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REPORT

A Multimethod Approach to Sourcing Maya Lowland Chert Resources

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Abstract

Within the Maya region, chert artifacts remain one of the most common material types recovered from archaeological excavations and are a core line of evidence for reconstructing ancient economies. However, methods for sourcing of chert throughout Mesoamerica have been underutilized. Archaeologists need to understand how these artifacts moved within regional and local exchange networks and the influence particular source areas had over settlement patterns and economic development. Recent advances in chert provenance analysis provide an opportunity to revisit these research issues. We discuss the preliminary results of microscopic and geochemical analysis from recent geological sampling of northern Belize chert outcrops.

Resumen

Dentro de la región maya, los artefactos de pedernal siguen siendo uno de los materiales más comunes recuperados de excavaciones arqueológicas y son una línea central de evidencia al reconstruir la economía antigua. Los métodos para estudiar fuentes de abastecimiento de pedernal a través de Mesoamérica, sin embargo, han sido en gran medida subutilizados. Los arqueólogos a menudo se preguntan cómo se movieron estos artefactos dentro de las redes de intercambio regionales y locales, y la influencia que tuvieron ciertas fuentes de abastecimiento sobre los patrones de asentamiento y el desarrollo económico. Recientes desarrollos metodológicos dentro del campo del análisis de procedencia del pedernal han brindado la oportunidad de revisar estos temas de investigación. Este artículo discutirá resultados preliminares del análisis microscópico y geoquímico de muestreos geológicos recientes de afloramientos de pedernal en el norte de Belice.

Keywords: lithics; northern Belize; sourcing

Palabras clave: litico; norte de Belice; abastecimiento

The ability to source archaeological artifacts has been fundamental in establishing trade and exchange networks, economic patterns, and systems of procurement and manufacture (Braswell and Glascock 2002; Moholy-Nagy et al. 2013; Nazaroff et al. 2015). Although the suite of material that can be sourced continues to expand (Pollard and Heron 2008), obsidian (see Braswell 2025; Ebert et al. 2019; Nazaroff et al. 2010) and ceramic (Jordan et al. 2022; Neff et al. 2006; Parker et al. 2022) sourcing still figures prominently in reconstruction of ancient Maya life. While obsidian and ceramics sourcing studies have provided key insights into Maya political economies, other material like granite (Burg et al. 2021; Tibbits 2016) and chert (Tobey 1986) have proven a challenge for sourcing research due to their complex geological and geochemical compositions.

Lithic analysis provides one of the most fundamental and productive paths for studying the organization and structure of the Maya economy. Unlike obsidian and greenstone whose sources are limited to the highlands of Guatemala or Central Mexico chert naturally forms in the limestone bedrock that makes up a large portion of the lowlands, making it a readily available material. Chert quality varies greatly both between and within chert bearing areas. Regional communities developed strong preferences for raw material from specific, local sources (Barrett 2004; Hester and Shafer 1983, 1984; Horowitz et al. 2020; Lewis 2003; Speal 2009). Currently, the ability to discern individual chert source groups from each other is limited (Cackler et al. 1999; Tobey 1986) within the Maya region. This report explores several potential methodological avenues for determining specific chert sources, and identifies potential source clusters within the Chert Bearing Zone (CBZ) of northern Belize.

Geology of Northern Belize

The Belize mainland is divided by the Maya Mountains into the Corozal Basin and the Belize Basin (Aitken and Stewart 2002). The Corozal Basin of northern Belize is an extension of the Yucatan platform and is stratigraphically part of the North Peten Basin of Guatemala. Four physiographic zones comprise this region from west to east: (1) a karst flat limestone plain where chert is plentiful, (2) a centrally located zone of coastal swamp, (3) a well-developed lagoonal zone, and (4) a barrier reef zone in the Caribbean (Gill et al. 2018). According to land and soil survey conducted by Wright et alia (1959), a "cherty soil zone" covering an area of more than 544 km^2 is present in northern Belize. Surveys by Kelly (1980) reduced the size of this area to approximately 181 km^2. This area was later termed the "Chert-Bearing Zone," or CBZ (Figure 1; Hester and Shafer 1984:159). Chert is largely confined to the Barton Creek and Doubloon Bank formations (Figure 1). Several archaeological sites are located within the CBZ. Among these sites is Colha, a large lithic production site that was advantageously situated to exploit the high-quality nodular chert located within the CBZ (Iceland 1997). Small chert tool workshops were found across the CBZ, including those at Kanahmul, Chicawate, Sand Hill, and Altun Ha (Kelly 1980).

Background

Northern Belize Chert Economy

The lithic economies of the Maya region were multifaceted and ever fluctuating, operating alongside multiple production-distribution spheres at different scales (Aoyama 2017; Hruby et al. 2011; Kovacevich and Callaghan 2019; Scarborough and Valdez 2009).

The uneven distribution of chert raw material across the lowlands has led to the development of more complex exchange networks than typically seen for other resources. At a regional scale, widely dispersed chert was more susceptible to being passed through embedded social networks among corporate households, relatives, associates, sold in local markets, or bartered away for other products (Horowitz et al. 2020). However, at the same time, chert products with a higher social value (e.g., stemmed macroblades, eccentrics, thin bifaces) or made from a high-quality material (CBZ material) circulated through more exclusive networks such as high-level trade, tribute, or elite gift-giving (McAnany 1993; Speal 2009).

A multitude of research projects have been critical in establishing regional chert exchange networks, often applying visual sourcing methods or looking at consumption patterns through lithic reduction processes. The distribution of chert sources through the northern lowlands has largely been a product of speculation, with visual sourcing of Colha chert forming the bulk of evidence for lithic exchange (Hester and Shafer 1984; Mitchum 1994). Based on evidence for formal tool production in specialized workshops at Colha and surrounding sites, the "producer-consumer" model was established and became the prevailing theoretical rubric for the chert economy of the central lowlands (Hester and Shafer 1984). This model was based on the idea of "producer" sites in which evidence of major tool manufacture and export occurred and "consumer" sites that received manufactured products. There is now evidence suggesting that consumer sites located in or near the CBZ procured localized raw material while also engaging in formal tool exchange (Dockall and Shafer 1993; McAnany 1989; McSwain 1991; Santone 1997; Stemp et al. 2010). However, with such broad similarities among chert sources across the 181 km^2 CBZ and an inability to identify other regional sources, there is no sure way to determine which sites were importing tools or procuring their own raw material (King 2017: 438).

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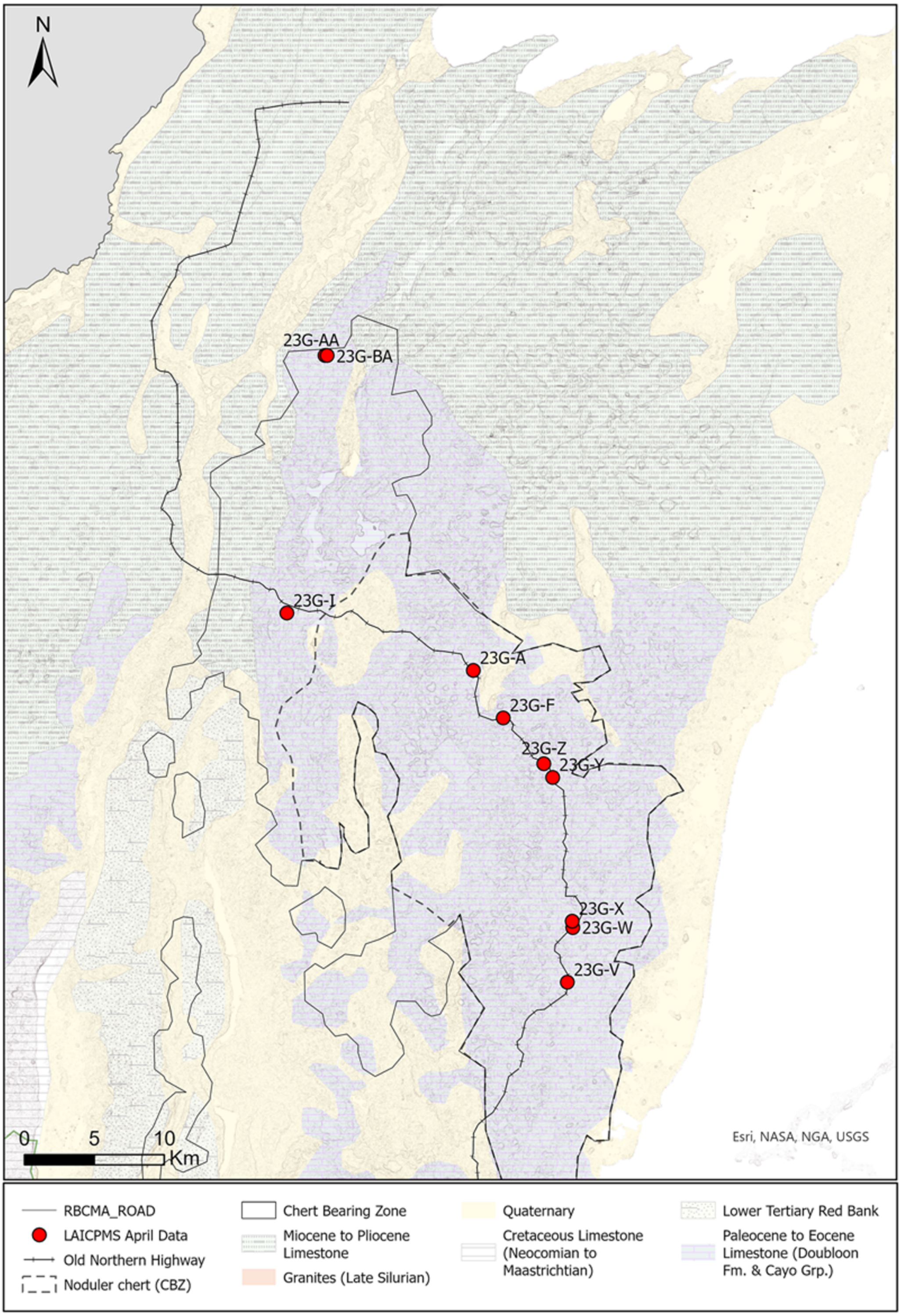

Figure 1. Map showing the geology of the study region and location of geological samples collected for this study. (Color online)

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Chert Sourcing

Provenance studies of Mesoamerican chert have been uncommon due to the methodological challenges posed by siliceous materials. Silicious raw materials exhibit considerable intrasource variability making it extremely difficult to identify individual source groups (Luedtke 1978). Many chert studies have difficulty in demonstrating clear differences among sources in the same manner that has been demonstrated for other materials Chert studies have been dominated by visual identification due to time, cost, and the complexities of geochemical analysis. Although visual sourcing is used (Hester and Shafer 1984), its validity remains controversial (Luedtke 1979; Parish and Durham 2015). Any chert source can exhibit a wide spectrum of visual variation within a formation or outcrop, and chert types from different formations can be visually identical (Hess 1996). Moreover, artifacts made of rare or yet unknown sources may be misattributed to known sources of identical appearance (Moholy-Naghy et al. 2013).

Methodological and technological developments within the last two decades have drastically improved the success of most chert provenance studies, with a particular emphasis on a multimethod approach. Such an approach emphasizes that archaeological artifacts and geological sources have an identical geological history reflected in mineralogy, fossil inclusions, and trace element chemistry. Such features reflect the geological provenance, depositional environment, and diagenetic conditions used for source recognition. To account for the natural variation across these multiple geological formations, a method integrating multiple analytical techniques should have more success than a simple approach (Brandl 2016; Tarantini Massimo et al. 2016).

To date, the application of trace element analysis to northern Belize chert sources has been minimal and unsuccessful (Tobey 1986; Cackler et al. 1999, 2000; Wurtzburg 1991). Tobey's (1986) use of neutron activation analysis (NAA) to analyze geological and archaeological samples from the CBZ remains the only major provenance study. While at the time he was unable to discriminate among distinct sources, Tobey (1986) remained optimistic that more intensive sampling of the area might provide more successful source differentiation.

Methods

Sampling

We applied a multimethod approach that combines macroscopic, petrographic, and geochemical analyses to the study of geological samples collected through fieldwork. Geological survey and sample collection were conducted along the Old Northern Highway from Orange Walk City to Belize City (Figure 1). Our pedestrian field survey focused on landscape depressions, limestone exposures, and creek beds. Samples were primarily collected from secondary sources ($n = 9$), and only one primary source, a layer of in situ nodular chert located within a modern quarry, was sampled (Table 1). In total, 120 samples were collected, washed, and analyzed. Primary chert sources are particularly difficult to locate in the study area as the majority of chert raw material in the CBZ occurs as surface nodules in the natural soil matrix or within creek beds, a by-product of postdepositional in situ erosion. The majority of raw material utilized by the Maya in the CBZ appear to be these secondary sources, as exemplified by the presence of utilized nodules, cores, and flakes within these contexts. For this reason, we believe that secondary sources within the CBZ are important indicators of local exploitation and focus this study on determining variation between such sources.

Macroscopic (Visual) Analysis

Despite issues with visual sourcing, macroscopic analysis is free and nondestructive, therefore establishing a reliable macroscopic characterization for source groups remains essential to comparative studies of geological and archaeological material. In combining macroscopic observation with other methods, the subjective components of such an approach can be minimized.

We macroscopically analyzed all samples in our study using predefined variables within the literature (Luedtke 1992; Figure 2). These include visual identification of color, fabric (homogeneous

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Table 1. Macroscopic Description of Raw Material within Each Source Group.

ID	Source Coordinates	Geological Context	#	Color	Translucency	Pattern
23G-AA	18.16071, 88.46701	Secondary	7	Grayish brown (10YR 5/2) to blueish gray (6/5 BP)	Opaque	Splotched, Streaking
23G-BA	18.16066, 88.46563	Secondary	12	Blueish gray (6/5 BP), very dark gray (7.5 YR 3/1) to gray (10YR6/1)	Subtranslucent, opaque	Speckling, irregular flecks, homogeneous
23G-A	17.95832, 88.37192	Secondary	12	Grayish brown (2.5YR5/2)	Opaque	Spotted/mottled, Laminated/streaked
				Dark gray (10YR4/1)		
				Brownish yellow (10YR6/6)		
23G-F	17.92818, 88.3525	Secondary	11	Grayish brown (10YR 5/1) to gray (10YR 6/1)	Opaque	Regular flecking, homogeneous
23G-I	17.99513, 88.49158	Primary	12	Strong brown (7.5 YR 4/6)	Opaque	Homogeneous
				Blueish gray (10B)	Subtranslucent	Irregular flecking
23G-V	17.75821, 88.31139	Secondary	7	Light brownish gray (10YR6/2)	Opaque	Homogeneous
				Gray (10YR5/3)		
23G-W	17.79339, 88.30782	Secondary	8	Light gray (2.5YR7/1)	Translucent	Spotted, Mottled
				Dark reddish gray (10YR3/1)		
				Gray (10YR5/1)		
23G-X	17.79749, 88.30818	Secondary	11	Gray (10YR5/1)	Opaque-translucent	Homogeneous
				Blueish gray (6/5BP)		
				Dark grayish brown (10YR4/2)		
23G-Y	17.88993, 88.32068	Secondary	9	Black (7.5YR2.5/1)	Opaque-translucent	Homogeneous, spotted
				Very pale brown (10YR7/4)		
				Gray (10YR6/1)		
23G-Z	17.89876, 88.32642	Secondary	13	Dark grayish brown (10YR 3/2) to gray (10YR 5/1)	Opaque, subtranslucent	Broad mottling, irregular flecking

Figure 2. Representative sample from each source group analyzed. (Color online)

or heterogeneous), translucency (highly translucent, translucent, subtranslucent, or opaque), texture (smooth, semismooth, rough), luster (shiny, medium, dull), fracture (conchoidal, subconchoidal, uneven), sorting, patination, and color and thickness of cortex.

Petrographic Analysis

We selected a representative sample ($n = 11$) from each geological source ($n = 10$) and distinct visual group within these sources for thin-section analysis to characterize the mineralogical composition, textural features, and impurities that may be present in the chert raw material. Thin sections were analyzed using a Zeiss Axioskop 40 Trinocular Microscope. Thin sectioning of samples is a destructive process; therefore, we also employed a handheld digital microscope (Dino-lite edge) that nondestructively allows for examination of micropaleontological remains within samples and can be replicated on cultural material. Skeletal grains of fossils may be preserved during the sedimentation process of chert formation and are restricted to specific environment and time intervals, which present an opportunity to allow for the identification of specific outcrops.

Petrographic analysis of samples demonstrates that chert from within the CBZ exhibits a cryptocrystalline quartz matrix (Figure 3). Foraminifera cavities that have been recrystallized with silica are present and vary with quantities between samples. These cavities appear to show a center of microcrystalline quartz and outer rim of chalcedony. Chert located within the Doubloon Bank Formation are known to contain faunal remains such as Miliolides, Globigerina, *Coskinolina floridana*, and *Diclyoconus cookie* (Flores 1952). Microscopic investigations demonstrate the presence of such material with samples located in the CBZ.

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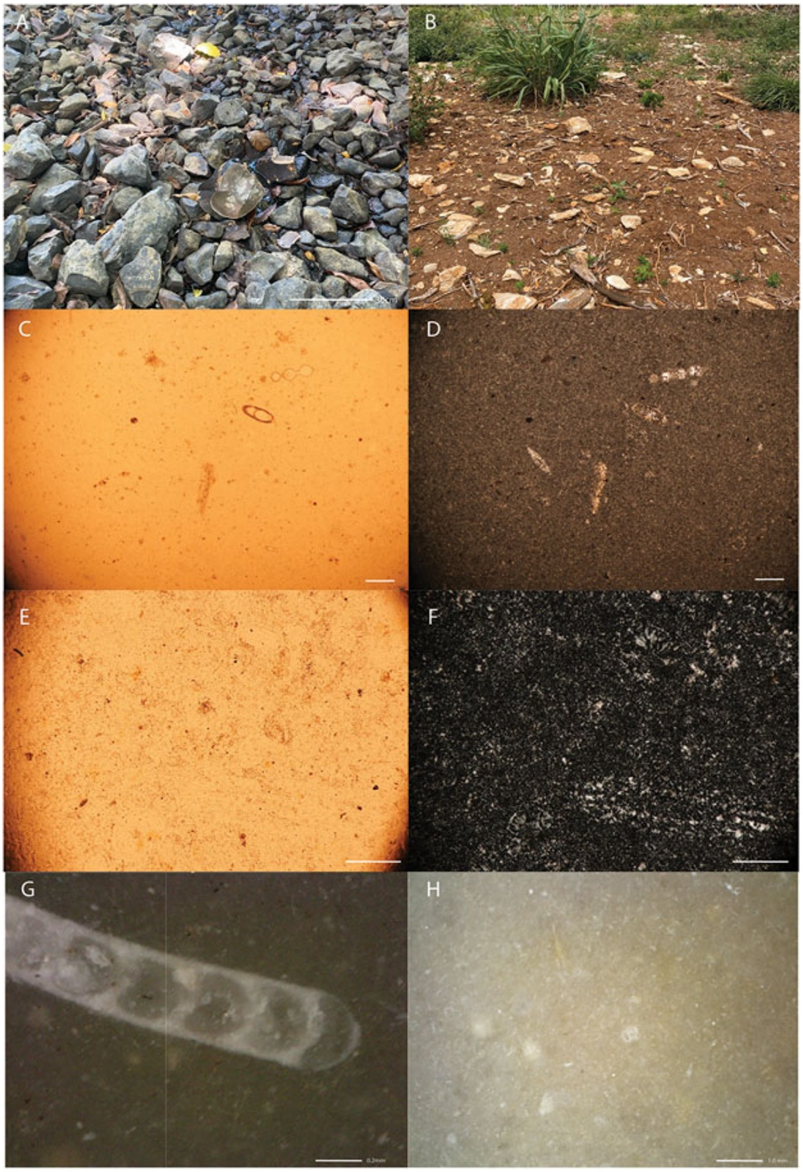

Figure 3. Macroscopic and microscopic views of chert samples: (A) Rancho Creek (Source Group A); (B) Chert bearing soil located within the CBZ; (C) F09 2.5x PPL; (D) F09 2.5x XPL—showing higher degree of foraminifera cavities that have been recrystallized with silica, these are surrounded by a cryptocrystalline quartz matrix; (E) A01 20x PPL; (F) A01 20x XPL—showing cryptocrystalline quartz matrix with radiolarian cavities that have been recrystallized with quartz and chalcedony; (G) A20 200x Mag showing microfossil; (H) A02 50x Mag, possible Globigerina. (Color online)

Trace Element Geochemistry Laser Ablation–Inductively Coupled–Plasma Mass Spectrometry (LA-ICP-MS)

Elemental variations across northern Belize chert sources were measured by LA-ICP-MS at the University of Texas at Austin Department of Geosciences, using an ESI NWR193 excimer laser ablation system (193 nm, 4 ns pulse width) coupled to an Agilent 7500ce ICP-MS. A small fragment (1–5 mm) was removed from each sample and imbedded in polished epoxy mounts. The LA-ICP-MS system is equipped with a large format, two-volume, sample cell with fast washout (<1s) that

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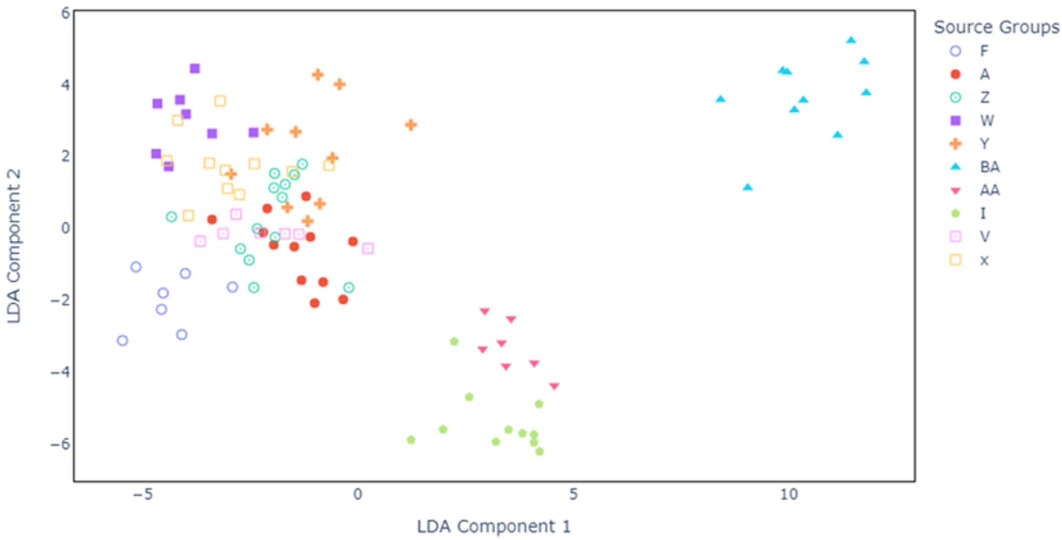

Figure 4. Results of LDA analysis; Component 1 and 2 show separation of visually similar chert sources from within the CBZ. (Color online)

accommodated all samples and standards in a single cell loading. The system was optimized daily for sensitivity across the AMU mass range by tuning to a standard (NIST 612), and parameters were checked with trial spots on representative specimens. Following preablation (150 μm spot, 7 J/cm^2 fluence) to remove shallow surface contaminants, we performed spots on each sample using a 125 μm diameter spot, 7.87 ± 0.02 J/cm^2 energy density (fluence), 10 Hz repetition rate, and carrier gas flows of 0.85 L/min for Ar and 0.8 L/min He. We determined baseline intensities before each standard and sample analysis from 20 s gas blank measurements, made while the laser was off, and scanned all masses by the quadrupole. The quadrupole time-resolved method measured a total of 42 masses, 26 with 10ms integration times (^{7}Li, ^{9}Be, ^{11}B, ^{24}Mg, ^{27}Al, ^{43}Ca, ^{47}Ti, ^{49}Ti, ^{51}V, ^{53}Cr, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{66}Zn, ^{69}Ga, ^{72}Ge, ^{85}Rb, ^{88}Sr, ^{89}Y, ^{133}Cs, ^{137}Ba, ^{208}Pb, ^{232}Th, ^{238}U), and 14 with 20ms integration times (^{139}La, ^{140}Ce, ^{141}Pr, ^{146}Nd, ^{147}Sm, ^{153}Eu, ^{157}Gd, ^{159}Tb, 163Dy, ^{165}Ho, ^{166}Er, ^{169}Tm, ^{172}Yb, ^{175}Lu). Time-resolved intensities were tuned into concentration (ppm) using Iolite software (University of Melbourne, Australia). Reduction of data resulted from fitting baselines and a spline for each element, standard and unknown values. Analytes showed good recovery rates in comparison to reference values obtained from GeoRem. See Supplemental Data 1 for raw data.

LA-ICP-MS Results

Linear discriminate analysis (LDA) was applied to the dataset. LDA is widely used for dimensionality reduction and classification and is often applied to determine variability patterns in sourcing studies (Speakman et al. 2008). LDA aids in source discrimination by generating source groups later used for assigning archaeological specimens to a group. All data was processed using Python. The preliminary results presented here demonstrate that source clusters can be identified within the CBZ.

Three source groups (AA, BA, and I) can be confidently distinguished from the larger dataset (Figure 4). These samples were obtained from chert bearing soils to the east of the Maya site of San Estevan in modern-day sugarcane plantation fields. Samples from Group BA were also obtained from a similar context, in close geographical proximity to Group AA, but exhibit higher Uranium (U) and lower Gallium (Ga) values than Group AA. Samples within Group BA also contain high quantities of microfossil remains. The third cluster contains samples from Group I, which were obtained from in situ geological layers within a modern quarry. These samples are also macroscopically distinct from the larger dataset and exhibit higher Aluminum (Al) values than the remaining dataset.

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The largest multi-element cluster in this dataset consisted of samples from seven different source groups, all of which are located along the old northern highway. There is some clustering within this grouping that show promise for further investigation into the chemical and petrographic variation that may be present. Both Group F and Z appear to cluster into two groups Group A and Z exhibit higher values of REEs (e.g., Gd, Tb, Er, Y), which influence the subclustering in the larger cluster. There is significant overlap in the geochemistry of the remaining five source groups; however, with further sampling we hope that these groups can be teased apart.

Reapproaching Sourcing of Chert in Northern Belize

Our results presented are preliminary but are promising for the further incorporation of chert sources into the dataset. By implementing a multimethod approach, variations between some source groups can be identified. Such an approach provides an avenue to identify less visually distinguishable material found in exchange networks. The results presented in this report show that although samples show similar macroscopic characteristics, variation of petrographic and chemical compositions between source areas can be identified.

Determining the source of CBZ artifacts has been an ongoing challenge for archaeologists working in the region. While it is assumed that Colha dominated production and exchange of chert tools in northern Belize, without a quantitative method to determine artifact to source correlations it is still possible that other workshops played important roles in production and exchange. In this report, we have outlined a method for characterizing chert raw material in northern Belize. While we continue to expand the dataset included in this report and develop our methods, these results already show promise for the future of chert sourcing. Ultimately, the systematic incorporation of hard to source raw material into discussions of craft production and distribution will provide insights into the dynamic of ancient Maya economic organization.

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Data Availability Statement. All raw data from LA-ICP-MS are included as supplemental data.

Competing Interests. The authors declare none.

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Supplemental Data 1. Raw LA-ICP-MS data.

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