NORTHWEST CAMBODIA AND THE MEKONG INTERACTION SPHERE: GLASS AND STONE BEADS FROM LOVEA, PREI KHMENG, AND SOPHY

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This paper reviews stone (agate and carnelian) and glass bead assemblages from three sites in northwest Cambodia: Lovea, Prei Khmeng, and Sophy. Beads from all three sites were largely found in burial contexts dating to the Iron Age or protohistoric period (500 BCE-500 CE). While stone and glass beads are frequently markers of contact with South Asia, they are also informative for understanding intra-regional exchange networks within Southeast Asia. An analysis of the glass beads identifies that most beads were made from a high-alumina mineral-soda glass. Compositional and morphological analysis of the stone beads suggests that they were likely produced from an Indian raw material source and using South Asian production techniques. Overall, the bead assemblages from all three sites show connections to other sites in Cambodia and Thailand and especially seem to be part of the broader Mekong Interaction Sphere exchange network.

INTRODUCTION

The Iron Age or protohistoric period of mainland Southeast Asia (ca. 500 BCE-500 CE) is notable for evidence of the earliest contact with South Asia, a process which kickstarted a variety of socio-political and ideological changes (Bellina and Glover 2004; Manguin, Mani, and Wade 2011; Murphy and Stark 2016). Early material evidence for this contact was frequently found in burial contexts and especially included glass and stone beads (Bellina 2003; Bellina and Glover 2004; Francis 1996; Glover 1989). On the one hand, studies of these beads are informative for identifying external connections, especially between South and Southeast Asia (Basa, Glover, and Henderson 1991; Carter and Dussubieux 2016; Dussubieux and Pryce 2016; Francis 1996; Glover and Bellina 2003; Lamb 1965). Scholars have, however, also demonstrated that beads can reflect local socio-political developments and connections within Southeast Asia (e.g., Bellina 2014, 2018; Carter 2015; Theunissen, Grave, and Bailey 2000).

In Cambodia, there were several robust and culturally distinct groups living in various parts of the country who were trading and consuming beads. Previous work has identified distinct differences between beads found at sites in the Mekong Delta, including the major center of Angkor Borei associated with the Funan polity, and the site of Prohear in southeastern Cambodia (Carter 2010, 2012, 2015; Carter et al. 2021). Bead assemblages at sites in northwestern Cambodia were, however, similar to those found in the Mekong Delta, prompting scholars to propose the presence of a "Mekong Interaction Sphere" that connected sites within the delta to communities further inland (Carter et al. 2021). This has been represented materially not just through the presence of stone and glass beads (Carter 2015; Carter et al. 2021), but also earthenware ceramics (Stark and Fehrenbach 2019) and inscriptions (Lustig, Evans, and Richards 2007).

In this paper, we present the results of a study of stone and glass beads from three sites in northwestern Cambodia that we argue were part of the Mekong Interaction Sphere: Lovea, Prei Khmeng, and Sophy (Figure 1). Following

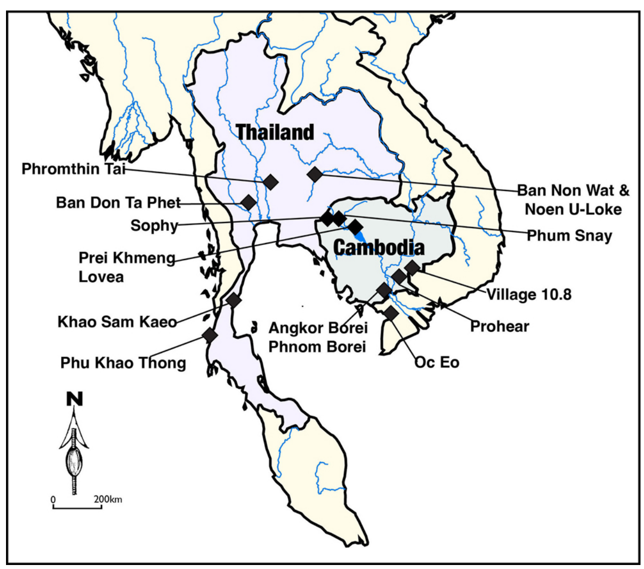

Figure 1. The location of Lovea, Prei Khmeng, Sophy, and other contemporary sites discussed in text (all images by A. Carter).

an introduction to the three sites in this study, we discuss the glass and stone beads from each site, contextualizing them with bead assemblages from contemporary sites in Cambodia and Thailand. We first consider the glass beads, focusing on their colors and compositions, noting that the bead assemblages at these three sites are similar to one another and some other sites in mainland Southeast Asia (MSEA). We then discuss the stone beads including their morphology, perforation technology, and geochemical composition that suggest connections with South Asia, but the overall patterning in stone bead assemblages presents linkages to different communities across Southeast Asia. We conclude with a consideration of the mortuary contexts in which beads were found and how the patterns from the assemblage data point towards a relationship between communities in northwest Cambodia and sites in the Mekong Delta.

SITE BACKGROUND

The three sites in this study were excavated as part of projects codirected by Dougald O'Reilly and Louise Shewan. Lovea and Prei Khmeng were excavated as part of the Paddy to Pura project, which aimed to investigate the origins and rise of the state in Southeast Asia through the excavation of sites in Cambodia and Thailand. Sophy was studied as part of the History in Their Bones Project, which focused on a bio-archaeological study of diet, mobility, and social organization in Cambodia. Appendix A contains information on the beads and their contexts from all three sites. Appendix B presents the results from compositional analysis with major elements reported in weight percent (wt%) and minor and trace elements in parts per million (ppm).

Lovea

Lovea is a circular earthwork site in Siem Reap province in northwest Cambodia (Figure 1). The site was initially investigated by Louis Malleret (1959) and later observed to be similar to moated sites found across northeastern Thailand (Moore 1988). The site was selected for excavations by the Paddy to Pura team as the presence of moats has been argued to indicate the emergence of hierarchical social structures (Higham 2011; O'Reilly 2014; O'Reilly and Shewan 2016). Twelve burials were excavated over the course of two field seasons, encompassing a time period from ca. 130-350 CE (O'Reilly and Shewan 2016). A total of 805 glass beads and 25 stone beads were recovered largely from burial contexts, of which 22 glass beads and 7 agate/carnelian beads were selected for LA-ICP-MS analysis (Table 1).

Prei Khmeng

Prei Khmeng is located in the Angkor plain, near the West Baray and just outside of the Tonle Sap Lake flood zone (Figure 1). The site is home to a small pre-Angkorian brick tower and lintel, one of the oldest in the Angkor area. Three excavations conducted from 2000-2003 by the Mission archéologique Franco-Khmère sur l'Aménagement du Territoire Angkorien (henceforth MAFKATA) project led by Dr. Christophe Pottier uncovered several prehistoric burials and an occupation area that dates from the 1st-6th centuries CE (Pottier et al. 2001a, 2001b, 2003; Zoppi et al. 2004). Glass beads from these earlier excavations were analyzed in previous studies and discussed below (Carter 2010, 2015; Latinis 2004). An additional excavation was conducted under the Paddy to Pura project in 2014, which uncovered an additional 11 burials or mortuary contexts dating from 200-400 CE (O'Reilly et al. 2020). A total of 534 glass beads and 15 agate and carnelian beads were recovered, largely from burial contexts. Of these, 19 glass beads and 3 stone beads were selected for LA-ICP-MS analysis (Table 1).

Sophy

Sophy (sometimes referred to in the literature as Phum Sophy) is a burial site located in Banteay Meanchey

Table 1. Quantities of the Analyzed Beads.

Site	Glass Beads	Stone Beads	Glass Beads Analyzed Using LA-ICP-MS	Stone Beads Analyzed Using LA-ICP-MS
Lovea	805	25	22	7
Prei Khmeng	534	15	19	3
Sophy	1842	327	17	11
Total	3181	367	58	21

province in northwestern Cambodia (Figure 1). The site has experienced significant looting and two field seasons of excavations in 2009-2010 were undertaken as part of the History in Their Bones Project. Fourteen mortuary contexts containing 20 individuals were identified dating to 87-526 CE (O'Reilly et al. 2015). A total of 327 agate and carnelian beads and approximately 1900 glass beads were recovered, of which 17 glass and 11 stone beads were selected for LA-ICP-MS analysis (Table 1).

METHODS

The glass and stone beads were examined to note shape/typology, manufacturing method, and compositions (Carter 2013). Both glass and stone beads underwent compositional analysis using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at the Elemental Analysis Facility (EAF) at the Field Museum, Chicago.

LA-ICP-MS combines laser ablation for the micro-sampling of the objects using a laser beam with a diameter of 100 µm or less with mass spectrometry for the measurements of a wide range of elements (50 or more) with concentrations ranging from several percent to less than a ppm (1 ppm = 0.0001%) (for more details *see* Dussubieux, Robertshaw, and Glascock [2009] and Carter and Dussubieux [2016]). This technique is now widely used to determine the compositions of ancient glass (e.g., Gratuze 2016). With the measurements of the major (present in the range of 1% and more) and minor (less than 1% but more than 0.1%) elements, it is possible to reconstruct ancient glass recipes that are often specific to a region and to a particular time period. Trace elements that are present in very small quantities (<0.1%) are indicative of the geological environment of the ingredients and can be indicative of the provenance of the glass (e.g., Schibille 2011). For stone, LA-ICP-MS is used to match the trace element signature measured in each artifact with the trace element signature specific to a given raw material source to determine where the stone comes from (Carter and Dussubieux 2016). Overall, elemental analysis of glass and stone beads provides an opportunity to examine similarities and differences in more detail for beads obtained from different sites.

GLASS BEADS

The majority of the glass beads from the three sites are of a type known as Indo-Pacific (Figure 2a). They are small, monochrome, oblate, and widespread in the ancient world (Francis 1990b, 2002; Kanungo 2016). Indo-Pacific beads were produced using a technique in which glass was melted in a furnace and then pulled or drawn into long tubes using an iron hook. The tubes were then sliced into small segments and reheated to round the edges (Francis 1990b; Kanungo 2016). A small number of non-Indo-Pacific glass objects were also identified and are considered in more detail below.

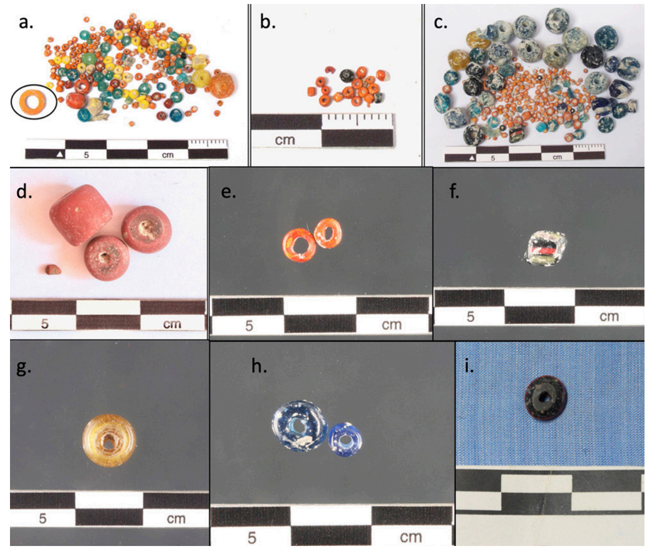

Figure 2. Glass beads from Lovea, Prei Khmeng, and Sophy: (a) typical Indo-Pacific glass beads from Sophy; the wrapped-glass bead is circled; (b) microbeads from Sophy; (c) beads from Burial 14 at Sophy, including the large blue beads; (d) large red beads with black interiors from Lovea; (e) mixed red-orange glass beads from Sophy; (f) polychrome striped bead from Sophy; (g) false gold-glass bead from Lovea; (h) dark blue m-Na-Ca-Al glass beads from Sophy; (i) black bicone with red trim from Prei Khmeng.

Opaque orange Indo-Pacific beads dominate the assemblages at all three sites (Figure 3), with opaque red and opaque black beads also present in significant quantities. In this respect, the three sites are similar to Phum Snay in northwestern Cambodia and Ban Non Wat and Noen U-Loke in northeastern Thailand, which also have large quantities of opaque orange glass beads. At Sophy and Prei Khmeng, there are also beads with a mix of opaque red and orange glasses (discussed below). Most beads are 2-5 mm in diameter, but there are also some interesting distinctions between sites. Notably, at Sophy, 78% of the total bead collection consists of opaque orange beads that are less than 2 mm in diameter (Figure 2b). Such tiny "microbeads" make up about half of the collection at Lovea (n = ca. 393) of which the majority (95%) are opaque orange. At Prei Khmeng, a previous study from the MAFKATA collections identified a large quantity of small opaque orange (n = 1078) and opaque black beads (n = 564) measuring approximately 1-3 mm in diameter within a single burial (Carter 2013). Only 52 beads in the current study from Prei Khmeng are less than 2 mm in diameter.

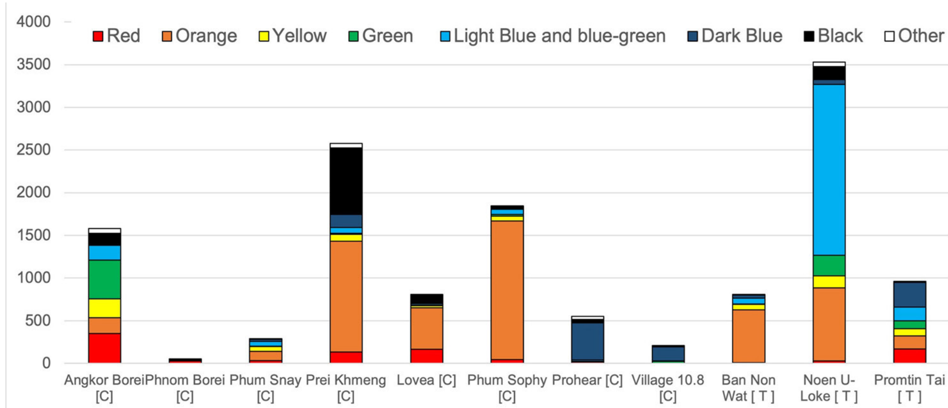

Figure 3. The distribution of glass bead colors by site including comparative sites in Cambodia [C] and Thailand [T].

A small number of translucent blue beads over 5 mm in diameter were also found in a single burial (no. 14) at Sophy (Figure 2c). At Prei Khmeng, most beads over 5 mm in size (n = 54) are opaque red or orange. At Lovea, there are several large (6-8 mm diameter) opaque red beads with a black ring around the hole (Figure 2d). It is not clear why these beads have this feature; James Lankton (2013: pers. comm.) has proposed it is related to the manufacturing technique in which a black core was encased in red glass, perhaps as a cost-saving measure. In these beads, and similar beads analyzed by Dussubieux (2001:157-158), the red and black glasses have differing concentrations of copper and other elements, suggesting the use of two different glasses.

Glass Compositions

Multiple glass recipes have been used to produce Indo-Pacific and other beads. While one is often not able to identify the glass recipe visually, compositional analysis of the glass using techniques like LA-ICP-MS can help determine them. They, in turn, can provide clues regarding when and where the beads were produced. A subset of glass artifacts from the assemblages at Lovea, Prei Khmeng, and Sophy was analyzed and several glass compositions were identified across the three sites, with two glass compositions dominating the assemblages: high-alumina mineral soda 1 (m-Na-Al 1) and a mineral-soda glass with variable amounts of alumina and lime (m-Na-Ca-Al). Two objects from non-burial contexts at Prei Khmeng have different compositions (potash and lead-potash). Also included in this discussion is a plant-ash soda-lime glass identified in a previous study at Prei Khmeng (Carter 2010).

High-Alumina Mineral-Soda Glass (m-Na-Al 1)

The majority of the glass beads analyzed from the three sites have compositions with alumina concentrations higher than 5wt%, high soda (ca. >10wt%), and low magnesia (<1.5wt%), classifying them as high-alumina mineral-soda glass (m-Na-Al) (Appendix B). Nearly all are monochrome, drawn, Indo-Pacific beads, although a small number are more unusual, including two specimens that are opaque red with black interiors, several mixed red-orange, a drawn polychrome bead (black with red and yellow or white stripes), and a false gold-glass bead (*see* below).

Previous work by Dussubieux, Gratuze, and Blet-Lemarquand (2010) has identified different subgroups of high-alumina mineral-soda glass, associated with different time periods and exchange networks. These can be distinguished by principal components analysis (PCA) using the elements Mg, Ca, Ba, U, Sr, Zr, and Cs (Dussubieux, Gratuze, and Blet-Lemarquand 2010). A comparison of the high-alumina mineral-soda beads from the three sites with different subgroups of m-Na-Al glass (Figure 4) demonstrates they are compositionally analogous with high-alumina mineral-soda glass type or group 1 (m-Na-Al 1). This subgroup of m-Na-Al glass is particularly abundant in South India where it was likely produced (Dussubieux 2001) and circulated in South and Southeast Asia from the 4th century BCE through the 1st millennium CE (Dussubieux, Gratuze, and Blet-Lemarquand 2010). Indeed, this particular type of high-alumina mineral-soda glass is the dominant glass type found in mainland Southeast Asia during the 1st millennium CE (Carter 2016; Lankton and Dussubieux 2006).

The beads in the m-Na-Al 1 group come in a variety of colors. Opaque black beads appear to have been colored using iron (ca. 1-2wt%), while the blue beads have significant levels of copper (0.7-1.2wt%). It is important to note that cobalt was not used to color blue beads in the m-Na-Al 1 group (Dussubieux, Gratuze, and Blet-Lemarquand 2010). The opaque orange and red beads have elevated concentrations of copper as a colorant (ca. 1-11.5wt%). Three beads with a mixed orange-red color (Figure 2e)

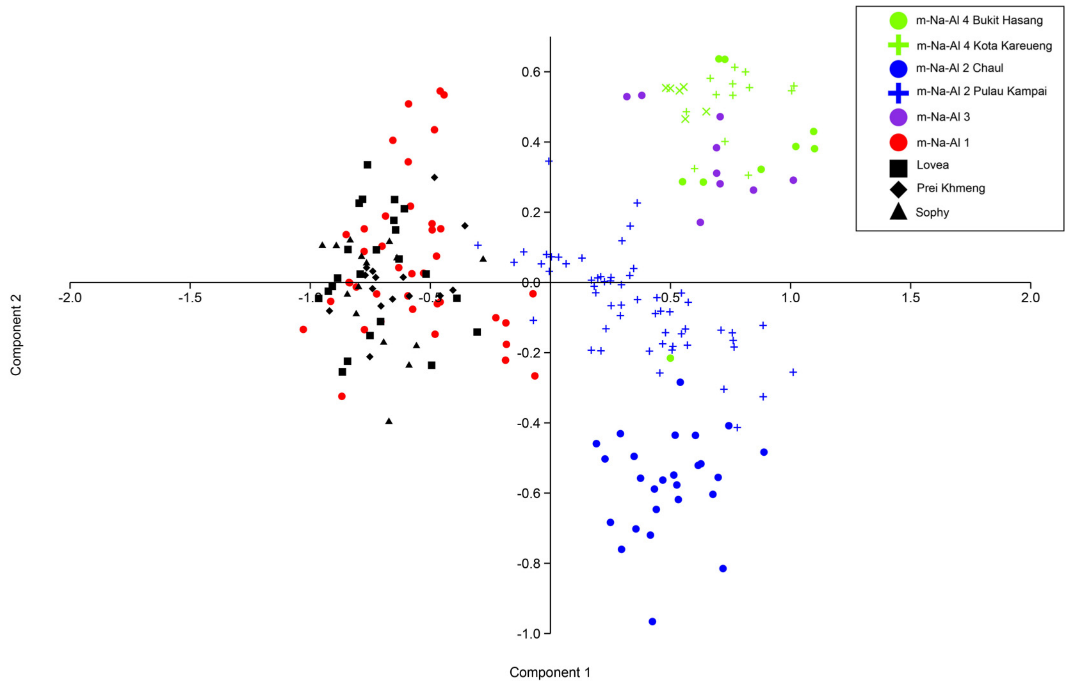

Figure 4. Biplot of components 1 and 2 from a PCA using Ca, Mg, Ba, Sr, Zr, U, and Cs to distinguish between different types of high-alumina mineral-soda glass.

from Sophy (AKC03850big, AKC03850sm, AKC03831) are also classified as belonging to the m-Na-Al 1 group, but have elevated levels of magnesia, lime, potash, phosphorus, and iron in comparison to other m-Na-Al 1 beads. This is common for this particular bead type and likely relates to the coloring process (Dussubieux and Gratuze 2013:403). Most of the opaque green and yellow beads have elevated concentrations of lead and significant concentrations of tin. Lead stannate is a known yellow opacifier in ancient glass. The green beads also have elevated concentrations of copper.

Several other unusual beads also have an m-Na-Al 1 composition, including the large opaque red beads with a black ring around the perforation from Lovea (AKC03906red2, AKC03921r). Additionally, a polychrome striped bead from Sophy belongs to this type (AKC03083black, AKC03803yellow, AKC03803red) (Figure 2f). The bead appears to have red and yellow stripes, but perhaps the stripes were white and have yellowed with age. A similar bead with red and white stripes has been identified at the Phromthin Tai site (Carter 2013; Carter et al. 2022; Lertcharnrit and Carter 2010) and at Khlong Thom (Francis 1990a). Francis (1990a:70-71) describes these beads as "children" of the more common monochrome Indo-Pacific beads, noting possible manufacturing centers at Mantai, Sri Lanka, and Takua Pa, Thailand.

A false gold-glass bead (Figure 2g) from Lovea (AKC03892) has an m-Na-Al 1 composition as well. The bead is made from a drawn tube, similar to the Indo-Pacific beads, but is likely part of a larger segmented bead that broke, as indicated by the rough edges around the hole. Although it appears gold in color, no significant amounts of gold were recorded. Francis (1990a, 2002) has argued that false gold-glass beads were produced at the site of Takua Pa, Thailand. Instead of sandwiching a piece of gold foil between two layers of clear glass, a false gold-glass bead is produced by layering a milky-white glass with amber-colored glass. It is also possible that an embedded gold foil layer was missed by the laser during LA-ICP-MS.

Mineral-Soda Glass with Variable Amounts of Alumina and Lime (m-Na-Ca-Al)

A small number of beads were classified as belonging to a mineral-soda glass group with variable amounts of alumina and lime (m-Na-Ca-Al). Compositionally, this glass type looks quite similar to the m-Na-Al 1 glasses but can be distinguished through a PCA using the elements Na, Al, Zr, Rb, La, Hf, and Th (Dussubieux and Gratuze 2010). Figure 5 displays a biplot of a PCA using these elements which shows the differentiation between the m-Na-Ca-Al and m-Na Al 1 beads at all three sites.

Four of the six beads in this group are a translucent dark blue and. colored with cobalt (Figure 2h). Scholars

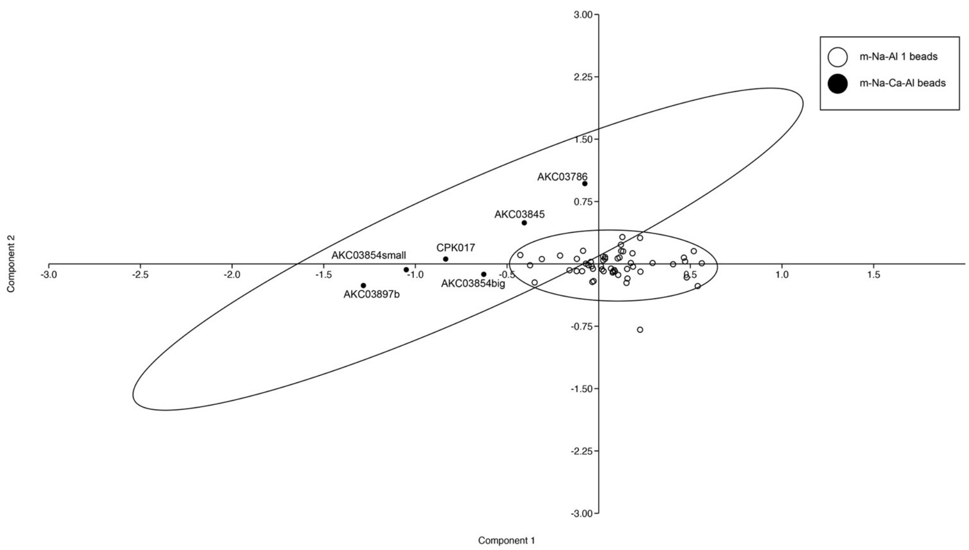

Figure 5. PCA displaying the m-Na-Ca-Al (black circles) and m-Na-Al 1 (white circles) beads from Lovea, Prei Khmeng, and Sophy. The 95% concentration ellipses estimate a region where 95% of the population points are expected to fall.

have proposed that beads with this composition may have been produced at Khlong Thom/Khuan Lukpat, Thailand (Lankton and Dussubieux 2013), Phu Khao Thong, Thailand, or Arikamedu, southern India (Dussubieux et al. 2012). Similar dark blue cobalt m-Na-Ca-Al glasses have also been found at Angkor Borei and Prohear in Cambodia (Carter 2010, 2013; Carter et al. 2021), Ban Non Wat in Thailand (Carter and Lankton 2012), Phromthin Tai, Thailand (Carter et al. 2022), and the sites of Aw Gyi and Maliwan in southern Myanmar (Dussubieux et al. 2020). Such glass has also been reported at sites in Indonesia, Thanh Hoa, Vietnam, Karaikadu, India, and Ridiyagama, Sri Lanka (Dussubieux 2001). One drawn yellow bead from Sophy also falls into this compositional group and is likely colored with lead stannate (Dussubieux, Gratuze, and Blet-Lemarquand 2010:252).

An unusual disc-shaped opaque orange bead with a large hole (AKC03845) from Sophy is the last bead to be classified in this compositional group (Figure 2a). Instead of being drawn, this bead appears to have been wrapped, similar to beads identified in northeastern Thailand at Ban Non Wat and Noen U-Loke (Carter and Lankton 2012). These beads may have been produced by wrapping a flat glass strip around a metal rod, forming a long tube from which discs could be sliced (Saitowitz and Reid 2001). Previous studies (Carter and Lankton 2012; Saitowitz and Reid 2001) have shown that these wrapped opaque orange beads have a mixed alkali composition, with elevated levels of both soda and potash. This bead, however, appears to belong to the m-Na-Ca-Al group (Figure 1). Opaque orange m-Na-Ca-Al beads have not been reported at other sites so it is unclear how these beads fit within the production and circulation of other m-Na-Ca-Al and/or wrapped glasses. This bead does have a notable quantity of cobalt (323 ppm), which may be related to the copper source used to color the glass. Dussubieux (2001:176) has observed that copper ore from the Khetri copper mine in India contains significant amounts of nickel and cobalt. This particular kind of glass has been found in high quantities at the port sites of Arikamedu, India, Phu Khao Thong, Thailand, and Aw Gyi, Myanmar on the Bay of Bengal, suggesting that these beads were brought by sea to these sites (Dussubieux et al. 2020). It is unclear how these beads may have then been circulated within Southeast Asia.

Other Glass Types

Two glass objects were identified that do not fall in the major glass compositional groups discussed above. Both were found at Prei Khmeng in non-burial and likely disturbed contexts. The first object is a dark blue glass bangle fragment containing high levels of potash (11.3wt%) and slightly higher alumina (2.7wt%) than lime (1.3wt%). The second object is a melon-shaped bead with elevated concentrations of lead (50wt%) and potash (5wt%). The addition of potash to lead-glass recipes appears to have begun around the 6th century CE in China and was initially used to produce glass vessels (Fuxi 2009:28). This glass recipe was used into the Ming Dynasty (1368-1644) (Brill, Tong, and Dohrenwend 1991; Gratuze 2001:10). This bead was found in a mixed context in the upper layers of the site from a unit that included materials dating to the late 20th century, as well as Angkorian ceramics and Pre-Angkorian or early Angkorian bricks. Melon-shaped beads are common across the ancient world (e.g., Eisen 1930), but opaque light blue melon glass beads have been popular within contemporary upland communities, with some beads perhaps dating as far back as the 15th century CE (Campbell Cole 2012).

A previous study of beads from Prei Khmeng identified two beads with elevated concentrations of magnesia (2-4.7%), soda (14-18wt%), and lime (6-9wt%) (Carter 2010, 2013), also called plant-ash soda-lime glass (v-Na-Ca). One is a broken drawn blue glass bead; the other is an unusual black bicone with red trim (Figure 2i). This glass composition is strongly associated with Middle Eastern glass production and long-distance exchange between this region and South and Southeast Asia (Carter et al. 2021). Other sites in mainland Southeast Asia where this glass type has been found include Angkor Borei, Cambodia, Oc Eo, Vietnam, and Phum Snay (Carter 2010; Gratuze 2005; Ly 2007; Song 2008).

Contextualizing the Bead Collections at Lovea, Sophy, and Prei Khmeng

The high quantities of m-Na-Al 1 beads found at the three sites is not unexpected for sites dating to the early 1st millennium CE, as this glass type was in wide distribution during this period (Carter 2016; Dussubieux, Gratuze, and Blet-Lemarquand 2010). Figure 6 presents an estimate of the proportions of the different glass compositions found at Lovea, Prei Khmeng, and Sophy, as well as other contemporary sites in Cambodia and Thailand. The proportions of different glass types at all sites were estimated based on bead contexts, visual similarities between bead types, and compositional data. Lovea, Prei Khmeng, and Sophy show similarities with Angkor Borei, Phum Snay, and Phnom Borei in Cambodia and Ban Non Wat and Phromthin Tai in Thailand in that their glass bead assemblages consist primarily of m-Na-Al 1 glass.

STONE BEADS

Agate and carnelian are the primary stone bead types found at all three sites. The term agate is generally used to describe banded translucent stone that usually includes shades of white, grey, and brown. These colors are sometimes enhanced by beadmakers using a dying process, resulting in darker browns and blacks that archaeologists have called onyx (Francis 2002; Kenoyer 2003). Carnelian refers to translucent stone that ranges in color from yellow, orange, to deep red, which are naturally occurring or enhanced by heating the stone (Kenoyer 2003). In this section, we first

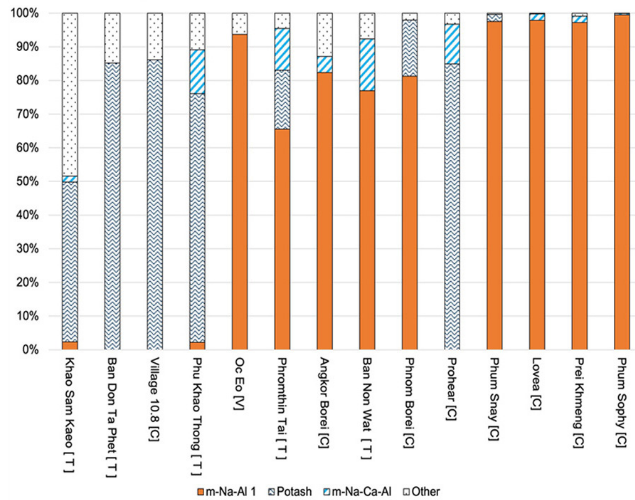

Figure 6. Estimated proportions of glass types by site in Southeast Asia: Khao Sam Kaeo (ca. 400-100 BCE); Ban Don Ta Phet (ca. 400-200 BCE); Village 10.8 (ca. 400 BCE-100 CE); Phu Khao Thong (200 BCE-200 CE); Oc Eo (1-600 CE); Phromthin Tai (ca. 400 BCE-500 CE); Angkor Borei (200 BCE-200 CE); Ban Non Wat Iron Age Period 2 (ca. 200 BCE-200 CE); Phnom Borei (200 BCE-1 CE); Prohear (200 BCE-200 CE); Phum Snay (350 BCE-200 CE); Lovea (130-350 CE); Prei Khmeng (200-400 CE); Sophy (87-526 CE). Based on Carter (2013, 2015) and Lankton and Dussubieux (2013). [C] Cambodia, [T] Thailand, [V] Vietnam.

discuss the results from a morphological study, including examination of the perforation type. We then discuss the results from compositional analyses of stone beads to determine the origin of the raw materials.

Bead Morphology

Previous studies of Southeast Asian stone beads have identified differences in their manufacturing methods that appear to vary over time (Bellina 2007, 2014; Carter 2015). Studies of stone beads in Cambodia and Thailand (Carter 2015), drawing on work by Bellina (2003, 2007, 2014), have identified two broad types of stone beads. Type 1 beads are generally made with higher-quality manufacturing techniques, frequently found in more complex shapes, such as faceted types, and with small perforation sizes (<1.5 mm). These beads are generally found at early Iron Age sites. Type 2 beads are found in simpler shapes and with evidence of lower manufacturing quality and larger perforation sizes (>1.5 mm). These beads are more frequently found at later Iron Age sites. Appendix A lists the beads from each site, their shape, color, context, and measurements. Table 2 summarizes the bead shapes found at each of the three sites. It should be noted that the shape typology used in this study is a general one and that scholars working elsewhere in Asia have used more specific typologies (e.g., Kenoyer 2017a;

Table 2. Quantities of Stone Bead Shapes at Lovea, Prei Khmeng, and Sophy.

Shape	Raw Material	Lovea	Prei Khmeng	Sophy	Total
Long cylinder	Agate	0	7	7	**14**
Spherical	Carnelian	6	0	289	**295**
Spherical	Agate	0	1 (broken)	0	**1**
Rough spherical	Carnelian	3	0	19	**22**
Long barrel	Agate	7	3	2	**12**
Long barrel	Carnelian	1	1	0	**2**
Short barrel	Carnelian	2	1	2	**5**
Short barrel	Agate	1	0	0	**1**
Long elliptical barrel	Carnelian	1	0	0	**1**
Long bicone/barrel	Carnelian	1	1? (broken)	0	**2**
Long bicone	Agate	0	1	0	**1**
Oblate disc	Carnelian	1	0	0	**1**
Short bicone	Carnelian	1	1?*	0	**2**
Long square bicone	Carnelian	1	0	6	**7**
Hexagonal faceted bicone	Carnelian	0	0	2	**2**
Long rectangular pendant	Agate	0	0	1	**1**
Total		**25**	**16**	**328**	**369**

*A possible short bicone that could not be examined due to being in a museum exhibit.

Kenoyer et al. 2022). Some researchers in Southeast Asia have also used slightly different terminologies (e.g., Bellina 2007; Georjon et al. 2021).

Simple shapes make up the majority of the assemblages at the three sites. Spherical, barrel, and bicone beads are fairly common and have been reported at numerous sites across mainland Southeast Asia (Bellina 2007; Carter 2013; Theunissen 2003). Long agate barrel beads (Figure 7a) have been found at all three sites but seem to have a more restricted distribution within mainland Southeast Asia, primarily being recorded at sites in northwest Cambodia and at sites like Ban Non Wat in northeastern Thailand (Carter 2013). Carnelian beads are generally more common than agate beads, with only 30 agate beads having been recorded, although agate beads are more numerous than carnelian at Prei Khmeng (n = 12).

Several unusual bead shapes were recorded at each site and worthy of discussion. Perhaps the most striking stone bead found at Lovea is a large carnelian in the shape of a short bicone (AKC03917/Cat 86) (Figure 7b). The bead is ca. 34 mm wide and 17 mm long. A smaller carnelian oblate disc (72/AKC03922) (Figure 7c) found with the same burial has a somewhat analogous shape. A similar but smaller bead may have been found at Prei Khmeng, but it has not been closely examined due to its being in a museum exhibit.

A striking, long, flat, agate pendant was found in a burial at Sophy (Figure 7d). A similar piece measuring almost 8 cm is reported from Oc Eo (Malleret 1962:214, Plate LV). These long rectangular pendants may be similar to smaller brown and white or black and white banded pieces found in central Thailand (Rammanat 2009) and Ban Non Wat in northeastern Thailand (Theunissen 2003).

Eight faceted carnelian beads are in the Sophy collection (Figure 7e), two of which have six facets (hexagonal) and six have four facets (square bicone). One of the hexagonal faceted bicones (AKC03768/Cat 168) (Figure 7e) at Sophy, as well as an additional bicone bead from Lovea (cat. no. 260, Burial 8), are roughly shaped with many nicks and scratches on the surface, similar to a group of hexagonal bicone beads found in Burial 9 at Phum Snay. A broken large spherical

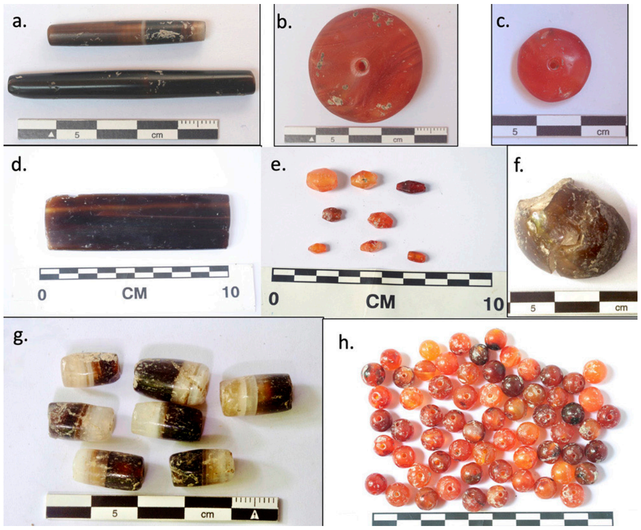

Figure 7. Agate and carnelian bead shapes: (a) long agate barrel beads from Lovea; (b) large carnelian short bicone from Lovea; (c) small carnelian bicone from Lovea; (d) long, flat, rectangular agate pendant from Sophy; (e) hexagonal faceted beads from Sophy; the rough hexagonal bead is in the upper left; (f) broken large spherical bead from Prei Khmeng; (g) agate cylinders from Prei Khmeng; (h) spherical carnelian beads from Sophy.

agate bead found at Prei Khmeng (Figure 7f) appears similar to spherical agate beads excavated in Bali (Calo et al. 2015). One burial (no. 3) at Prei Khmeng contained seven agate cylinders, with one half of the bead white or transparent in color and the other half dark brown or black (Figure 7g). These may be related to the fairly common banded-agate barrel beads found at multiple sites in mainland Southeast Asia, which have dark black or brown ends and white opaque centers (Carter 2013:200-201; Theunissen 2003:122). Many of the agate beads appear to have been dyed to enhance their dark brown to black color, including those in Figure 7g.

Bead Manufacturing and Perforation Technology

In addition to primarily being made with simple shapes, the beads at all three sites largely show manufacturing methods and quality associated with the Type 2 category. Many of the Lovea beads have smooth surfaces exhibiting a medium or low luster polish, but have imperfections such as nicks and chips. The presence of rough spherical beads at Lovea and Sophy is also indicative of expedient and less-careful bead production. Rough spherical beads were usually intended to be spherical, but one end becomes damaged during the drilling process (i.e., the force of the drill causes a "pop-out"), creating a concave and uneven shape.

Only one bead in burial 4 at Lovea, a large bicone (AKC03917/Cat 86), is well-made with a smooth and highly polished surface. At Prei Khmeng, several of the agate beads do have a medium-high polish, indicative of a more careful finishing technique. Most of the carnelian beads were, however, roughly made with some damage around the perforation. An exception is a large short bicone, with a smooth medium-low luster. This broken agate bead has numerous flake scars on the surface and may not have been carefully finished. Determining the quality of the stone and polish on beads from Sophy was difficult due to the concretions on their surfaces. Several beads are roughly made, such as the spherical and faceted bicones discussed above, but many spherical beads and faceted bicones are largely symmetrical with a smooth, polished surface (Figure 7h).

The size of the bead hole or perforation can also be used in conjunction with morphological observations to assist in assigning a bead to Type 1 (smaller perforation sizes) or Type 2 (generally larger perforations). Table 3 summarizes the mean perforation sizes from each of the three sites. The large perforations at all three sites classify the beads as Type 2 and are similar to average bead perforation sizes at Phum Snay (1.72 mm), Angkor Borei (1.63 mm), and Ban Non Wat (1.66 mm) (Carter 2015).

Previous studies of bead perforations from sites in Cambodia and Thailand have revealed that agate and carnelian beads were drilled using a diamond or double-diamond drill (Carter 2013; Carter et al. 2022; Gorelick, Gwinnett, and Glover 1996). In India, a diamond-tipped drill has been used to perforate beads since at least 600 BC (Kenoyer 2003). Modern Indian bead drillers use a special drill with two diamond chips mounted on the drill tip (Kenoyer and Vidale 1992). These drills produce a straight cylindrical perforation with distinctive spiraling striations on the hole's walls. The double-diamond technique appears to be limited to South Asian beadmakers, specifically peninsular India, and is still widely practiced in Khambhat, Gujarat (Kenoyer, Vidale, and Bhan 1991). Single-diamond drills were also used, but this drill type is more commonly found in the northern and western parts of Asia (Kenoyer 1992, 2003).

Silicone impressions were made of the perforations of several beads from Sophy: the long agate pendant (AKC03701), the long agate barrel (AKC03702), and three spherical carnelian beads (AKC03714, AKC03746, AKC03756). These were examined under a Scanning Electron Microscope (SEM) by Mark Kenoyer at the University of Wisconsin-Madison (Gorelick and Gwinnett 1978; Kenoyer 2017b; Kenoyer and Vidale 1992). Figures 8 and 9 display the beads and their SEM images. All impressions display a pattern of regular, spiraling striae or grooves, representative of the double-diamond drilling technique (Gorelick and Gwinnett 1988). Notably, the SEM

Table 3. Mean Perforation Diameters of the Agate and Carnelian Beads.*

Site	Mean Perforation Size (mm)	Standard Deviation (mm)	Total Perforations/ Beads Measured
Lovea	1.96	0.46	47/24
Prei Khmeng	2.01	0.33	26/13
Sophy	1.84	0.41	156/78

*Perforation measurements taken from both sides of the bead when possible. Due to the large number of spherical beads at Sophy, a subsample of perforations was measured.

image of AKC03714 exhibits evidence of heavy string wear in the perforation that has obscured the drilling striae (Figure 9 top).

Compositional Analysis of the Stone Beads

One persistent question regarding the agate and carnelian beads found in Southeast Asia is: were they produced locally or imported as finished products (Bellina 2003; Carter and Dussubieux 2016; Francis 1996; Glover 1989; Theunissen et al. 2000)? One method to address this question is to undertake geochemical analysis of the beads and determine the source of the raw material (Law et al. 2013; Theunissen, Grave, and Bailey 2000). A previous compositional study of agate and carnelian beads from sites in Cambodia and Thailand compared these artifacts to four potential raw-material sources (Carter and Dussubieux 2016): two sources in the Deccan Traps in western India (Mardak Bet and Ratanpur), one source in Iran (Shahr-i-Sokta), and another in central Thailand (Ban Khao Mogul). Artifacts in this earlier study were compositionally analogous to the raw material from the Deccan Traps in western India (Carter and Dussubieux 2016).

Twenty-one beads from the three sites in this study (Table 1) were selected for compositional analysis using LA-ICP-MS and compared to the four potential sources described above following Carter and Dussubieux (2016). In the earlier study, it was found that three elements were able to separate the four geologic sources: B, Sb, and Sc. Figure 10 presents a 3D scatterplot of the geologic sources and artifacts from this study plotted by these elements. As with previous studies, this analysis shows that the artifacts from

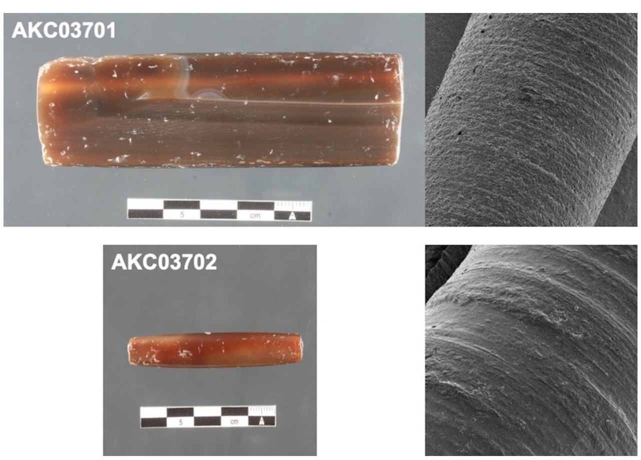

Figure 8. Beads from Sophy and SEM images of their perforations at 50x magnification. Note the parallel striae typical of the diamond-drilling technique.

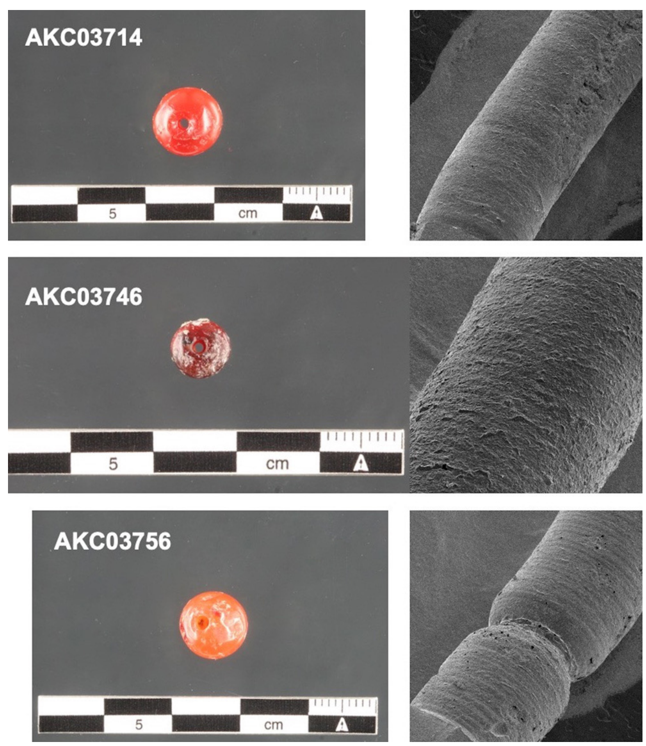

Figure 9. Beads from Sophy and SEM images of their perforations. The top and bottom images are at 25x magnification, the middle image is at 50x. The bottom image shows the juncture of the two perforation segments drilled from either end.

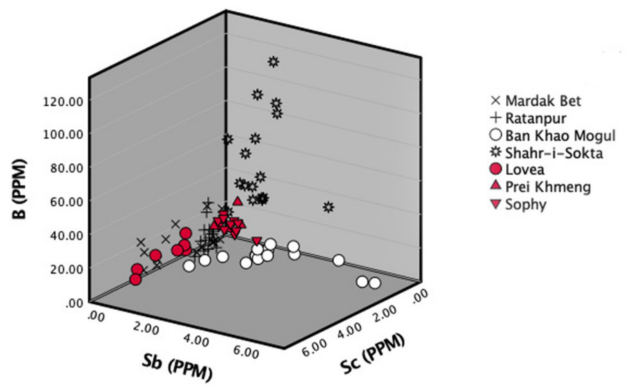

Figure 10. Three-dimensional scatterplot of agate/carnelian geographical sources and the beads from Lovea, Prei Khmeng, and Sophy.

northwestern Cambodia are most compositionally analogous to the Deccan Traps sources in India. The compositional data combined with analyses of bead perforations strongly suggests connections to the South Asian stone beadmaking industry. It is not clear if beads were imported as finished products or produced in Southeast Asia usin g imported raw materials at sites like Khao Sam Kaeo, Thailand (Bellina 2017). This study is limited in its small number of raw material sources, but expanding the comparative database is a long-term goal. This may help to identify the sources of the different bead types.

THE DISTRIBUTION OF BEADS IN BURIALS

As most of the beads in this study were found in burial contexts as grave goods, we can use the associated bioarchaeological and mortuary data to consider who was utilizing beads at these sites. First, it should be noted that beads were not evenly distributed within burials (Table 4). Not all burials contained beads, and stone beads were less commonly found in burials than glass beads. This observation is not statistically significant as we do not know the total number of mortuary contexts at each site. It is, nevertheless, consistent with the distribution of beads in burials at other sites in mainland Southeast Asia (Carter 2015).

Table 5 lists the mortuary contexts at each site, the number of stone and glass beads in each burial, as well as available information on the individual(s). More information on the beads and their contexts can be found in Appendix A. Beads from both the Paddy to Pura and MAFKATA excavations at Prei Khmeng are reported (Bâty 2003; Demeter 2004a, b; O'Reilly et al. 2020). Burials at Prei Khmeng and Lovea were more poorly preserved than at Sophy. Due to these poor preservation conditions, there were several contexts in the Prei Khmeng MAFKATA excavations that contained beads but had no bone, making it unclear if they were burials. It is uncertain how representative these burials are of the communities at each site and in the case of Sophy, looting has made comprehensive analysis of the mortuary data impossible. Nevertheless, some preliminary observations can be made. Agate and carnelian beads appear to have been more common grave goods at Sophy, where they are found in higher quantities than at Prei Khmeng or Lovea. Beads appear primarily in adult burials, but at Prei Khmeng and Sophy, juveniles and young children were also buried with beads, indicating that these objects were not exclusively for adults in these communities.

The large number of stone beads in Burial 14 at Sophy and glass beads in MAFKATA Burial 4 at Prei Khmeng may shed light on the nature of the bead trade during this period. While beads might have traveled individually or in small quantities in down-the-line exchange networks, the number of spherical beads in Burial 14 and black and orange glass beads

Table 4. Number of Mortuary Contexts with Agate/Carnelian and Glass Beads.

Site	Total Number of Mortuary Contexts	Mortuary Contexts with Agate/Carnelian and Glass Beads	Mortuary Contexts with Agate/Carnelian Beads Only	Mortuary Contexts with Glass Beads Only	Mortuary Contexts Without Beads
Lovea	11	6	0	5	0
Prei Khmeng (MAFKATA)*	ca. 12	1	0	6	ca. 5
Prei Khmeng (P2P)	11	2	0	7	2
Sophy	14	7	0	1	6
Total	**ca. 48**	**16**	**0**	**19**	**ca. 13**

* The Prei Khmeng MAFKATA data include contexts that contained artifacts but no bone, yet may have been burials.

Table 5. Burials with Beads at Lovea, Prei Khmeng, and Sophy.

Site	Burial Number/ Mortuary Context	Age/Sex	Number of Agate/ Carnelian Beads	Number of Glass Beads
Lovea	1	Adult, sex unknown	3	109
Lovea	2	Adult, sex unknown	0	10
Lovea	3 intermingled with Burial 3.2	Adult, possibly male	0	49
Lovea	3.2 intermingled with Burial 3	Young adult, male	0	48
Lovea	4	Adult, sex unknown	4	411
Lovea	6	Adult, sex unknown	7	7
Lovea	7	Adult, sex unknown	4	11
Lovea	8	Adult, sex unknown	2	72
Lovea	9	Adult, possibly male	4	48
Lovea	10	Adult, possibly male	0	19
Lovea	11	Adult, sex unknown	0	4
Prei Khmeng (MAFKATA)*	12-1 (12221)	Unknown	1	7**
Prei Khmeng (MAFKATA)	Burial 2 (16016/15017)	Juvenile, sex unknown	0	36 (includes 12 beads analyzed by Latinis 2004)
Prei Khmeng (MAFKATA)	Burial 3 (21040/15021)	ca. 28 years old, female	0	144
Prei Khmeng (MAFKATA)	Burial 4 (21045/15061)	25-28 years old, female	0	1766 (includes 16 beads analyzed by Latinis 2004)
Prei Khmeng (P2P)	1	13-15 years old, sex unknown	0	54
Prei Khmeng (P2P)	2	Mid-old adult, male	0	34
Prei Khmeng (P2P)	3	1.5 years old, sex unknown	7	53
Prei Khmeng (P2P)	5	Middle-aged adult, possibly female	0	72
Prei Khmeng (P2P)	6	Young adult, male	0	16
Prei Khmeng (P2P)	7	Neonate	0	87
Prei Khmeng (P2P)	8	0.5 year old, child	0	31
Prei Khmeng (P2P)	9	Young adult, male	2	20
Prei Khmeng (P2P)	10	Young adult, possibly female	0	162

Table 5. Continued.

Site	Burial Number/ Mortuary Context	Age/Sex	Number of Agate/ Carnelian Beads	Number of Glass Beads
Sophy	5 (contained three individuals)	Young adult, female; adult, sex unknown; young adult, sex unknown	1	181
Sophy	6	5-7 years old, child	20	329
Sophy	7	Adult, male	17	448
Sophy	8	2-4 years old, child	1	4
Sophy	9	2.5 years old, child	1	9?
Sophy	10	6-9 years old, child	7	441
Sophy	11	15-18 years old, female	0	119
Sophy	14	Middle aged, female	280	264

*Only burial contexts with bone from Prei Khmeng are included.
**Burial 12-1 beads were observed on display in the National Museum, Phnom Penh, but not recorded.

in Burial 4 point towards the movement of large quantities of goods through more organized bead exchange networks.

Within each community, a small number of burials/ individuals had a larger quantity of beads than others. A study of ceramics and grave goods from these three sites by Lim (2020) identified the wealthiest burials at each site as determined by the quantity of associated bronze artifacts. At Sophy, the three wealthiest burials (nos. 7, 4, and 10) contained most of the stone and glass beads found at the site. Similarly, a relationship was identified between the distribution of glass beads and the wealthiest burials at Prei Khmeng and Lovea. Adult Burial 4 at Lovea contained hundreds more glass beads than other burials at the site, as well as the large carnelian bicone. At Prei Khmeng, the burial of an adult female contained over 1700 glass beads. Few burials at Prei Khmeng contained stone beads, but one child was buried with seven agate cylinders. At Sophy, the burials with the highest number of stone beads also contained the highest quantity of glass beads. Burial 7 is notable for containing the long agate pendant, as well as two other agate beads, and 14 spherical carnelians. One of the wealthiest burials at the site (no. 14) contained 280 beads, including over 250 spherical carnelians. This burial has the highest number of stone beads from a single burial thus far recorded in Cambodia, and perhaps mainland Southeast Asia.

Who were these individuals whose burials contained high quantities of beads? It does appear that they were largely adults who may have earned their status within the community through their achievements in life. The presence of children or infants with beads, however, also points towards emerging inequality and inherited wealth or ascribed status in some contexts (Peebles and Kus 1977). While most people at all three sites were likely agriculturally focused, there is evidence for iron working, and pottery and textile production at Sophy (O'Reilly et al. 2015). Similarly, Lovea and Prei Khmeng also show evidence for textile production and iron working, in addition to an agrarian economy (O'Reilly and Shewan 2015, 2016; O'Reilly et al. 2020). Did some individuals at these sites acquire beads due to their particular crafting skills similar to the notable "princess" of Khok Phanom Di? This burial contained thousands of shell beads that are believed to be related to her status in the community as a skilled ceramicist (Higham 1991). It is also possible that individuals with beads held other roles of status within their community that may be archaeologically invisible, such as a spirit medium or healer.

DISCUSSION AND CONCLUSION

The presence of beads at Lovea, Prei Khmeng, and Sophy are material indicators that these communities were participating in long-distance exchange networks. All three have large quantities of orange high-alumina soda-glass beads. The distributions of stone beads shows some variation in the bead morphologies present, but all three sites contained primarily Type 2 agate/carnelian beads. A small number of unusual stone bead shapes show possible connections to communities in the Mekong Delta and northeastern Thailand. Overall, all three sites share a pattern of bead assemblages dominated by high-alumina soda-glass beads and Type 2 agate/carnelian beads. This is typical of other sites within the Mekong Interaction Sphere and in contrast to sites with different glass and stone bead assemblages (those that contain largely Type 1 stone beads and potash-glass beads) that date to the early Iron Age and/or are more connected to a South China Sea exchange network (Carter 2015; Carter et al. 2021). This result is not entirely unexpected as previous work on bead collections at Prei Khmeng and the northwestern site of Phum Snay has shown similar patterns in their bead assemblages (Carter 2010, 2015).

Studies of earthenware ceramics show comparable linkages between the Mekong Delta, northwestern Cambodia, and northeastern Thailand (Lim 2020; Stark and Fehrenbach 2019). All three regions share similar earthenware production techniques called the Reduced Ceramic Horizon in which vessels were fired in a reduced or incompletely oxidizing environment that resulted in ceramics with a dark grey, brown, or black surface (Stark and Fehrenbach 2019). Within this broad regional tradition were more localized ceramic practices of which, it appears, Sophy was more closely linked to sites in northeastern Thailand, while Prei Khmeng and Lovea showed stronger affinities to the Mekong Delta (Lim 2020:441). Within the bead assemblage, the best evidence for similar connectivity between Sophy and sites in northeastern Thailand is the presence of the orange wrapped disc bead, which has been found in large quantities at several sites in northeastern Thailand, including Ban Non Wat and Noen U-Loke (Carter and Lankton 2012; Saitowitz and Reid 2001).

In an earlier study, it was proposed that the similarity in bead assemblages seen at many sites in Cambodia was likely due to the emergence of a powerful polity in the Mekong Delta around the site of Angkor Borei and referred to as Funan in Chinese historical documents (Carter et al. 2021). Further work is needed to better understand the relationship between communities in the Mekong Delta and those in northwestern Cambodia. Nevertheless, the present study demonstrates that the communities of Lovea, Sophy, and Prei Khmen benefitted from the growth of this polity and its seemingly increasing access to South Asian goods, including beads.

Other localized bead exchange networks are difficult to discern within the existing dataset, but the broad patterns in the beads from northwestern Cambodia demonstrate that these sites were not isolated backwaters, but part of a robust regional exchange network. Future work can add nuance to these regional networks by identifying more specific bead subgroups. This should include reanalysis of stone beads using an expanded, comparative, agate/carnelian raw-material database (an ongoing project being developed by several scholars), continued careful analysis of bead perforations, and updating the stone-bead-shape typology to use more precise terminologies. Overall, this study joins others in demonstrating the utility of studying bead assemblages to assess intra-regional exchange within Southeast Asia, rather than focusing on imported beads solely as indicators of connectivity with South Asia (Bellina 2018; Carter 2015; Dussubieux and Pryce 2016; Lankton and Dussubieux 2013; Theunissen, Grave, and Bailey 2000).

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APPENDICES

Lovea, Prei Khmeng, and Sophy Bead Datasets (Appendix A: Bead Morphology and Context Information and Appendix B: Glass and Stone Bead Compositions) are archived at the University of Oregon Scholar's Bank/Harvard Dataverse and can be accessed at the following address: https://doi.org/10.7910/DVN/MDXVTU.

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