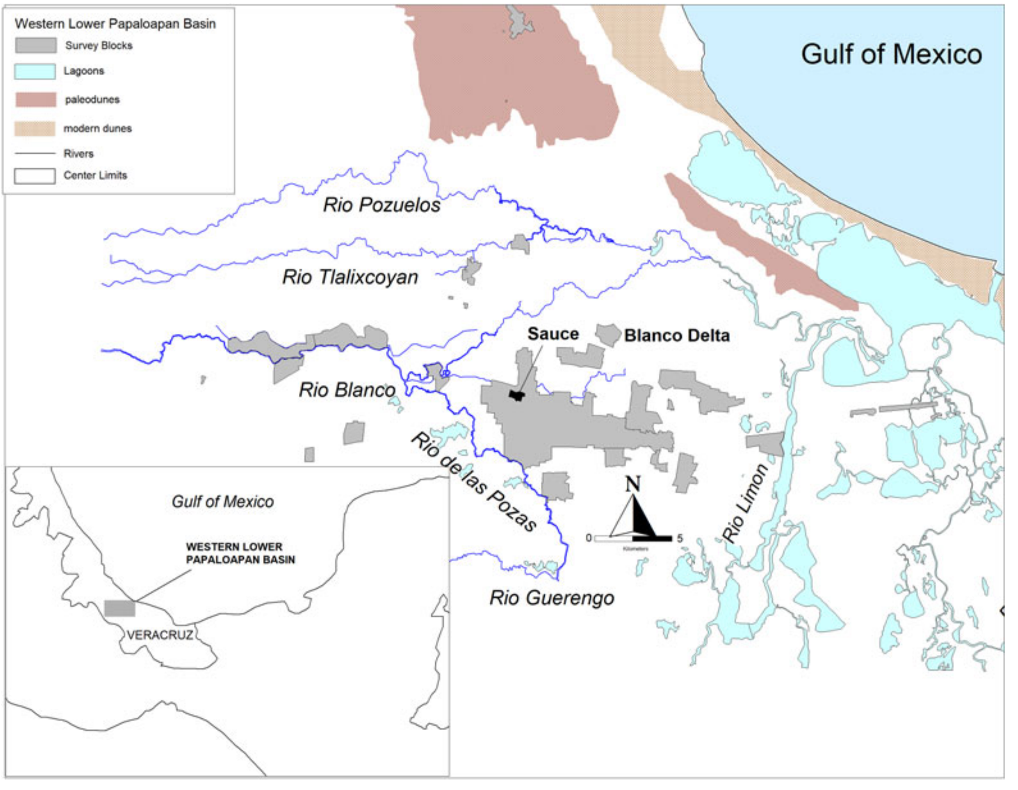

Figure 1. Map showing Sauce center and PALM and Speaker survey blocks in south-central Veracruz, Mexico. (Color online)

the information from multiple projects, separately, provides multiple lines of evidence for evaluating the organization of exchange and its articulation within larger regional trends without sacrificing the precision afforded by the recent field project, Sauce Archaeological Project (SAP; Ossa 2011). I show how an existing survey can be used to obtain new information to test ideas and formulate better models of how people acquired and disseminated one of the most basic household items in Mesoamerica.

A previous distributional analysis of Sauce's economic organization focused on decorated ceramics; it found that the majority of these decorated ceramics were circulated through open market exchange and were most likely obtained near the center itself (Ossa 2013). In contrast, obsidian was a material every household possessed, so a distributional analysis using household exclusion patterns alone is not advisable. Near-universal household access to material from the same source (Pico de Orizaba), used locally during the Middle Postclassic period, makes an exchange analysis different for obsidian than for ceramics. The requirement for importation may lead to obsidian acquisition bottlenecks in a way that ceramics made from local clays may not have. Therefore, both the organization of production and socially significant greater access need to be assessed to make accurate inferences about the form of exchange of obsidian. The main dataset is drawn from the 65 archaeological residential collections obtained by SAP. Additional production data about obsidian are also drawn from the earlier Proyecto Arqueológico La Mixtequilla (PALM I, II) and its associated 2001 survey that provided the basis for SAP (Figure 1).

A previous study using the PALM survey materials (Stark and Ossa 2010) looked at the dispersion of obsidian during four periods: the Early Classic (AD 300–600), Late Classic (AD 600–900), Middle Postclassic (AD 1200–1350), and Late Postclassic (AD 1350–1521); it

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found indirect evidence for market-based dispersion based on gradual falloff curves from the centers. The spatial dispersion of obsidian for multiple eras was supportive of market exchange, but the problem of equifinality, in which different forms of exchange result in the same spatial pattern, was a significant complicating factor that was unresolved. If different processes such as central- place market exchange and redistribution look the same spatially, how can one distinguish them archaeologically?

The SAP study was designed to examine the organization and mechanisms of exchange by obtaining statistically comparable artifact densities from individual households. The SAP collections made it possible to directly evaluate household inventories and use the distribution of individual artifact types among households to identify exchange networks. My study on Middle Postclassic period obsidian addresses three interrelated questions: (1) can market exchange be identified for obsidian, (2) how was obsidian exchange and production organized, and (3) at what spatial scale was obsidian articulated with the Sauce center and associated settlements?

Identifying Markets in Prehistory

Considerable evidence exists that market exchange systems developed and flourished in prehistoric societies prior to the development of Western capitalism (Blanton and Fargher 2010:211). Exchange studies have long been a staple of archaeology, but the 1970s saw a large increase in spatially sophisticated studies of exchange, partly due to the influence of social anthropologists building on the work of economic geographers (Smith 1976). Many of these early studies used falloff curves to describe different prehistoric exchange systems. At that time, archaeologists such as Hodder and Orton (1976:239–241) and Renfrew (1977:88), identified the problem of equifinality in spatial distributional analyses, in which different exchange systems produced spatial patterns that were difficult to differentiate from each other. Later advances in identifying exchange systems in archaeology have used distributional concepts derived from Hirth (1998) to account for exchange complexity and assess exchange mechanisms in prehistoric economies (Eppich and Freidel 2015; Garraty 2009; Ossa 2013; Watts and Ossa 2016). Hirth's original approach described in 1998 provided the starting point for designing SAP.

Identifying Exchange Mechanisms

Hirth's (1998) original concept relies on the assumption that artifact exchange mechanisms are identifiable because they follow distinct networks (e.g., a market and its customers or a patron and their clients; Ossa 2013:418). Network-based approaches can apply this distributional concept to archaeological data directly and have been used often to identify both social and economic networks archaeologically (Brughmans and Peeples 2017:7; Golitko and Feinman 2015). Networks offer a compelling way of conceptualizing relational connections among social groups in archaeology because they allow for the analysis of complex interactions from often indirect and fragmented sources.

In my study, a network refers to any set of agents (individuals or groups) that participate in the exchange of an item; agents exchanging the items—whether connected via kinship, status, or community—represent the network nodes. Distributions of individual artifact types can be used to identify exchange networks because flows of products between agents form identifiable distribution patterns over time among a set of households within a reasonable transport catchment for exchange. Of course, spatial location and transportation costs are still a factor. However, if a reasonable transport catchment is used, distributional expectations can be effective for identifying exchange networks. Identifying similarities and differences in networks across multiple media can pinpoint the creation of new exchange connections between regions and the related access to materials within communities (Stoner and Pool 2015; Wilson 2016).

Identifying Individual Exchange Networks

Using distributional expectations, openly exchanged items in a market will be found in most households and will show gradual changes in amounts depending on purchasing power, consumption preferences, or distance from the market or production source. The expectation of access rather than equitability in open exchange has been well established in other applications of distributional expectations (Marino et al. 2020; Masson and Friedel 2012). In restricted exchange, some distributional variety is to be expected based on the nature of the social network in play. These social networks are often elite exchanges, involving gift-giving, preciosity acquisition, and redistribution, so I deployed them as subcategories of restricted exchange (Ossa 2013:416). For example, if items were circulating via elite gift-giving, then they would be expected to be recovered from elite residences and those of clients. If items were circulated only among contiguously located kin, then spatial patterning might identify pockets of kin-exchanged items. Restricted exchange could involve the restriction of specific goods to particular social groups, such as with sumptuary laws. Redistribution, the controlled distribution of items via the political elite and typically along socially significant networks, also fits under the term "restricted exchange," with some explanation required of how it could work.

For my study, redistribution is a special case of restricted exchange in which all participants may have some quantity of a redistributed item, but its presence in much higher quantities is attached to socially significant networks, such as residences with higher socioeconomic status or social connections. In the case of the Sauce polity, if redistribution were a significant mechanism of obsidian exchange—as opposed to gift-giving or one-time client–patron largess—I would expect most households to have access to a redistributed item, but the control and administration of its distribution would result in political or social elites having much higher quantities. In addition to identifying the degree of openness of exchange networks, these methods can help map political and social aspects of the exchange of individual artifact types such as obsidian blades and blade segments.

Expectations for Exchange Modalities

The expectations for different exchange modal tendencies are straightforward, but tabulating them in practice requires some probabilistic reasoning. To evaluate the individual distributions, I generated relative row percentages for each individual artifact attribute (e.g., ceramic type) among the set of households being analyzed and ordered them by percentage rank. Using distributional expectations, openly exchanged items will show gradual changes in rank-percentage distribution among households, whereas items circulating in restricted networks will show higher frequencies in a subset of residences and will most likely be absent or have very low frequencies in others.

Figure 2, which is redrawn from Watts and Ossa (2016:Figure 2), shows that a plot of a rank-percentage distribution of an openly exchanged item is gradual, without any sudden increase in the relative percentages from one household to the next (Figure 2a). Restricted items, in contrast, should show a more concave-shaped rank-percentage distribution, with a sharper hinge or step where the ranking shifts from households that were out of the network to those that were within the restricted network (Figure 2b). The application of these distributional network expectations, in combination with spatial results, can produce interpretive information about the shape, size, and openness of the networks. Potential sampling errors can be mitigated by using simulated distributions to generate probabilistic interpretations (Ossa 2013; Watts and Ossa 2016). Additionally, this method allows for different artifact types to have distinct distributional shapes that support open market exchange while still circulating in separate networks from each other. This method can also show that processes other than exchange mechanism affect their shape. For the current study, I modify my distributional approach to use the combination of obsidian blade production and spatial scaling of production materials to infer the organization of production and exchange (see also Renfrew 1977; Stark and Garraty 2010:43–44) and to separately consider the distributional results of the most commonly used obsidian materials.

Drivers of Economic Development in Postclassic Period South-Central Veracruz

In Mesoamerica, the Middle to Late Postclassic period (AD 1200–1521) saw the rise of an independent interconnected market system that was

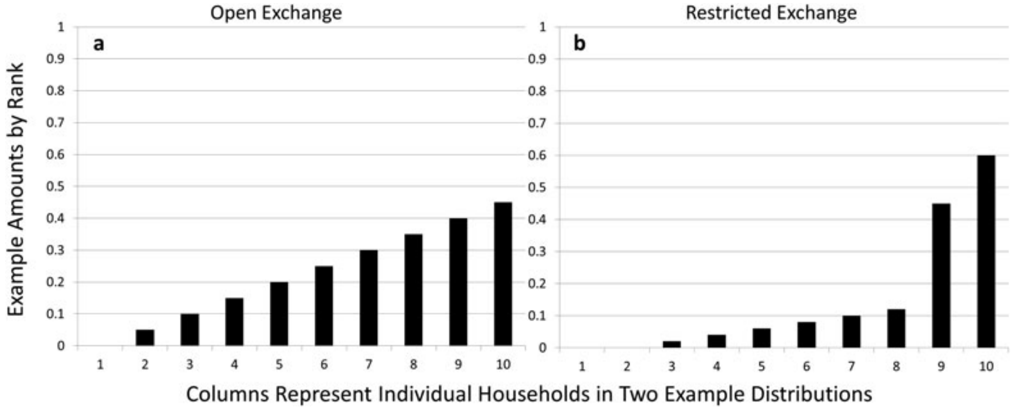

Figure 2. Rank-percentage distributions: (a) openly exchanged items; (b) restricted exchanged items (redrawn from Watts and Ossa 2016:Figure 2).

particularly well developed in central Mexico (Blanton 1996). Some have argued that the market system in central Mexico predated the Aztec Empire. In this model, the interest created by Classic period state-sponsored or elite-supported craft production continued after the collapse of states in Mexico and created an interested group of consumers, with the Aztec political control of the market and market taxes occurring only after their political rise (Blanton and Fargher 2010). Which combination of these co-occurring processes best describes what happened in south-central Veracruz, an area with small polities far from central Mexico? To what extent did Sauce's economic organization occur through its elite- or polity-level sponsorship? Describing this interplay effectively relies on refined modeling of production and household acquisition.

Decades of intensive regional survey and domestic excavations have occurred in the Western Lower Papaloapan Basin (Stark 2001). The detailed studies of SAP and PALM produced in-depth research into production and commerce at a larger scale than is typically possible for surface collections and surveys. These studies described changes in commerce over time in the area, with craft production associated more with the Late Classic centers (AD 600–900), a pattern that holds true for some of the decorated ceramics. Stark (2008a) suggests that the association of craft production with Late Classic centers reflected an attempt by newer, less entrenched dynasties to gain influence by supplying important items. However, until Stark and Ossa (2010) demonstrated the relationship between centers and obsidian blade distributions, it was not clear that obsidian blade supply and exchange access were consistent with market exchange.

Archaeological studies of economic development have demonstrated that socially constructed values for goods, state financial institutions, and political practices each play important roles in regional economic development processes (Garraty and Stark 2010). The identification of market exchange for obsidian blades in south-central Veracruz before the Postclassic era suggests that most of the obsidian was circulating openly in Sauce (Stark and Ossa 2010). Given the break in settlement between the Classic and Postclassic eras in Veracruz observed by both PALM and surveys in the adjacent Cotaxtla Basin, new populations may have played a role in economic changes, although that issue remains a subject for future investigation (Daneels 1997; Stark 2008b). The current study, in combining both individual residential analysis and the organization of prismatic blade production, will provide a stronger framework for understanding blade exchange in Sauce.

Field Sampling Strategies for Residential Collections

The SAP project was designed to obtain residential collections with high artifact frequencies under statistically comparable conditions; the data thus obtained would meet the statistical requirements for applying distributional and spatial methods with greater precision and accuracy. Residential mounds were sampled from within a 12.5 km radius extending from Sauce to capture both the distributional and geographic patterning of products in relation to the center and to cover as much of the potentially associated settlement as possible. Five concentric rings were created as sampling tools; they extended in increments of 2.5 km from Sauce and were arranged with Sauce as the bullseye to enable analysis of the degree and scale of spatial artifact distributions. Sixty-five surface collections were made from 65 residential mounds from the rings (Figure 3). Given the spacing observed between centers, it is possible that other Middle Postclassic settlements had been missed previously, particularly given that Postclassic mounds in the area are known for having fewer structures and less built-up walls generally (Daneels 1997). However, the SAP project observed several areas of low-lying mounds outside the existing survey blocks near rings 4 and 5 during reconnaissance and only saw Classic era artifacts. No potential Postclassic occupation was identified either in or near the extensive project area.

I thus have two sampling populations: (1) robust collections that had large amounts of Middle Postclassic pottery and (2) scant collections that targeted potentially poorer residents, identified by selecting mounds from the PALM surveys that had Postclassic pottery recovered in low amounts despite having excellent ground visibility. The robust collections were obtained from a stratified random sample of 55 (40%) of the 130 Middle Postclassic residential mounds identified in the prior PALM projects. For the scant collections, an additional 10 collections were sampled from a pool of 120 mounds that had much scarcer Postclassic materials to obtain better representation of possibly the poorest residential mounds. Thus, there were a total of 65 mounds (Figure 3). Even numbers of mounds were selected in each 2.5 km ring for sampling population, thereby producing more representative spatial variation without oversampling high-density areas. During the prior survey, vegetation coverage was recorded, showing that plowed areas yielded more artifacts. SAP's sampling procedures tilted the sample toward mounds that had better initial collections (typically in plowed fields). Therefore, during artifact collection, project staff engaged in intensive vegetation clearing, including removing any grass pasture and breaking up the topsoil to obtain larger artifact collections under similar conditions akin to collecting in the plow zone. The sample for each residential mound was collected using one 5 × 5 m collection square, so the mound inventories are statistically comparable to each other —a key requirement for exchange analyses.

Independent Assessment of Residential Mound Socioeconomic Rank

Expectations for different forms of exchange required identification of the socioeconomic rank of occupants of the mounds to determine whether access was restricted by socioeconomic status. In SAP, I used residential mound size, which is independent of residential inventories, to assess rank during exchange analyses, although I recognize that no single set of criteria will prove to be reliable (Ossa 2013). Powerful and wealthy people do not always have large residences, although dwellings are important signifiers (after Cowgill 1992:206–218). However, residential size has been applied in Mesoamerica to establish some independent measure of socioeconomic rank and has general utility, even if exceptions occur (Kowalewski and Feinman 1992:261; Smith 1987).

Any calculation of mound size in this region requires a correction for antecedent occupation, because these mounds were "tells in miniature" (Hall 1994:34–35). I weighted each residential mound volume by its relative proportion of Postclassic period diagnostic pottery and used this weighted volume to establish a proxy for comparative residential status that approximately dated to the right era, given that the mounds have a multi-period occupation (Ossa 2011, 2013). I then ordered the mounds according to their adjusted volumes, which showed a continuum, an expected result from accumulated mound deposits (Figure 4). However, breaks exist in the mound volumes that present useful cutoff points for ordinal size groups from 1–5, as shown in Figure 4. Previous analyses showed

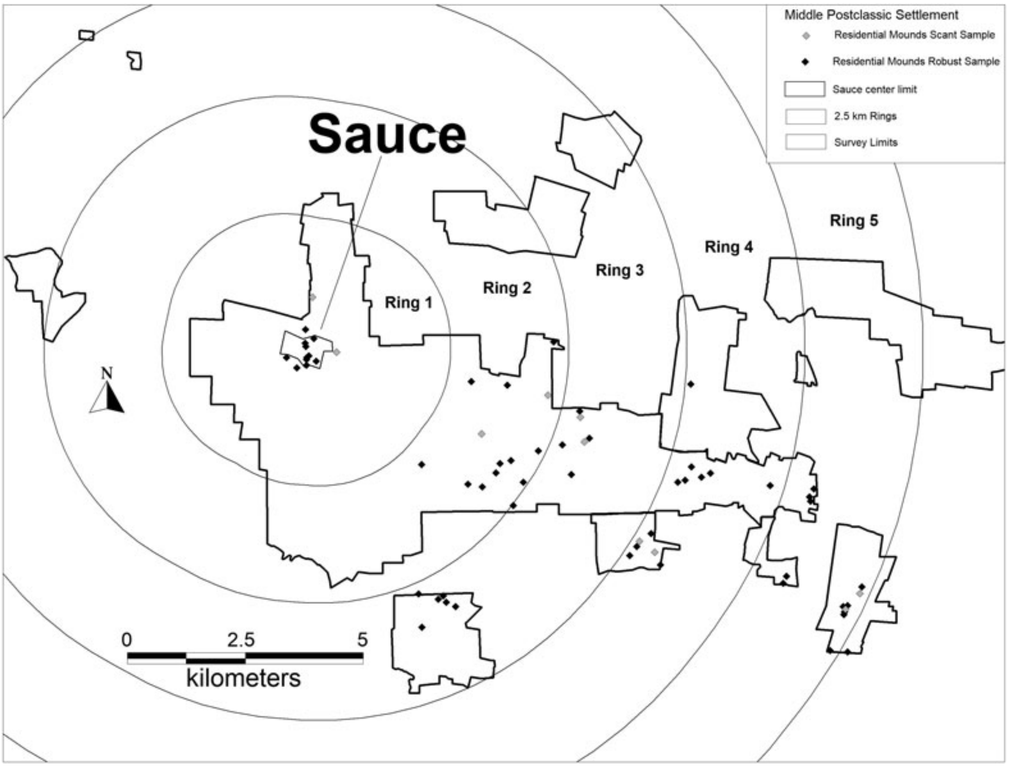

Figure 3. Map showing SAP collections and sampling rings.

that none of the size groups 1–5 shows an association with the central ring 1 alone; instead, each of the distance rings has a few of the higher-ranked (larger weighted volume) mounds (Ossa 2013:Figure 6). Finally, although research in the Cotaxtla Basin indicated that Postclassic occupations created less mound construction, the 1–3 mound size groups were associated

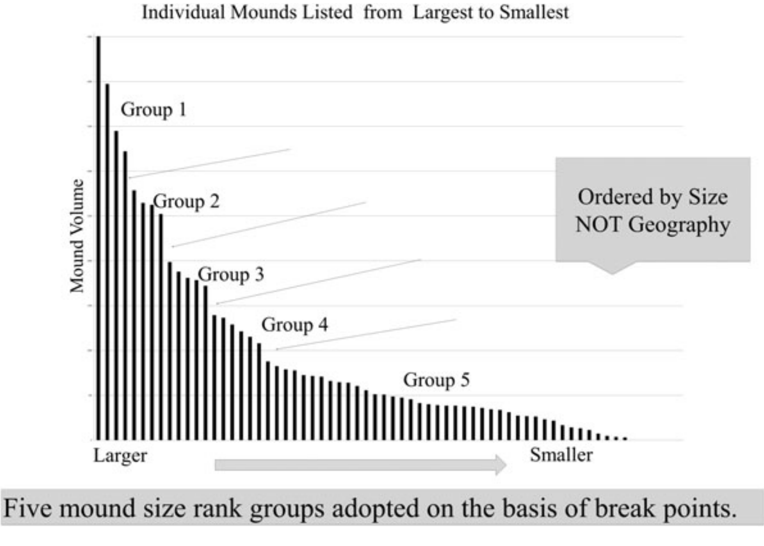

Figure 4. Ordinal size groupings of individual mound volumes weighted by their Postclassic pottery percentages.

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with higher ceramic densities in SAP (Daneels 1997; Ossa 2011:132). These findings support the inference that larger mounds were associated with higher status; perhaps later occupants were claiming prime areas that had wealthier Classic era construction. I used the weighted mound volume groups as a proxy for relative status among residential mounds to evaluate socially driven access to obsidian materials.

Residential Mounds and Surface Collections

This research uses surface collections from two projects, SAP and the PALM. I briefly describe the field methods for each, because they differed from each other, which has important interpretive implications for my study. For SAP, surface collections of artifacts were taken only from the sampled residential mounds. Intensive vegetation clearing was used to clear a 5 × 5 m collection square per mound. For PALM, surface collections of artifacts were taken primarily from residential mounds, but some were in areas where artifact concentrations were observed outside of obvious mounds (Stark and Ossa 2010). In PALM projects, the domestic mounds were not cleared of vegetation prior to collection. For mounds that did not have observable high artifact concentrations, a "grab sample" of anything that could be seen in the vegetation was taken from the entire mound's surface. For PALM areas with high ground visibility, samples were collected within measured collection areas of varying size based on artifact concentrations to obtain comparable artifact densities. Because of the disparate ways in which artifacts were collected, obsidian results are reported separately for each project, and the results are compared rather than combined.

Current Information on Sauce's Obsidian Industry

Within Mesoamerica, the obsidian industry is recognized as a major economic factor: obsidian was the material used to make the main cutting tool for most households, which often, though not always, required specialists to produce (Hirth 2008:436). Prismatic core-blade technology in Mesoamerica has been defined primarily on the basis of a few sites such as Teotihuacan and Ojo de Agua, but there are spatial and temporal variations across Mesoamerica that are not well understood (Clark and Bryant 1997; Hirth and Andrews 2002:1). Hirth and Andrews (2002:1–2) argue that researchers tend to view prismatic core-blade technology as homogeneous, but regional and temporal variation are likely in both the production sequence and the production stages at which cores and blanks are imported into regions. Differences in household inventories and the evidence of different debris from production stages can be used to evaluate how blades were being produced and traded within regions; this is the approach that I use to evaluate Sauce's blade trade (De León et al. 2009:114–115).

For the Middle Postclassic period, clear gray obsidian was ascribed to Pico de Orizaba (Puebla/Veracruz), using instrumental neutron activation analysis (INAA) chemical characterization (Heller and Stark 1998:122; Stark et al. 1992). Additionally, the use of ground platforms on prismatic blade cores was particularly associated with the Postclassic period prismatic technology in the Sauce region, although some recent work on this technology in other parts of Veracruz has found earlier associations (Heller 2000:141; Santley and Barrett 2002; Wilson 2016). Using these studies as a baseline to establish Postclassic associations, I considered all the clear gray obsidian and those prismatic materials from a different obsidian source (dark gray or black from Zaragoza-Oyameles, Puebla) with ground platforms from SAP and PALM collections. The same analyst sampled both PALM materials for chemical characterization studies and SAP materials. Although the color identifications of the source were not tested by additional chemical characterization studies for SAP, the visual identifications of obsidian for this study are defensible. Venter and colleagues (2018) have shown that geological source assignments based on visual color assessments of obsidian were about 81% accurate when visual source identifications were blind-tested using pXRF. Additionally, prior research evaluating the use of color distinctions between Pico de Orizaba and Guadalupe Victoria, two sources that were used locally, indicate that these sources are difficult to distinguish by color in thinner, more translucent pieces (Stark et al. 1992:229; Wilson 2016). However,

Table 1. SAP Totals for the Individual Artifact Type Categories for Clear Gray Obsidian.

Artifact Types	Counts	Weights (g)
Blade Related		
Ribbon blades: very small, delicate	11	1.3
Blades: shatter	56	14.6
Blade Tools		
Blades/flakes retouched to points/punches	4	2.5
Notched blades	1	0.4
Projectile points on prismatic blades	2	1.2
Flake/Blade Tools		
Scrapers on transverse core tab	1	9.2
Scraper on longitudinal core fragment	1	15.2
Debitage and Macrodebitage		
Percussion flakes	20	17.0
Macro flake: whole	2	19.1
Macro flake: proximal	1	3.3
Flake Tools/Polyhedral Core Reduction		
Unidentified flakes without platforms	6	2.5
Polyhedral Core Reduction		
Prismatic cores: distal	2	6.5
Hinge recovery blades	1	0.5
Flake fragments/probable platform trimming flakes	2	2.0
Distal rejuvenation flake	1	19.2
Chunks	4	6.3
Platform trimming/faceting flakes	2	2.0
Bipolar flakes	1	1.8
Irregular pressure blades	3	2.1
Transverse core flake with faceted dorsal	1	11.7
Prismatic cores: shatter	3	4.1
Pressure flakes	9	2.6
Transverse core flake with nonfaceted dorsal	3	8.7
Prismatic core face flakes: longitudinally struck off	4	20.2
Transverse core flake fragment	1	1.6
Small shatter	3	1.7
Probable platform trimming/faceting flakes	1	0.8
Prismatic cores: whole	2	48.9
Prismatic cores: proximal	3	52.3
Prismatic cores: medial	1	6.4
Unidentified blades	1	0.8
Prismatic Blades		
Percussion blades: medial	1	0.5
Prismatic blades with platform reversal scars	1	1.0
Percussion blades: proximal	4	8.9
Prismatic pressure blades: proximal	216	118.5
Prismatic pressure blades: medial	590	270.3
Prismatic pressure blades: distal	102	44.7

both Stark and collaborators (1992:229) and Wilson (2016) emphasize that the Guadalupe Victoria source is not of sufficient quality to allow the production of prismatic blades, making source misidentification less of an issue for this study. For SAP, color-based source assignments were also made in tandem with ground platforms, and prior established temporal associations from PALM mitigate sourcing errors. Chemical characterizations of SAP materials were not feasible with available grant funding, but future work is planned.

All the SAP obsidian was characterized by a combination of artifact categories that were based on flake and prismatic blade-core production sequences (blade, core, shatter, etc.) and color (Table 1; Clark and Bryant 1997; Heller 2000, 2001; Heller and Stark 1998:159). Heller (2000:140) describes the prismatic blade-core production sequence for Middle Postclassic period Sauce based on a workshop assemblage from Mound 1756 near the center. Preformed obsidian cores were imported, although some may have arrived in small, naturally blocky forms (Heller 2000:141). Grinding the platform of prismatic blade cores is a technological advance that is sometimes applied prior to core preparation. It allows for better purchase of a tool on the ground surface for pressure blade removal, weakens surface tension, provides better control of the angle of blade removal, and overall produces a great reduction in errors during blade production (Healan 2009:107). It was adopted at varying times and places across Mesoamerica (Healan 2009:104; Hirth and Andrews 2002:3–4). Ground platforms were identified in PALM excavation contexts associated with the Postclassic period, because they were found in the upper layers; the great majority of the clear gray prismatic cores and core proximal segments in the obsidian workshop had ground platforms (Heller 2000).

Obsidian cores with or without ground platforms are typically further prepared for blade removal by removing the cortex (resulting in decortication flakes) and macroflakes to create platform surfaces (Hirth and Andrews 2002:3–4). The next step may include the removal of crested/ridged blades, percussion blades, or both to prepare the polyhedral core. However, the process varies from place to place. For the PALM Sauce assemblage, Heller (2000:142) found percussion blades and initial series blades to be more common than ridged blades (Table 2).

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Table 2. Primary and Secondary Production Indicators Recovered for the PALM and SAP Datasets.

Primary Production	PALM Counts	SAP Counts	SAP Weights (g)
Prismatic cores: whole, proximal, medial, distal, and Shatter	27	11	118.2
Longitudinal blade core fragments	2	4	20.2
Prismatic core rims	1	0	0.0
Rejuvenation flakes	0	1	19.2
Totals	**30**	**16**	**157.6**
Secondary Production	PALM Counts	SAP Counts	SAP Weights (g)
Bipolar: flakes, shatter, cores, blades	9	1	1.8
Transverse core flakes	13	5	22.0
Platform trimming flakes	3	5	2.8
Macro flakes	0	3	22.4
Flakes without platforms	1	6	2.5
Second and initial series blades	3	0	0.0
Irregular pressure blades	24	3	2.1
Ridged, secondary ridged, unidentified, and plunging blades	1	1	0.8
Small pressure flakes	1	9	2.6
Hinge recovery blades	0	1	0.5
Totals	**55**	**34**	**57.5**

After the initial series of blades are removed, pressure prismatic blades are removed. At this point a series of core rejuvenation and flake removal techniques can be applied so that more blades can be removed until the core is depleted. Also resulting from these sequences are flakes and debitage that are related to knapping errors or material imperfections that knappers had to handle by making corrections during core reduction. SAP artifacts were analyzed and organized specifically to capture information about obsidian use and production. In my SAP analyses, I used the divisions defined by Heller for PALM as reported in Table 2.

Expectations for Evaluating Obsidian Exchange

SAP obsidian materials included formal tools from repurposed blades and blade segments. Three significant complicating factors to my exchange analysis are (1) the use of a single geological source—clear gray obsidian was imported from Pico de Orizaba, approximately 125 km northwest from Sauce; (2) near-universal access to obsidian; and (3) the potential for specialized activities creating different collections not based in exchange. Almost all households had some obsidian blades, so restricted exchange would result in a pattern in which some households had access to high amounts of obsidian. This access would more closely follow social networks, and those obsidian-rich households would presumably have social or political importance. In contrast, an open access interpretation would show household obsidian to be more affected by distance from a production or distribution point. Determining the relative quantities of blades and blade segments associated with socioeconomic ranks will allow the differentiation between redistribution or markets and whether these exchanges are associated with the Sauce center.

For Sauce, we know that a production locale was near the Sauce center itself (Stark and Heller 1998), as further described by Heller (2001). I use a basic statistical graphing approach to illustrate my expectations for identifying market exchange versus directed redistribution, adapting a technique developed in Stark and Ossa (2010). In the case of redistribution or socially managed exchange, I expect clustering of items within high-ranked households, even outside the locations where production and distribution were taking place (e.g., near Sauce). For open exchange such as markets, I expect dispersion of items across a region, with no obvious concentrations within higher-ranked households and a gradual decrease in quantities the farther from the place where they were being produced or marketed.

Obsidian Production Indicators, Provisioning, Spatial Patterns, and Exchange

In prior research on Mesoamerican obsidian assemblages, production indicators were deployed to investigate both how production was organized and to describe aspects of the political economy (Clark and Bryant 1997:134; Hirth 2008). Daneels and colleagues (2018) used refined analysis of production errors to distinguish between itinerant and local producers, a promising approach that is beyond the scope of this article. As mentioned, previous research on the spatial patterning of obsidian production for the Middle Postclassic period found an association of obsidian blade production with Mound 1756 near the Sauce center that was identified as part of Sauce's occupation (Heller 2000). Although there is settlement disruption between the Classic and Postclassic with a potential influx of a new population by the Middle Postclassic, craft production was periodically associated with centers in this area despite these major shifts (Stark 2008a): it was identified with centers in the Early Classic period for obsidian and for the Late Classic period for multiple crafts (Stark 2008b; Stark and Ossa 2010).

I used production indicators to provide insights into the ways in which obsidian blades/segments were being provisioned to households and where that production took place in the settlement. For SAP, I followed the approach of De León and colleagues (2009) to identify aspects of Formative blade production in Mesoamerica: they used blade production byproducts to identify both where blade production was taking place and at what scale. Blade production is a process that is well documented and described for Mesoamerica (Hirth and Andrews 2002). It is a reduction technology that reduces raw nodules of obsidian first into cores and then into blades in a sequence that is roughly similar throughout Mesoamerica, although there are certainly variations. De León and colleagues (2009) used the reduction sequence to divide blade production indicators into two groups: primary and secondary. In their model, primary production includes pieces of core and core-related debris, whereas secondary production includes pieces of core and core reduction that are farther along in the sequence and could be related to the processing of used cores or blade segments. The indicators I used for this study are based on Heller's (2000) research design for PALM materials (Table 2). Mapping these groups of indicators in both SAP and PALM collections permitted the identification of primary versus secondary production. For example, I was able to determine whether primary production was mainly found near the center, in close association with elite residences, or both. I also determined whether obsidian production occurred in the settlement overall and, if so, if there was more than one producer or evidence for multiple production loci.

Sauce Production Results from PALM and SAP

Production indicators associated with primary production were more strongly associated with the Sauce center (Figure 5). However, some small quantities of primary indicators were found in all five rings, indicating that production was not limited to Sauce's environs. In addition, secondary production indicators showed that limited production or repurposing of some blade materials, including cores, took place within all five rings. Thus, although the association of blade production with the Sauce center is strong, it is not exclusive, indicating that Sauce's political elite probably did not exercise tight control on the movement or even on all the production of obsidian within Sauce's likely hinterland.

Exchange of Obsidian in Sauce and Its Hinterland Settlements

In this section, I consider the evidence for how tools, blades, and blade segments were being exchanged by evaluating both their spatial distribution and associations with the mound rank groups, my proxy for socially important households. Because statistically comparable artifact densities are required to evaluate exchange access for individual households, I rely only on the information collected for that purpose by SAP. For the blade analysis, I use information about the ratio of blade segments to infer whether whole or processed (segmented) blades were exchanged. No whole prismatic blades were recovered in the SAP; therefore, I use blade

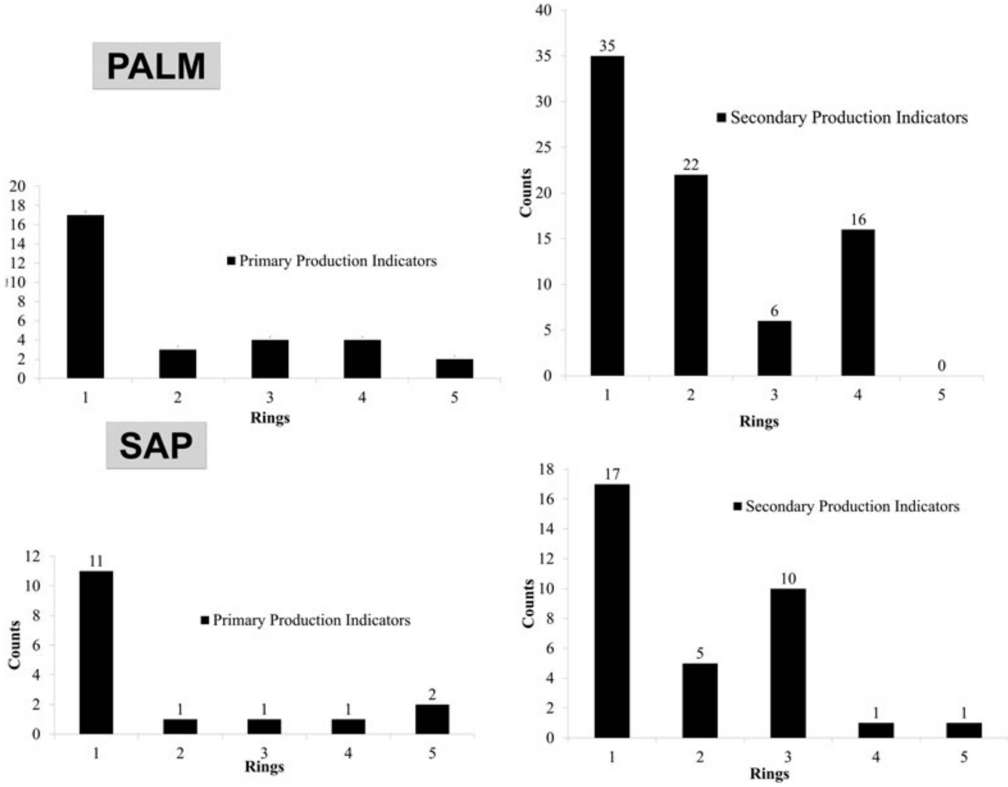

Figure 5. Production indicators by rings for PALM and SAP.

segments to infer how blades were being exchanged. My basic premise is this: if blades are traded as whole blades, processed blade segments, or through local blade production, each alternative blade form or production method would leave a signature in the ratios of different blade segments to each other (such as proximal to distal) within a set of households (De León et al. 2009; Hirth 2008). Therefore, obtaining blade segment statistics is the first step in evaluating obsidian exchange.

The general idea behind evaluating blade segments for exchange is that blades typically break into three main segments—proximal, medial, and distal (near, middle, and far)—that are identifiable based on curvature and the presence of a platform or end (distal) of a blade. De León and colleagues (2009) hypothesized that when whole blades are being moved, one would expect to find similar proximal to distal ratios. Distal segments are small, making them easy to miss in screens or during intensive surface collections; they can be misclassified as nondescript flakes. They are also the most fragile, so it is possible that 2:1 ratios might still indicate whole blades. In cases where processed blades are being traded, medial segments would be expected to dominate, with much higher medial to proximal ratios being found. Although it is also true that medial segments may increase because consumers may have broken up whole blades for hafting and use, blade segment evaluation is a good starting point to consider for exchange.

Results of Blade Segment Exchange Analysis

The evidence from the blade segment ratios shows that prismatic blades were being produced near Sauce, with some smaller amount of production throughout the entire settlement, and blades and medial segments in particular (i.e., processed blades) were the primary focus of exchange (Figure 6). The high medial to distal ratios in all rings are an indication of processed blade trade, in addition to the occasional trade of whole blades (Table 3). Some amount of whole blade exchange is supported by the

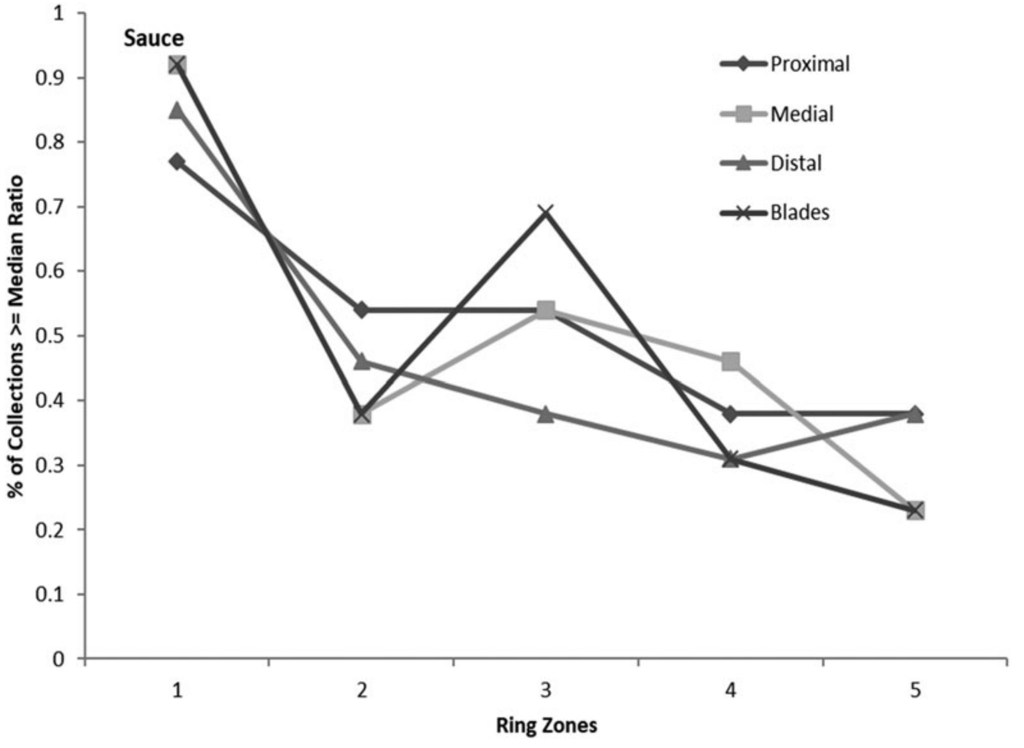

Figure 6. Summary blade segment falloff curves from Sauce.

lower ratios of proximal to distal segments in rings 1 and 5 compared to much higher ratios in rings 2–4 (Table 3). The observed blade segment patterns may have been affected by the fragility of distal segments; however, the relative differences in amounts are too great for this factor to explain all the variation. Blade segments were most likely the main subject of exchange rather than whole blades.

After establishing the forms in which obsidian blades were exchanged, I used two statistical graphing methods to evaluate blade segment distributions among Sauce households. Using the summary method described earlier and applied in Stark and Ossa (2010), two-dimensional charts were created to show the percentages of individual residential collections above the median ratio, separated out by evaluating the percentages of the three blade segment types (proximal, medial, distal) and total blade segments (listed as blades) separately, to total Postclassic pottery by ring (Figure 6). The spatial evidence from the blade segments was considered separately based on my initial findings and on research suggesting that ratios of different blade segments within households can indicate the type of end product being exchanged (i.e., blade segments versus whole blades). The spatial distribution of all blade segments and different segment types did not show the significant clustering of large amounts outside of ring 1 that would be expected if there were socially directed exchange versus market exchange (Figure 6). Additionally, no blade concentrations, either spatial or social, indicated their use in other specialized crafts.

I also created a more detailed bar chart for total blade segments per individual residential

Table 3. Blade Part Ratios for the SAP Dataset.

Ring Zones	Proximal Counts	Medial Counts	Distal Counts	Proximal/ Distal	Medial/ Distal
1	90	260	54	2.0 to 1	4.8 to 1
2	30	87	11	3.0 to 1	8.0 to 1
3	34	89	10	3.0 to 1	9.0 to 1
4	43	106	15	3.0 to 1	7.1 to 1
5	19	48	12	1.6 to 1	4.0 to 1
Totals	216	590	102	2.1 to 1	6.0 to 1

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mound to show the counts and column percentages across space, while also showing the mound size groups for each (Figure 7). There are similar results for both total blade segments and for the individual blade segment types, with most concentrations found near Sauce and showing a falloff from ring 1. Figure 7 also shows that, even in cases where there were higher amounts of blade segments outside ring 1, the individual collections were not exclusively associated with the larger mound-size groups. Of the eight individual collections with higher blade segment frequencies (>20) in rings 2–4, only two collections were associated with mound groups above 3 weighted size rank (Figure 7). These results support the market exchange of processed blades, with some whole blade trade evident (based on inferences about blade segment ratios only—no physical whole blades were recovered) and some blade production and reprocessing in Sauce and its hinterland.

Conclusions and Insights from Sauce's Obsidian Exchange

This study answers major questions about the exchange of obsidian at Sauce, including how the production and exchange of blades and blade segments were organized, as well as the scale and articulation of exchange and production within Sauce and its associated settlements. Results support market exchange as the main mechanism for the observed distribution of obsidian blade segments among the 65 residential mounds. The largest number of residences with primary blade production indicators were found within Sauce and ring 1 using both PALM and SAP data, although some evidence for prismatic blade production is found throughout all rings. Similarly, the highest numbers of residences with large quantities of obsidian blade segments were also found in Sauce and ring 1 during SAP's exchange analysis; although some residences outside of these areas also had large quantities, they were not all identified as high status based on relative mound size.

Overall, these findings suggest that, even though political elites played a role in encouraging the market exchange of obsidian, they did not monopolize its exchange for elite households, as might be expected in politically or socially directed redistribution. Importantly, the production evidence from both PALM and SAP shows that obsidian blades and blade segments were provided to households by means other than just market exchange located physically at

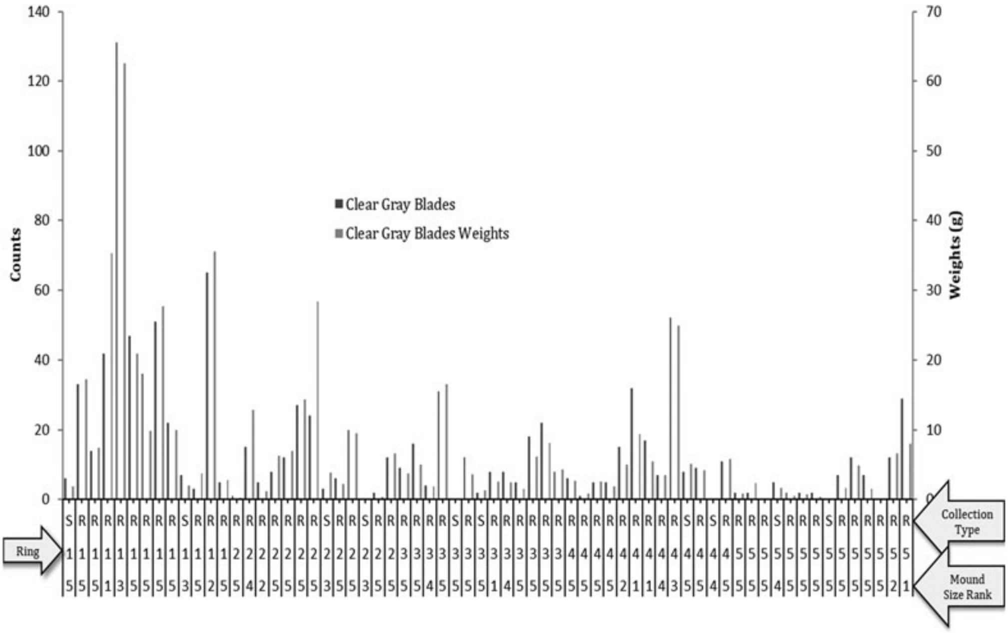

Figure 7. Detailed blade segment falloff from Sauce.

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the Sauce center. The very low but still visible amount of primary and secondary production indicators found within most of the rings and Heller's (2000) original study suggests that an unknown combination of local and itinerant producers were provisioning some households.

This study goes much further than the previous spatial analyses by Stark and Ossa (2010) that used dropoff patterns of obsidian blades from sites to evaluate likely exchange mechanisms. By deploying intensively collected surface collections selected from a fine-grained regional study (PALM), SAP's study maximized the scale and intensity of materials collected. The use of comparable household inventories enabled the analysis of larger numbers of individual residences than is typical or feasible for most studies using household data from excavations. In sheer numbers, 65 is a significant amount of household inventories, especially for a modest community like Sauce. By comparison, Hirth's original sample of excavations and surface collections of households in Xochicalco was 74, which was for a much larger urban center than Sauce (Hirth 1998:164). The complementary analysis of two aspects of obsidian tool production—spatial associations of high percentages of materials with ranked households (after Stark and Garraty 2010; Stark and Ossa 2010) and the stage of production indicators (primary versus secondary, after De León et al. 2009)—also enabled a more refined analysis of how producers may have acted to supply consumers and whether high frequencies were restricted to a subset of the population. The innovative blade ratio analysis model of De León and colleagues (2009) as applied to SAP materials indicated that the primary products being exchanged were mostly processed blade medial segments and some few whole blades.

Generally, better quantitative methods to identify strands of evidence (such as multiple forms of exchange) can help identify the mix of competing factors and often unintended consequences of exchange, trade, and production. These new methods work well when combined with existing survey data, which are often dismissed as not as useful as excavation-level inventories. I recommend that we use existing survey data to design intensive systematic surface collections with the goal of maximizing residential sample counts and cross-inventory consistency (Ossa 2011). The application of distributional-based testing on older datasets was effective for evaluating the exchange networks for obsidian, a material imported into this region. How these essential items were apportioned is a vital question that gets at the heart of political and social organization of the Sauce center and its associated settlement.

For Sauce, the elites, who were likely newcomers to the region (Stark 2008a), were not directing exchange exclusively. Instead, most residences apparently acquired processed blades via market exchange with some degree of localized production/reprocessing. These results are consistent with previous findings for the decorated ceramics, which showed that most ceramics were acquired via an open market at Sauce (Ossa 2013). Future work focused on more chronologically controlled residential excavations in Sauce could help determine the relative roles that new populations, settlement disruption, and new exchange networks played in supporting the expansion of market exchange documented for the Postclassic period (Stark et al. 2016). This study reframes the known economic expansion of Postclassic Mesoamerica from the perspective of a small place in a lesser-known region, Veracruz, further contributing new methods for identifying economic development using portable conceptual models and methods, allowing for comparative advances.

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Data Availability Statement. The entire SAP dataset is available online at the Center for Comparative Archaeology website at the University of Pittsburgh. The link can be accessed here: http://www.cadb.pitt.edu/ossa/index.html.

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