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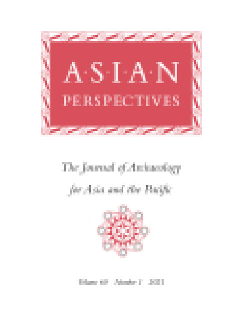

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ABSTRACT

Angkor Borei, Cambodia was an important urban center related to the early first millennium C.E. polity known as Funan. Excavations in the protohistoric period Vat Komnou Cemetery site uncovered over 1300 glass and stone beads, which are important material indicators of trade. In this article, we review data from earlier studies and add new previously unpublished data on glass and stone beads from this collection as well as previously unpublished glass compositional analyses from the nearby site of Oc Eo, Vietnam. Examinations of the glass beads highlight the presence of large quantities of high alumina mineral soda glass associated with Sri Lankan or South Indian bead production as well as smaller quantities of other glass types in circulation throughout Southeast Asia. Compositional and morphological studies of agate/carnelian beads show strong affinities with the Indian bead industry, while the garnet beads came from raw material sources in southern India. Overall, Angkor Borei's bead collection shows strong contacts with different regions of South Asia. Comparison with the bead assemblages of other contemporaneous sites demonstrate strong affinities with sites farther inland, such as Phum Snay and Prei Khmeng, Cambodia and Ban Non Wat, Thailand rather than other maritime coastal sites in Southeast Asia. We argue that the stone and glass beads at Angkor Borei are related to intensified interaction with South Asia and that elites at Angkor Borei used these exotic prestige goods to build alliances with sites farther inland forming an intraregional exchange network we call the Mekong Interaction Sphere. Keywords: trade, stone beads, glass beads, Mekong Interaction Sphere, Funan, Cambodia.

INTRODUCTION: ANGKOR BOREI, THE MEKONG DELTA, AND "FUNAN"

In the third century C.E., two Chinese emissaries from the Wu kingdom traveled to Southeast Asia to visit a kingdom they called Funan, located in the Mekong Delta region of Cambodia and Vietnam (Coedès 1968; Ishizawa 1995). Chinese chronicles described a king named Fanzhan, who had sailing vessels that enabled him to control a large region of the Thai-Malay peninsula, perhaps as far up the coast as Myanmar. Chinese chronicles also document a kingdom in this region that sent emissaries to China and traded with India (Coedès 1968; Ishizawa 1995). Excavations at the 450 ha

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walled and moated site of Oc Eo, Vietnam by French archaeologist Louis Malleret in the 1940s uncovered a wide range of artifacts including stone and glass beads, silver and gold jewelry, intaglios, coins, and ceramics, mostly from India, but some artifacts came from Rome and the Sassanian empire (Malleret 1962) (Fig. 1). This varied collection of objects demonstrated that the people of Oc Eo were involved in international trade and Malleret argued that it was the site of a trading port for the Funan kingdom (Stark 1998).

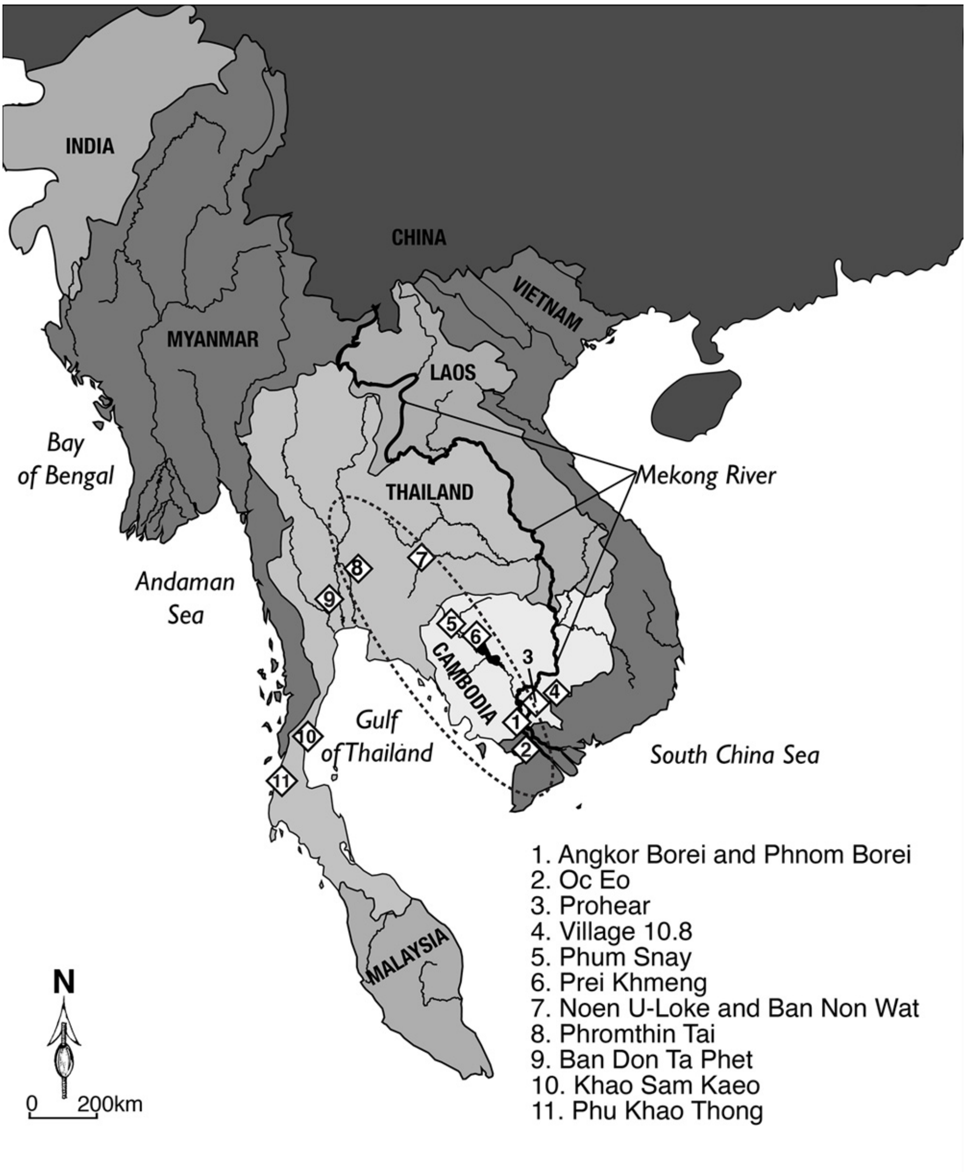

Fig. 1. Map of sites in Southeast Asia mentioned in the text. Dotted circle denotes proposed area of Mekong Interaction Sphere.

The Cambodian site of Angkor Borei, located just 70 km northeast of Oc Eo, is also believed to have been an important center for Funan and several scholars have argued that it might have been the capital of Funan (e.g., Aymonier 1903; Pelliot 1903; Vickery 2003) (Fig. 1). The walled and moated site measures over 300 ha (Fig. 2). Numerous artifacts testify to the Mekong Delta's importance during the middle of the first millennium C.E. The oldest dated Khmer language inscription (dated to C.E. 611) was found at Angkor Borei and numerous other inscriptions have been found in the Mekong Delta region describing the activities of local rulers and elites (Jacob 1979; Vickery 1998). The French geographer Pierre Paris (1931) identified a series of canal networks linking Angkor Borei with other sites in the region, including Oc Eo. Some of the earliest examples of Khmer sculpture are at the site of Phnom Da, a small hill located just a few kilometers south of Angkor Borei (Dowling 1999; Jacques and Lafond 2007). Archaeological research at Angkor Borei has also identified numerous collapsed brick structures within the city walls as well as a cemetery dating from 200 B.C.E. to C.E. 200 (Ikehara-Quebral et al. 2017; Stark 2001; Stark and Bong 2001; Stark et al. 1999; Stark et al. 2006). Excavations have also determined that people were

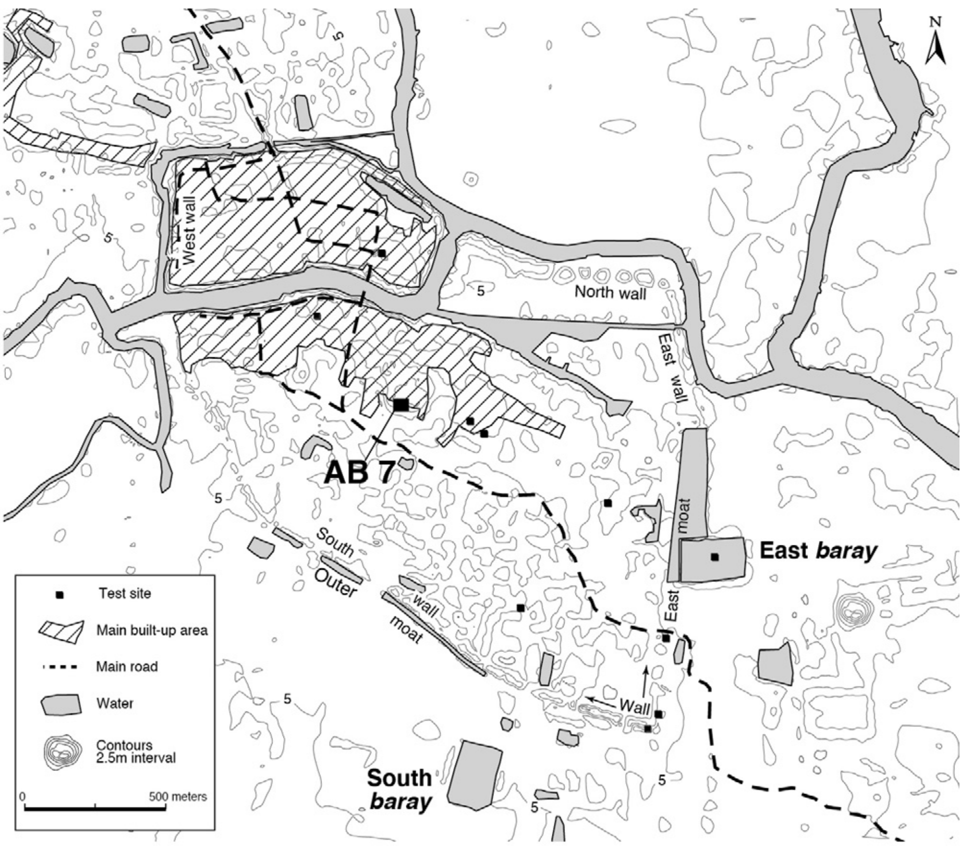

Fig. 2. Contour map of Angkor Borei showing location of Vat Komnou cemetery (AB 7) (adapted from Bishop et al. 2003:361, fig. 3).

living at Angkor Borei perhaps as early as ca. 500–400 B.C.E., through the Angkorian period, and into the present day (Stark 2004).

Historical and archaeological data support the interpretation that by the early centuries C.E., the Mekong Delta region was home to a powerful polity that seems to have grown as a result of international maritime trade (Manguin 2009*a*, 2019*a*; Stark 2004, 2006*b*). Historic documents record a decline in Funan's power in the sixth or seventh centuries C.E., likely due to the shifting of trade networks to Island Southeast Asia (Manguin 2004; Stark 2006*b*). Chinese historic documents and pre-Angkorian inscriptions also describe some internal competition between rulers as power centers began to move further inland (Stark 2006*b*; Vickery 1998).

The importance of maritime trade in Funan's emergence as an early state is now conventional wisdom, but few scholars have explored the nature of this trade. We do so here by posing two specific questions that examine Angkor Borei's role in both inter- and intra-regional exchange networks. First, does the archaeological bead data enable us to identify specific regions of South Asia whose populations interacted with people in the Mekong Delta? Scholars have noted that multiple regions in South Asia were interacting with Southeast Asian communities during the late first millennium B.C.E. (e.g., Bellina and Glover 2004; Dussubieux and Pryce 2016; Guy 2011; Ray 1989). Second, could the bead assemblages of Angkor Borei (and Oc Eo to a lesser extent) provide scholars with a deeper understanding of the social and economic networks in which beads were circulating such that we could elucidate the importance and impact of external (maritime) trade versus internal (overland) trade and connections.

This article uses previously unpublished and updated information from Angkor Borei's extensive bead assemblage to begin addressing these questions. In the following section, we review several of the predominant theories regarding the role of trade in the development of sociopolitical complexity and the development of a polity in the Mekong Delta. We also include a discussion of who may have been involved in trade and exchange. Following this, we examine the glass bead assemblage from Angkor Borei by analyzing previously unpublished compositional data and comparing it with similar data from other contemporary sites, including the nearby site of Oc Eo. Discussion of sites with similar glass bead types can be used to consider broader regional trading networks. We then review previous morphological and compositional studies of agate and carnelian beads and add new data examining bead perforations to identify the manufacturing tradition of these beads. Lastly, we review morphological and compositional studies of garnet beads from Angkor Borei and update our earlier interpretations with new compositional data from archaeological and geological sources in southern India.

Our observations point toward strong connections with southern India and Sri Lanka especially. We argue that these connections were taking place during a period of intensified interaction with South Asia (Bellina and Glover 2004). This period saw the circulation of higher quantities of imported glass and stone beads that appear to have been mass-produced (Carter 2015). This was different from earlier phases of interaction that saw less intense interaction with South Asia, but frequently with higher quality products (Bellina and Glover 2004).

This novel analysis of Angkor Borei's bead assemblage suggests that the settlement had stronger ties to inland sites in the Lower Mekong Basin (Cambodia and Thailand) than with contemporary coastal sites that fringed the South China Sea. This inland system, which we call the Mekong Interaction Sphere (MIS), linked Angkor Borei with communities to the northwest (i.e., in northwestern Cambodia and northeastern Thailand) through prestige goods exchange networks. Our study identifies promising patterns suggesting that intensified interaction with South Asia (Bellina and Glover 2004) and the increased availability of imported objects such as mass-produced beads facilitated the building of alliances and connections with these communities in the MIS. We argue that this interaction facilitated the growth of Angkor Borei as a major urban center for the Funan polity (Carter 2015). While the reasons for Funan's growth as an early complex polity were multifaceted, the bead assemblage data shows connections to inland communities became increasingly important in subsequent periods.

FUNAN AND MARITIME TRADE IN SOUTHEAST ASIA

Evidence for far-flung interactional networks linking Southeast Asia to neighboring regions extends back more than a millennium before contact with South Asia (Hung et al. 2007; Hung et al. 2013; Wu 2019). However, it is contact with South Asia that brought communities in mainland Southeast Asia into a wider interaction network, during what is sometimes called a period of proto-globalization (Bellina and Glover 2004; Carter and Kim 2017; Glover 1989). Current evidence suggests that interaction between the two regions changed over time (Bellina and Glover 2004). During the period Bellina and Glover (2004) call Phase 1 (ca. 400 B.C.E.–C.E. 100), exchange with South Asia was less intense, with small quantities of diverse artifacts including pottery, bronze containers, stone and glass beads, and coins and intaglios. These objects were frequently found in "non-Indianized" contexts such as burials (Bellina and Glover 2004:73). During Phase 2 (ca. 100–300 C.E.), exchange increased dramatically, with greater quantities of Indian objects found at sites in Southeast Asia (Bellina and Glover 2004). The types of objects were less diverse, however, and, in the case of stone beads, lower quality (Bellina 2003). Angkor Borei, Oc Eo, and Funan seem to have developed during the transition between these two phases, with clearer evidence for expansion during Phase 2 (Reinecke 2012; Stark 2004).

Stone and glass beads were among those objects being imported from South Asia during both phases (Bellina and Glover 2004), with increased quantities found at sites during Phase 2 (Carter 2015). Because they were made from exotic materials (agate/carnelian and garnet) or using a new technology (glass), beads are widely considered to have been "status markers" (Bellina 2003:287; Francis 2002) or "prestige objects" (Glover 1989:11; Ray 1996:43; Theunissen et al. 2000). Cross-culturally, numerous scholars have observed the importance of prestige goods, specifically the control over their production and exchange, as a key factor in the emergence of complex societies (Bacus 2000; Blanton et al. 1996; Brumfiel and Earle 1987; D'Altroy and Earle 1985; Junker 1999; Kipp and Schortmann 1989; Renfrew and Shennan 1982; Sabloff and Lamberg-Karlovsky 1975; Schortman and Urban 1996, 2004; Wells 2006). During Phase 1, and likely before contact with South Asia, numerous coastal communities were connected to one another via the South China Sea and the exchange of prestige objects such as locally produced nephrite ear ornaments (Hung and Bellwood 2010; Hung et al. 2007; Hung et al. 2013) and Dongson bronze objects (Calo 2014). Several Southeast Asian archaeologists have used such models to explain the growth of sociopolitical complexity in coastal communities that ostensibly controlled the exchange of prestige objects with inland populations (Bellina et al. 2019; Bronson 1977; Christie 1990, 1995; Junker 1994; Manguin 2002, 2009*b*).

The polity of Funan and especially its coastal settlement of Oc Eo was clearly involved in international maritime trade, with both long-distance connections and linkages to other coastal communities in Southeast Asia (Hall 1982, 1985; Malleret 1962; Manguin 2004, 2009*a*, 2019*a*). We argue that elites in the Mekong Delta were also expanding their sociopolitical and economic alliances with inland communities through the trade of exotic prestige objects, including stone and glass beads. As part of the maritime trading state of Funan, Angkor Borei had access to new foreign goods. These were perhaps initially traded into the more coastally oriented site of Oc Eo and then moved to Angkor Borei via canal. We argue that as exchange with South Asia intensified (Bellina and Glover 2004), the greater availability and quantity of objects from South Asia, including beads, facilitated expanding social and economic networks with these inland sites as part of the MIS network. These expanding connections enabled the growth of elite power in Angkor Borei and Funan.

Who was Involved in Trade?

Identifying who exactly was involved in protohistoric maritime exchange networks is difficult given the current limited archaeological record, however evidence suggests long-standing, multidirectional, interactions between communities in South and Southeast Asia across the Bay of Bengal (Gupta 2003). Southeast Asia was an important source of raw materials such as gold, tin, spices, and precious wood; it is possible ceramic production and shipbuilding techniques were also exported to South Asia (Manguin 2019*a*; Selvakumar 2011; Smith 1999). Some scholars have argued that the rapid transmission of new ideas and information across Southeast Asia might have been due to local traders moving goods on Malay or Indonesian ships (Christie 1995:277; Manguin 2019*a*).

During Phase 1, evidence from the Thai/Malay peninsula suggest that Indian artisans were settling and perhaps travelling between Southeast Asian communities and producing objects, including stone and glass beads, for local elites (Bellina 2014, 2018*b*). The period in which exchange was expanding with Southeast Asia is also one of increasing urbanism in southern India (Smith 2006) and these expanding markets might have helped the growth of southern Indian craft products such as glass beads (Abraham 2016). Perhaps during Phase 2 and especially after C.E. 300, there was an additional period of "intensified ideological contact" in which Hindu and Buddhist ideology and the associated material culture (e.g., architecture, sculpture) appear across mainland Southeast Asia (Stark 2006*a*:411). Buddhism and its favorable views towards wealth accumulation and trade as an occupation may have had a major impact on the expansion of trade into Southeast Asia. South Asian artifacts with ties to Buddhism at sites in Southeast Asia were already well known (Glover 1989), although how these artifacts were understood by Southeast Asians is not clear. Ray (1989) notes that the expansion of Buddhism into southern India and the subsequent restructuring of the economic base, which placed economic power in the hands of Buddhist monasteries, might also have been taking place in parts of Southeast Asia.

Manguin (2010, 2019*b*) has also suggested that Vaishnavism played an important role in the political, religious, and economic parts of life in Southeast Asia during the second half of the first millennium C.E. In India, Vaishnavism was associated with business and wealth accumulation and its exportation to Southeast Asia, likely via Brahmans, merchants, and shipmasters, provided a mechanism for Southeast Asians to be integrated into this sociopolitical and economic network (Manguin 2019b). Adoption of these Hindu religious practices would have created a shared community and facilitated economic transactions (Manguin 2019*b*). Guy (2011) has argued that Tamil merchants were key figures in the transmission of goods and Hindu-Buddhist ideology in the first millennium C.E., and points towards southern India as a key area interacting with communities in coastal mainland and Island Southeast Asia. However, it should be noted that these particular developments took place several centuries after the time period under discussion here.

It is likely that diverse groups of people were involved in maritime trade between South and Southeast Asia and that the groups changed over time. Although the bead assemblage from Angkor Borei does not yet fully clarify who these groups were, the analyses discussed here do add some depth to understanding which particular regions of South Asia may have been interacting with the Mekong Delta; we hope this can be refined with future work.

The next section of this article provides further background on the stone and glass beads from Angkor Borei and we review what is known about the bead assemblage from the nearby site of Oc Eo. We then discuss the results of compositional and morphological analyses of the Angkor Borei beads. Through this work, we begin to identify connections to specific parts or "micro-regions" of South Asia (Ray 1989). We also contextualize these results as part of the broader exchange of stone and glass beads in the region, highlighting the connections between Angkor Borei and sites farther inland in Cambodia and Thailand.

THE VAT KOMNOU CEMETERY

The glass and stone beads from Angkor Borei came entirely from excavations at the Vat Komnou cemetery, which is located in an elevated area approximately in the center of the site near the Wat Komnou pagoda (Fig. 2). A 5 × 2 m unit was excavated over the course of two field seasons. The stratigraphy in this area was quite deep, with some units extending almost 7 meters below the surface. Radiocarbon dates were taken from organic materials above and below the burial layers and show the cemetery was in use from 200 B.C.E. to C.E. 200 (Stark 2001). Unfortunately, the tightly packed cemetery, occasionally with burials cutting into one another, prevents a more detailed seriation within this four hundred year time span. A total of 111 burials were recovered; 33 of these were primary inhumation burials (Ikehara-Quebral 2010; Ikehara-Quebral et al. 2017). Bioarchaeological work on the skeletal remains from Vat Komnou suggests the population was relatively healthy (Ikehara-Quebral et al. 2017). Isotopic studies show the presence of two populations, one with a local strontium isotope signature and those with isotopic signatures from the wider region (Shewan et al. 2020).

Many beads, especially the glass beads, were found within the cemetery matrix and not directly associated with a burial. Due to bioturbation and postdepositional processes, the small size of the beads, as well as heavy use of the cemetery during which burials were intercut with one another, the beads within the matrix were certainly not in their primary context. Despite this, we do believe they date to the use of the cemetery; the proportions of different glass bead types in the burials were similar to those found in the cemetery matrix. Furthermore, glass beads were not found in layers above or below the cemetery. A small number of beads were found in direct association with skeletal material such as a skull, pelvis, or ribs. The contexts and more detailed information on the beads found within the Vat Komnou cemetery are listed in Appendix A (see also Carter 2020: Glass Contexts; Stone Contexts).

STONE AND GLASS BEADS FROM OC EO

Louis Malleret (1962) reported many thousands of beads from Oc Eo, but less than a thousand of them came from his excavations; the others were from looted contexts. He found both monochromatic, drawn, Indo-Pacific beads (discussed further below), as well as polychrome beads and glass beads in other sizes and shapes. He also identified a variety of beads and pieces of jewelry made from stone, including amethyst, quartz, garnet, carnelian, agate, jade or nephrite, zircon, topaz, beryl, or serpentine.

A persistent question is whether beads were not only imported to Oc Eo, but also made on site. Malleret (1962:147–148) argued for local production of glass beads, especially polychrome ones. He identified and described several objects that might be related to the production of beads or working of glass at Oc Eo, including the discovery of colorless and translucent blue teardrop shaped droplets, fragments of glass in a variety of colors, glass rods, and chunks of melted and agglomerated beads (Malleret 1962:147–148, 243–246). Some of the glass fragments were concentrated in a specific area, causing him to speculate that there may have been a workshop in that location (Malleret 1962:245). Also of note was a ceramic vessel with a black glassy chunk adhering to the surface, which may have been a crucible used in the glass industry (Malleret 1960:137–138).

Although Malleret did not explicitly describe the production of Indo-Pacific glass beads, Peter Francis Jr. (2002:31) was confident that Oc Eo was an Indo-Pacific bead production center and argued that Malleret did not understand the glass by-products he had recorded. Francis was able to view some of the Oc Eo materials, now housed in the National Museum in Ho Chi Minh City, which he believed were wasters from pulling the Indo-Pacific tubes as well as some cut ends of tubes (Francis 2002:224). More recent work at Oc Eo by a French-Vietnamese team has identified similar evidence for possible glass production, including chunks of glass (Pierre-Yves Manguin, pers. comm. 2015). Dussubieux has noted that craftsmen at Oc Eo could have had access to sources of raw materials such as granite, sand, and soda (Dussubieux 2001:207). Evidence for primary glass production has yet to be found at this site, however.

Some of the glass beads from Oc Eo have been studied previously, although none were from secure contexts. Despite this, Oc Eo's clear connections to Angkor Borei make consideration of these data useful when trying to understand the role of Funan in the exchange of beads during the protohistoric period. As part of her doctoral research, Dussubieux analyzed 11 glass objects from Oc Eo provided by Pierre-Yves Manguin (Fig. 3). Six were monochromatic drawn glass Indo-Pacific beads, identical to those found at Angkor Borei. One additional drawn glass bead was black with opaque white and red stripes, a less common variant of the drawn Indo-Pacific bead (Francis 1990*a*). In addition to these finished beads, Dussubieux also analyzed five small chunks or glass fragments. These objects came from insecure contexts dated to either C.E. 50–250 or C.E. 400–550 (Dussubieux 2001). We report on the results of these analyses here as well as refer to published data from earlier studies.

To the best of our knowledge, none of the Oc Eo stone beads have been comprehensively studied; we mention Malleret's observations where relevant, however. As with glass bead production, evidence for the manufacture of stone

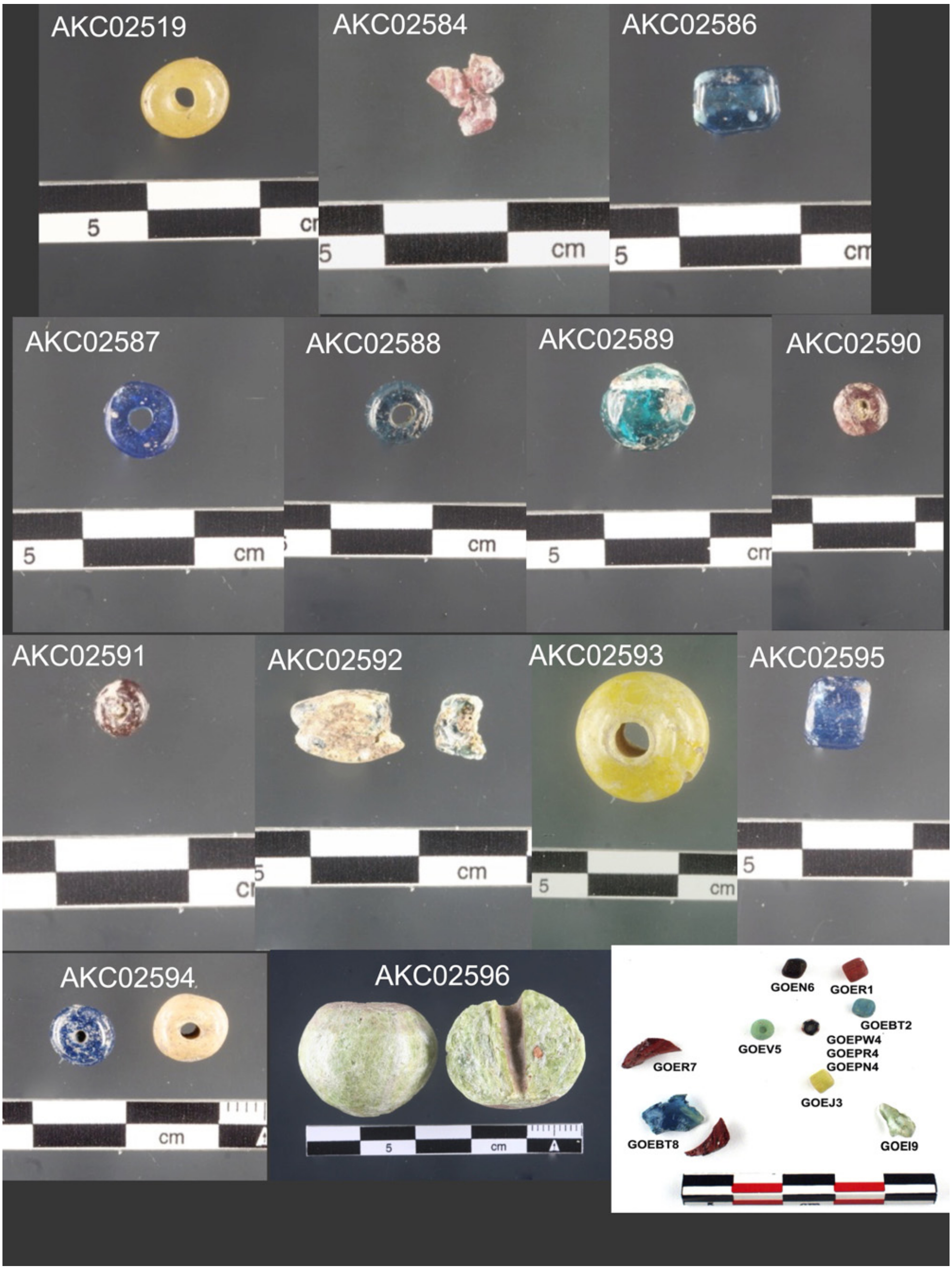

Fig. 3. Glass beads and other objects analyzed as part of the current study: Oc Eo artifacts labeled GOE (bottom right) (photographed by Laure Dussubieux); Angkor Borei artifacts labeled AKC (photographed by Alison Carter).

beads at Oc Eo is unclear. Malleret argued that there was evidence for the drilling and polishing of stone beads at the site, including flakes that he believed could have derived from the drilling process (Malleret 1962:47). Most of the evidence for bead manufacture appears to be of quartz and amethyst beads. He also recorded unfinished and undrilled agate, carnelian, and garnet beads.

Although there is evidence suggesting stone and glass bead production at Oc Eo, we believe it should be taken with caution. The site was heavily looted and possible production areas were not carefully studied. Waste products and partially finished or unfinished beads can move through the landscape to nonbead manufacturing sites (Kanungo 2000). Therefore, to convincingly identify a glassmaking or bead production site, one must find waste products, tools, and, in the case of glass beads, a furnace (Kanungo 2000). A prior review of putative bead production sites across Southeast Asia found that few of them had strong evidence for local production (Carter 2016*b*).

METHODS

The glass and stone beads were examined using a variety of methods, details of which have been summarized in previous publications (Carter 2010, 2016*a*; Carter and Dussubieux 2016; Dussubieux et al. 2009). Both glass and stone beads underwent compositional analysis using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS). Ninety-seven glass beads were analyzed in 2001 at the Centre Ernest Babelon, IRAMAT, CNRS, Orléans, France. Descriptions of the LA-ICP-MS instrumentation, analytical protocol, and data calibration method are reported in Gratuze (1999). These results were first reported in Dussubieux's (2001) doctoral thesis. Fifteen glass beads (representing unusual bead types or colors that had not been previously analyzed by Dussubieux) and all stone beads were analyzed in 2011 at the Elemental Analysis Facility at the Field Museum (see Dussubieux et al. 2009 for more detail on instrumentation). Results of these analyses first appeared in Carter's (2013) doctoral thesis. In 2019, 15 beads that had been previously analyzed by Dussubieux in 2001 were reanalyzed at the Elemental Analysis Facility. The compatibility of the results obtained at the two laboratories has been demonstrated in the past (Dussubieux et al. 2008); however, certain elements that are now recognized as diagnostic in the study of ancient glass in Southeast Asia are missing from the elemental list measured at the Centre Ernest Babelon. Stone beads were also carefully examined to determine their bead shape and manufacturing methods (Carter 2015). Impressions were taken of several of the bead perforations and examined using a Scanning Electron Microscope (SEM) to determine the drilling method used to make the beads (Carter 2012; Kenoyer 2017).

GLASS BEADS FROM ANGKOR BOREI

Carter recorded 1320 glass beads from the Vat Komnou cemetery excavations. Of these, 763 were associated with burials while the remaining 557 were from within the general cemetery matrix (see Carter 2020: Glass and Stone Contexts; Glass Composition). Glass beads were found in a greater number of burials than stone beads (Appendix A). Nearly all glass beads were small, drawn, monochromatic, and roughly spherical, a type which is frequently referred to as "Indo-Pacific" (Francis 2002) (Fig. 4). Drawn glass beads are made by pulling or drawing a hollow glass tube

Fig. 4. Glass beads from Angkor Borei: typical drawn "Indo-Pacific" beads (top); glass microbeads (bottom left and right) (1 mm unit scale at left) (photos by Alison Carter).

from a cone of molten glass. Beads are then sliced or cut from this tube and then remelted to round their sharp edges (Francis 1990*b*).

The beads were found in a variety of colors including opaque red, yellow, orange, green, white, and black and translucent blues, purple, and blue-greens. When compared to other contemporaneous sites in Cambodia and Thailand, Angkor Borei had a larger proportion of opaque green beads than elsewhere (Fig. 5). The reasons for this disparity are unclear. It is possible that people at Angkor Borei preferred green beads or that larger quantities of this bead type were available. Given that bead color and style is significant for many ethnographically studied Southeast Asian peoples (Francis 1992), it is worth pursuing this question in future studies. It should also be noted that the bead colors recorded reflect what has been found in excavation and may not be representative of the overall bead assemblage at each site.

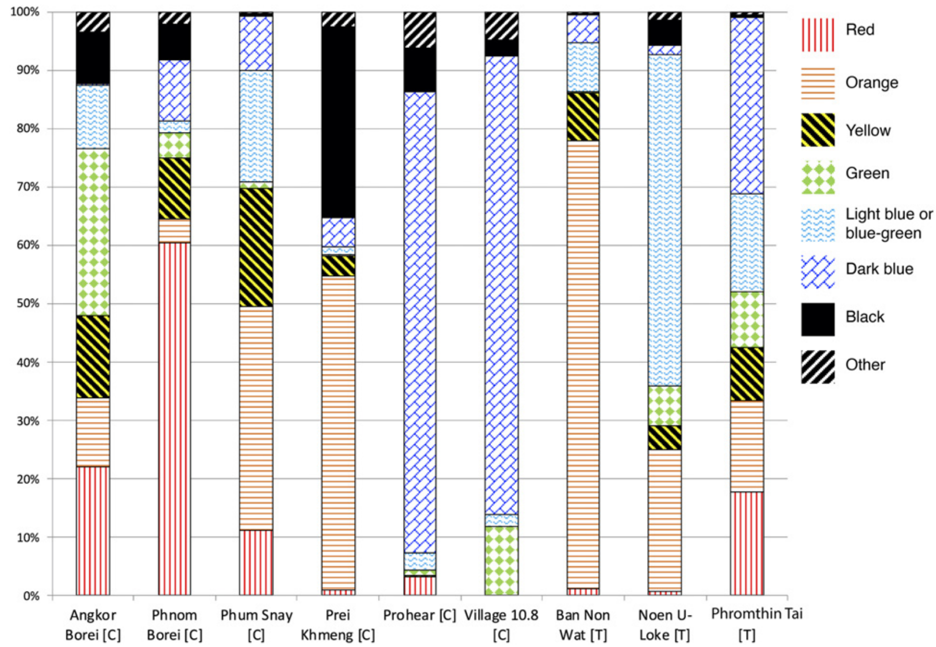

Fig. 5. Distribution of different glass bead colors at sites in Cambodia [C] and Thailand [T].

There also appear to be some change in the sizes of the drawn monochromatic beads over time. The majority of drawn beads from all periods ranged between 2 and 6 mm in width. However, during the early to middle of the first millennium C.E., smaller beads between approximately 1 and 2 mm in width began appearing at sites such as Angkor Borei, Prei Khmeng, and Phum Snay in Cambodia and Phromthin Tai (sometimes spelled Promtin Tai), Ban Non Wat, and Noen-U Loke in Thailand (Fig. 4). These smaller beads are associated with the high alumina mineral soda glass recipe (discussed below) and also occur during a period in which increased quantities of this type of glass bead were found at sites across Cambodia and Thailand (Carter 2015). Smaller size beads are created as tubes of glass are drawn from a furnace with thinner or smaller tubes being created as the glass is pulled more quickly (Kanungo 2000). The appearance of these smaller size beads may be related to the increased skill of the glassworkers and seeming emphasis on mass production of glass beads.

Glass Bead Compositions

The period from ca. 500 B.C.E. to C.E. 500 was a period with a great diversity of glass bead types in Southeast Asia. While many of the drawn beads look visually similar to one another, compositional analysis of them has identified specific glass recipes associated with particular sites, regions, and trade routes; thus helping us identify connections between sites where these beads were traded (Carter 2015, 2016*b*; Dussubieux and Bellina 2018; Dussubieux and Gratuze 2013; Dussubieux et al. 2012; Dussubieux and Pryce 2016; Lankton and Dussubieux 2013). For example, lead glass beads are associated with Chinese glass production, while high-alumina soda glass has strong connections with South Asian glass manufacturing, although specific recipes for both glass types varied over time (Dussubieux and Gratuze 2013; Fuxi 2009).

Here we discuss results from compositional analyses of beads from Angkor Borei and Oc Eo (Carter 2020 Glass Compositions dataset). Of the 15 beads analyzed by Carter, three with low alkali were too weathered to properly classify and will not be discussed further (i.e., AKC02593, AKC02594, and AKC02596 seen in Fig. 3). Dussubieux analyzed a total of 96 beads from Angkor Borei and 11 glass beads and objects from Oc Eo. Two beads with odd compositions were omitted from further discussion: AB08O, which had high alumina, and AB063J. We discuss the compositions of the remaining 117 glass beads and objects and the four major glass compositions that were identified in these two bead assemblages. We discuss these different compositions in light of the most current knowledge about their possible manufacturing locations and where other glass of this type has been found in order to situate these assemblages within regional exchange networks.

Plant Ash Soda-Lime Glass (v-Na-Ca) — Seven glass beads and one glass chunk contained a soda-rich composition, with magnesia levels over 1.5 weight percent and higher lime than alumina; we classified beads with this composition as plant ash (or vegetal) soda-lime glass (v-Na-Ca). From Angkor Borei, these included four dark blue glass beads identified by Dussubieux and three dark blue beads, including one that has a square barrel shape, identified by Carter (2020 Glass Compositions dataset). From Oc Eo, Dussubieux identified this composition in a small transparent greenish glass chunk (GOEI9).

Six of these beads were small drawn dark beads colored with cobalt (300–769 ppm). This bead type seems to have been exchanged in South and Southeast Asia during the late centuries B.C.E. and early centuries C.E., with drawn dark cobalt blue beads found at contemporaneous sites in Sri Lanka such as Ridiyagama (ca. 400 B.C.E.–C.E. 0) and Giribawa (ca. 300 B.C.E.–200 C.E.) (Dussubieux 2001) and in Southeast Asia at Khao Sek, Thailand (400–200 B.C.E.) (Dussubieux and Bellina 2018), Khlong Thom, Thailand (ca. C.E. 100–700) (Lankton and Dussubieux 2013), Phum Snay, Cambodia (350 B.C.E.–C.E.200) (Carter 2010; Gratuze 2005; Vanna 2007), and Prei Khmeng, Cambodia (ca. C.E. 0–600) (Carter 2010). The seventh bead (AKC02592) was a dark blue or greenish blue broken square barrel with heavy weathering on the surface (Fig. 3). This bead was colored with copper (1.9 wt%).

The glass chunk or fragment from Oc Eo is broadly similar in composition to a transparent greenish blue waste glass (6440) and a blue transparent nugget or cullet (6441) collected from Oc Eo and analyzed by Brill (1999*a*, 1999*b*). All three samples are from surface collections and fewer elements were analyzed for them than for those measured at the Elemental Analysis Facility, which makes further comparison and interpretation of these samples difficult.

This v-Na-Ca composition is strongly associated with glass production from the ancient Near East. In fact, the earliest glass ever produced was a soda plant ash glass, with production centers in both Egypt (Rehren and Pusch 2005; Smirniou and Rehren 2011; Smirniou et al. 2017; Tite and Shortland 2003) and Mesopotamia (Degryse et al. 2010; Shortland et al. 2018) by the middle of the second millennium B.C.E. Starting around the ninth or eighth century B.C.E., soda from mineral deposits (e.g., natron) replaced soda plant ash in beads made in Egypt and the Syro-Palestinian region. The natron composition lasted until the end of the first millennium C.E., when the use of natron declined and a return to plant ash glass occurred (Shortland et al. 2006). However, the soda plant ash glass tradition may have continued uninterrupted in Mesopotamia and Sasanian glassmakers produced this glass type from the third to the seventh centuries C.E. (Mirti et al. 2009; Mirti et al. 2008). Specific colors of soda plant ash might also have been produced in the Mediterranean in parallel with natron glass (Jackson and Cottam 2015; Nenna and Gratuze 2009). At this point, it is not clear from where the Angkor Borei and Oc Eo glass beads and objects came; however, the K_2O and MgO concentrations could point toward an Egyptian origin (Rosenow and Rehren 2018). It is certain that they are imports, most likely from farther west (i.e., Middle-East or Mediterranean area), and for this reason their presence at the site is evidence of long-distance exchange.

Lead Glass — Three glass beads with high concentrations of lead (45–69 wt% as PbO) were identified by Dussubieux; no lead beads were identified in Carter's analysis. These beads were blue, yellow, and blue-green in color; the two blue beads were annular and visually distinct from the drawn Indo-Pacific beads. The lead beads could be from China where lead glass was common during C.E.200–700 (Fuxi 2009). Lead beads are less common in Southeast Asian archaeological sites dating to the first millennium C.E. and earlier, so a distinct trade network for them is difficult to identify. Lead glass beads have been found at some coastal sites that are associated with a South China Sea exchange network, including the Sa Huynh site of Lai Nghi in Vietnam (Karsten Brabender, pers. comm. 2012) and the site of Prohear, Cambodia (Carter 2013). However, they have also been found at the inland site of Ban Non Wat, Thailand (Carter and Lankton 2012). Further work is needed to understand how lead glass beads were being exchanged within Southeast Asia.

Mineral Soda Glass — The remaining beads had magnesia levels under 1.5 weight percent and high concentrations of soda, classifying them as belonging to the mineral soda glass group. Of these, there were two sub-groups: one with high concentrations of alumina (m-Na-Al) and one with moderate concentrations of both alumina and lime (m-Na-Ca-Al).

High alumina mineral soda glass (m-Na-Al) — Ninety-three glass beads and objects analyzed from Angkor Borei and Oc Eo belong to the high alumina mineral soda glass (m-Na-Al) group. This includes six beads from Carter's analysis, 77 beads from Dussubieux's analysis of the Angkor Borei beads, and 10 glass beads and objects from Oc Eo. This glass type included multiple colors including opaque red, yellow, orange, green, and black, transparent blue, and some polychrome beads, either red-orange or black, red, and white. Occasionally, some of the opaque red, orange, or black beads have higher concentrations of MgO (>1.5 wt%), which is likely related to their coloration (Dussubieux et al. 2011). Several purple beads were also classified as belonging to this group; however, these beads are unusual and no other purple beads have been reported for the m-Na-Al 1 sub-group (discussed further below). Based on similarities in context, color, and association, we estimate that approximately 80 percent of the bead assemblage at Angkor Borei was made from this glass composition (Carter 2020: Glass Compositions; Glass Contexts).

High alumina mineral soda glass was a wide-spread and long-lived glass recipe with strong connections to South Asian glass production (Dussubieux and Gratuze 2013;

Dussubieux et al. 2010). Multiple sub-groups have been identified that are associated with different time periods and production locations (Carter et al. 2016; Dussubieux et al. 2010). The Angkor Borei beads were compared to three potential sub-groups used to make drawn glass beads in order to determine which glass bead types were present at the site. The m-Na-Al 1 sub-group is distinguished by having low uranium concentrations and high concentrations of barium and other trace elements (Dussubieux et al. 2010). This glass was found in South and Southeast Asia from the late centuries B.C.E. to the first millennium C.E. The m-Na-Al 2 sub-group is similar to the m-Na-Al 1 sub-group, but has higher uranium and lower barium concentrations. This glass was initially identified at sites dating from the late first millennium C.E. to second millennium C.E. in western India and eastern Africa (Dussubieux et al. 2010; Dussubieux et al. 2008). More recently, it has been identified in jar burial sites in Cambodia's Cardamom Mountain and sites around Angkor (Carter et al. 2016; Carter et al. 2019). The m-Na-Al 4 glass has been found at maritime sites in Southeast Asia and across the Indian Ocean dating to the second millennium C.E.. Although sub-groups m-Na-Al 2 and m-Na-Al 4 were found at sites dated later than the proposed time period under examination at Angkor Borei, their presence could indicate mixing with later contexts, which would be useful in determining the extent of bioturbation in the cemetery. Therefore, we have included these two sub-groups in our discussion.

The different sub-groups of m-Na-Al glass can be distinguished using a principal components analysis (PCA) of Ca, Mg, Ba, U, Sr, Cs, and Zr. The beads analyzed by Dussubieux (2001) did not measure Cs, therefore this element was left out of our analyses. Cs is most effective for distinguishing between m-Na-Al 2 and m-Na-Al 3 bead compositions (Dussubieux et al. 2010), but the latter sub-group (m-Na-Al 3) is not under consideration here, so its omission does not affect our interpretations.

Fig. 6 displays a biplot of PCA components 1 and 2 (69 percent of the total variance) for the Angkor Borei and Oc Eo glass objects as well as comparative datasets of beads from the sites of Prei Khmeng, Cambodia (C.E.0–600), representing the m-Na-Al 1 group (Carter 2010); Chaul, India (ninth to nineteenth centuries C.E.), representing the m-Na-Al 2 group (Dussubieux et al. 2008); and glass from the Wrecked Junk of Brunei, representing the m-Na-Al 4 group (Gratuze 2001). It is clear from this PCA that the beads from Angkor Borei and Oc Eo are compositionally analogous to the m-Na-Al 1 group and do not overlap with the m-Na-Al 2 or m-Na-Al 4 sub-groups. It should be noted that several opaque orange, red, and black beads plot somewhat away from this group and are notable for having higher concentrations of magnesia (>1.5 wt %), phosphorous, lime, iron, and lead, which is apparently related to their coloration and manufacturing environment (Dussubieux et al. 2011). Previous studies of glass beads from Oc Eo, including those found by Malleret (1962), also found them to be made from high alumina mineral soda glass (Brill 1999*b*; Francis 2002; Kim et al. 2016).

A group of four translucent purple glass beads (AKC02584, AKC02585, AKC02590, AKC02591) originally classified as garnet were found to be glass upon analysis (Fig. 3). They fall into the m-Na-Al 1 category although three of the beads (AKC02584, AKC02585, and AKC02590) have lower alumina levels (ca. 5 wt%) and all have lower Sr (at 170–246 ppm). The beads do not appear to have been colored with manganese, a common colorant used to make purple glass, as the concentrations of this element are low. Visually similar dark red to purple glass beads have been found at the south Indian port site of Arikamedu, India, although these beads had higher

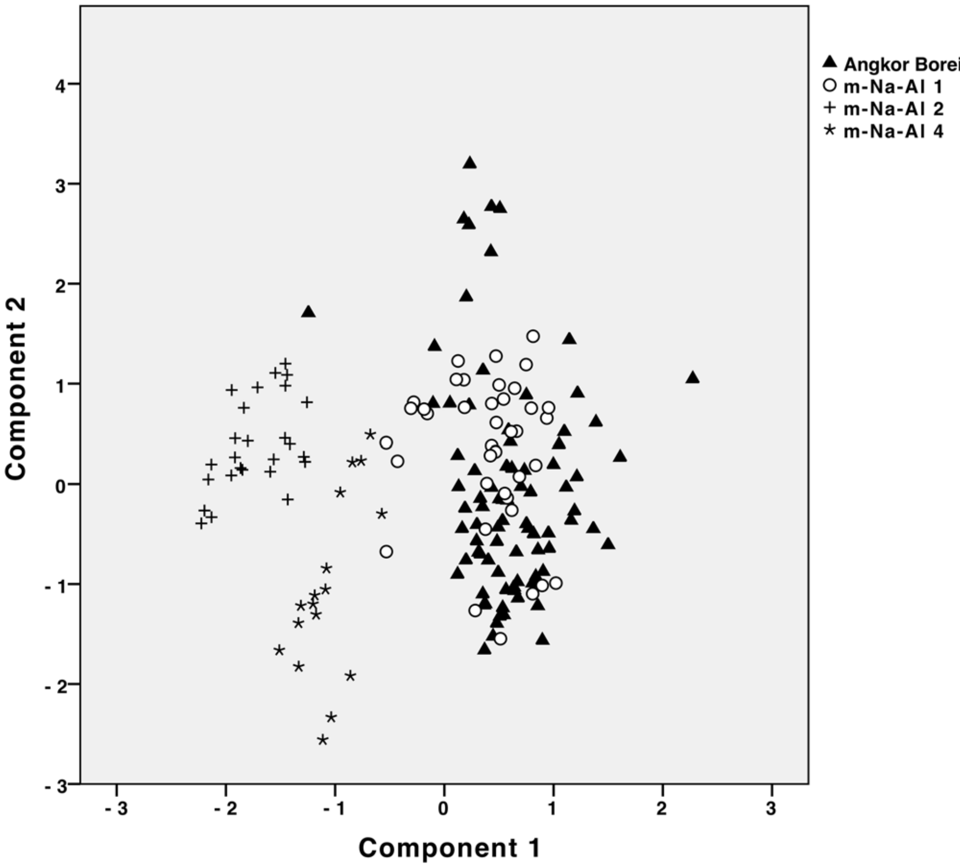

Fig. 6. Biplot of components 1 and 2 comparing beads from Angkor Borei to dataset of m-Na-Al Type 1, Type 2, and Type 4 glasses.

manganese than the samples from Angkor Borei (Schmetzer et al. 2017). It is not clear if these Arikamedu beads belong to the m-Na-Al 1 category; this would be noteworthy as few glass beads of this type have been reported from this site (Dussubieux and Gratuze 2013). Further work is needed on these beads to clearly determine their origin.

Mineral soda glass with moderate amounts of alumina and lime (m-Na-Ca-Al) — The m-Na-Ca-Al type is found at many sites dating from ca. 300 B.C.E.–C.E. 400. (Dussubieux et al. 2012). It has been found at sites in northern and central Vietnam, peninsular Thailand, Myanmar (Dussubieux and Bellina 2018; Dussubieux et al. 2012; Lankton and Dussubieux 2013), and inland sites in Cambodia and Thailand (Carter 2016*b*; Lankton and Dussubieux 2013). A possible production center for this glass type could be Khlong Thom, where it has been found in high quantities (Lankton and Dussubieux 2013); this type of glass may also have been worked at the site of Phu Khao Thong (Dussubieux et al. 2012).

This glass type is compositionally similar to the m-Na-Al glass type discussed above, but can be distinguished through a principal component analysis (PCA) using the elements Na, Al, Zr, Rb, La, Hf, and Th (Dussubieux and Gratuze 2010). These elements were not all measured in Dussubieux's initial analysis, so we are unable to use this particular method to confidently separate these groups in the current study. However, it was found that these glass beads can still be distinguished from the other mineral soda glass beads using a PCA of Al, Ce, and Rb. Fig. 7 displays a biplot of components 1 and 2 of a PCA of these elements. The two components account for 81 percent of the total variance. Dussubieux classified seven opaque green and opaque yellow as m-Na-Ca glass in the original analysis, but these were subsequently revised to be called the m-Na-Ca-Al type (Table 1). Carter identified an additional three dark blue beads that belonged to this group (Table 1). These beads are notable for having a mineral soda composition but are colored with cobalt, a colorant that is not found in the m-Na-Al 1 glass type (Dussubieux et al. 2010). Based on the PCA, it is possible to add AB004J and AB0108V to this group, as well as AB009BC due to its coloration with cobalt, for a total 13 beads in this compositional group.

Based on context, association, color, and visual similarity of beads, we estimate that between 2 and 18 percent of the glass bead assemblage at Angkor Borei was made up of m-Na-Ca-Al glass (Carter 2020: Glass Compositions). This wide variation is due to the visual similarity between beads made up of this glass type and the m-Na-Al 1 and v-Na-Ca glass. We observed that the identified opaque green and yellow m-Na-Ca-Al glass beads were smaller (ca. 3 mm or less), while m-Na-Al 1 beads were generally larger (ca. 3–5 mm). The translucent dark blue m-Na-Ca-Al beads were approximately 5–6 mm, similar to the v-Na-Ca glass beads. Further compositional work is needed to more accurately determine the proportion of this glass type found at Angkor Borei.

Questions persist regarding how these beads were being traded to the site. Did the green, yellow, and blue beads arrive together or were they the products of different workshops or trade routes? If these beads are only a small proportion (2%) of the site bead assemblage, then they may have been traveling in a down-the-line exchange network, but larger proportions of this glass type could indicate more direct exchange. For now, these questions remain unanswered.

TABLE 1. LIST OF M-NA-CA-AL BEADS AND POTENTIAL M-NA-CA-AL BEADS

DATABASE ID	BEAD COLOR	NOTES	SOURCE
AB004J	Opaque yellow	Possible m-Na-Ca-Al	Dussubieux 2001
AB009BC	Translucent dark blue	High concentrations of cobalt	Dussubieux 2001
AB085V	Opaque green	Formerly m-Na-Ca	Dussubieux 2001
AB086J	Opaque yellow	Formerly m-Na-Ca	Dussubieux 2001
AB097V	Opaque green	Formerly m-Na-Ca	Dussubieux 2001
AB098J	Opaque yellow	Formerly m-Na-Ca	Dussubieux 2001
AB099J	Opaque yellow	Formerly m-Na-Ca	Dussubieux 2001
AB0108V	Opaque green	Possible m-Na-Ca-Al	Dussubieux 2001
AB115V	Opaque green	Formerly m-Na-Ca	Dussubieux 2001
AB116V	Opaque green	Formerly m-Na-Ca	Dussubieux 2001
AKC02586	Translucent dark blue	High concentrations of cobalt	Carter 2013
AKC02587	Translucent dark blue	High concentrations of cobalt	Carter 2013
AKC02588	Translucent dark blue	High concentrations of cobalt	Carter 2013

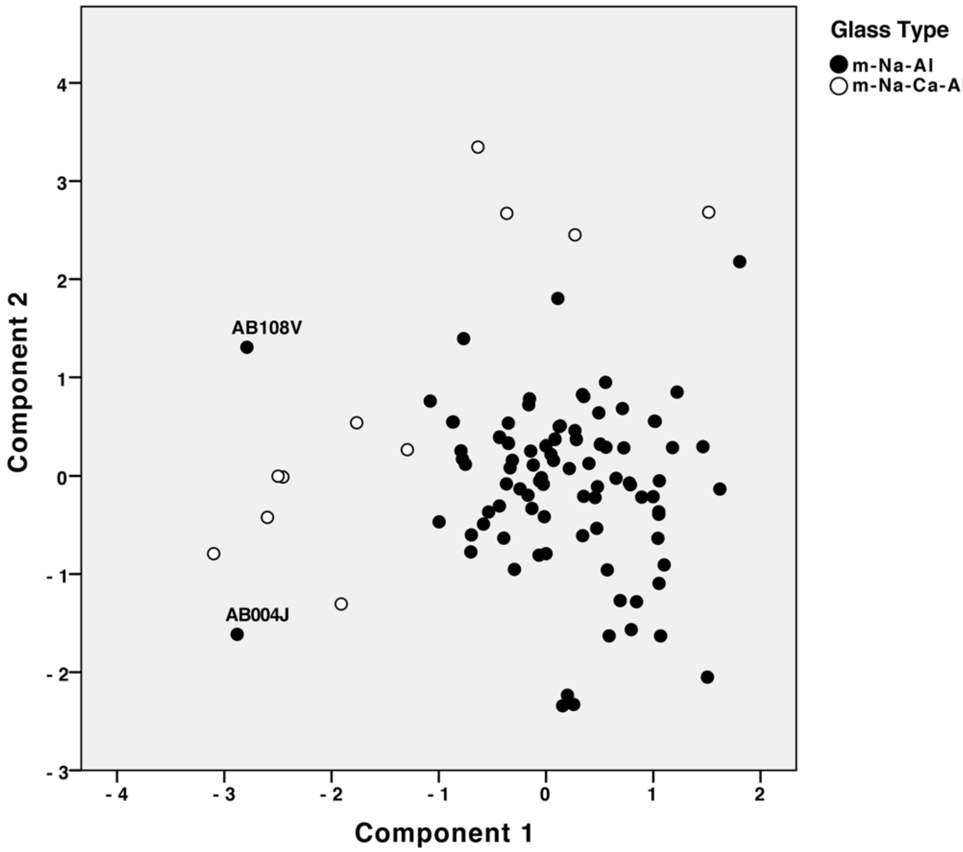

Fig. 7. Biplot of components 1 and 2 to distinguish m-Na-Ca-Al beads from m-Na-Al beads.

Patterning in the Glass Beads

Earlier studies have identified m-Na-Al 1 glass as the dominant type in the glass beads exchanged in Southeast Asia during the first millennium C.E. (Lankton and Dussubieux 2006). This glass type is strongly associated with South Asian production, with at least one manufacturing location identified in Giribawa, Sri Lanka (Dussubieux 2001). Similar drawn glass beads have been found in large quantities at other sites in southern India, so that region may also represent other possible production locations, although additional work is needed to clarify the glass recipes and chronology (Abraham 2016). Angkor Borei and Oc Eo have disproportionately large quantities of the m-Na-Al 1 beads relative to other sites in mainland Southeast Asia from this time period (Dussubieux 2001). This difference can clearly be seen in Fig. 8, which displays an estimate of the proportions of major glass types found at several protohistoric sites in mainland Southeast Asia.

Notably, both Angkor Borei and Oc Eo also lack potash glass beads, a glass bead type that is found widely in Southeast Asia during the protohistoric period (Dussubieux 2001; Lankton and Dussubieux 2013). Lankton and Dussubieux (2006) have noted

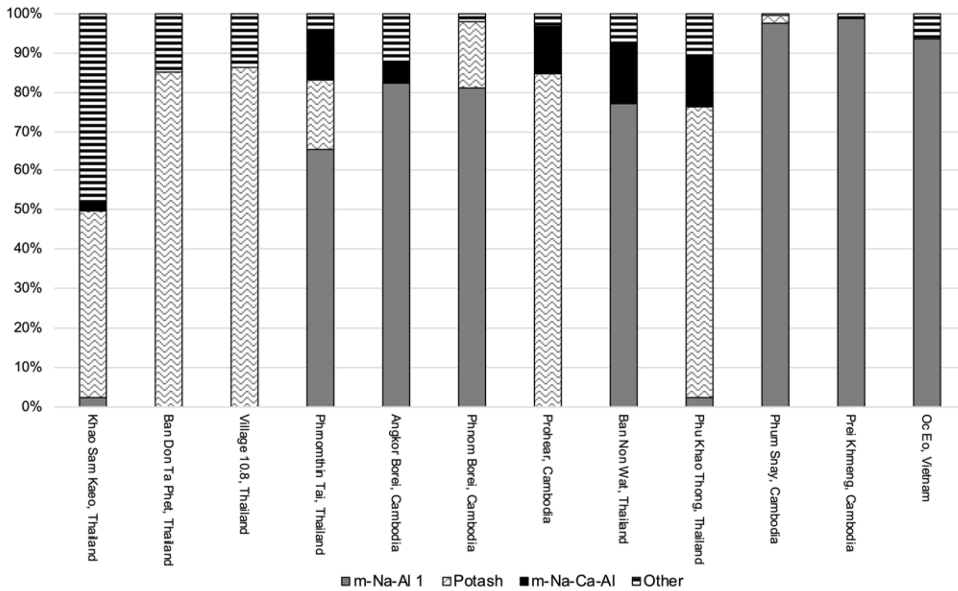

Fig. 8. Glass types from some sites in Southeast Asia, using bead data from following contexts: Khao Sam Kaeo (ca. 400–100 B.C.E.);Ban Don Ta Phet (ca. 400–200 B.C.E.);Village 10.8 (ca. 400 B.C.E.–C.E. 100);Phromthin Tai (ca. 400 B.C.E.–C.E. 500); Angkor Borei (200 B.C.E.–C.E. 200); Phnom Borei (200 B.C.E.–C.E. 0); Prohear (200 B.C.E.–C.E. 200); Ban Non Wat Iron Age Period 2 (ca. 200 B.C.E.–C.E. 200); Phu Khao Thong (200 B.C.E.–C.E. 200); Phum Snay (350 B.C.E.–C.E. 200); Prei Khmeng (C.E. 0–600); Oc Eo (C.E. 0–600) (data from Carter 2013, 2015; Lankton and Dussubieux 2013).

that the lack of potash glass in the Angkor Borei cemetery could date the transition from potash to high alumina soda glass across Southeast Asia. However, roughly contemporaneous sites, including sites in southern Cambodia such as Phnom Borei (200 B.C.E.–C.E. 0) and Prohear (second century B.C.E.–C.E. second century) contained potash glass, therefore it appears that it was still in circulation during this period, but that sites in the Mekong Delta were not major participants in this exchange network.

Elsewhere, Carter (2015) and Lankton and Dussubieux (2013) have argued that the two glass types reflect different bead exchange networks, which slightly overlapped in time. Potash glass circulated on a seemingly older South China Sea network, which linked coastal localities to one another (Bellina 2018*a*; Hung et al. 2013). The current evidence from Southeast Asia indicates that when m-Na-Al 1 beads were introduced from South Asia, they were not being traded on the same networks for reasons that are unclear. Perhaps high alumina mineral soda glass was being traded from a different region or community in South Asia that did not have a preexisting relationship with sites in the South China Sea Network. Indeed, previous work has suggested there are likely multiple bead exchange networks across Southeast Asia from the late centuries B.C.E. to middle of the first millennium C.E. (e.g., Bellina 2014; Carter 2012, 2015, 2016*b*; Dussubieux and Bellina 2018; Dussubieux and Pryce 2016; Lankton et al. 2008).

Earlier studies from Cambodia and Thailand demonstrate large numbers of high alumina soda glass at sites in the Mekong Delta, as well as sites farther inland such as

Phum Snay and Prei Khmeng in northwest Cambodia and Ban Non Wat and Phromthin Tai in Thailand (Carter 2015). We argue that the m-Na-Al 1 glass beads are material indicators of the Phase 2 intensified interaction between South and Southeast Asia (Bellina and Glover 2004) and that they were traded between the Mekong Delta and sites farther inland as part of a Mekong Interaction Sphere exchange network (discussed further below).

STONE BEADS IN THE MEKONG DELTA

Earlier studies have shown that stone bead types changed over time, much like the glass bead types (Bellina 2003, 2014; Carter 2015). For this reason, it is important to consider the stone bead data in addition to glass bead data, as this information can elucidate trade networks. Stone beads from Angkor Borei have been more comprehensively studied than those from Oc Eo. As discussed above, Malleret (1962) identified stone beads made from multiple materials at Oc Eo, but few of these beads have been found outside Oc Eo. Most of the beads found at Angkor Borei were carnelian, with only one agate and one quartz bead uncovered in excavation contexts (Fig. 9). This pattern is consistent at other inland sites in Cambodia and Thailand that are dominated by carnelian and, to a lesser extent, agate beads. A small number of garnet beads have been found at Angkor Borei and sites in southwest Cambodia such as Prohear, Bit Meas, and Village 10.8, however earlier studies suggest that the garnet beads in southwest Cambodia were locally produced and distinct from those found in the Mekong Delta (Carter 2012, 2016*a*). It is not clear why these other stone bead types were not widely exchanged outside Oc Eo. They are certainly found in fewer quantities than carnelian and agate beads; perhaps their rarity imparted a higher value and elites at Oc Eo kept them for themselves. Unfortunately, the heavy looting at Oc Eo limits the interpretations that can be made and further excavations of beads in undisturbed contexts are needed. Despite this, analyses of the agate, carnelian, and quartz beads and garnet beads from Angkor Borei's excavations can at least begin to

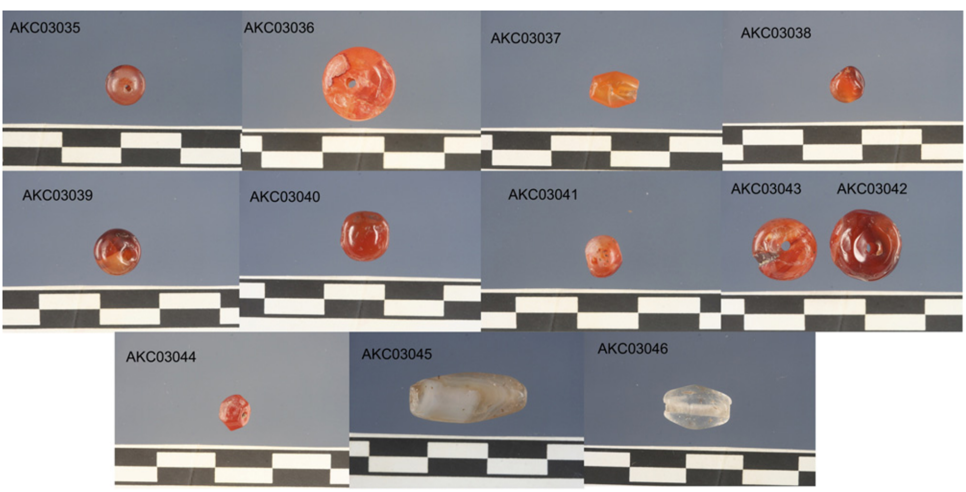

Fig. 9. Stone beads from Angkor Borei: 10 carnelian (AKC03035–AKC03044); 1 agate (AKC03045); 1 quartz (AKC03046) (scale: 1 cm units).

address questions regarding the nature of inter- and intra-regional exchange of these objects. In this section we summarize previous studies and present new data highlighting the connections to South Asian bead industries as well as arguing that these stone beads were also part of an intra-regional Mekong Interaction Sphere.

Agate, Carnelian, and Quartz Beads

A total of 11 agate, carnelian, and quartz beads were identified in the Angkor Borei excavations (Fig. 9). Of these, only two carnelian beads were directly associated with a skeleton (Appendix A). The remaining agate and carnelian beads (n = 9) as well as one quartz bead were found within the cemetery matrix, but not associated with a specific burial.

Morphology of the Agate, Carnelian, and Quartz Beads — The morphology of stone beads in Southeast Asia has been shown to be important for understanding manufacturing and socioeconomic trade and interaction patterns (Bellina 2003; Carter 2015). Drawing on work by Bellina (2003), Carter (2015) previously identified two different agate or carnelian bead types in circulation in Cambodia and parts of Thailand that varied according to shape, craftwork, and temporal distribution. Type 1 stone beads are generally made with higher-quality manufacturing techniques, including using higher quality stones with few imperfections, putting a high polish on the beads, and carving them into complex, time-consuming shapes (e.g., facets). Additionally, these beads had small perforation sizes. Type 1 stone beads are generally found at sites dating to the late centuries B.C.E. and early centuries C.E. Type 2 stone beads refer to those produced in simpler shapes (e.g., spherical or barrel shapes) and using lower quality manufacturing techniques, including low-luster polish, nicks or chips on the surface, and using stones with imperfections. These beads also generally had larger perforation sizes. The Type 2 stone beads are more frequently found at sites dating to the early first millennium C.E. and appear to represent mass production of particular stone bead types (Carter 2015).

Overall, most of the beads from the Angkor Borei bead assemblage were classified as belonging to the Type 2 stone bead group (Carter 2020: Stone Contexts). Several other sites dating to the early-mid first millennium C.E. were also dominated by Type 2 stone beads, including Phum Snay in Cambodia and Ban Non Wat and Phromthin Tai in Thailand (Carter 2015). These sites also had high quantities of high alumina mineral soda glass beads.

Chemical Composition of Angkor Borei Agate, Carnelian, Quartz Beads — Early scholars assumed that agate, carnelian, quartz, and other hard stone beads found in Southeast Asia had been imported there from South Asia (Francis 1996; Glover 1989). However, the presence of unfinished and unusual styles of beads led some scholars to later argue that some of these objects might have been manufactured in Southeast Asia using locally available raw materials (Theunissen et al. 2000). Excavations at the coastal Thai peninsular sites of Khao Sam Kaeo (Bellina 2017*b*) and Khao Sek (Bellina 2018*b*) have uncovered clear evidence of bead manufacturing, likely by South Asian craftspeople. However, evidence for stone bead manufacturing at other sites in Southeast Asia, including Oc Eo, is more problematic (see discussion in Carter 2016*b*).

Geochemical analysis of stone beads is an effective way to determine if South Asian or Southeast Asian raw materials were being used (Carter and Dussubieux 2016;

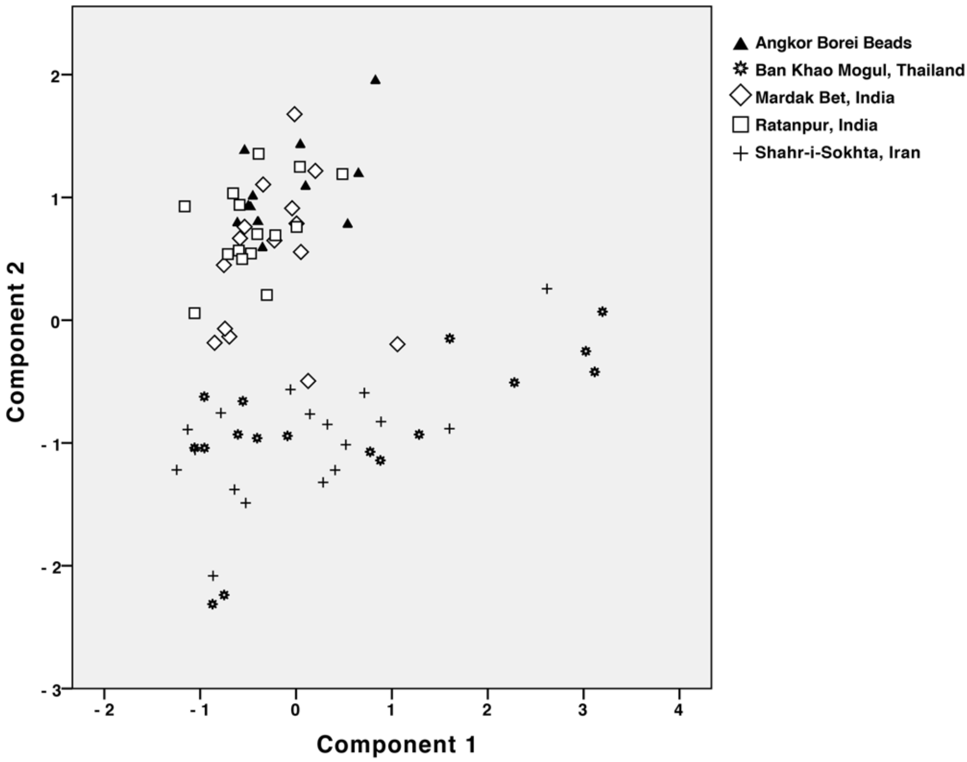

Fig. 10. Biplot of components 1 and 2 comparing agate, carnelian, and quartz beads from Angkor Borei to four geologic sources from Central, South, and Southeast Asia.

Theunissen et al. 2000). In an earlier study, Carter and Dussubieux (2016) undertook a geochemical study of the agate, carnelian, and quartz beads from Angkor Borei using LA-ICP-MS and compared the compositions to four geologic raw material sources from Central, South, and Southeast Asia. The results of this preliminary analysis demonstrated that the raw materials used to produce the Angkor Borei beads were most compositionally consistent with the raw material sources from the Deccan Traps in India (see full discussion and compositional data in Carter and Dussubieux 2016). Figure 10 displays a biplot of components 1 and 2 (55% of total variance) from a PCA of agate, carnelian, and quartz beads from Angkor Borei and four geologic sources from Central, South, and Southeast Asia using the elements: Si, Na, Mg, Al, K, Ca, Fe, Pb, B, Sc, Ti, Ni, Rb, Sr, Zr, Sb, Ba, La, Ce, Y, and U. Although this study does not include all potential sources, it does suggest that beads found at Angkor Borei were made from raw materials originally from western India.

Examination of Agate/Carnelian Bead Perforations — The connections to the western Indian bead industry are reinforced when bead perforations are considered. The use of a diamond-tipped drill to manufacture beads has been practiced in India since at least 600 B.C.E., with the west Indian bead industry being strongly associated with a double-diamond tipped drilling technique (Kenoyer et al. 1991). Bead makers in other regions of India did not always use a diamond-tipped drill. For example, stone bead makers at

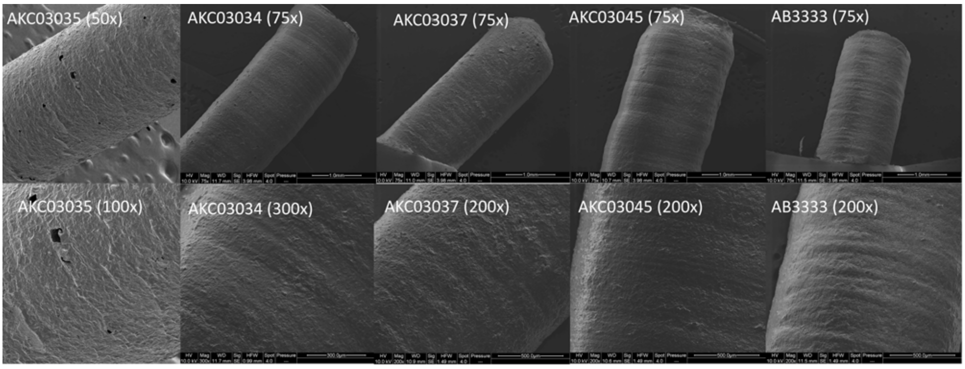

Fig. 11. SEM images of perforation impressions from stone beads from Angkor Borei: carnelian (AKC03035, AKC03034, AKC03037); agate (AKC03045); garnet (AB3333).

sites in southern India would sometimes use a single-diamond tipped drill or rod and abrasion method to perforate beads (Kelly 2016).

Perforations in the Angkor Borei beads were examined to determine the drilling method used and, by extension, better understand the possible manufacturing location. Impressions of the bead perforations from four beads were taken using dental impression material and examined under an SEM. Figure 11 displays SEM images of the perforations; all four beads have the regular, parallel, drilling striae typical of a diamond-tipped drill, likely a double-diamond drill (Gorelick and Gwinnett 1988; Kenoyer 2017).[1] Moreover, the bead perforations are straight and cylindrical in shape, typical of the use of a diamond-tipped drill (Kenoyer 2017; Kenoyer et al. 1991). The other agate, carnelian, and quartz beads also have this straight cylindrical drill hole, suggesting they too were drilled using a diamond-tipped drill.

Patterning in the Agate/Carnelian Beads — The manufacturing method and raw material make western India a likely source of these objects. However, we cannot rule out the possibility that the raw materials were transported to other locations and that south Indian craftspeople or even local craftworkers trained in Indian drilling techniques could have produced these beads. For example, stones from the Deccan Traps were used in South Indian bead workshops (Francis 2000) and South Indian bead workers also used double-diamond tipped drills (Francis 2000; Kelly 2016). Additionally, evidence from the site of Khao Sam Kaeo, Thailand suggests that beads could be manufactured in Southeast Asia using imported raw materials and South Asian techniques (Bellina 2014), although evidence that this was happening in the Mekong Delta is not clear. While we are not able to determine if beads at Angkor Borei were imported as finished objects or produced in Southeast Asia following Indian bead production methods, the raw materials and manufacturing methods reviewed above show connections to South Asia. Lastly, as noted above, the similarities in the types of beads found at Angkor Borei and those at inland sites show connections between this site and communities further inland.

Garnet Beads

Garnet beads are relatively rare in Southeast Asia, although they were found in a variety of shapes at Oc Eo (Malleret 1962:221–222). Additional sites where garnet beads have

Fig. 12. Garnet beads from Angkor Borei (image reproduced with permission from Carter 2016*a*:241, fig. 16.2).

been reported include the coastal site of Giong Ca Vo, Vietnam (Nguyen 2001), the southern Vietnamese site of Go O Chua, Lai Nghi in central Vietnam, and sites such as Khao Sam Kaeo and Phu Khao Thong in peninsular Thailand (Borell 2017; Carter 2013:364–366). Five spherical garnet beads were recorded from the Angkor Borei bead collection. Three of these were associated with specific burials and the remaining two in the cemetery matrix (Appendix A; Carter 2020: Stone Contexts). The garnet beads from Angkor Borei are a deep reddish-purple, round or spherical in shape, and approximately 3 to 4 mm in diameter, with one bead slightly larger at about 5 to 6 mm in diameter (Fig. 12). This is similar to the two size categories of garnet beads identified at the site of Arikamedu, India (Schmetzer et al. 2017).

Examination of Garnet Bead Perforations — As with the agate and carnelian beads, similar questions persist regarding the manufacturing location and method of the garnet beads. An earlier study examined impressions of bead perforations from two (AKC03031 and AKC03033) of the five garnet beads from Angkor Borei using a SEM (Carter 2012). An additional impression of garnet bead AB3333 was examined as part of the current study (Fig. 11). The two previous impressions and the newly examined impression demonstrate the regular, spiraling striae or grooves representative of the double-diamond drilling technique (Gorelick and Gwinnett 1988; Kenoyer 2017). This suggests that, like the agate/carnelian beads, the garnet beads were manufactured in India or by craftspeople trained in Indian bead manufacturing methods. It should be noted that this drilling method is different from that reported at Arikamedu. In their study of garnet beads from Arikamedu, Schmetzer and colleagues (2017) noted that the B3 and B4 spherical beads were drilled from one end with a tapered or conical drill hole. However, the five spherical beads from Angkor Borei have straight cylindrical

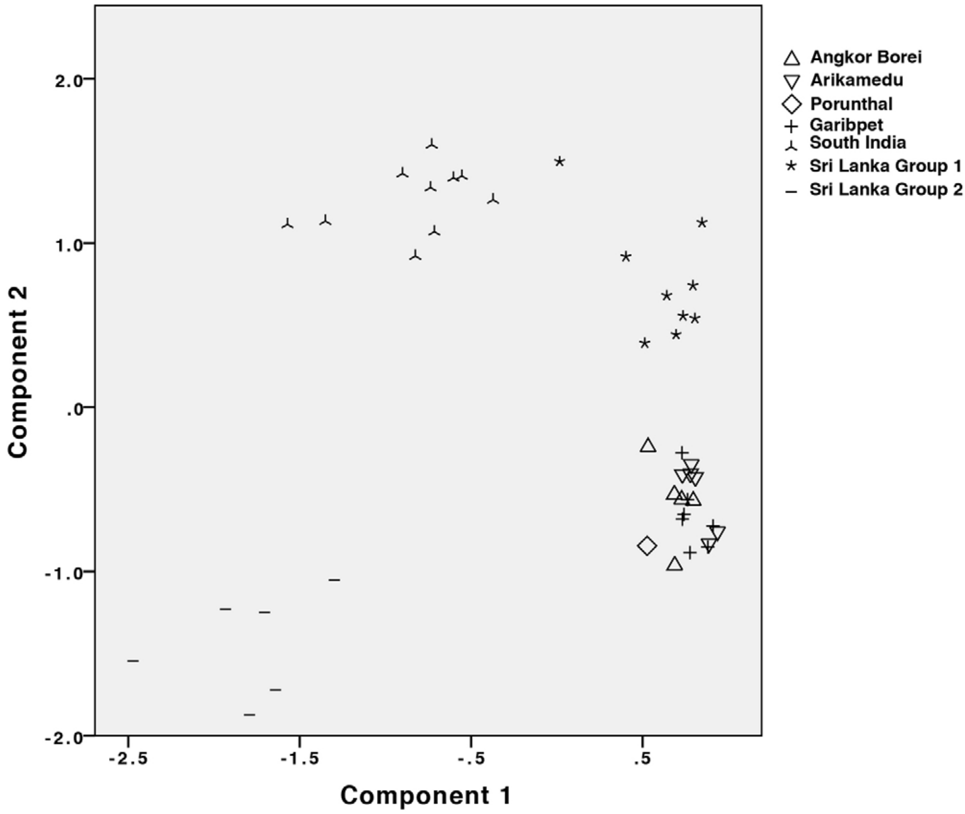

Fig. 13. Biplot of components 1 and 2 comparing garnets from Angkor Borei with a variety of South and Southeast Asian sources.

bead perforations and some were drilled from both sides. This does not exclude the possibility that garnet beads were produced in southern India, however. Kelly (2016) notes that South Indian bead workshops often used multiple different drilling techniques, including sometimes using two different techniques on a single bead.

Chemical Composition of the Angkor Borei Garnet Beads — As with the carnelian and other stone beads, the garnet beads from Angkor Borei underwent LA-ICP-MS analysis to determine their chemical compositions and identify potential raw material sources. An earlier study was limited by the number of geological sources available for comparison and unclear provenience information for some of the sources, however, the almandine-rich garnets from Angkor Borei were found to be compositionally similar to a garnet bead from the site of Porunthal, India (see discussion and compositional data in Carter 2016*a*). The exact archaeological context of the Porunthal garnet bead is unknown, but a cultural deposit containing thousands of glass beads and other materials has been tentatively dated from ca. 100 B.C.E. to C.E. 300 (Rajan 2009).

A recent study of garnet beads from the site of Arikamedu showed that they were compositionally analogous to garnets from the Garibpet source in Telangana State in northeastern South India (Schmetzer et al. 2017). To determine whether the beads from Angkor Borei were also compositionally similar to this potential source, they were compared to the compositional data from the Arikamedu and Garibpet garnets (Schmetzer et al. 2017) and a dataset of additional pyrope-poor almandine garnets from other potential geologic raw material sources in South and Southeast Asia (see full discussion of sources in Carter 2016*a*). A PCA was undertaken using the elements Li, P, Ca, Sc, Ti, V, Cr, Mn, Co, Ni, Zn, Y, and Zr. Figure 13 presents a biplot of the first two components, accounting for 62 percent of the total variation. In this figure, it is clear that the Angkor Borei garnets are geochemically similar to the beads from Arikamedu and the Garibpet raw material source. The Porunthal bead also plots with this group.

Patterning in Garnet Beads — The compositional and bead perforation data strongly indicate that the garnet beads were imported from India, with connections specifically to southern India. It is possible the beads were produced at Arikamedu, which had both a stone and glass bead production industry and was a well-known port site (Francis 1991). However, we cannot rule out other workshop sites. For example, there is evidence for garnet bead manufacture in the region at sites such as Kodumanal (Kelly 2009) and the Early Historic period sites of Tissamaharama and Anuradhapura in Sri Lanka (Coningham et al. 2006; Hannibal-Deraniyagala 2001, 2005). It is also possible raw material was brought to Southeast Asia and crafted into beads locally.

DISCUSSION AND CONCLUSION: THE MEKONG INTERACTION SPHERE

The glass and stone bead collection from Angkor Borei provides a snapshot of the broader inter- and intra-regional trade connections at the site (Table 2). We now return to the questions proposed in our introduction.

Does Data from Stone and Glass Beads Point Towards Interaction with Specific Regions of South Asia?

Based on morphological and compositional analyses of stone and glass beads, we argue that we can see interaction in the Mekong Delta with specific parts of South Asia. Agate and carnelian beads show affinities with the west Indian bead industry in their geochemical composition and drilling method, although they could also have been

TABLE 2. SUMMARY OF DIFFERENT TYPES OF GLASS AND STONE BEADS FROM ANGKOR BOREI AND THEIR PROVENIENCE

BEAD	TYPE	PROVENIENCE
Glass	m-Na-Al 1	Known glass bead production site in Giribawa, Sri Lanka; connections with Sri Lankan or South Indian production
Glass	m-Na-Ca-Al	Unknown manufacturing location, possibly manufactured in peninsular Thailand
Glass	v-Na-Ca	Composition related to Western (near East or Mediterranean) glass production
Glass	Lead	Composition related to Chinese glass production
Stone	Agate/carnelian	Morphology and drilling method suggest South Asian bead production (western or southern India); raw material source consistent with Deccan Traps, western India
Stone	Garnet	Morphology and drilling method suggest South Asian bead production; raw material source consistent with Garibpet deposit, Telangana, South India

produced in southern India or even Southeast Asia. The garnet beads are compositionally tied to southern India, with a drilling method primarily associated with the west Indian bead industry. The m-Na-Al 1 glass beads are linked to at least one manufacturing center in Sri Lanka or South India. The nature of interaction between these areas of South Asia and the Mekong Delta is not clear, so further work is needed to understand who was involved in the bead trade and how it was organized. The similar timing in the changes between different glass and stone beads types suggest that the exchange of stone and glass beads are linked together. Analyses of additional types of archaeological materials may help clarify these issues. For example, pottery sherds that are visually similar to those from Angkor Borei were recently identified at the site of Tissamaharama, Sri Lanka, which dates to the fourth to fifth centuries C.E. (Schenk 2014).

What is the Importance and Impact of External Maritime Trade Versus Internal Overland Trade?

As exotic objects, the stone and glass bead data confirm the importance of maritime trade for communities in the Mekong Delta. The stone beads show strong connections to South Asian bead traditions and the diversity of glass types suggest contacts with Sri Lanka and/or South India (m-Na-Al 1), the Middle-East or Mediterranean area (v-Na-Ca), and China (lead), as well as possible maritime glass bead manufacturing centers in peninsular Southeast Asia (m-Na-Ca-Al). However, we note that it is not clear that beads were directly traded from these locations to Angkor Borei. For example, objects from the Middle East were likely traded via India (Bellina and Glover 2004; Borell et al. 2014).

When viewed regionally, however, the types of stone and glass beads from Angkor Borei show strong similarities to the bead assemblages of sites farther inland in Cambodia and Thailand than those from coastal sites such as Phu Khao Thong, Thailand (Chaisuwan 2011; Dussubieux et al. 2012). As noted earlier, the bead assemblages from Cambodia and Thailand reveal the presence of two different exchange networks that seem to have slightly overlapped in time (Carter 2015). During the late centuries B.C.E. through early centuries C.E., coastal sites and elites were linked to one another through the exchange of locally produced prestige objects like Dong Son Drums and nephrite ornaments (Bellina 2017*a*; Borell 2017; Calo 2014; Hung and Bellwood 2010; Hung et al. 2007; Hung et al. 2013). During this period, glass beads largely made from potash glass and high-quality Type 1 stone beads were also exchanged on this network. This network also appears to include some specific inland sites such as Prohear and Village 10.8 in southeast Cambodia, which have bead assemblages that are more strongly associated with the South China Sea exchange network (including a unique type of garnet bead) despite overlapping in time with Angkor Borei (Carter 2012, 2015).

By the early centuries C.E., exchange with South Asia was intensifying with the appearance of lower quality Type 2 stone beads and high quantities of beads made from high alumina mineral soda glass (Bellina and Glover 2004). These bead types are not found in large quantities at sites participating in the South China Sea network, but they dominate the bead assemblages at sites like Angkor Borei and those farther inland such as Phum Snay and Prei Khmeng in northwest Cambodia and Ban Non Wat and Phromthin Tai in Northeast and central Thailand respectively (Carter 2015). The bead assemblages at Angkor Borei and these inland sites differ from those that were participating in the South China Sea exchange network: there are little to no potash glass beads, Dong Son bronzes, or nephrite ornaments.

What does this mean about the nature of trade in the first millennium C.E. Mekong Delta? Following the previously discussed models for trade and state development in Southeast Asia, we argue that control over the exchange of exotic prestige goods, such as stone and glass beads, was a key factor in the growth of the Mekong Delta as an early complex polity. As exchange with South Asia intensified (Bellina and Glover 2004), larger numbers of high alumina mineral soda glass beads were imported, as well as lower-quality, simpler shaped, and likely mass-produced agate and carnelian beads. We hypothesize that the greater availability of these objects could have facilitated the growing power of emerging elites in the Mekong Delta who might have used these beads to build alliances with inland communities, especially, through riverine transportation routes (Bronson 1977). In this model, Angkor Borei in particular was more strongly connected to these inland communities (than to South Asia) as part of what we call the Mekong Interaction Sphere (MIS). To be sure, the exchange of beads would have been just one strategy elites could have used to solidify their growing power, but the widespread trade of beads across Cambodia and Thailand is an indicator of their importance to communities during this period.

There are other preliminary lines of evidence showing movement of goods and shared cultural transmission reflected in technological traditions within the MIS. Studies of ceramics from Angkor Borei and contemporary protohistoric sites have identified a "Reduced Ceramic Horizon" linking the Mekong Delta, northern Cambodia, and northeast Thailand by a particular type of ceramic production technique that was similar in color, surface treatment, and decoration (Stark and Fehrenbach 2019). Evidence from mid-first millennium C.E. pre-Angkorian inscriptions also shows the expansion of elite power and relationships between sites in the Mekong Delta and elites at sites farther inland (Lustig 2009). We argue that the stone and glass bead data are material indicators that these inland connections began by at least the late first millennium B.C.E.

This does not preclude the participation in and importance of more outward facing exchange networks in the emerging complexity of Funan and sites in the Mekong Delta (Manguin 2019*a*). Indeed, there are notable similarities in artifacts demonstrating connections between Oc Eo and sites elsewhere in Southeast Asia, including the Thai-Malay peninsula (Manguin 2009*a*), Sumatra (Lucas et al. 1998), Pyu sites in Myanmar (Bennett 2009), and possibly Dvaravati sites in Thailand (cf. Barram and Glover 2008; Glover 2010). However, we argue that the bead data from Angkor Borei show promising patterns and that relationships between communities within the MIS should also be considered as part of the emerging sociopolitical complexity of this region.

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Appendix A. Burials with Beads at Angkor Borei

Burial number	Sex (age in years)[a]	Glass beads total no.: no. per color	Stone beads no. type (database id)	Other ornaments	Other grave goods
F1	M (YA); M (7–10)	5: 3 yellow, 1 orange, 1 red	N/A	N/A	Ceramics
F2	F? (20–25); M (A); C (5.5–6.5)	1 yellow	N/A	N/A	N/A
F3	F? (MA)	2:1 orange, 1 green	N/A	N/A	Animal rib bone
F4	F (40–50); F? (16–20); F? (Unkn); M (YA); 4 M? (Unkn)	8: 6 green, 1 orange; 1 white/cream	N/A	N/A	Ceramics; pig remains
F5	F (19–21); M (A); Unkn (12–16)	45: 43 white/cream, 1 orange, 1 red	N/A	N/A	Animal (pig?) bones
F8	M (19–25); F? (MA); C (1–1.5)	29: 13 orange, 7 red, 6 green, 1 blue, 2 black	N/A	N/A	N/A
F10	M (35–40); M? (A); F? (A); C (7–12)	9: 4 yellow, 3 orange, 2 green	N/A	N/A	N/A
F16	F (25–30); M? (YA); Unkn (12–20)	8: 7 dark blue, 1 yellow	1 garnet (AKC03030)	N/A	N/A
F17	2 F? (A); M (30–35); 2 M? (A)	1 opaque dark blue	N/A	N/A	N/A
F20	F? (18–25); F? (10–12); C (9–10)	5 yellow	N/A	N/A	Animal bones; ceramics
F21	F (17–18); M (30–35); M? (30–50); Unkn (A)	N/A	1 garnet (AKC03032)	N/A	N/A
F22	F? (YA); C (6–8)	6: 5 orange, 1 red	N/A	N/A	N/A
F25	M? (A); M? (9.5–11)	1 orange	N/A	N/A	N/A
F26	Unkn	1 light green	N/A	N/A	N/A
F27	M (YA)	32: 25 light green, 4 yellow, 1 black, 2 orange	N/A	N/A	N/A
F30	Part of Burial F35	1 yellow	N/A	N/A	N/A
F31	F? (3–5); M? (25–35)	12: 10 yellow, 1 green, 1 black	N/A	1 tooth pendant	
F35[b]	F? (17–20); C (3–5)	213: 132 green, 42 black, 19 orange, 15 red, 5 yellow	N/A	4 gold beads	

(*Continued*)

Appendix A. (*Continued*)

BURIAL NUMBER	SEX (AGE IN YEARS)[a]	GLASS BEADS TOTAL NO.: NO. PER COLOR	STONE BEADS NO. TYPE (DATABASE ID)	OTHER ORNAMENTS	OTHER GRAVE GOODS
F36	(M 34–35); M? (MA)	218: 133 orange, 47 green, 27 black, 6 red, 4 purple, 1 white/cream	N/A	3 tooth pendants	Ceramic anvil; animal bones
F37	M? (YA); M? (18–19)	8: 3 yellow, 1 green-yellow, 3 red, 1 black	N/A	N/A	N/A
F39	F (YA); M (YA or MA); M? (YA)[c]	12: 3 orange, 6 green, 1 blue-green, 1 light blue, 1 yellow	N/A	2 gold beads	
F42	M? (A)	1 red	N/A	N/A	Ceramics; pig mandibles
F43	M (45–55+); M (35–45); M? (A?); C (7.5–9.5); I	2: 1 orange; 1 green	N/A	N/A	
F44	F (35–45); F? (YA)	82: 46 orange, 35 black, 1 dark green	1 carnelian (AKC03036)	10 gold beads	Animal bones
F48	F (30–35); M? (A)	60: 43 orange, 16 black, 1 white	1 garnet AKC03031	N/A	
F51	F? (1.5–2)	N/A	1 carnelian (AKC03035), 7 opaque white (not glass?)	N/A	Animal bones
F52	F? (MA); F? (6–8)	1 green	N/A	N/A	Animal bones

[a] F = female, M = male, F? or M? = sex indeterminate; A = adult, YA = young adult, C = child, I = infant, MA = middle-aged; Unkn = unknown age or sex (skeletal data from Ikehara-Quebral 2010).
[b] Includes disturbed remains from F30.
[c] May be associated with F56.

NOTE

1. AKC03035 was analyzed at the University of Wisconsin Department of Animal Sciences Microscopy Laboratories; the remaining impressions were analyzed at the University of Oregon CAMCOR laboratory.

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