LA-ICP-MS Analysis of Agate and Carnelian:

Analysis of Geological Sources from Central, South, and Southeast Asia and Beads from Iron Age sites in Cambodia

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Figure 1:Examples of Beads

Prohear (A, B);Village 10.8 (C, D, E); Phnom Borei (F); Krek (G); Prei Khmeng (H); Phum Snay (I, J, K); Bit Meas (L,M). Not to scale.

Where are agate and carnelian beads in Cambodia coming from?

The Iron Age period of Southeast Asia (approx. 500 BC- AD 500) is when we see the first concrete evidence for sustained trade and socio-political interaction with South Asia. Later Southeast Asian kingdoms incorporated a range of Indian cultural, socio-political, and religious ideologies (Hindu and Buddhist) into their own local traditions, adapting what they borrowed to address their own needs. Beads made of glass and stone—especially agate and carnelian—were among the first signs of contact with South Asia and some scholars have assumed that the presence of Indian origin beads represents direct Indian influence (Francis 1996; Ray 1996). However, more recent archaeological research suggests that Southeast Asian communities were not simply the passive recipients of Indian trade goods, but were active agents in the procurement and distribution of these objects. It is also possible that many glass and stone beads were locally produced to supplement or compete with the Indian trade beads (Bellina and Glover 2004; Bellina 2007; Lankton et al. 2006; Theunissen et al. 2000). In 2008, I was able to collect agate and carnelian beads from seven Iron Age archaeological sites in Cambodia (see Figure 1 and Map 1). Using LA-ICP-MS I wanted to determine if the beads were coming from a South Asian or Southeast Asian geological source (Figure 2).

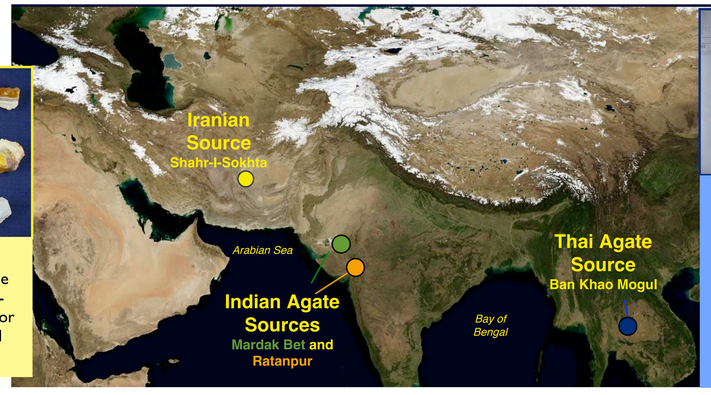
My research shows that LA-ICP-MS analysis can accurately distinguish between agate geological sources. Furthermore, agate and carnelian beads analyzed from Iron Age sites in Cambodia appear to originate from geological sources located in South Asia.

Map 1: Map of Cambodia

Beads were analyzed from sites marked in red. Angkor Borei and Oc Eo were important trading centers during the Iron Age period. *Map adapted from Higham 2002.*

Figure 2: Map of Geological Sources

Shahr-i-Sokhta
Iranian agate samples from the archaeological site of Shahr-i-Sokhta were used as proxies for an unknown agate geological source in eastern Iran.



Thai Source: Ban Khao Mogul
The agate source at Ban Khao Mogul has been noted by several scholars as a possible raw material source that could have been used for local production of beads (Glover 1989; Theunissen et al. 2000).

Mardak Bet
Agate samples from India were taken from two different sources located in the state of Gujarat. Gujarati agate sources have been in use by beadmakers for thousands of years. These samples were collected from agate beds on the island of Mardak in the Little Rann of Kutch.

Ratanpur
The area around the village of Ratanpur has been mined for agate for thousands of years. These samples were collected from a 3 km area near Jagadia village and Bawa Ghori Hill.

LA-ICP-MS Results

Figure 3

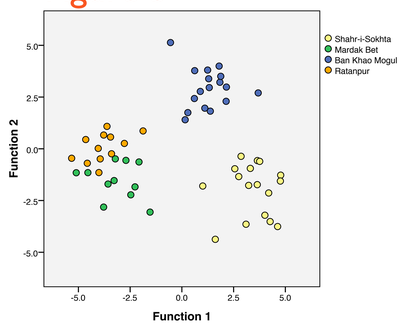


Figure 3 shows the four different sources plotted by their first and second discriminant functions. An excellent degree of separation was found between the sources, with 98.2% of cross-validated grouped geologic cases classifying correctly. The misclassification occurred between the two Gujarati sources of Mardak Bet and Ratanpur.

Figure 4

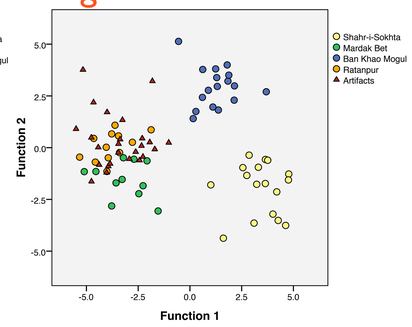
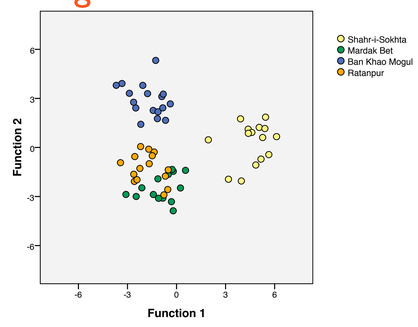


Figure 4 illustrates both the agate geological sources and the agate and carnelian beads plotted by their first and second discriminant functions. Interestingly, almost all of the agate and carnelian beads (n=22) from Cambodia were assigned to the Ratanpur source group. Two beads were assigned to the Mardak Bet source group, and one bead was assigned to the Shahr-i-Sokhta source group. Only one artifact, a small agate nodule found at the site of Prei Khmeng (Figure 1h above) was assigned to the Ban Khao Mogul group. Although we cannot say for certain that all the beads were coming from these exact source locations, we can say that they do not belong to the Thai geological source group.

Comparison with INAA

Figure 5



These four geological sources had been previously analyzed using iNAA at the University of Missouri Research Reactor (MURR) (for further discussion see Law et al. in press). **Figure 5** shows the sources plotted by their first and second discriminant functions. This analysis used the elements Al, Ce, Co, Fe, La, Mn, Na, Sb, Sc, and Sm, which were determined to best discriminate the sources based on the iNAA data. The results are nearly equal to that achieved with LA-ICP-MS; with 95.1% of the cross-validated grouped cases classifying correctly.

Conclusion and Discussion

Beads were an important prestige object and my research is focusing on the reassessment of bead trade and its impact on the socio-political and economic trajectories of the Iron Age in Southeast Asia. Through geochemical analysis of both the archaeological beads and raw materials collected from source areas in India and Southeast Asia it is possible to refine our understanding of trade, exchange, and socio-political networks at play during this formative period. Based on this research we can say that **LA-ICP-MS is able to distinguish the different geological sources from one another. Furthermore, all of the beads that I sampled from Cambodia were made from non-local carnelian or agate, probably derived from South Asian sources.** The bead shapes and specific aspects of manufacturing, particularly the drilling technique using diamond drills (Kenoyer, personal communication), also match those found during this same time period in South Asia. While local elites may have been requesting specific bead styles or shapes (Bellina 2003), it does seem that the materials were still being produced in South Asia or using South Asian techniques. There were multiple raw material sources and bead manufacturing centers in South Asia at this time, and it is possible that the beads in Southeast Asia were coming from more than one source area.

The agate nodule from the site of Prei Khmeng presents an interesting anomaly. Only one other agate/carnelian artifact, a small bead, was found at this site. Therefore the presence of this agate nodule does not seem to indicate local bead manufacturing. My ongoing research continues to explore questions regarding the local production of agate and carnelian beads. Additional agate and carnelian beads from Thailand will be analyzed to determine if sites closer to the Ban Khao Mogul source are producing beads from this local material. I am also continuing to analyze geological sources from sites in South and Southeast Asia in order to better understand where these beads were coming from and how they were moving across the landscape. LA-ICP-MS is an ideal method for this research as it allows one to examine the elemental composition of objects with only minimal damage to the artifact.

Methods

Four geological source samples were selected for LA-ICP-MS analysis (Figure 2). These samples were chosen to initiate the study for two reasons: first they are geographically distinct, therefore I was expecting to see clear geochemical differences between the different sources. Secondly, these sources had already been analyzed using instrumental neutron activation analysis (iNAA)(Law et al. in press), which would allow me to compare the results of the two techniques.

The samples were analyzed at the LA-ICP-MS lab in the Field Museum, Chicago, Illinois, managed by Dr. Laure Dussubieux. 54 elements were recorded in the final results. After visual analysis of bivariate plots, 7 elements (Al, Hf, Na, Sb, Sc, U, Zn) showed the greatest differentiation between the sources and were used in Canonical Discriminant Analysis (CDA). CDA was chosen for its effectiveness in differentiating agate geological sources and assigning a possible provenience to agate artifacts (Baxter 1994).

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