



The exchange of beads in Central Thailand in the protohistoric period: Glass objects from Phromthin Tai

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Part II

Glass Beads in South and Southeast Asia

The exchange of beads in Central Thailand in the protohistoric period: Glass objects from Phromthin Tai

Alison Carter,¹ Laure Dussubieux,² Thomas R. Fenn,³ Thanik Lertcharnrit⁴ and T.O. Pryce⁵

1. Introduction and background

Phromthin Tai, sometimes spelled Promptin Tai, is a multi-component site located in Central Thailand, about 20 km from the provincial capital of Lopburi (Figure 8.1). The Thai Fine Arts Department undertook a small excavation in 1991, which uncovered prehistoric and Early Historic period artifacts. Since 2004, Dr. Thanik Lertcharnrit from the Department of Archaeology at Silpakorn University has led frequent excavations at the site (Lertcharnrit 2006). These more recent studies show evidence for habitation from the late Bronze Age period (approx. 700 BCE) through the mid-late first millennium CE or Dvaravati period (Lertcharnrit 2014). The most intensive habitation at the site dates to the Iron Age or protohistoric period (approx. 500 BCE – 500 CE) and in 2007 a cemetery was uncovered (PTT-S3) containing 36 individuals in 35 burials (Liu 2012). Although comprehensive radiocarbon dating of the burials has not yet been undertaken, burials can be divided into Earlier and Later Iron Age periods (Liu 2018, see [Table S8.1](#) for details on the beads and their contexts). While beads were common throughout the cemetery matrix only 12 burials, which primarily dated to the Earlier Iron Age period, contained stone and glass beads as grave goods and of these just eight contained glass beads. Five subsequent field seasons between 2009 and 2019 have uncovered a further 34 burials from unit PTT-S4, although these burials have fewer beads than the S3 burials.

The protohistoric period was a time of great change in Southeast Asia. It is during this period that contact with South Asia began, as evidenced by South Asian products appearing in Southeast Asian archaeological sites, especially burials

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(Bellina and Glover 2004). Glass and stone beads are one common marker of this period across Southeast Asia (Bellina 2003). While early scholars assumed beads were largely imported as finished products, excavations in peninsular Thailand and Myanmar demonstrate the presence of stone and glass jewelry workshops using both local and South Asian beadmaking techniques to produce beads and ornaments for local markets (Bellina 2014, 2018; Dussubieux et al. 2020). Analysis of glass and stone beads has demonstrated that there was a great diversity of bead types in circulation, which represented different manufacturing, trading, and interaction networks both within Southeast Asia and between South Asia and Southeast Asia (Bellina 2014; Bellina and Glover 2004; Carter et al. 2021; Carter 2015, 2016; Dussubieux and Bellina 2018; Dussubieux et al. 2020; Lankton and Dussubieux 2013).

Several studies have noted differing intensities of interaction with South Asia, with an earlier period dating to the late first millennium BCE that was less intense but circulated higher-quality imported goods and a later period dating to the early-mid first millennium CE in which interaction was more frequent and contained higher quantities of mass-produced or lower-quality goods (Bellina and Glover 2004). These changing interaction networks extended to the exchange of beads, which saw differing types and qualities of beads moving on different networks within mainland Southeast Asia (Bellina 2003; Carter 2015). An earlier South China Sea exchange network connected sites primarily on the coasts or with coastal connections and especially circulated potash glass (Bellina 2014; Carter 2015; Hung et al. 2013). A later network circulated larger quantities of glass beads, largely made from high alumina mineral soda glass, connecting sites farther inland via the “Mekong Interaction Sphere” (Carter 2015; Carter et al. 2021).

Located in central Thailand near a highly productive copper mining and bronze-working region (Pigott 2019), the community at Phromthin Tai was well-suited to participating in interaction networks with communities in the north, east, and west (Lertcharnrit 2014). Previous studies of glass beads in mainland Southeast Asia have largely focused on Cambodia and northeast Thailand (Carter 2015; Carter and Lankton 2012), peninsular Thailand (Dussubieux and Bellina 2018; Lankton et al. 2008b), and most recently Myanmar (Dussubieux et al. 2020; Dussubieux and Pryce 2016). An analysis of beads from Phromthin Tai fills a geographic gap in our knowledge regarding the circulation of beads in this region. The goal of this study was to determine the types of glass beads and objects found at the site and begin connecting Phromthin Tai to existing glass exchange networks. In doing so, we aim to elucidate Phromthin Tai’s place within these regional systems.



Fig. 8.1: Map showing the location of the Phromthai site.

2. Materials

This chapter reviews the results of analyses of 63 glass artifacts, primarily beads, recovered from burial contexts ([Figure 8.S1-S3](#)). Carter recorded over 1000 glass and stone beads, of which approximately 960 were glass, from the 2007 excavation as part of her PhD dissertation research (Carter 2013). From this collection, 23 glass objects were analyzed using laser ablation - inductively coupled plasma - mass spectrometry (LA-ICP-MS) to represent the diversity of glass bead types found at the site. In addition to Carter's study, Dussubieux undertook analyses of an additional 25 glass objects provided by Dr. Lercharnrit. Of these, all but three objects were from Late Iron Age layers (1900-1500 before present [BP]) from the PTT-S3 unit. One sample (LAP020) is from an older Iron Age layer (2500-2000 BP) in PTT-S3 and two samples (LAP018 and LAP019) are from older Iron Age

layers (2500–2000 BP) in PTT-S4. A final group of 15 glass objects was selected and analyzed by Fenn, all from the PTT-S3 unit. Most of the glass beads in this study were drawn glass beads, sometimes called Indo-Pacific beads (Francis Jr. 1990), that are common across the ancient world and especially Southeast Asia. However, some additional unusual bead types as well as bangle and earring fragments were also examined. Analyses were undertaken in the Elemental Analysis Facility at the Field Museum in 2010, 2014, and 2018 (see discussion of analytical methods in [Annex A](#)).

3. Results

Results show four well defined glass groups including:

- 27 samples with a high potash composition
- 20 soda-rich samples with potash concentrations higher than 1.5% and high alumina concentrations
- 9 soda-rich samples with potash contents generally lower than 1.5% and rather high but variable alumina concentrations
- 3 more beads are soda-rich with potash concentrations lower than 1.5% and alumina level rather low
- 2 beads have a soda-potash mixed composition
- finally, three beads have a composition that might be explained by the sampling of weathered glass.

3.1. Potash glass

Potash glass is distinguished by its high levels of potash (approximately 15%) with low magnesia and soda concentrations (see [Annex B](#)). Several sub-types of potash glass were in circulation in Southeast Asia during the Iron Age period, with varying levels of alumina and lime (Carter 2016; Dussubieux 2016). These different sub-types suggest the presence of multiple workshops, although the exact locations are still unknown. Possibilities include Southeast Asia (Dussubieux and Pryce 2016; Dussubieux 2016; Lankton et al. 2008a) or China (Li 1999; Lin et al. 2019; Liu et al. 2015).

Twenty-seven beads in this study were assigned to the potash glass group with two sub-types represented (Figure 8.2; [Table S8.1](#)). Based on visual similarities with other beads examined and the contexts in which beads were found, Carter projected that there were an additional 61 potash glass beads within the 2007 burial contexts, with more possible examples from the cemetery matrix. Based on these estimates, approximately 29% of the glass objects found in burial contexts during the 2007 season could be made from potash glass. However, when considering

the overall assemblage from the PTT-S3 unit, including beads from the cemetery matrix and non-burial contexts, potash glass is estimated to make up only 17.5% of the total collection (Carter 2013).

All but one of the objects had alumina levels between 2-6% and lime levels of less than 1.5%, placing it in the low Ca-high Al potash glass sub-type. Two of these were translucent green fragments (LAP018 and LAP019) of a bangle or bracelet with a rectangular cross-section, similar to the Type E bangle type identified at Khao Sam Kaeo (Dussubieux and Bellina 2017: 557), and the remaining objects were drawn beads. Most beads (n=20) were various shades of blue; dark blue beads were colored with cobalt (approx. 300-500 ppm) while lighter blue or turquoise beads were colored with copper (approx. 1.25-3%). Two beads (LAP015 and LAP021) were opaque yellow and had elevated levels of lead (25-34%) and tin (3-5%) suggesting the use of lead-stannate as a yellow opacifier (Turner and Rooksby 1959). The violet bead (AKC01073_violet) was seemingly colored with manganese (3.3%), a common colorant in purple glass (Degryse and Shortland 2020). The sole colorless glass drawn bead (AKC00909) did not have elevated levels of any common decolorants and may be related to furnace conditions (Degryse and Shortland 2020; Henderson 2013). Low Ca-high Al potash glass is not uncommon in Southeast Asia, having been identified at sites in Myanmar (Dussubieux and Pryce 2016; Dussubieux et al. 2020), Vietnam (Lankton and Dussubieux 2006) and Cambodia (Carter 2013; Gratuze 2013).

One bead had a high Ca-low Al composition (LAP017). This bead was a colorless drawn faceted bicone, an unusual shape in South and Southeast Asian glass bead assemblages. As with the other low lime potash bead, there were not elevated levels of any elements to account for the coloring of this bead. High lime potash glass is comparatively rare in Southeast Asia and is usually associated with earlier periods (4th-3rd century BCE), especially the site of Ban Don Ta Phet, Thailand (Dussubieux 2016; Lankton et al. 2006) where several colorless beads with a similar composition were found (Dussubieux, unpublished results). Recent isotopic studies on potash glass beads from Myanmar indicate that this glass type has a distinctly different strontium and neodymium isotopic signature than the other potash sub-types (Dussubieux and Pryce 2016).

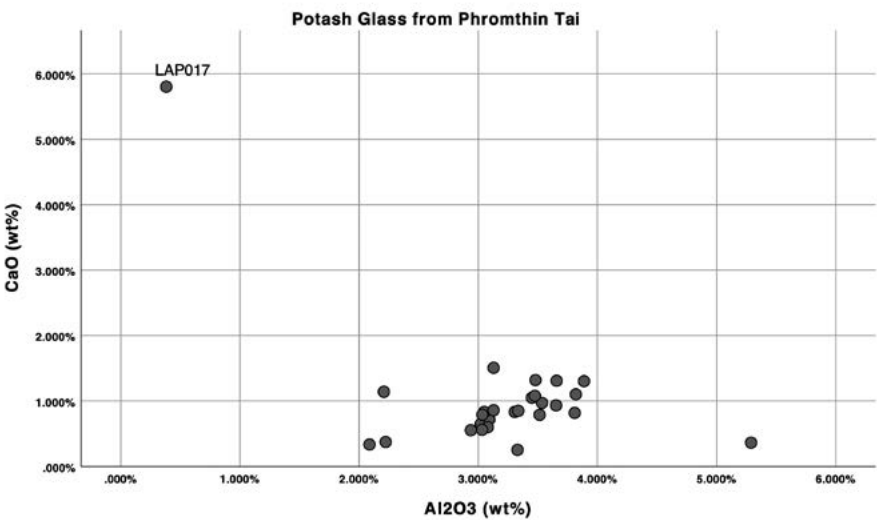


Fig. 8.2: Biplot of potash glass from Phromthai Tai showing the concentrations of alumina and lime. Most of the beads were low Ca-High Al potash glass, while one bead (LAP017) has a high lime concentration.

3.2. Mineral soda glass

The next major glass type found at Phromthai Tai were glass beads with high concentrations of soda (approx. 10-22%) and magnesia generally less than 1.5%, classifying them as a type of mineral soda glass. Within this group were two major sub-types: beads with high concentrations of alumina (5-12%), a common glass type known as mineral soda alumina glass (m-Na-Al), and those with moderate amounts of alumina (approx. 3-5%) and lime (approx. 4-8%) (m-Na-Ca-Al) (see further discussions in [Annex B](#)). In Carter’s initial study of the PTT-S3 cemetery, it was estimated that 65.5% of the total glass assemblage consisted of m-Na-Al glass beads, but only a small number of these were found in burial contexts (approximately 3% of the assemblage), with the remaining amount having been found in the upper layers of the cemetery matrix (Carter 2013). In contrast, the m-Na-Ca-Al glass group was estimated to have made up only 12.4% of the total assemblage, but represented approximately 43% of the beads found in burial contexts (Carter 2013).

3.2.1 High alumina mineral soda glass (m-Na-Al)

Twenty drawn glass beads and one bicolor glass bi-cone belonged to the m-Na-Al glass group. Notably, there are multiple glass sub-groups within this group that correspond to different workshops, time periods, and geographic locations (Dussubieux et al. 2010). Of relevance to this study are four groups that have been found in Southeast Asia; we also include a newly described group identified in East and South Africa. The m-Na-Al 1 sub-group is widespread in South and Southeast Asia at sites dating from approximately the 4th century BCE to the early 2nd millennium CE (Carter 2016; Dussubieux and Allen 2014; Dussubieux et al. 2010). The m-Na-Al 2 sub-group has been found at sites in Africa, the western coast of India, and Southeast Asia at sites dating to the 2nd millennium CE (Dussubieux et al. 2010; Dussubieux et al. 2008; Dussubieux and Soedewo 2016; Carter et al. 2016; Carter et al. 2019). The m-Na-Al 3 sub-group has only been found at a limited number of sites in Southeast Asia, primarily peninsular Thailand, as well as northern India dating to the late centuries BCE (Dussubieux and Bellina 2018; Dussubieux and Kanungo 2013; Lankton et al. 2008a). The m-Na-Al 4 sub-group has also been found in later 2nd millennium CE sites in Southeast Asia as well as eastern Africa (Carter et al. 2016; Dussubieux 2009; Dussubieux et al. 2008; Dussubieux et al. 2010). The newly identified m-Na-Al 6 sub-group is close in composition to the m-Na-Al 2 sub-group, and has been found at sites that date from the 9-13th centuries CE, while the m-Na-Al 2 type dates to the 14th century CE onward (Dussubieux and Wood, 2021).

These sub-groups can be distinguished from one another via a principal component analysis (PCA) using the oxides and elements MgO, CaO, Sr, Zr, Cs, Ba, and U (Dussubieux et al. 2010). Beads from the Phromthai Tai site were compared to m-Na-Al 1 unpublished beads and objects from South India and Sri Lanka, m-Na-Al 2 beads from Chaul, India (Dussubieux et al. 2008), m-Na-Al 3 glass from Kopia, India (Dussubieux and Kanungo 2013), m-Na-Al 4 glass from Kuta Kareueng, Sumatra (Dussubieux 2009), and m-Na-Al 6 glass from Juani Primary School, Mafia Island, Tanzania (Dussubieux and Wood 2021). Although the timing of the Phromthai Tai site made it most likely that only m-Na-Al 1 or m-Na-Al 3 glass would be present, samples from the later m-Na-Al groups were included to determine if any of the beads might have been intrusive or bioturbated from upper layers.

Figure 8.3 displays a biplot of the first two components accounting for approximately 80% of the variance. The majority of the beads are most compositionally analogous to the m-Na-Al 1 sub-type. The m-Na-Al 1 beads came in a variety of colors, including an opaque red, orange, yellow, green, and black, and translucent turquoise blue. This glass type is amongst the most common and

widespread found in glass beads across Southeast Asia dating to the late centuries BCE and into the first millennium CE (Carter 2016; Dussubieux et al. 2010). The blue beads are colored by copper (0.7-1.5%) and the yellow opaque beads have elevated concentrations of lead (approx. 3-4%) and tin (approx. 0.5-1%) pointing towards the use of lead stannate as a colorant. Previous studies have observed that opaque red, black, and orange beads in this sub-type typically have elevated levels of copper, magnesia, lime, iron, and phosphorous related to their coloring (Dussubieux et al. 2011; Dussubieux et al. 2010). This is true for the beads in this collection, with the orange beads especially having high concentrations of MgO (approx. 1-3%). The presence of higher concentrations of magnesia, often combined with higher concentrations of phosphorus and lime for specific colors, was noted for other types of glass (e.g., natron glass) and was interpreted as resulting from the introduction of fuel ash to the glass melt, that in the case of copper orange glass could have been intentional to create a reducing environment to more easily obtain cuprite (Schibille and Freestone 2013). One opaque orange bead (LAP024) plots away from all known m-Na-Al groups and is notable for a high concentration of Cs; it is currently unclear why this bead is compositionally distinct.

The black and white bi-cone bead (AKC01043) is unique and may have been imitating agate beads (Francis Jr. 2002: 94-95). The opaque black glass base (AKC01043b) plots with the m-Na-Al 1 glass in the two-dimensional biplot, however it is notable for elevated levels of magnesium perhaps related to the coloring of the glass (Dussubieux et al. 2011; Lankton and Dussubieux 2006: 133-134), as well as high Cs, and lower U and Ba concentrations unlike other m-Na-Al 1 glass. The white stripe (AKC01043w) appears to sit on the surface of this glass and its composition is unusual; low levels of Na₂O suggest it was likely corroded.

One glass object (PTT02), a blue-green translucent chunk or bead fragment was assigned to the m-Na-Al 3 group. This glass type is strongly associated with early (4th – 3rd century BCE) glass bead production workshops located in peninsular Thailand and northern India at the site of Kopia (approx. 1st century AD) (Dussubieux and Kanungo 2013; Kanungo 2010; Lankton et al. 2008a). Elevated levels of copper in this sample (1.4%) likely account for its greenish color and indicate a direct connection to northern India rather than a connection with the 4th – 3rd BCE sites of peninsular Thailand that exclusively yielded opaque red and black and transparent greenish (colored naturally by the presence of iron) glass. A larger range of colors is available in northern India.

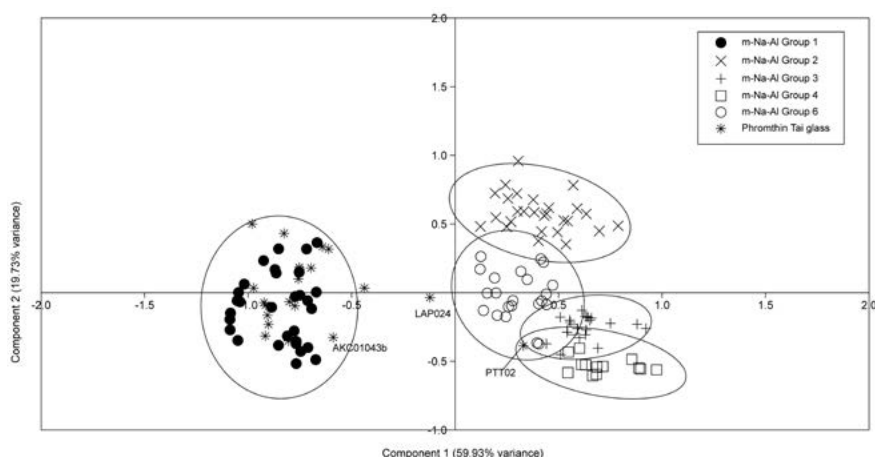


Fig. 8.3: A PCA of beads from Phromthai Tai and different groups of m-Na-Al glass.

3.2.1 Mineral soda glass with moderate amounts of alumina and lime (m-Na-Ca-Al)

Nine beads were assigned to the m-Na-Ca-Al group; all were drawn glass beads in dark blue, red, and black or dark green colors. This glass type frequently overlaps with the m-Na-Al type, but can be distinguished using a PCA of Na, Al, Rb, Zr, La, Hf, and Th (Dussubieux and Gratuze 2010) (Figure 8.4). The dark blue beads, seemingly the most common color of this glass type, were colored with cobalt (approx. 850-1200 ppm), while the opaque red bead had elevated concentrations of copper (1.4%) and iron (1.6%). The black bead also had elevated iron (1.7%). Although the dark blue potash glass and m-Na-Ca-Al dark blue beads looked similar to one another, the m-Na-Ca-Al beads tended to be slightly smaller (2.5-5 mm) than the potash glass beads (4-5 mm), with a deeper cobalt blue color.

This glass type shares a compositional similarity to a type of glass produced at Arikamedu, south India, called Arika glass, although it is distinct enough to be classified separately (Dussubieux and Gratuze 2013; Dussubieux et al. 2012; Lankton and Dussubieux 2013). Although seemingly related to Arikamedu glass, its production center is currently unknown, although one possibility is the site of Khlong Thom in peninsular Thailand, where it was found in large quantities (Lankton and Dussubieux 2013) and Phu Khao Thong where there is evidence of this glass having been worked (Dussubieux et al. 2012). Glass beads made from m-Na-Ca-Al glass have been found at numerous sites in mainland Southeast Asia dating from the late centuries BCE to the mid-first millennium CE, suggesting that its production was long-lived and well-circulated (Carter 2016; Dussubieux et al. 2020; Lankton and Dussubieux 2013).

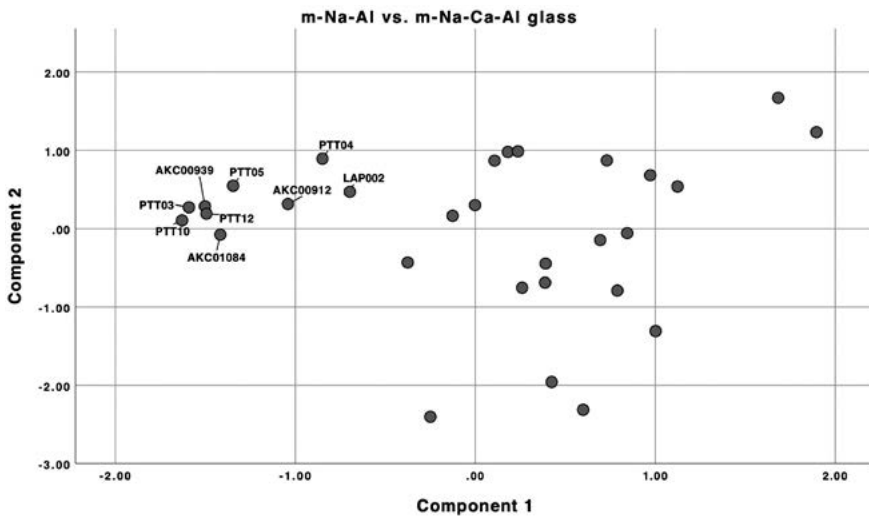


Fig. 8.4: Scatterplot of first and second components of a PCA to distinguish between m-Na-Al 1 and m-Na-Ca-Al glass accounting for 71.7% of the variance. The m-Na-Ca-Al glass beads are labeled.

3.3. *Less common glass types*

A small number of more unusual glass types were also identified in the Phromthin Tai assemblage. Three gold-glass beads were found in Burial 20. These small beads were originally segmented, and later broken into individual beads leaving a spherical bead with a jagged protrusion around the bead hole. One bead (AKC01057) was analyzed as part of the current study and found to be made from a soda-lime glass, typical of Mediterranean glasses made with a natron flux. The diffusion of this type of bead covers a huge area from Europe (Boon 1977) to Japan (Tamura and Oga 2016). Gold-glass beads were believed to have been imported from Egypt and the Mediterranean to India. Segmented gold-glass beads were found at the port site of Pattanam in Kerala, south India, and correspond mainly to contexts dating from the 3rd century BCE to the 3rd century CE (Abraham 2021). From India, those beads were traded into Southeast Asia. Recently, 43 gold-glass beads including segmented ones, with a composition originating from Egypt, were discovered at Pangkunk Baruk on Bali Island, a site dated from the 2nd to 4th century CE (Calo et al. 2020). Gold-glass beads also were found at the sites of Oc Eo, Vietnam, Kuala Selinsing, Malaysia, Ban Tha Kao, Thailand, and even Guangzho, China (Francis Jr. 2002; Lankton and Dussubieux 2006). Similar gold-glass beads have been reported at Khlong Thom and analysis indicates

they were also made from a Syro-Palestinian or natron glass (Lankton and Dussubieux 2013).

Two black beads with three white stripes, one complete and one broken, from Burial 20 appear to be imitating a striped agate bead (AKC01059) (Francis Jr. 2002: 94-95). Both the black and white portions of the broken bead were analyzed and found to be the same unusual glass type: a variety of potash glass with high levels of soda. Only a few other beads have been identified with a similar composition, including a blue-green glass bead from Ban Don Ta Phet and beads from southern India and Sri Lanka (Lankton and Dussubieux 2006: 139). It has been suggested that this high soda potash glass is a mixture of potash glass and Arikamedu glass, and that this particular glass type may have been made at Arikamedu (Lankton and Dussubieux 2006: 140).

A group of three collared white faience beads were found in Burial 18 and one bead was selected for analysis (AKC01093). This particular type of faience bead is fairly common at south Indian sites, including Arikamedu (Francis Jr. 2004: 510). In Southeast Asia, collared faience beads have also been found at Ban Bon Noen in central Thailand (Pilditch 1992). Pilditch reports that a blue-green glaze was visible on some of the faience beads from Ban Bon Noen under a microscope, however the Phromthin Tai beads appear to be unglazed. Due to their ubiquity at south Indian sites, Peter Francis Jr. (2004: 511) has speculated they may have been manufactured there. Unfortunately, the faience bead from Phromthin Tai was corroded making its original composition difficult to determine.

Lastly, there were three glass objects that were too weathered to obtain an accurate composition. One bead was analyzed from a group of 13 small black tubular beads that were identified in Burial 6 (AKC01022). This bead was quite curious in that it had high levels of alumina (16%) and iron (5%). The weathering and corrosion make further interpretation of this bead impossible at this time. The second object was an earring/ring fragment made from turquoise blue glass from Burial 7 (AKC00901). Although too corroded to determine the recipe, it appears similar to other turquoise glass ring/earring fragments from Phum Snay that were classified as potash glass (Carter 2010). Lastly, a colorless transparent glass chunk (PTT02) was also found to be too corroded to accurately determine its original composition.

4. Conclusion

Phromthin Tai's diverse glass collection demonstrates that this community participated in several bead exchange networks over the course of its long occupation. The predominance of potash glass beads in burials suggests people

at this site were connected to the larger South China Sea bead exchange routes during the early Iron Age that also included coastal sites in peninsular Thailand, as well as Sa Huynh and Dong Son sites in Vietnam, the Samon Valley and peninsular Myanmar, and southeast Cambodia (Carter 2015, 2016; Dussubieux et al. 2020; Dussubieux 2016; Lankton and Dussubieux 2013). Several unusual beads are similar to beads found largely in peninsular Thailand, such as those made with m-Na-Ca-Al glass, gold-glass beads, and faience and imitation agate beads, signifying a trade relationship with these communities or that they were part of the same trade network(s). The presence of numerous high alumina mineral soda glass beads in the cemetery matrix and upper layers indicate that people at this site maintained regional connections as bead exchange networks shifted in the early first millennium CE and exchange within the Mekong Interaction Sphere expanded (Carter et al. 2021). Lankton and Dussubieux (2013) had previously suggested the shift from potash to high alumina mineral soda glass took place between 200 BCE–200 CE, based on a lack of potash beads in cemetery layers at the site of Angkor Borei, Cambodia. Burial 20 at Phromthai Tai is especially important in this regard, as it contained both potash glass and m-Na-Al 1 glass and may help date the transition or overlap between these two exchange networks within mainland Southeast Asia (Carter 2015). Further investigations at this site would likely go far in helping to date these changing bead networks and filling a gap in understanding regional exchange networks across mainland Southeast Asia during the Iron Age period.

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References

- Abraham, S.A. 2021. A Review of Selected Glass Bead Types from the 2007-2009 Seasons of Excavation at Pattanam, India, in A.K. Kanungo & L. Dussubieux (eds) *Ancient Glass of South Asia – Archaeology, Ethnography and Global Connections*: 345-359. Singapore: Springer Nature and Gandhinagar: IIT Gandhinagar.
- Bellina, B. 2003. Beads, Social Change and Interaction Between India and South-east Asia. *Antiquity* 77: 285-297.
- Bellina, B. 2014. Maritime Silk Roads' Ornament Industries: Socio-political Practices and Cultural Transfers in the South China Sea. *Cambridge Archaeological Journal* 24: 345-377.
- Bellina, B. 2018. The Elaboration of Political Models in Maritime Southeast Asia and of Pan-Regional Culture: Contribution from Khao Sek Stone Ornament Craft System Study. *Archaeological Research in Asia* 13: 13-24.
- Bellina, B. & I. Glover 2004. The Archaeology of Early Contact with India and the Mediterranean World, from the Fourth Century BC to the Fourth Century AD, in I. Glover & P. Bellwood (eds) *Southeast Asia: From Prehistory to History*: 68-87. New York: Routledge/Curzon.
- Boon, G. 1977. Glass-in-Gold Beads from the Ancient World. *Britannia* 8: 193-207.
- Calo, A., P. Bellwood, J.W. Lankton, A. Reinecke, R.A. Bawono & B. Prasetyo 2020. Trans-Asiatic Exchange of Glass, Gold and Bronze: Analysis of Finds from the Late Prehistoric Pangkung Paruk Site, Bali. *Antiquity*: 1-17.
- Carter, A.K. 2010. Trade and Exchange Networks in Iron Age Cambodia: Preliminary Results from a Compositional Analysis of Glass Beads. *Bulletin of the Indo-Pacific Prehistory Association* 30: 178-188.
- Carter, A.K. 2013. *Trade, Exchange, and Sociopolitical Development in Iron Age (500 BC – AD 500) Mainland Southeast Asia: An Examination of Stone and Glass Beads from Cambodia and Thailand*. Unpublished Ph.D. diss., University of Wisconsin-Madison.
- Carter, A.K. 2015. Beads, Exchange Networks and Emerging Complexity: A Case Study from Cambodia and Thailand (500 BCE – CE 500). *Cambridge Archaeological Journal* 25: 733-757.
- Carter, A.K. 2016. The Production and Exchange of Glass and Stone Beads in Southeast Asia from 500 BCE to the Early Second Millennium CE: An Assessment of the Work of Peter Francis in Light of Recent Research. *Archaeological Research in Asia* 6: 16-29.
- Carter, A.K., L. Dussubieux & N. Beavan 2016. Glass Beads from 15th-17th Century CE Jar Burial Sites in Cambodia's Cardamom Mountains. *Archaeometry* 58: 401-412.
- Carter, A.K., L. Dussubieux, M. Polkinghorne & C. Pottier 2019. Glass Artifacts at Angkor: Evidence for Exchange. *Archaeological and Anthropological Sciences* 11: 1013-1027.
- Carter, A.K., L. Dussubieux, M.T. Stark & H.A. Gilg 2021. Angkor Borei and Protohistoric Trade Networks: A View from the Glass and Stone Bead Assemblage. *Asian Perspectives* 60: 32-70.
- Carter, A.K. & J.W. Lankton 2012. Analysis and Comparison of Glass Beads from Ban Non Wat and Noen U-Loke, in C. Higham & A. Kijngam (eds) *The Origins of Angkor, Volume 6: The Iron Age: Summary and Conclusions*: 91-114. Bangkok: Fine Arts Department of Thailand.
- Degryse, P. & A.J. Shortland 2020. Interpreting Elements and Isotopes in Glass: A Review. *Archaeometry* 62: 117-133.

- Dussubieux, L. 2009. Compositional Analysis of Ancient Glass Fragments from North Sumatra, Indonesia, in E. Surachman & D. Perret (eds) *Histoire de Barus III: regards sur une place marchande de l'océan Indien (XII e--milieu du XVII e s.)*: 385-417. Paris: Archipel.
- Dussubieux, L. 2016. Potash Glass: A View from South and Southeast Asia, in G. Fuxi, Q. Li & J. Henderson (eds) *Recent Advances in the Scientific Research on Ancient Glass and Glaze*: 95-112. Hackensack, NJ: World Scientific Publishing.
- Dussubieux, L. & J. Allen 2014. Chemical Compositions of Glass Artifacts from Malaysia: New Data from the Sites of Kampung Pengkalan Bujang and Kampung Sungai Mas, in D. Perret & Z.B. Jaafar (eds) *Ancient Glassware in Malaysia: The Pengkalan Bujang Collection*. Kuala Lumpur: Department of Museums Malaysia.
- Dussubieux, L. & B. Bellina 2017. Glass from an Early Southeast Asian Producing and Trading Centre, in B. Bellina (ed.) *Khao Sam Kaeo. An Early Port-City Between the Indian Ocean and the South China Sea*: 547-585. Paris: École française d'Extrême-Orient.
- Dussubieux, L. & B. Bellina 2018. Glass Ornament Production and Trade Politics in the Upper-Thai Peninsula During the Early Iron Age. *Archaeological Research in Asia* March: 25-36.
- Dussubieux, L., Bellina, B., W.H. Oo, U.M.S. Win, H.M. Tut, K.M.M. Htwe & K. Kyaw 2020. First Elemental Analysis of Glass from Southern Myanmar: Replacing the Region in the Early Maritime Silk Road. *Archaeological and Anthropological Sciences* 12 (7):139.
- Dussubieux, L. & B. Gratuze 2010. Glass in Southeast Asia, in B. Bellina, E.A. Bacus, T.O. Pryce & J.W. Christie (eds) *50 Years of Archaeology in Southeast Asia. Essays in Honour of Ian Glover*: 247-260. Bangkok: River Books.
- Dussubieux, L. & B. Gratuze 2013. Glass in South Asia, in K. Janssens (ed.) *Modern Methods for Analysing Archaeological and Historic Glass*: 397-412. West Sussex: Wiley and Sons.
- Dussubieux, L., B. Gratuze, B. & M. Blet-Lemarquand 2010. Mineral Soda Alumina Glass: Occurrence and Meaning. *Journal of Archaeological Science* 37: 1646-1655.
- Dussubieux, L., Gratuze, B. & Blet-Lemarquand 2011. Innovation dans les techniques de coloration: les verres rouges et orange en Asie du Sud, in S. Lagabrielle & C. Maitte (eds) *Actes du deuxième colloque international de l'association Verre & Histoire, Nancy 26-28 mars 2009*: 11-20. Paris: Verre & Histoire.
- Dussubieux, L. & A.K. Kanungo 2013. Trace Element Analysis of Glass from Kopia, in A.K. Kanungo (ed.) *Glass in Ancient India: Excavations at Kopia*: 360-366. Nalanda: Kerala Council for Historical Research.
- Dussubieux, L., C.M. Kusimba, V. Gogte, S.B. Kusimba, B. Gratuze & R. Oka. 2008. The Trading of Ancient Glass Beads: New Analytical Data from South Asian and East African Soda-Alumina Glass Beads. *Archaeometry* 50: 797-821.
- Dussubieux, L., J.W. Lankton, B. Bellina-Pryce & B. Chaisuwan 2012. Early Glass Trade in South and Southeast Asia: New Insights from Two Coastal Sites, Phu Khao Thong in Thailand and Arikamedu in South India, in M.-L. Tjoa-Bonatz, A. Reinecke & D. Bonatz (eds) *Crossing Borders: Selected Papers from the 13th International Conference of the European Association of Southeast Asian Archaeologists, Volume 1*: 307-328. Singapore: NUS Press.
- Dussubieux, L. & T.O. Pryce 2016. Myanmar's Role in Iron Age Interaction Networks Linking Southeast Asia and India: Recent Glass and Copper-Base Metal Exchange Research from the Mission Archéologique Française au Myanmar. *Journal of Archaeological Science: Reports* 5: 598-614.
- Dussubieux, L. & E. Soedewo 2016. The Glass Beads of Kampai Island, Sumatra. *Archaeological and Anthropological Sciences* 10: 1129-1139.

- Dussubieux, L. & M. Wood 2021. Indian Glass: Chronology and Distribution in Eastern Africa, in A.K. Kanungo & L. Dussubieux (eds) *Ancient Glass of South Asia: Archaeology, Ethnography and Global Connections*: 511-532. Singapore: Springer Nature and Gandhinagar: IIT Gandhinagar.
- Francis Jr., P. 1990. Glass Beads in Asia. Part 2. Indo-Pacific Beads. *Asian Perspectives* 29: 1-23.
- Francis Jr., P. 2002. *Asia's Maritime Bead Trade. 300 B.C. to the Present*. Honolulu: University of Hawai'i Press.
- Francis Jr., P. 2004. Beads and Selected Small Finds from the 1989-1992 Excavations, in V. Begley (ed.) *The Ancient Port of Arikamedu: New Excavations and Researches 1989-1992, Volume 2*: 447-604. Paris: Ecole Française d'Extrême Orient.
- Gratuze, B. 2013. Glass Characterisation Using Laser Ablation Inductively Coupled Plasma Mass Spectrometry Methods, in K. Janssens (ed.) *Modern Methods for Analysing Archaeological and Historic Glass*: 201-234. West Sussex: Wiley and Sons.
- Henderson, J. 2013. *Ancient Glass. An Interdisciplinary Exploration*. Cambridge: Cambridge University Press.
- Hung, H.-C., K.D. Nguyen, P. Bellwood & M.T. Carson 2013. Coastal Connectivity: Long-Term Trading Networks Across the South China Sea. *The Journal of Island and Coastal Archaeology* 8: 384-404.
- Kanungo, A.K. 2010. Antiquity of Glass in India: Excavations at Kopia, in V. Tripathi & P. Upadhyay (eds) *Archaeology of the Ganga Basin, Paradigm Shift, vol. II*: 451-476. Delhi: Sharada Publishing House.
- Lankton, J.W. & L. Dussubieux 2006. Early Glass in Asian Maritime Trade: A Review and an Interpretation of Compositional Analysis. *Journal of Glass Studies* 48: 121-144.
- Lankton, J.W. & L. Dussubieux 2013. Early Glass in Southeast Asia, in K. Janssens (ed.) *Modern Methods for Analysing Archaeological and Historic Glass*: 415-457. West Sussex: Wiley and Sons.
- Lankton, J.W., L. Dussubieux & B. Gratuze 2008a. Glass from Khao Sam Kaeo: Transferred Technology for an Early Southeast Asian Exchange Network. *Bulletin de l'École française d'Extrême-Orient* 93: 317-351.
- Lankton, J.W., L. Dussubieux T. Rehren 2008b. A Study of Mid-First Millennium CE Southeast Asian Specialized Glass Beadmaking Traditions, in E. Bacus, I.C. Glover & P.D. Sharrock (eds) *Interpreting Southeast Asia's Past: Monument, Image, and Text*: 335-356. Singapore: NUS Press.
- Lertcharnrit, T. 2006. The Moated Site of Promtin Tai and the Transition from Late Prehistory to Early History in Central Thailand, in E. Bacus, I. Glover & V. Pigott (eds) *Uncovering Southeast Asia's Past – Selected papers from the Tenth Biennial Conference of the European Association of Southeast Asian Archaeologists, London, 14th – 17th September 2004*: 258-265. Singapore: NUS Press.
- Lertcharnrit, T. 2014. Phromthin Tai: An Archaeological Perspective on its Societal Transition, in N. Revire & S. Murphy (eds) *Before Siam: Essays in Art and Archaeology*: 119-131. Bangkok: River Books.
- Li, F. 1999. *Elemental and Isotopic Analysis of Ancient Chinese Glass*. Unpublished MS, University of Hong Kong.
- Lin, Y.-X., T. Rehren, H. Wang, X.-Y. Ren & J. Ma 2019. The Beginning of Faience in China: A Review and New Evidence. *Journal of Archaeological Science* 105: 97-115.
- Liu, C.-h. 2012. *Human Skeletal Health and Dietary Assessment of Metal Age Central Thailand: The Impact of Changing Social Complexity and Regional Variation*. Unpublished PhD thesis, University of Florida.

- Liu, C.-h. 2018. Human Foodways, Metallurgy, and Landscape Modification of Iron Age Central Thailand. *Asian Perspectives* 57: 83-104.
- Liu, S., Q. Li & F. Gan 2015. Chemical Analyses of Potash-Lime Silicate Glass Artifacts from the Warring States Period in China. *Spectroscopy Letters* 48: 302-309.
- Pigott, V.C. 2019. Prehistoric Copper Mining and Smelting in Southeast Asia: Evidence from Thailand and Laos, in White, J. & E. Hamilton (eds) *Ban Chiang, Northeast Thailand, Volume 2C: The Metal Remains in Regional Context*: 5-56. Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology.
- Pilditch, J.S. 1992. The Glass Beads of Ban Bon Noen, Central Thailand. *Asian Perspectives* 31: 171-181.
- Schibille, N. & I.C. Freestone 2013. Composition, Production and Procurement of Glass at San Vincenzo Al Volturno: An early Medieval Monastic Complex in Southern Italy. *PLoS One* 8: e76479.
- Tamura, T. & K. Oga 2016. Archaeometrical Investigation of Natron Glass Excavated in Japan. *Microchemical Journal* 126: 7-17.
- Turner, W.E.S. & H.P. Rooksby 1959. A Study of the Opalising Agents in Ancient Opal Glass Throughout Three Thousand Four Hundred Years. *Glastechnische Berichte* 32K VIII 17: 20-28.