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Middle Preclassic period Maya greenstone “triangulates”: Forms, contexts, and geology of a unique Mesoamerican groundstone artifact type

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ABSTRACT

Over the past twenty years our understanding of the Middle Preclassic (900–300 BCE) period has become much clearer through archaeological investigations at a number of sites located in the Upper Belize River Valley region of the eastern Maya Lowlands. While the picture of Middle Preclassic Maya life, including their material culture, has sharpened, there are aspects that remain uninvestigated. One artifact type, identified as greenstone triangulates, has been found at several Belize Valley sites and in a variety of contexts. Although a number of these multifaceted, polished groundstone items have been recovered, little research has focused on their distribution and function in the archaeological record. An evaluation of these items from primary contexts provides data for determining how they were used in daily social and/or ritual activities throughout the lowlands. Comparative data from other regions of Mesoamerica are also discussed. A detailed geological and petrographic pilot study of a sample of greenstone triangulates is provided, pointing conclusively to early, long-distance and complex exchange networks in exotic raw materials.

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1. Introduction

The deep roots of Maya settlement in the Belize River Valley were recognized by Gordon Willey and colleagues (1965; Sharer 1976) with the definition of the Middle Preclassic Jenney Creek phase (c. 900–350 BCE) at Barton Ramie. Subsequent research has extended this chronology to include some of the earliest ceramic-using populations in the eastern Maya Lowlands (c. 1100/1000 BCE) and illuminated aspects of the social, economic, and political systems that characterized Middle Preclassic communities in the region (e.g., Awe, 1992; Brown, 2003; Garber et al., 2004; Healy and Awe, 1995, 1996; Healy, 1999; Hohmann, 2002; Iannone, 1996; Powis, 1996; Powis and Cheetham, 2007). Similarities in artifacts and architecture suggest enduring connections between the Belize Valley and Middle Preclassic settlements elsewhere in Mesoamerica, although certain elements of shared

material culture indicate more intensive interaction among groups at the regional scale (Awe, 1992; Cheetham, 1998; Horn, 2015).

Artifacts described as “greenstone triangulates” represent one such class of regionally significant Middle Preclassic materials with few parallels outside the Belize Valley. These objects have received little attention to date, despite their potential to reveal early exchange networks and prevailing views of the importance of green-colored stone artifacts in Preclassic Mesoamerica (e.g., Taube, 2004, 2005). We address this shortfall through a combination of descriptive and contextual analysis that documents the distribution of “greenstone triangulates” through time and space. A pilot petrographic study confirms that visible differences in triangulate colors and textures result from different mineral compositions and metamorphic histories, suggesting that multiple geologically distinct resource zones, some up to several hundred kilometers from the Belize Valley, were exploited to produce these objects. This finding has significant implications for models of resource procurement and exchange networks at a time when lowland Maya community organization was becoming increasingly complex.

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2. The Middle Preclassic Maya Lowlands and the symbolic importance of “greenstone”

The Middle Preclassic outside of the Maya Lowlands was traditionally seen as a dynamic period of interaction and cultural change that developed out of Early Preclassic (c. 2000–1000/900 BCE) innovations in settlement, trade, and social organization. Large-scale public architecture and stone monuments, many carved with shared mythico-religious iconography, became characteristic features at several widely separated Middle Preclassic centers. Interregional interactions, inferred from similarities in architecture and iconography and demonstrated through sourcing of exotic materials, played an important role in the rise of more complex societies across much of Mesoamerica. The circulation of jadeite and other green-colored stones, usually in the form of ground axes or celts, became an important part of socioeconomic exchanges between distant seats of political power.

For most of the twentieth century, archaeologists envisioned Middle Preclassic communities in the Maya Lowlands as small, relatively egalitarian, autonomous farming villages that lacked the trappings of more complex societies (e.g., papers in Adams, 1977; Ricketson and Ricketson, 1937; Willey et al., 1967). These groups were thought to be largely self-sufficient, engaging occasionally in long-distance exchange but remaining disconnected from the networks that moved goods and ideas among their more advanced non-Maya neighbors. The Maya Lowlands were seen by some as a “cultural backwater” whose inhabitants did not yet participate in the pan-Mesoamerican traditions that developed into Classic-period civilizations (Lowe, 1977: 198).

Recent discoveries have forced a reappraisal of Middle Preclassic Maya societies in the broader context of Mesoamerican cultural history. Communities across the Maya Lowlands built public architecture and engaged in long-distance exchange from the beginning of Middle Preclassic times, and intensification of these activities over 550 years produced truly monumental constructions and complex webs of socioeconomic relationships between far-flung settlements (e.g., Anderson, 2011; Doyle, 2012; Hansen, 1998, 2005; Inomata et al., 2013; Laporte and Valdés, 1993; Micheletti and Powis, 2015; Powis et al., 2009). Scholars now acknowledge the Middle Preclassic as a critical period in the development of lowland Maya civilization, occupying a transitional position between the earliest permanent occupations of the region and the emergence of stratified Late Preclassic societies (see Powis, 2005). This recognition has prompted a renewed focus on Middle Preclassic community organization and social interactions to unravel the origins of complex society in the Maya Lowlands.

Investigations over the past three decades have produced a growing body of evidence for complex social organization and participation in Middle Preclassic interaction networks at several communities in the Belize Valley (Fig. 1). Incised Cunil- and Kanocha-complex (c. 1100/1000–900 BCE) serving vessels bearing pan-Mesoamerican symbols suggest Belize Valley communities were connected to more distant regions from the earliest days of settlement (Awe, 1992; Cheetham, 1998; Garber and Awe, 2009; Garber et al., 2004), and trade in exotic materials such as obsidian, basalt, and marine shell increased through time. Objects made from green-colored stone, referred to as “jade,” “jadeite,” or “greenstone” in reports, comprise an additional class of materials assumed to be non-local in Belize Valley contexts and include beads, polished mosaic inlays or adornos, possible manufacturing debris, and the triangulate artifacts described in this report. Greenstone pieces are rare compared to other materials and are interpreted as socially valuable, symbolically charged items that may have belonged to important members of Middle Preclassic Maya society. Their presence in the Belize Valley suggests that communities there participated in broader Mesoamerican interaction and exchange networks that fostered the growth of shared ideologies and systems of material expression.

The symbolic meanings that green-colored stone artifacts possessed in Middle Preclassic Mesoamerica must be inferred from analogies to

later societies, contextual associations of recovered artifacts, and interpretations of a relatively small corpus of iconographic representations. Karl Taube (2004, 2005) discusses jade in Classic Maya religion and the considerable antiquity of green-colored stone artifact use in Mesoamerican ideological displays. Green-colored stones were used by the Olmec from at least 1500 BC to make a range of objects, including head-dress plaques, earspools, beads, belt celts, pectorals, and carved figurines. The celt was the dominant greenstone object manufactured by the Gulf Coast Olmec and other Middle Preclassic peoples, with large numbers of greenstone celts occurring at sites such as La Venta and La Merced (Rodríguez and Ortiz, 2000). Taube (2005) suggests that greenstone celts, made of jadeite and more commonly serpentinite, served both as basic units of economic exchange and cosmological symbols of the Mesoamerican world as a four-sided maize field (also see Taube, 2000: 303). Certain greenstone stelae may have even represented giant celts, with examples from La Venta (Monuments 25/26, 27, 58 and 66) portraying the Maize god as a ‘celtiform world tree’ (Porter, 1996; Taube, 2005: 24–25). Other symbolic associations of greenstone objects include the cardinal directions, centrality, breath spirit, authority, fertility, rebirth, animation rituals, and communication with the gods and ancestors (Awe, 2013: 39–40: 56–57; Digby, 1964: 25–26; Miller and Martin, 2004: 57; Stross, 1988; Taube, 2005). The durability of greenstone objects might have also contributed to perceptions of their value as materialized connections to past events, especially if they were used in religious or other ceremonial proceedings (Joyce, 2000: 13–15).

Distributions of morphologically similar artifacts made from different types of green-colored stone suggest Middle Preclassic communities employed flexible strategies to acquire these symbolically important objects. In a recent literature review of the occurrence of jadeite and non-jadeite greenstone artifacts from sites in Gulf Coast Mexico and Pacific Coastal Chiapas, Cara Tremain (2014) provides three interpretations for varying frequencies of different types of green-colored stone: 1) they indicate Middle Preclassic communities were aware of different geological sources; 2) community members understood characteristics of the workability of different rocks and the visual appearance of finished products; and 3) that different communities preferentially selected certain rocks over others. Preclassic Mesoamericans may therefore have distinguished between green rocks with different colors and physical properties in ways similar to the categorical distinctions made by the Aztecs during the Late Postclassic times (see discussions in Andrieu et al., 2014: 141; Jaime-Riverón, 2010; Kovacevich, 2013: 259). An additional factor contributing to these patterns was likely differential access to different types of green-colored rocks, determined by both the geographic proximity of communities to different sources and their ability to acquire different materials through exchange. Variability observed in Middle Preclassic “greenstone” artifacts necessitates a discussion of this term and its usage by archaeologists before considering the Belize Valley triangulates and their potential geological sources.

3. Greenstone: what's in a name?

The definition of “greenstone” varies even within the Earth Sciences, let alone in reports in which archaeologists have played fast and loose with the term. A “greenstone” can be described, *sensu stricto*, as a greenish-colored, low- to medium-grade metamorphic rock that lacks foliation and typically contains chlorite, actinolite, epidote, and albite. Greenstones form by metamorphism of mafic igneous rocks (e.g., basalt, gabbro, diabase) or greywacke, with the chlorite, actinolite, and epidote deriving from ferromagnesian minerals and imparting a green color to the rock. The term denotes a fairly restricted range of metamorphic rocks characterized by particular colors, mineralogical compositions, and textural characteristics (e.g., Winters, 2010: 470–476).

The term “greenstone” has been used by Mesoamerican archaeologists to describe a generic category comprising a variety of rocks with

Fig 1. Map of the Belize Valley showing sites discussed in the text. (Map courtesy of Sherman W. Horn III).

greenish hues. Examples of this smorgasbord include jadeite, omphacite, serpentinite, metagabbro, albitite, basalt, gabbro and porphyry. Jadeite, defined as a rock in which the mineral jadeite is the main component, is an exception and is normally distinguished from other greenish-colored stone artifacts. Jadeite itself displays considerable variation in color, including blue greens with and without grayish tones; dark, apple, and olive greens; and even lavender, pink, and blackish hues (e.g., Andrieu et al., 2014; Hammond, 1991a; Harlow et al., 2011; Jaime-Riverón, 2010; Kovacevich, 2013). Jadeite has a distinctive luster, semi-translucency, and a high hardness (Mohs hardness = 6.5 to 7.0), however, that aid in its differentiation from other types of green-colored stones.

Detailed characterization studies leave little doubt that jadeite artifacts recovered from sites throughout Mesoamerica, Central America, and several islands in the Caribbean derive from the Motagua Fault Zone of Guatemala and neighboring areas of northeastern Honduras (e.g., Bishop et al., 1985, 1993; Garcia-Casco et al., 2013; Hammond et al., 1977; Harlow, 1993; Harlow et al., 2006; Kovacevich et al., 2005; Lange and Bishop, 1988; Lange et al., 1981). More than two decades of work on the mineralogy, crystal chemistry, and petrogenesis of jadeites and related rocks in the Motagua Fault Zone by George Harlow and colleagues (Harlow, 1993, 1994, 1995; Harlow et al., 2006, 2007, 2011;

Harlow and Sorensen, 2005; Sorensen et al., 2006; Tsujimori et al., 2006a, 2006b) has identified multiple jadeite-bearing locations within the extensive bodies of serpentinite melange that occur north and south of the fault over more than 200 km. This research documented a range of other jade-like rocks that occur widely within the Motagua Fault Zone and often have macroscopically visual, mineralogical, and microtextural characteristics that correspond to specific locations. The comparatively dark colors of some eclogites, amphibolites, and serpentinites are visually comparable to examples of greenstone triangulates from Pacbitun reported below. Similar amphibolites, serpentinites, and a range of other green-hued rocks (e.g., chlortitic/chlorite schists and gray-green phyllites), however, also occur in several other areas of Central America, Mexico, and the Caribbean (Fig. 2).

The dark-colored metamorphic rocks that archaeologists tend to call “greenstones” have been classified rather less rigorously than “jadeites” in terms of their different hues and textural characteristics. This tendency relates, in part, to the widely held view that these rocks were used interchangeably to manufacture celts and other objects and were not as highly valued as “true jadeite,” especially during the Classic period. Instead, they are thought to have formed an undifferentiated class of “social jade” that was distinguished from “true jadeite” in terms of its quality and value (Hammond, 1991a; Hammond et al., 1977).

Fig. 2. Map of Mesoamerica showing sites mentioned in the text and potential geologic source locations identified through petrographic analysis of the eight greenstone triangulates from Pacbitun, Belize. Box shows area presented in Fig. 1. Geologic source abbreviations: BB = Baldy Beacon; BVU = Baja Verapaz Unit; ETG = El Tambor Group; JPU = Juan De Paz Unit; MPR = Mountain Pine Ridge; SSC = Sierra de Santa Cruz Unit. Map courtesy of Sherman W. Horn III.

Hammond's (1991b: 99–103) study of Middle and Late Preclassic ground stone artifacts at Cuello, Belize, exemplifies this approach by separating “dark metamorphic greenstone” from “non-greenstone metamorphic and igneous” axes and celts, and distinguishing others between jadeite and “jade-like greenstone” artifacts. These categories provide intuitive ways to classify visually distinctive materials but gloss variability that may relate to geological source areas. Andrieu and colleagues (2014) classification of jade artifacts from Late Classic Cancuen, Guatemala, provides a more recent example: “black jade” and “various metamorphic rocks” are grouped together in one category that subsumes any visual variability among its constituents, while fine-grained distinctions are made among jadeites of different colors.

Jaime-Riverón (2010) made comparatively fine-grained distinctions among greenstone artifacts in his study of Early Preclassic celts at the sites of El Manatí, Veracruz, and Cantón Corralito, Chiapas. He described rocks according to type, tone, and color, and distinguished between metagabbros (metamorphic intrusive rocks), gabbros and basalts (intrusive and extrusive igneous rocks), serpentinites (a metamorphic rock consisting of minerals in the serpentine group), and mineralogical jadeite. The metagabbros (“black jade”) used in some celts were traced to scarce deposits in the Sierra de las Minas range in highland Guatemala, and the Motagua River Valley was suggested as the probable source for other varieties of greenstone. In the case of serpentinite, potential sources also include formations in southern Mexico (Jaime-Riverón, 2010: 130).

A previous study demonstrated that similar serpentinite celts from San Lorenzo-Tenochtitlán and La Merced derived primarily from quarries in Cuicatlán, Oaxaca, whereas the later La Venta celt assemblage exhibited more source variability, comprising Cuicatlán celts alongside examples from Tehuiztzingo, Puebla, and other unknown areas (Jaime-Riverón et al., 2009). This study employed thin-section petrography, scanning electron microscopy with energy dispersive spectrometry (SEM/EDS), neutron activation analysis (NAA), and particle-induced X-ray emission (PIXE) to determine the geologic origins of celts from Gulf Coast Olmec sites. As far as we are aware, this is the only detailed sourcing study of dark-colored, metamorphic “greenstone” materials involving a large set of artifacts and provenanced geological samples reported to date in Mesoamerica. Case-specific studies have focused on identifying rock types among smaller sets of greenstone artifacts, usually from a single site or collection, and comparing these findings to descriptions of geologic deposits to narrow the range of potential source areas (e.g., McAnany and Ebersole, 2004; Smith and Gendron, 1997). These studies suggest the potential of non-jadeite greenstone artifacts to reveal overlooked facets of early Mesoamerican exchange networks and warrant reviewing known geological sources of green-colored stones.

The geologic landscape of southern Mexico and Central America is described as a collage of tectonostratigraphic terranes or crustal blocks (Campa and Coney, 1983; Dickinson and Lawton, 2001; Estrada-Carmona et al., 2009; Martens et al., 2007). The history of

Table 1

Frequencies and contexts of green-stone triangulates at Belize Valley sites.

Sources: Cheetham, 1995, 1996; Hohmann and Powis, 1996, 1999; Horn III, 2015; Iannone, 1996; Powis, 2010; Powis and Hohmann, 1995; Powis et al., 2009).

Site	Frequency	Context	
		Primary (use-related/deliberate)	Secondary (redeposited/unknown)
Blackman Eddy	3	3 (100%) – ritual debris in structure 1 13 (46.4%) – cache 2	–
Cahal Pech	28	6 (21.4%) – floor 2 (7.1%) – off-platform refuse 16 (47.1%) – floor	2 (7.1%) – construction fill 4 (14.3%) – subfloor plaza B 1 (3.6%) – subfloor eastern ballcourt (plaza C)
Pacbitun	34	8 (23.5%) – on basal stairs of temple Q 2 (66.7%) – Off-platform refuse 1 (33.3%) – chultun midden	10 (29.4%) – midden
Tolok	3	–	–
Zubin	16	–	12 (75%) – looter's trench 4 (25%) – construction fill

tectonic and volcanic processes is highly complex and has been the subject of an extensive and ever-expanding corpus of formation-, complex- and terrane-specific studies and regional syntheses. Metamorphic rocks are distributed widely across this region and occur at multiple locations in Southern Mexico (e.g., Acatlán and Oaxaca Complexes), extending into Eastern (e.g., Chiapas Massif) and south-central (Motagua Fault Zone) Guatemala, Belize (Maya Mountains), and the mountainous regions of Honduras, Nicaragua and Costa Rica. Detailed characterization of metamorphic rocks, using a broad spectrum of analytical techniques, has been integral to petrogenetic interpretations, and a wide variety of greenstones are reported and described in the geological literature (e.g., Bateson and Hall, 1977, and references therein; Giunta et al., 2002a, and references therein; Keppie, 2004, and references therein; Lewis et al., 2006, and references therein; Martens et al., 2007, and references therein; Ortega-Gutiérrez, 1978, 1981; Schaaf et al., 2002; Sedlock et al., 1993, and references therein; Weber et al., 2007, and references therein).

Greenstones relating to metamorphic formations that contain ophiolitic and kyanite-bearing blueschist facies components are particularly relevant to the current study. Formations containing dismembered fragments of ophiolites, which are pieces of oceanic lithosphere, and/or related metamorphic rocks, have highly restricted distributions on the Central American mainland. They are confined to the Acatlán Complex in south-central Mexico; the Sierra de Santa Cruz, Baja Verapaz and Juan De Paz Units, and the El Tambor Group in the Motagua Fault Zone (Beccaluva et al., 1995; Giunta et al., 2002a, 2002b, 2002c); and specific localities in Costa Rica (Beccaluva et al., 1999) and Nicaragua (Lewis et al., 2006). They also occur on the north coast of South America (Venezuela and Colombia) and on several islands in the Caribbean, including Cuba, Hispanola, Jamaica, and Puerto Rico (Giunta et al., 2002b; Lewis et al., 2006). Blueschist facies metamorphic rocks often occur in these same formations (García-Casco et al., 2006; Harlow, 1994; Joyce, 1991; Martens et al., 2007), but the occurrence of kyanite-bearing rocks is far more restricted. Kyanite-bearing schists occur within the Chuacús Complex, part of the Sierra De Chuacús of the Motagua Fault Zone (Martens et al., 2007: 486–492; Ortega-Gutiérrez et al., 2004). The existence of kyanite-bearing rocks in the vicinity of the Maya Mountains in Belize is suggested by reports of kyanite along with minerals that commonly occur with it in medium- to high-grade metamorphic rocks, such as sillimanite, andalusite, staurolite and garnet, in heavy-mineral concentrates obtained from alluvial sands collected in the Middlesex area (Ower, 1928), the Sittee River, and the Belize River (Krueger, 1963; also see Martens et al., 2010: 818).

4. Greenstone triangulates in the Belize Valley: description, distribution, and context

The term “greenstone triangulate” was first used by Jaime Awe and Gyles Iannone to describe a new and relatively rare class of Middle Preclassic artifacts discovered at a handful of Belize Valley sites in the 1990s (Iannone, 1996). They were initially described as ground and

polished pieces of greenstone or low-quality jade with roughly triangular outlines and plano-convex cross sections. Only the convex surfaces of these artifacts, which regularly included multiple facets, showed signs of smoothing or polishing; their flattened faces were rough and thought to be unworked, which set them apart from greenstone celts that were highly polished on all surfaces.

The temporal and spatial distributions of greenstone triangulates appear restricted to Middle Preclassic occupations in the Belize Valley (see Fig. 1). Objects matching both the formal and material characteristics of triangulates have only been reported from the major centers Blackman Eddy, Cahal Pech, and Pacbitun, and from the smaller settlements Tolok and Zubin near Cahal Pech. Nearly all triangulates were recovered from Middle Preclassic deposits, although single examples were encountered in Late Preclassic construction fill at Cahal Pech and Zubin.

Contextual associations suggest greenstone triangulates were valuable items possessed and used by households and larger social groups (Table 1). Nearly half of the triangulates recovered from Cahal Pech, for example, were deposited in a single cache (Cache 2) placed inside the corner of a large Middle Preclassic platform (Platform B) at the time of its construction (Fig. 3). Cache 2 consisted of thirteen greenstone triangulates, three slate bars, and a headless ceramic figurine fragment stacked vertically and surrounded by sediment and cobble construction fill; it has been interpreted as a “creation cosmogram” and part of a ritual circuit of four platform-corner caches that symbolically represented the death and rebirth of an important community member (Garber and

Fig. 3. Photograph of Cache 2 at Cahal Pech. Photo courtesy of Sherman W. Horn III.

Awe, 2008). Horn (2015: 645–649) sees the construction of Platform B as an event that created a new co-residential group from previously separate domestic units, involving an initial pooling and deliberate removal of valuable materials from circulation, followed by recurring ceremonial proceedings that reinforced a newly created group identity.

Triangulates embedded in the floors of low residential platforms at Pacbitun (Fig. 4) and Cahal Pech (Hohmann and Powis, 1996; Horn, 2015: 389), and an example recovered with Middle Preclassic household trash inside a collapsed and sealed chultun at Tolok (Powis and Hohmann, 1995), suggest the use of these objects within domestic spheres, although little evidence indicates precisely how they were used. Additional examples encountered along the base of a large circular platform at Tolok (Aimers et al., 2000; Powis, 1996: 122), on top of the basal stairs of a large radial late Middle Preclassic (550–400 BCE) temple (known as Temple Q) buried beneath Plaza A at Pacbitun (Micheletti and Powis, 2015, Micheletti et al., 2016), and near a disturbed burial found in core inside a terraced platform at Zubin (Iannone, 1996: 382), hint that triangulates were also used in community-focused, public rites that transcended individual households.

Recent excavations have increased the sample of greenstone triangulates and permitted some refinement of their definition, although they remain problematic as an artifact category due to considerable variability in their size and shape. They are most commonly shaped as elongated, scalene triangles, but pieces with quadrilateral, ovoid, and

irregular outlines have been included in this class based on their material, cross sections, and opposed polished/rough faces (Table 2). The implications of this variability are not presently understood; it suggests that triangulate manufacture was not a standardized process, but it may also indicate that more than one functional artifact type has been included in the class.

Of particular interest to this study are material differences among triangulates, visible to naked eye, that may indicate different mineralogical compositions and metamorphic histories that can be tied to known geologic deposits. Visual inspection of the triangulates included in Cache 2 from Cahal Pech (see Fig. 3), for example, suggests that nearly all of these artifacts were made from different types of stone that may derive from separate, as it turns out, distant locations. Six appear to contain jadeite, omphacite, or albite, and may well derive from the Motagua Fault Zone; two are probably eclogites, which only occur along the Motagua and on islands in the Caribbean. The remaining five pieces include possible examples of fine-grained serpentinite, unknown medium-grained metamorphosed mafic rock and porphyry, and garnet-bearing amphibolites. Source locations of these stones cannot be determined without more precise identification of their mineral constituents and microtextural characteristics, but they demonstrate the range of mineralogically and texturally different rocks present in this artifact class and show the utility of visual inspection as a first step toward recognizing source variability.

Nearly all triangulates recovered from Zubin and Pacbitun visibly resemble the final category of fine- and medium-grained metamorphic rocks from Cache 2 described above, as do the remaining triangulates from other contexts at Cahal Pech. These stones clearly do not contain jadeite or other minerals known to be restricted to the Motagua Fault Zone, and their dark green color and metamorphic textures fit descriptions of non-jadeite greenstone artifacts from other Middle Preclassic sites (e.g., Hammond, 1991c; McAnany and Ebersole, 2004). We are aware of no studies explicitly directed toward determining the mineralogy and identifying sources of these non-jadeite greenstones, which were the most commonly used materials in triangulate manufacture. To address this problem, we selected eight non-jadeite triangulates from the Pacbitun assemblage for petrological characterization to identify their materials and narrow the range of their possible sources.

5. Petrographic pilot study of Pacbitun greenstone triangulates

Tracing stone artifacts to source locations reveals patterns of resource exploitation and the circulation of raw materials and/or finished products. Exchange networks and economic systems can be reconstructed by linking the areas where materials originated to depositional contexts at archaeological sites. Narrowing or pin-pointing source locations, through comparing the mineralogical and textural characteristics of stone artifacts with published descriptions of rocks with known geologic provenience, becomes possible once sufficient information is gathered to accurately identify the stones used in artifact manufacture. Connections between raw material source localities and specific sites can then be mapped and quantified through rock-type-based artifact counts.

The goals of this pilot study were to determine if all the sampled Pacbitun triangulates were made from the same type rock, and to

Fig. 4. Three different views of a single Middle Preclassic greenstone triangulate from Sub-Str. B-2, Plaza B, Pacbitun, Belize. (Photograph courtesy of Terry G. Powis).

Table 2
Descriptive Statistics for all triangulates listed in Table 1.

	Range	Minimum	Maximum	Mean	Std. deviation
Length (cm)	2.6	2.2	4.8	3.559	0.7197
Width (cm)	2.7	1.2	3.9	2.569	0.6741
Thick (cm)	1.3	0.8	2.1	1.408	0.3861
Mass (g)	35.3	4.4	39.7	16.716	9.1703

narrow or identify the potential source areas of these rocks to investigate Middle Preclassic exchange networks. An additional objective was to document mineralogical and microtextural characteristics of the rocks, in ways both geologically and archaeologically meaningful, to facilitate future comparative studies and stimulate further research on “greenstone” artifacts. The eight samples reflected the range of variation in morphology and visual appearance in the Pacbitun assemblage and derived from primary contexts in Middle Preclassic platform floors (Figs. 4 and 5).

5.1. Methods

Provenance studies often begin with visual inspections of stone artifacts and the recognition of variability in their appearances that suggests they derive from different geologic contexts. These observations are then followed by accurate characterization and identification of rock types based on mineralogical composition, microtextural characteristics, and evidence of geologic formation and alteration processes; optical microscopy (analysis of thin sections in polarized light), electron beam examination (microprobe; WDS, EDS, and X-ray imaging), and spectroscopic methods (e.g., XRF, XRD, PIXE, PIGE, Raman, Neutron Activation, Mass Spectrometry and Mossbauer) may be used to obtain this more detailed information. The techniques chosen depend on research goals, the characteristics of the samples being studied, and access to instrumentation, and several may be used in concert to understand the environments where rocks formed and were altered. Petrographic analysis – the examination of whole specimens with a hand lens and thin-sectioned samples with a polarizing microscope – is an essential first phase in sourcing studies that generates a descriptive baseline for geologic materials according to recognized standards, terminology, and rock classification criteria. Petrographic results also guide analyses with other techniques, which extract more specific and detailed information but require some foreknowledge of the materials being studied to be effectively used and interpreted.

All triangulates were initially examined with a hand lens and stereoscopic microscope to assess characteristics such as color, texture, common minerals, and alteration due to natural and cultural processes. Since archaeologists most often work with stone artifacts as hand specimens, we first characterized the samples using these methods to facilitate comparisons with other assemblages. The Pacbitun triangulates are all fine-grained rocks with surfaces smoothed by fabrication and/or weathering processes, however, which have obscured physical features useful for accurate identification. It was therefore necessary to examine thin-sectioned samples to accurately identify microtextural characteristics, mineral assemblages, and index minerals indicative of formation and alteration conditions. Compositions of mineral species were also *approximated* from optical properties observed in thin section.

The strategy for sampling artifacts for thin-section analysis differs from that used to sample natural rocks in important respects. In addition to isolating an area that captures essential textural and compositional characteristics of the rock, for example, sampling should be aimed at minimizing physical alteration of the artifact and preserving as much of the original morphology as possible. Sampling decisions should consider both geological and conservation concerns, and sampling should only proceed after thorough macroscopic examination and photographic documentation. Three-dimensional scanning and printing can also be used to preserve information. A high-precision saw was used to obtain a small cross-sectional sample (20- $\times$ -10- $\times$ -2-mm) of each Pacbitun triangulate that included the modified exterior surface and a portion of the interior. These samples were encapsulated in epoxy resin to ensure adequate stability during thin sectioning. Polished thin sections were then produced to meet the instrumentation requirements of both optical microscopy and microprobe analysis, the latter of which is an intended second phase of the current study.

5.2. Petrographic results and potential geologic sources

Three groups of rocks were identified in the Pacbitun triangulate sample that had visual characteristics indicative of different geologic origins (Fig. 5). The only group with multiple members (Group 1) was further characterized by internal heterogeneity in mineralogical and textural features, which suggests the rocks derived from the same geologic formation but from different localities on the landscape. Attributes of the samples are presented in detail in Table 3 and Table 4 contains more specific descriptions of the geologic units referred to in this section. Corrosion crusts were also identified on all triangulate samples and are described after the petrographic groups.

5.3. Group 1 - ophiolitic metamorphic rocks (PGS2, PGS3, PGS4, PGS5, PGS6, and PGS7)

The green-colored rocks in samples PGS2–PGS7 are “mafic greenstones” identified as low- to medium-grade metabasites, or metamorphosed basalts. Mineral assemblages and microtextural characteristics (Fig. 5) common to this group indicate the protoliths (original rocks) were oceanic basalts, called ophiolites when uplifted above sea level, although little of the original magmatic structure could be discerned in most cases. Chlorite is the dominant mineral in all ophiolitic triangulates, which is partly responsible for their greenish appearance and is represented by at least two episodes of mineral generation. Groundmasses are dominated by early-formed secondary chlorite, which vary from iron- to magnesium-rich among different specimens and are characterized by a distinctive radiating crystal structure. Epidote is a main associated mineral of the groundmass assemblages, and titanite, quartz, and opaques are present in minor and varying quantities in some samples and absent in others. Relic plagioclase phenocrysts, present only in PGS4, are the lone vestiges of the protolith. These mineralogical and textural characteristics suggest the original ophiolitic rocks underwent extensive ocean-floor metamorphism under greenschist-facies conditions.

Other characteristics indicate different but related histories of metamorphism for these six samples, involving distinct temperature-pressure conditions that suggest different formation environments. In PGS2–PGS4, the chlorite-dominated groundmass is overprinted by a later vein assemblage with coarse-grained chlorite (Fe-rich or Fe- to Mg-rich varieties) as a main constituent and quartz, epidote, and calcite as accessory minerals. Additional, mineralogically contrasting vein assemblages formed before the coarse-chlorite veins in PGS2 and after them in PGS3 and PGS4. The potential presence of serpentine in PGS2 further suggests a different metamorphic history for this rock.

Evidence of higher iron and magnesium content in the chlorite-dominated groundmasses of PGS6 and PGS7, suggested by optical properties of color and pleochroism, indicates a slightly different mafic-to-ultramafic composition for their protoliths, although these rocks also appear to be metamorphosed ophiolites. PGS6 contains a third episode of chlorite generation in the form radiating fans with transitional chemical compositions, while PGS7 is distinguished by a vein assemblage composed mainly of white mica and talc. The mica and talc veins overprint the groundmass and are themselves overprinted by later aggregations of opaques (sulphides), chlorite, and epidote. Microtextural characteristics of these two triangulates, which are coarser-grained and more fibrous than the other examples in this group (Fig. 5), also suggest a more serpentinized assemblage.

Shared characteristics of rocks in this group help narrow the list of possible sources among the continental ophiolite-containing rock formations presented in the preceding section. These include: 1) their inferred oceanic component, albeit generally lacking relic features (minerals/textures) of the original protolith; 2) the dominance of chlorite with radiating crystal structures in their groundmass; 3) the lack of platy, directionally aligned and interwoven crystal structures characteristic of schists; and 4) the multiple episodes of metamorphism indicated

Fig. 5. Exemplary photomicrographs of the three rock types differentiated showing typical textural and mineralogical differences in hand specimen (a) and thin section (b [PPL] and c [XPL]). PGS2 (a,b,c) and PGS7 (a,b,c) are Group 1 – ophiolitic metamorphic rocks; PGS8 (a,b,c) is Group 2 – rock with oceanic affinities and sedimentary origins; PGS1 (a,b,c) is Group 3 – kyanite-bearing rock. Examples of typical variability in the characteristics of modified surfaces of triangulates include: PGS5 (smoothed, convex exterior surface from which the corrosion crust has been removed during shaping); PGS8 (smoothed exterior, convex surface with a comparatively thick corrosion crust); PGS8 b (flat, rough obverse side from which the corrosion crust has been removed); PGS 3 (smoothed, convex exterior surface with a comparatively thin corrosion crust, thinned during shaping).

by overprinted veins and other textural features. Ophiolitic formations in Costa Rica, Nicaragua, and Venezuela can be immediately discounted because their greenschist-facies rocks are characterized by a different

mineral assemblage and retain textures of the igneous protolith (Martens et al., 2007: 514–515). Of the two remaining possibilities, the triangulates from this group more closely match published

Table 3

Detailed descriptions of Pacbitun triangulate physical attributes and rock types.

Sample #	Hand specimen	Minerals	Microtexture	Rock type and comment
PGS1	Color: greenish, dark gray Texture: coarse-grained/porphyritic; large phenocrysts in fine groundmass; whitish veins and fine foliations Visible minerals: Feldspar and quartz phenocrysts	Relic phenocrysts: abundant quartz, alkali feldspar; rare perthite and plagioclase partially altered to sericite and epidote Groundmass: secondary chlorite; minor quartz, seriticized feldspar and devitrified glass Metamorphic overprint: kyanite, muscovite, epidote; rare garnet	Pressure shadows (vugs) infilled with coarse-grained chlorite Later microveins of calcite	Highly-altered felsic igneous porphyry Blueschist facies grade metamorphism with retrograde greenschist alteration Corrosion crust present on convex surface
PGS2	Color: greenish-black Texture: fine-grained, whitish veins Visible minerals: sulphides (possibly pyrite) and calcium in veins	Groundmass: secondary Fe-rich chlorite with radiating crystal structure, epidote Veins: deformed calcite, quartz, chlorite, and opaques (sulphides) Late microveins: hematite	No dynamic metamorphic foliation Veins and late microveins present	Metabasite (protolith: oceanic basalt/ophiolite) Extensive greenschist seafloor metamorphism/hydrothermal alteration; 250 °C–350 °C Primary mineral assemblage elusive, including predicted minor accessory phases
PGS3	Color: greenish-black Texture: very fine-grained, brownish veins Visible minerals: calcium in veins	Groundmass: secondary Fe-rich chlorite with radiating crystal structure, epidote Veins: undeformed calcite; occasional overprint of Mg-rich chlorite grains Serpentine	No dynamic metamorphic foliation Veins present	Corrosion crust present on convex surface Metabasite (protolith: oceanic basalt/ophiolite) Extensive greenschist seafloor metamorphism/hydrothermal alteration; lower temperature than PGS2 (~200 °C) Primary mineral assemblage elusive, including predicted minor accessory phases
PGS4	Color: greenish-black Texture: coarse-grained; large, cleaved black phenocrysts; abundant veins Visible minerals: possible amphibole or pyroxene phenocrysts; calcite and epidote veins	Relic phenocrysts: occasional plagioclase Groundmass: secondary Mg-rich and Fe-rich chlorite with radiating crystal structure, epidote, titanite Veins: early fine calcite, quartz, epidote; later coarse calcite, quartz, minor epidote and Mg-rich chlorite	No dynamic metamorphic foliation Veins present	Corrosion crust present on convex surface Metabasite (protolith: oceanic basalt/ophiolite) Extensive greenschist seafloor metamorphism/hydrothermal alteration; higher temperature than PGS2 and 3 (300 °C–350 °C) Primary mineral assemblage elusive, some relic phenocrysts
PGS5	Color: greenish-black Texture: coarse-grained; abundant veins Visible minerals: calcite and epidote veins; sulphides (pyrite and possible chalcocopyrite)	Groundmass: Fe-rich chlorite with radiating crystal structure, later calcite and opaques Veins: highly deformed calcite, minor quartz and epidote	No dynamic metamorphic foliation Veins present	Corrosion crust present on convex surface Metabasite (protolith: oceanic basalt/ophiolite) Extensive greenschist seafloor metamorphism/hydrothermal alteration; higher temperatures than PGS2–4 (>350 °C) Primary mineral assemblage elusive, including predicted minor accessory phases
PGS6	Color: dark greenish-black Texture: coarse-grained, fibrous texture; rare veins; mineral patches (“blebs”) Visible minerals: epidote and minor sulphide blebs; unknown veins	Ghost phenocrysts: Fe- and Mg-rich chlorite, epidote, titanite, opaques (sulphides); occasional quartz Groundmass: secondary Fe-rich chlorite with radiating crystal structure, epidote Fans: Mg- to Fe-rich chlorite	Coarser/more fibrous texture than all preceding examples Veins present Radiating fans of chlorite transitioning from Mg- to Fe-rich	Corrosion crust present on convex surface Ultra-mafic igneous rock Extensive greenschist seafloor metamorphism/hydrothermal alteration Texture may indicate more serpentinized assemblage Mg-rich chlorites might be serpentine phyllosilicate
PGS7	Color: dark greenish-black Texture: coarse-grained, fibrous texture; common veins; mineral patches (“blebs”) Visible minerals: epidote and minor sulphide blebs; white mica, possible talc veins	Groundmass: secondary Fe-rich chlorite transitioning to Mg-rich chlorite with radiating crystal structure, epidote; white mica and talc overprint Veins: white mica, opaques, quartz; opaques (sulphides), chlorite, epidote overprint	No dynamic metamorphic foliation Veins present Coarser/more fibrous texture similar to PGS6	Corrosion crust present on convex surface Ultra-mafic igneous rock Extensive greenschist seafloor metamorphism/hydrothermal alteration Texture may indicate more serpentinized assemblage
PGS8	Color: greenish, dark gray Texture: fine-grained; foliated; deformed blebs follow foliations Visible minerals: micaceous phyllosilicate (muscovite?)	Groundmass: Fe-rich chlorite transitioning to Mg-rich chlorite Foliation: white mica (muscovite), chlorite Blebs: relic feldspar phenocrysts altered to sericite, epidote, titanite, and quartz Lithic fragments: quartz, muscovite	Prominent/clear foliation Lithic fragments	Corrosion crust present on convex surface Altered sedimentary rock formed near basaltic igneous rocks More dynamic history of metamorphism than other sample caused foliation; greenschist facies Lithic fragments suggest sedimentary origin Corrosion crust present on convex surface

Table 4
Descriptions of geologic units in potential green stone source areas.

Larger unit	Sub-units	Lithology
Acatlán complex	Xayacatlán formation	Fine-grained greenstones; metagabro; metabasite; serpentinite; eclogite; amphibolites; metasedimentary rocks with ophiolitic affinities
	Interface	Chloritites; talc rock; epidotite; other monomineralic rocks
	Cosoltepec Formation	Amphibolites; quartzites; phyllites; greenstones; schists; fragments of oceanic crust
	El Tambor group	Serpentinized oceanic peridotites; jadeite; eclogite; mylonitized gabro; pillow lavas; amphibolites; low-grade metasediments;
Motagua fault zone	Chucús complex	Prehnite-pumpellyite-chlorite rocks Hydrothermally altered prehnite-chlorite-actinolite-crenulated greenschist rocks Mafic eclogites; eclogitic relicts with oceanic affinities; phyllites
		Sericitic schists with chlorite (quartz + albite + chlorite + sericite + epidote + actinolite + stilpnomelane)
		Kyanite-bearing gneisses (quartz + plagioclase + white mica + garnet + kyanite) Metasedimentary rocks (sericite, chlorite)
Maya mountains	Mountain pine ridge granitoid	Hydrothermally altered granitoids (chloritized biotite, tourmaline, sericitized feldspars, perthite)
	Bladen formation (formerly Bladen Volcanic Member)	Rhyolites, rhyolitic tuffs, volcanic sediments
		Metamorphosed felsic porphyries (quartzo-feldspathic matrix; quartz, perthite, sericitized plagioclase feldspar phenocrysts; chlorite patches; white mica, quartz, chlorite in fine-grained aggregates)

descriptions of rock samples from the Acatlán Complex in south-central Mexico than those from the Motagua Fault Zone in Guatemala.

The Acatlán Complex contains a petrographically varied suite of rocks that experienced a complex history of tectonic, deformational, and metasomatic metamorphism (Elías-Herrera and Ortega-Gutiérrez, 2002; Galaz et al., 2013; Ortega-Gutiérrez, 1978, 1981; Ortega-Gutiérrez et al., 1999; Yanez et al., 1991). The complex is subdivided into a number of lithostratigraphic units, including the Xayacatlán and Cosoltepec Formations that include oceanic components (Table 4). Rocks in the Xayacatlán Formation were thrust over Cosoltepec deposits, creating several new monomineralic rocks through metasomatism close to the interface of the two formations and along the periphery of lenticular serpentinite bodies in the Xayacatlán Formation. Ortega-Gutiérrez (1978: 121) describes the textures of these rocks as varying from unfoliated to intensively foliated or mylonitized, while González-Mancera et al. (2009) report that minerals such as antigorite form radial crystal aggregates in the serpentinitized rocks that lack foliation. Associated with the serpentinitized rocks are examples of chloritite formed through two episodes of chlorite generation, which are represented by an earlier groundmass and later vein assemblage that vary from Fe-rich to Mg-rich compositions. Taken together, the characteristics of these Acatlán Complex rocks are comparable to those of the triangulate rocks described above. Differences among the triangulates, such as the presence/absence of talc veins and variably serpentinitized assemblages, are also consistent with the grading and varying lithologies reported

Fig. 6. Photograph of a pulidor with a wooden handle from Mexico, dating to 1200–900 BCE. This object, with a finely shaped and highly polished stone mounted on a long, tapering handle, is extremely rare because the wooden handle has survived. The translucent stone, shading to amber in center, is attached to the hollowed out top of the handle with sinew and pitch ... “It may have been used by a shaman to effect cures” (Tate and Reilly, 1995: 295).

for the greenstones, serpentinites, and associated monomineralic rocks of the Xayacatlán and Cosoltepec Formations (e.g., Carballido-Sanchez and Delgado-Argote, 1989; Galaz et al., 2013; Proenza et al., 2004).

Chlorite-containing metamorphic rocks and ophiolitic components are also reported from the El Tambor Group and the Chucús Complex in the Motagua Fault Zone (Table 4), which raises the possibility that the ophiolitic triangulates derive from this area. The El Tambor group contains abundantly serpentinitized oceanic peridotites that bear blocks of jadeite, eclogite, mylonitized gabbros, pillow-lavas, amphibolites, and low-grade metasedimentary rocks. Prehnite-pumpellyite-facies metamorphism and hydrothermal alteration produced rocks containing chlorite, prehnite, and actinolite, and crenulated greenschists that differ from chlorite-bearing rocks in the Acatlán Complex (Beccaluva et al., 1995; Martens et al., 2007: 502–506). The Chucús Complex contains mafic eclogites and eclogitic relicts with oceanic affinities, as well as chlorite containing phyllites and chlorite-containing sericitic schists that formed under greenschist facies conditions (Martens et al., 2007: 492–495). The mineralogical and textural characteristics of the El Tambor and Chucús rocks differ substantially from those observed in the ophiolitic triangulates. In surveying the extensive literature dealing with metamorphic rocks of the Motagua area, we found no descriptions of unfoliated rocks with textures comparable to these triangulates that were dominantly composed of chlorite. Current evidence therefore suggests that this group of triangulates more likely derives from the Acatlán

Complex of South-Central Mexico than the Motagua Fault Zone of Southern Guatemala.

5.4. Group 2 – rock with oceanic affinities and sedimentary origins (PGS8)

Mineralogical and textural attributes of PGS8 (Fig. 5) indicate affinities to oceanic basalt, although this rock was distinctly different from the previously described group. PGS8 is dominantly composed of chlorite with that of the groundmass formed in radiating crystals similar to those observed in the ophiolitic triangles; a foliation consisting primarily of white mica and quartz, however, indicates a more dynamic history of metamorphism. Relict feldspar phenocrysts altered into sericite, epidote, titanite, and quartz occur sporadically as blebs (i.e., small bubble-like inclusions). Lithic fragments of quartz and muscovite are an additional distinguishing characteristic of PGS8 that suggest a sedimentary component.

The mineralogical and textural characteristics that PGS8 shares with the ophiolitic triangle group more closely match descriptions of Acatlán Complex rocks than rocks from the Motagua Fault Zone (Table 4). Although foliations are absent in the other triangles, the mineral assemblage of the foliation in PGS8 is consistent with components of the Acatlán Complex. Metasedimentary rocks intergrade with other rock types in both the Cosoltepec and Xayacatlán Formations, which could explain the lithic fragments observed in this sample.

5.5. Group 3 – kyanite-bearing rock (PGS1)

PGS1 displays distinctive color, mineralogical, and microtextural characteristics (Fig. 5) that clearly differentiate it from the other triangles and suggest a different source. This specimen derives from a different type of metamorphic rock that can be described as highly altered felsic porphyry, with abundant relic phenocrysts of quartz, alkali feldspar, perthite, and plagioclase dispersed in a groundmass consisting of secondary chlorite with minor quartz, sericitized feldspars, and devitrified glass. A foliation composed of kyanite, muscovite, epidote, and rare garnet wraps around the relic phenocrysts and continues into the groundmass, and later microveins of calcite are present but rare. The mineral assemblage and metamorphic overprint indicate the igneous protolith underwent some degree of blueschist metamorphism (i.e., high temperature/low pressure) and was subsequently altered under greenschist-facies conditions (retrograde alteration). This distinctive metamorphic history, together with the presence of kyanite and garnet, substantially narrow the potential sources of this rock.

Kyanite-bearing rocks occur only in the Chuacús Complex on the Central American mainland, which is also distinguished by locally retrograded high-grade metamorphic rocks of both igneous and sedimentary origin (Solari et al., 2011). The kyanite-bearing rocks, generally described as gneisses, have a very restricted geographic distribution and primarily occur in the Palibatz-El Chol area of the Sierra de Chuacús in central Guatemala (Martens et al., 2007; Solari et al., 2011; Ortega-Gutiérrez et al., 2004). Sporadic kyanite-bearing schists are also reported from the El Progreso-San Agustín area, which straddles the Motagua River immediately to the east (Martens et al., 2007: 496–497).

Descriptions of kyanite-bearing rocks in the Motagua Fault Zone (Table 4) compare favorably to mineralogical and textural characteristics observed in PGS1. Retrograde greenschist-facies alteration in this area involved the replacement of kyanite by white mica, plagioclase by epidote, and the chloritization of garnet (Martens et al., 2007: 490–492), and each of these minerals were observed in the specimen. The fine foliations, chloritized groundmass, and later microveins in PGS1 further suggest a complex metamorphic history involving multiple events under different environmental conditions that is parsimonious with regional geologic models. There are significant differences, however, between some characteristics of PGS1 and descriptions of the Chuacús Complex rocks that preclude a definitive assignment of artifact to

source. These include the presence of volcanic glass in the groundmass of the sample and the overall abundance of chlorite, as well as the apparent lack of perthite in Chuacús Complex rocks.

The Maya Mountains of central Belize are a second potential source of the PGS1 rock. Kyanite-bearing rocks are suggested by kyanite in the heavy-mineral concentrates of alluvial sands from the east-trending Belize and Sitté Rivers, although parent rocks have not been identified. These rivers and their tributaries drain rugged upland terrain, where metasediment contact aureoles were created by granitoid plutons intruding into older sedimentary formations (Krueger, 1963; Martens et al., 2010; Ower, 1928). The same heavy mineral fractions contain garnet, epidote, and other minerals identified in the PGS1 assemblage. Metasedimentary rocks contain sericite and chlorite near the intrusive Mountain Pine Ridge pluton, and the granitoids show evidence of hydrothermal alteration and contain perthite as a characteristic feldspar component (Table 4) (Jackson et al., 1995; Shipley, 1978).

Felsic porphyries and related volcanic sediments are reported from the area around Baldy Beacon (Table 4), which is a peak situated on the northeastern margin of a contact aureole drained by the rivers with heavy mineral sediments. The porphyries are part of the Bladen Formation, formerly called the Bladen Volcanic Member (Martens, 2009; Martens et al., 2010), and are commonly deformed and weakly metamorphosed into rocks with fine-grained, quartz-feldspathic matrices embedded with phenocrysts of quartz, perthite, and sericitized plagioclase feldspar. Patches of chlorite and fine-grained aggregates of white mica, quartz, and chlorite have also been noted (Bateson and Hall, 1977: 16; Martens et al., 2010: 828). The descriptions of Bladen Formation rock samples resemble the mineral assemblage and porphyritic texture of PGS1, although these rocks have comparatively less-complex metamorphic histories and lack kyanite and garnet. Taken together, the existence of rocks comparable to PGS1 in the vicinity of Baldy Beacon and the Mountain Pine Ridge suggests the Maya Mountains cannot be discounted as a potential source area for triangle raw materials. Additional information about metamorphic rocks in this area of Belize is required, however, before more definitive provenance assessments can be made.

5.6. Corrosion crusts on triangle surfaces

Corrosion crusts that varied in thickness were identified on the convex surfaces of all triangles (Fig. 5). These crusts, formed through the chemical weathering of iron-bearing minerals in rocks by water, appeared as thin layers or rinds that were rich in oxides and visually distinct in thin section from the unaltered rock of the sample interiors. Constant exposure to water over long periods of time is necessary for rocks to develop corrosion crusts, which indicates the raw materials used to make the Pacbitun triangles derived from sedimentary deposits (e.g., alluvial gravel) rather than outcrop sources. The restriction of corrosion crusts to the convex surfaces further suggests these represent the original exteriors of river cobbles that were naturally rounded by fluvial transport and deposition. Variation in crust thickness may have resulted from differential smoothing and polishing across these surfaces, and the absence of equivalent crusts on the flat, rough faces of the sampled triangles suggests their removal during manufacture.

6. Discussion of the petrographic study and “greenstone” in the Middle Preclassic Maya Lowlands

Three findings of the initial petrographic study have direct implications for understanding Middle Preclassic economic interactions and deserve further discussion: 1) the rocks used to make triangles varied in mineralogical and textural characteristics; 2) corrosion crusts were present on the convex surfaces of the artifacts; and 3) most of these greenstones traveled great distances before arriving in the Belize Valley. Decentralized procurement strategies and opportunistic participation in exchange, suggested by raw material variability and availability

in sedimentary deposits, may have been important elements in Middle Preclassic greenstone circulation networks that have not been addressed by previous research. The results further suggest that complex socioeconomic networks connected Belize Valley communities to faraway places in Mesoamerica before institutionalized social hierarchies emerged in the region.

Mineralogical and textural variability among the triangulate samples indicates different geologic sources were exploited for raw materials. Put another way, the non-jadeite greenstones used to make triangulates do not all derive from the same area on the landscape, which has implications for current models of Middle Preclassic exchange systems. The assumption that greenstone artifacts in the Maya Lowlands originated in the jadeite-bearing Motagua Fault Zone has rarely been challenged through detailed materials analysis, although the Maya Mountains have also been suggested as a potential source area for green rocks (Dunham, 1996; Thompson, 1970: 140). Some triangulates from the Pacbitun sample may derive from the Motagua Fault Zone, but many more likely do not, and a single geographic source for these materials is not supported by the data. This complicates models of directional trade that link the movement of greenstone into the lowlands with obsidian traced to highland sources, since only the Motagua Fault Zone falls along postulated highland-lowland trade routes. Source variability instead suggests the inhabitants of Pacbitun, and probably other nearby communities (e.g., Cahal Pech and Blackman Eddy), participated in multidimensional exchange networks that transported green-colored rocks from several different areas into the Belize Valley.

The origin of triangulate rocks in sedimentary deposits, as indicated by corrosion crusts along their convex surfaces, is consistent with both the variability observed in the materials and the hypothesis that they derived from different geographic locations. Mineralogical and textural variability among rocks identified as metamorphosed ophiolites, for example, would be expected if cobbles were gathered from widely separated stream beds draining different areas of a rock formation. A single gravel deposit comprising materials transported from a large geographic area might also produce this result, although this scenario does not account for rocks with substantially different mineral constituents (e.g., the kyanite-containing rock PGS1). The availability of suitable green-colored rocks in gravel deposits, which may have been less centralized than outcrop locations, raises the possibility of decentralized procurement of these materials for exchange and triangulate manufacture. Access to diffuse and dynamic rock sources, such as seasonally renewed stream gravels, would be more difficult to control than with stationary quarries, and anyone living in the right locations with an eye for green rocks may have been able to obtain these materials. The use of available river cobbles also fits with the non-standardized size and shape of triangulates, which retained substantial sections of the original rock surface and were probably constrained by raw material dimensions.

If material variability and availability imply informal actions within triangulate exchange systems, the distances most rocks traveled before arriving in the Belize Valley suggest complex interaction networks were responsible for their circulation. Metamorphosed ophiolite triangulates, comprising most of the sample from Pacbitun, probably originated in the Acatlán Complex of south-central Mexico, which lies over 900 km as the crow flies from the Belize Valley. These materials likely covered even more ground to reach their destinations, given the rugged terrain that separates the two regions and the distance of coastal routes from the Gulf of Mexico to the Caribbean. Less distant green-rock sources in the Motagua Fault Zone, which do not closely match the Pacbitun materials but may be represented by the Cahal Pech jadeite and eclogite triangulates, are still separated from the Belize Valley by over 100 km of aerial distance and many more along the river and coastal trade routes postulated for other highland mineral resources (Hammond, 1972; Healy et al., 1984; McKillop, 1989). Only the Maya Mountains source around Baldy Beacon is located within 100 km of the Belize Valley, and only one triangulate (PGS1) potentially derives from this area.

Bladen Formation outcrops exist in other areas of the Maya Mountains, however, and this triangulate may have originated farther to the south-east where green metamorphic rocks have been collected along the Trio Branch watercourse (Dunham, 1996). We do not yet know how the socioeconomic relationships that transported these materials over such large areas were structured, but they must have promoted interactions among widely separated settlements. Exchange relationships would have facilitated information flow within a network of distant but connected communities, which may have been critical to developments in sociopolitical complexity across the Maya Lowlands during Middle Preclassic times (Horn, 2015: 672–678).

The prevalence of metamorphosed ophiolites from the Acatlán Complex is an unexpected result that suggests strong connections to early monumental centers far beyond the Maya Lowlands. A large area of the Acatlán Complex is located within 50 km of Chalcatzingo, which was an important Middle Preclassic community and ceremonial center marked by numerous carved stone monuments (e.g., Grove, 1987). Numerous greenstone artifacts were recovered from Chalcatzingo, including drill cores and partially worked fragments that indicate some amount of lapidary production occurred on-site, and material similarities with greenstone artifacts from La Venta led analysts to suggest these communities shared a source or supplier (Thomson, 1987). The Chalcatzingo greenstone assemblage has not been petrographically or geochemically studied, but the serpentine, fuchsite (chromium-rich green mica), and chrysoprase (chlorite-rich green chalcedony) noted seem compatible with chloritic Acatlán Complex rocks (Grove, 1987). Analysis of materials from La Venta, the important Middle Preclassic Olmec center in Gulf Coast Tabasco, indicates that Acatlán Complex greenstones were used alongside rocks from other areas to make celts (Jaime-Riverón et al., 2009). These two early seats of sociopolitical development may have engaged in exchange relationships that transported green rocks from Acatlán Complex sources, although the social contexts of the exchanges and how the materials moved between communities are not clear.

If the Acatlán Complex was a common source of green rocks for Chalcatzingo and La Venta, the occurrence of similar materials in the Belize Valley suggests communities there were somehow connected to these far-away centers of political and religious authority. We do not know how interactions between Belize Valley settlements and monumental centers in Mexico were structured during Middle Preclassic times, but hierarchical political relationships seem unlikely. Apart from the large distance between the two regions, Belize Valley communities differed substantially from their Gulf Coast and central Mexican counterparts in site layout, architecture, caching patterns, and material culture (e.g., greenstone celts vs. triangulates). These dissimilarities contrast with similarities between La Venta and settlements in Chiapas and the Rio Pasión drainage of Guatemala (Inomata et al., 2013), which suggest more intensive interactions among these communities than between them and groups in the Belize Valley.

The identification of rocks from different geographic sources at Pacbitun also resembles the variability in the La Venta greenstone assemblage, and similar variability is suggested from macroscopic observation of the Cahal Pech triangulates. Green rocks from multiple sources were used to make stylistically identical artifacts and may have been viewed as equivalent materials from a functional standpoint, although the dominance of rocks likely to have come from the Acatlán Complex in the Pacbitun sample indicates these stones were favored over others. This preference for visually similar rocks from a very distant source suggests some of their importance derived from the exchange relationships that brought them to the Belize Valley and the connections to distant communities they symbolized.

7. Conclusions

Contextual and compositional data suggest greenstone triangulates were valuable objects in the Middle Preclassic Belize Valley that were

obtained from disparate and possibly distant sources through complex exchange networks. Triangulates form a regional subset of green-colored stone artifacts from the Middle Preclassic Maya Lowlands that indicate participation in a pan-Mesoamerican symbolic tradition that endured for millennia. They further represent the durable remains of exchange networks that connected far-flung communities at a time of developing social and political complexity. Their restricted distribution to settlements in the Belize Valley, however, suggests some of their importance derived from more intensive interactions among communities and individuals at the regional scale. Triangulates may therefore represent a regional expression of an ideological system that imbued greenstones with cosmological significance and linked distant regions of Mesoamerica through exchange of materials and information.

The present restriction of greenstone triangulates to the Middle Preclassic Belize Valley is supported by a comprehensive review of reports from Preclassic sites around Mesoamerica, which found no mention of artifacts that matched the characteristics of these objects. Some of this apparent constraint may result from earlier ambiguity in the definition of triangulates and the use of different terms to describe similar artifacts elsewhere (e.g., “jade pebbles” at Cival, Guatemala [Estrada-Belli, 2003: Fig. 5]), but the constellation of formal and material attributes presented above does not fit well with published descriptions of artifacts discovered outside the Belize Valley. Rough parallels exist with polished-stone *pulidores* (“pot polishers”) from Early and Middle Preclassic sites in central Mexico, Chiapas, and the Gulf Coast region, which have smooth, multi-faceted surfaces and are roughly the same size (c. 2–5 cm) as triangulates (Agrinier, 1984: 88; Coe and Diehl, 1980: Fig. 231; Tate and Reilly, 1995: 295; Thomson, 1987: Fig. 17.13; Tolstoy, 1971: Fig. 6c; Vaillant, 1930: Plate 41). The resemblance is far from complete (Fig. 6), however, as *pulidores* differ from triangulates in outline and cross section, lack a single rough, flat face, and are frequently made from different-colored rocks (e.g., red jasper, clear rock crystal, fine-grained black rock).

So-called *pulidores* may have been used in shamanic divination rites rather than as actual polishing stones (Tate and Reilly, 1995; Thomson, 1987), and we cannot rule out a related function for greenstone triangulates. No direct analogs of these artifacts have yet been reported beyond the Belize Valley; however, if triangulates were used for similar purposes as *pulidores*, the way they functioned in these practices was specific to the region. The rough, flattened surfaces of triangulates were most likely not visible during use, since no effort was made to match the smoothness of their obverse faces. Roughened surfaces would have promoted adherence to other objects if the intention was to fix triangulates onto another material with an adhesive, but exactly what these objects were attached to remains unknown.

The confinement of triangulates to the Belize Valley contrasts with the widespread circulation of other Preclassic greenstone items, such as celts and beads. We have noted the broad distribution of celts across Mesoamerica during Middle Preclassic times, although few of these artifacts have been reported from the Belize Valley. Beads were the most common green-colored stone artifacts in the Middle Preclassic Maya Lowlands and appear to represent shared value systems and practices of adornment across much of the area. Beads of various shapes and sizes have been recovered at Middle Preclassic settlements in northern Belize (e.g., Bartlett, 2004; Buttles, 2002: 245–257; Hammond, 1991a; Pendergast, 1982), the Petén (e.g., Willey, 1972), and the Belize Valley (e.g., Awe, 1992: 304–307; Cheetham, 1996; Iannone, 1996; Hohmann and Powis, 1996; Horn, 2015: 380–383), and they were most frequently deposited with caches and burials. The circulation and consumption of greenstone beads were interregional phenomena that linked the Belize Valley to communities across the Maya Lowlands, but the apparent dearth of celts in the region requires additional study to explain. Celts may have functioned as currency and preforms for small carved artifacts in other contexts (Taube, 2000, 2005), and triangulates could have fulfilled similar roles at Belize Valley settlements. This might explain the lack of overlap in the distributions of these artifacts, although a

better understanding of triangulate use is necessary to further this argument.

Sourcing triangulate materials to distant geologic formations indicates the Belize Valley was connected to other areas of Mesoamerica from the earliest days of settlement in the region and raises the possibility of expansive trade relationships. Triangulates were frequently deposited in the same contexts as marine shell ornaments, and evidence of extensive shell ornament production has been recovered at several Belize Valley settlements (Cochran, 2009; Hohmann, 2002; Horn, 2015: 453–458). Marine gastropods from the Caribbean Sea were the most common sources of material for shell beads and other ornaments, and ophiolitic rocks and jadeites are known to occur on several Caribbean islands (García-Casco et al., 2013: Fig. 1; Lewis et al., 2006: Fig. 1). These rocks do not appear to match the mineralogical and textural characteristics of the Pacbitun ophiolitic triangulates as well as those from the Acatlán Complex, but variability in the greenstone materials and their association with Caribbean marine shells suggests trans-Caribbean trade should not be quickly dismissed. Small jadeite celts that resemble triangulates have also been reported from later periods at sites in the Dominican Republic and Puerto Rico (Rodríguez Ramos, 2010: Fig. 6), and the later exchange networks that crisscrossed the Caribbean and coastal Mesoamerica may have been rooted in much earlier times.

The descriptions of greenstone triangulates and their recovery contexts provided in this paper can be used for future comparative research, and the questions raised by this study should stimulate interest in the circulation of non-jadeite greenstones in Middle Preclassic Mesoamerica. Petrographic analysis of the Pacbitun triangulates produced information on raw material form (i.e., river cobbles), potential source areas, production techniques, and material variability that challenges traditional understandings of greenstone procurement and exchange in early time periods. Additional research is needed to expand our understanding of Middle Preclassic greenstone circulation, and we hope this study will provide a methodological basis for researchers interested in tracing exchange networks during this critical period of Mesoamerican social development.

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