CHAPTER 8

AGATE ACQUISITION NETWORKS

CHAPTER INTRODUCTION: SOURCING HARAPPAN AGATE

The roughly 4700 finished objects (mostly ornaments but also the occasional stone weight) and pieces of raw material or manufacturing debris from Harappa that have been designated *agate* or *jasper* exhibit a bewildering range of macroscopic variability (recall Figure 4.3 C for just a handful of examples). Although HARP co-director Dr. J. Mark Kenoyer has developed an intricate coding system for describing such variation, visual attributes alone cannot be used to identify their geologic sources. As was the case for steatite, multiple macroscopic types of agate and jasper are usually found at source locations (*personal observations*) and, in fact, often are present in individual specimens (note, for instance, the variegated appearance of some of the agate samples pictured in Figure 8.28). Moreover (and also like for steatite), Indus craftspeople likely altered the original appearance of certain sub-varieties of these microcrystalline silicates when they heat-treated them (described in Kenoyer *et al*. 1991). The secondary contexts from which agates and jaspers are frequently obtained, like riverbeds and conglomerates, may contain materials that formed across extremely wide areas and in very different geologic episodes and/or environments. Recent attempts to provenience of *carnelian* (red-orange agate) artifacts using PIXE analysis (Theunissen *et al*. 2000) and LA-ICP-MS (Insoll *et al*. 2004) have produced largely equivocal results. It was for all of the above reasons that I initially approached the sourcing of this material sub-assemblage with low expectations of success.

In order to make this aspect of my research more manageable, I narrowed the focus to just agate and a very specific research question. I decided to evaluate the long and widely held "assumption" (Ratnagar 2004: 146) that Harappans derived their agate primarily from sources in Gujarat; most probably the deposits of the Ratanpur area in the southern part of that Indian state (Allchin and Allchin 1997: 173; Asthana 1993: 274; Biwas 1996: 49; Lal 1997: 163-164; Pascoe 1931: 681; Vidale 2000: 42). Using INAA, agate samples collected from Ratanpur and two other sources located in northern Gujarat were analyzed. These were then compared, using CDA, to one another and to agate artifacts from the prehistoric site of Shahr-i-Sokhta in eastern Iran, which were treated as proxy samples for sources in that distant region. Good to excellent (≈ 85 to 95%) statistical separation between grouped samples from these sources/proxy sources was achieved. When agate artifacts from Harappa and five other Indus Tradition sites were compared to them, it was found that although most are analogous to geologic samples from the Gujarati deposits, very few appear to be from the Ratanpur source. The results also indicate that Harappans may have been acquiring some agate from sources in regions other than Gujarat.

In this chapter, I recount what, despite my initial expectations, has turned out to be a successful provenience study of Harappan agate. It is presented in two main parts. In the first, I discuss the formation of agate and agate deposits and then outline potential sources of that stone in the Greater Indus region and beyond. I begin the second part by presenting the geologic dataset and the agate artifacts (from Harappa and five other sites) that are compared to it. Multiple discriminant analyses involving different

combinations of source samples are then carried out and provenience determinations are assigned. Afterwards, the results are scrutinized and, when necessary, qualified. In the final section, I discuss their implications for future research of this kind and summarize the provisional conclusions.

GEOLOGY AND POTENTIAL SOURCES OF AGATE IN THE GREATER INDUS REGION AND BEYOND

Even after centuries of study, "the origin of agate remains incompletely understood" (Götze *et al*. 2001: 527). Nevertheless, a brief overview of what is known about the stone's formation and the primary and secondary geologic contexts in which it is found is useful for the upcoming outline of the its potential sources in the Great Indus region and beyond.

The formation of agate and agate deposits

Agates are translucent microcrystalline sedimentary rocks that form when silica precipitates in cavities within some type of host rock. The mechanisms behind their growth, frequent banding and other distinctive characteristics are the subjects of much debate (for detailed discussions and different views see Fallick *et al*. 1985; Heaney and Davis 1995; Merino *et al*. 1995; Moxon 1996; Pabian and Zarins 1994; Wang and Merino 1990, 1995). The rocks in which agates form may also be sedimentary (limestone, dolomite, claystone) but they are more commonly igneous (Luedtke 1992: 31-32; Pabian and Zarins 1994: 7). As certain types of volcanic lavas and tuffs cool, cavities (vesicles) form within them that later become filled in with secondary minerals like calcite, crystalline quartz and/or microcrystalline quartz – i.e, agates and jaspers. The filled cavities are called *amygdales* and the igneous host rocks containing them are described as *amygdaloidal* (Lapidus and Winstanley 1990: 24-25). A good example of this primary geologic context for agates (Figure 8.1) and other microcrystalline silicates would be the "highly amygdaloidal" volcanic trap (basalt) rocks Fedden described (1885: 20, 62) in Gujarat's Saurashtra Peninsula. Although I encountered only jasper-filled amygdales (Figure 8.2) during my visit to that area, Fedden reported agate, moss agate and chalcedony in the region to the northwest of Rajkot.

As their host rocks erode, loosened agates (many retaining the nodular shapes of the cavities in which they formed) fall away. These then may be carried by fluvial action or other processes and end up in a range of secondary geologic contexts (Figure 8.3). In Gujarat at least (*personal observation*), it is not uncommon to encounter agate nodules or fragments when walking across the fields of India's famously rich "black cotton soils," which formed due to the decomposition of the basaltic rock of the Deccan Traps (Hegde 1989). In other places, such as sources that I will shortly discuss in eastern Kutch, all remnants of host rocks have disappeared leaving behind only loose "agates ... so numerous as sometimes to form a coarse gravelly layer on the surface" (Wynne 1872: 116-117). Loose agates, often carried far from their original host formations, can be found in the beds of certain rivers, streams, nalas and wadis across South Asia, the Iranian Plateau and Arabia. In some places, fluvially transported microcrystalline silicates have been deposited and reconsolidated. The famous Ratanpur area sources are part of the early Miocene epoch conglomerate called the *Babaguru Formation* (Gadekar 1977). P.K. Chatterjee noted (1963b: 166) that "chalcedonic silica, carnelian, chalcedony, chrysophrase, plasma, bloodstones, onyx, jasper, agate jasper, flint, chert, etc ... [all] occur" within it.

It was extensive and materially diverse secondary agate deposits like the Babaguru Formation that initially caused me to be skeptical about whether or not it was possible to source this variety of stone. That

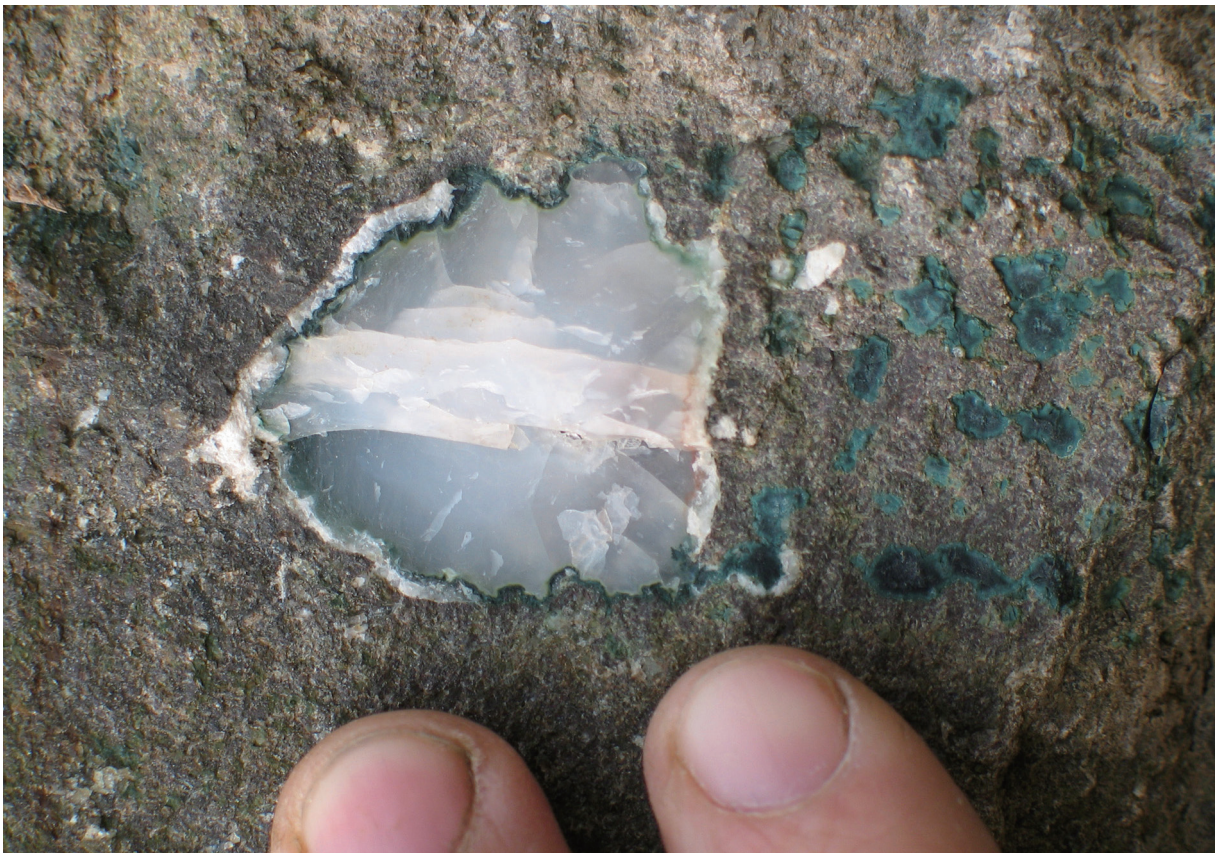


Figure 8.1 Primary geologic context agate: an amygdale of chalcedony in basalt, near Ellora, Maharashtra.

Figure 8.2 Amygdales of jasper in basalt, near Khokhari Village, Jamnagar District, Gujarat.

Figure 8.3 Secondary geologic context agate.

A. Agate-filled agricultural field at Undari, Yavatmal District, Maharashtra.

B. Large agate nodule at Undari.

C. Agate nodules in the Godavari River near Paithan, Aurangabad District, Maharashtra.

D. Detail of agate nodules at Paithan.

particular formation is thought to be the remnant of a "fluvial delta" (Gadekar 1977: 555), most likely of a river that drained the west-central Deccan Plateau, not unlike the Narmada River does today. Agates and other microcrystalline silicates deposited within it could, therefore, have come from primary sources occurring over an enormous geographic area. Moreover, the Deccan Traps from which those stones eroded are not a homogenous geologic unit but rather succession volcanic events (see Sukheswala *et al*. 1972: Fig. 2a for a diagram depicting the layered amygdaloidal basalts of the western Deccan Traps). The Babaguru Formation might well then contain agates that formed in multiple basalts of slightly different ages and chemistries. As I stated in the introduction, it has thus far been possible differentiate Ratanpur agate samples from those of other deposits in Gujarat and elsewhere. It is important to realize, however, that as additional sources are analyzed, particularly from other locations in the Deccan Traps, this *may* become increasingly more difficult.

Potential Harappan agate sources

In this section, the agate sources that Harappans potentially may have had access in the Greater Indus region (Figure 8.4) and beyond (Figure 8.5) are outlined. We begin with an overview of Gujarat and then briefly examine deposits elsewhere in the Deccan Traps. Minor agate occurrences to the west and north of the Indus Valley are then discussed followed by potential sources in regions that Indus Civilization peoples had clear contacts with such as Afghanistan, southern Central Asia, the Iranian Plateau and eastern Arabia.

Agate deposits in Gujarat

There are a number of reasons why Gujarat (Figure 8.6) is assumed to have been an important source area, perhaps even the primary source area, for the agates used by Indus Civilization peoples. Firstly, Harappans were present there; often (as I show below) in very close proximity to some significant occurrences. In fact, ornamental microcrystalline silicates were probably among the resources (some other being marine shell, salt and pasturage) that attracted them to the region in the first place. Secondly, although occurrences of agate can be found in many parts of Asia, the extent, diversity and sheer richness of sources in Gujarat is unparalleled. The region could aptly be characterized as the "Saudi Arabia" of agate. Lastly, Gujarat was a historically important source area. Greek (McCrindle 1885: 77, 334; Schoff 1912: 42), Mughal (Khan 1756: 250) and early European colonial (Barbosa 1517: 66-67; Foster 1906: 52, 178) records all make reference to the agate resources there. The city of Khambhat (Cambay) has been a major center for the manufacture of agate ornaments since at least the 16th century (Arkell 1936; Campbell 1880: 206-207) and the traditional methods still employed there have been the subject of several ethnoarchaeological studies (Kenoyer *et al*. 1991, 1994; Possehl 1981; Roux 2000).

Throughout the historic era, the preeminent agate source within Gujarat has been the deposits around Ratanpur (Figure 8.7) in the southeast part of the state (Allchin 1979a; Ball *et al*. 1881: 506-507; Bose 1908; Francis 1983; Sahni 1948). This review begins there.

- Southeastern Gujarat – Ratanpur area deposits

Among the low hills around the village of Ratanpur, Bharuch District, Gujarat (Figure 8.8), there are hundreds of agate mining pits and shafts (Figure 8.9) sunk into the Miocene conglomerate of the Babaguru Formation. Although these workings are often referred to as the "Rajpipla" deposits/mines (as they were within the confines of that princely state prior to 1947), "Ratanpur" is a more appropriate designation (Ball 1886: 238). Mining locations having published geographic coordinates (Chatterjee 1963a: 166; Insoll *et al*. 2004: 1162) are plotted on Figure 8.7. Trivedi noted (1964: Map 2) most of these localities,

Figure 8.4: Greater Indus Valley region agate occurrences and sites discussed in this chapter.

Figure 8.5: Agate sources outside of the Greater Indus region.

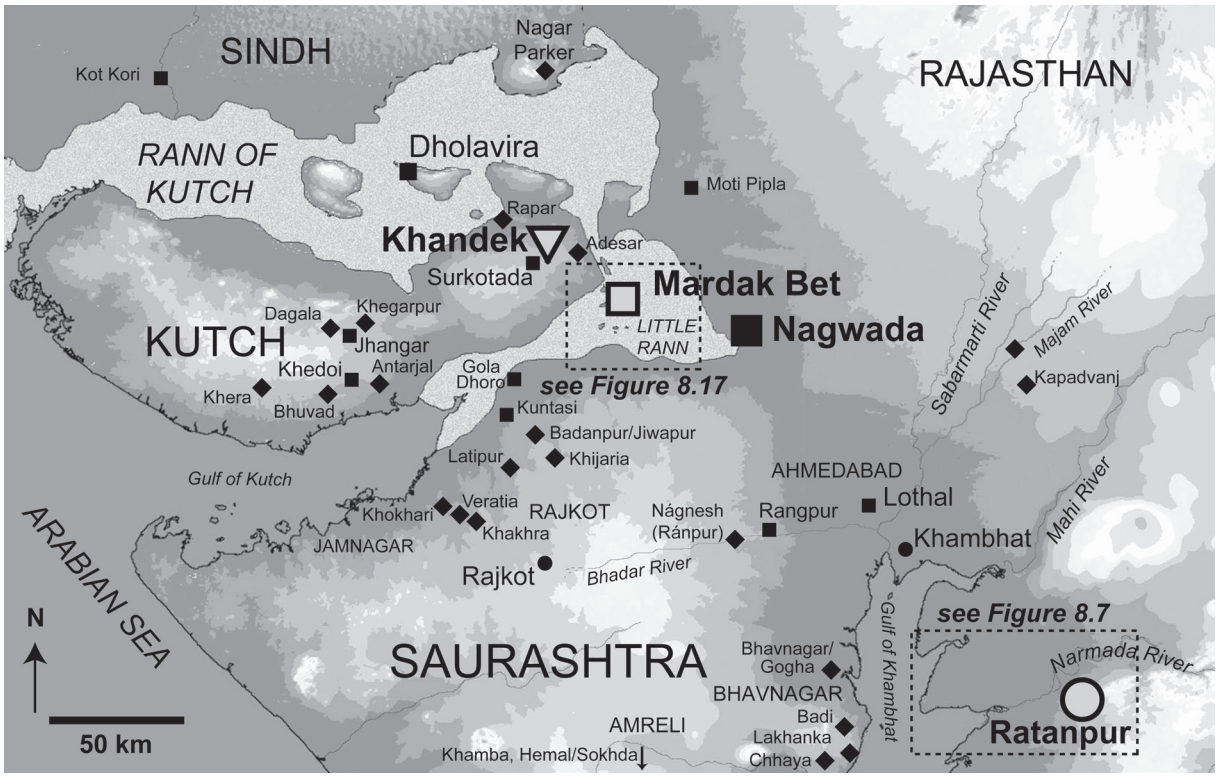


Figure 8.6 Agate sources, archaeological sites and modern towns in Gujarat.

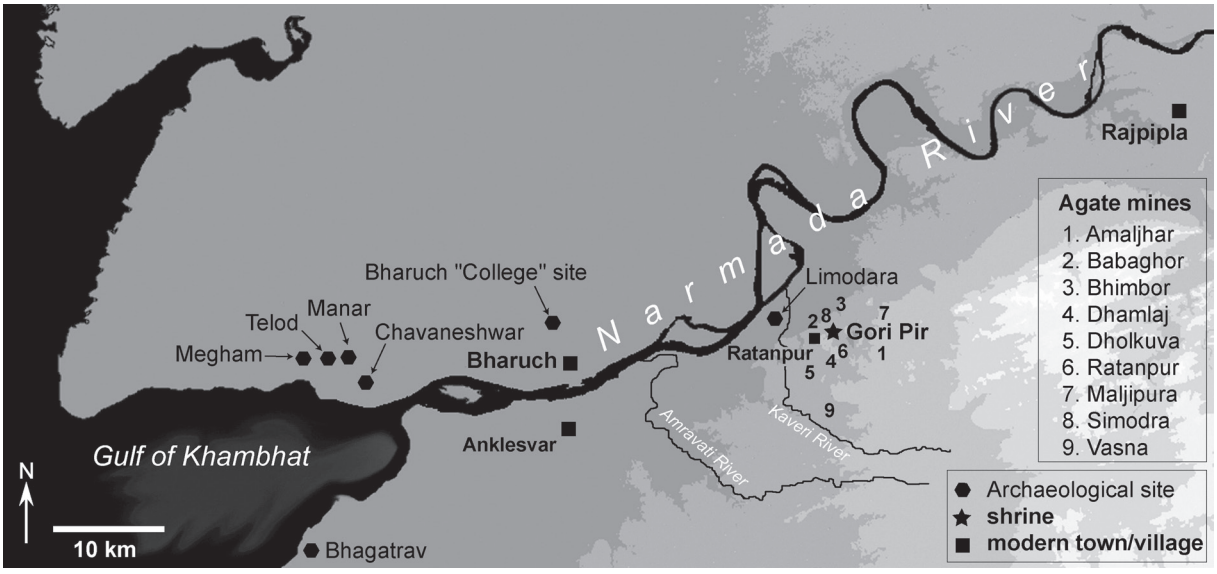


Figure 8.7 Ratanpur area agate sources and archaeological sites.

as well as around a half dozen others, in his review of the Khambhat bead industry (Figure 8.10), which to this day consumes tons of Ratanpur agate (Figure 8.11). All occur within fifteen kilometers of the hilltop tomb/shrine of Gori Pir (or Baba Ghor) – a Muslim saint who is said to have come from Africa in the 15th century and established bead-making operations at nearby settlements such as Limodara (Francis 1986; Kenoyer and Bhan 2005). M.R. Sahni (1948: 248-250, 253) noted that agates could also be obtained from the beds several small rivers (the Karad, Kaveri and Amravati) southwest of the Ratanpur area as well as to the east along the banks of the Narmada River near Rajpipla town. The nodules found in the former are said to be "rarely, if ever, of large size" (ibid.: 253). Those nearer to Rajpipla, while larger, tend to be

Figure 8.8 Ratanpur Hills area, Bharuch District, Gujarat.

Figure 8.9 Agate mine shaft sunk into the Miocene conglomerate (Babaguru Formation).

Figure 8.10 Worker in Khambhat, Gujarat making beads roughouts using Ratanpur agate.

Figure 8.11 Sacks of Ratanpur agate in Khambhat.

composed of clear chalcedony (*personal observations*).

Samples for this study were collected from pits (figures 8.12 and 8.13), shafts and tailings along a three kilometer zone extending from the base of Gori Pir Hill south-southeast to point #6 on Figure 8.6. Because the Babaguru Formation is a materially diverse secondary context agate deposit (discussed above), an attempt to assess geochemical variation across that zone was deemed to have little utility. All samples from this occurrence are, therefore, treated as coming from a single source, which is simply designated "Ratanpur."

It is unclear if Harappans might have had direct access to agate from the Ratanpur area deposits. Lothal – the nearest site that is inarguably an Indus Civilization settlement, is located around 130 km to the northwest of Gori Pir Hill. A handful of prehistoric sites are encountered as one moves west from Ratanpur toward the mouth of the Narmada River. Possehl identifies these as "Sorath Harappan" settlements in his *Gazetteer of Indus Age Sites* (Possehl 1999: Appendix A). If Indus Civilization peoples did acquire Ratanpur agate then doing so likely entailed interaction with the residents of these sites (or of other similar sites in the area) regardless of whether or not they were fellow Harappans or members of a separate, locally distinct cultural phase (recall the discussion on pp. 46-47).

- Northern Gujarat

The agate sources of northern Gujarat would have been the ones most directly accessible to Indus Civilization peoples. There are number of occurrences (at Antarjal, Bhuvad, Dagala, Khera and Khegarpur) reported in central Kutch (Geological Survey of India 2001a: 47), which have not been described in detail but are likely derived from nearby outliers of the Deccan traps. Many are located in close proximity (less than 10 km) to Harappan settlements like Jhangar (Joshi 1990: 418) and Khedoi (IAR 1976-77: 15). I visited a several of these occurrences and observed only fragments (some quite large) of milky

Figure 8.12 Whenever possible, agate samples were taken from the interiors of mine shafts at Ratanpur.

Figure 8.13 Removing a sample of agate-carnelian from the Miocene conglomerate at Ratanpur.

Figure 8.14 Fragments of milky white agate-chalcedony near Antarjal, central Kutch District, Gujarat.

white agate-chalcedony (Figure 8.14).

Toward the east, A.B. Wynne noted (1872: 72-73) that the "agate-bearing laterites of North-Eastern Kutch are far removed from the stratified [Deccan] traps, resting to their entire exclusion upon Jurassic rocks ... the source of the agates rather widely disseminated in them is somewhat mysterious, there being no evidence that the bedded traps ever existed in that part of the district, nor does any outlier of them occur within a distance of about forty miles" (≈ 65 km). Occurrences of this type are found around Adesar (Geological Survey of India 2001a: 47), northwest of Rapar on the eastern shore of the Great Rann (Merh 1995: Figure 17) and near Khandek village. A deposit on Mardak Bet in the Little Rann (Trivedi 1964: 10-11) is, however, associated with trap rock (Satyanarayana and Narasimha Rao 1955: 88). The latter two sources mentioned were sampled and analyzed for this study.

Khandek, Eastern Kutch

The Khandek agate source (Figure 8.15) was first brought to my attention by R.S. Bisht, the excavator of the Harappan city of Dholavira, which is located some 70 km to its west-northwest on the island of Khadir. Ravaji Solanki – the local stone expert (pattarwala) at Dholavira provided directions to Khandek village and his brother Narsingh, who resided there, guided me to the source itself (located at N 23° 38' 28", E 70° 52' 22"). A pavement-like layer (Figure 8.16) of loose agates (natural carnelian, yellow-brown agate, clear chalcedony, moss agate) and other microcrystalline silicates (red, green, brown and variegated jaspers) covers an area of perhaps four hectares (roughly 200 x 200 meters) just east of the village. This source is located around five kilometers from the small fortified Indus Civilization settlement of Surkotada (Joshi 1990). Although no clearly prehistoric workings or cultural materials were identified, numerous "window" flakes (pieces

Figure 8.15 With Narsingh Solanki at the Khandek agate beds, eastern Kutch District, Gujarat.

Figure 8.16 Pavement-like surface of the agate bed at Khandek.

of cortex that were struck from nodules in order to observe the quality of the agate inside) were found that indicate it had been exploited for materials at some time in the past.

Mardak Bet, Little Rann of Kutch

The agate deposits on the island (bet) of Mardak, in the salt marsh southeast of Kutch known as the "Little Rann" (Figure 8.17), can be difficult to reach due to seasonal flooding of the area surrounding them (Trivedi 1964: 11). A sampling trip with Arun Malik (a PhD student at Maharaja Sayajirao University) in early 2003 ended with us stuck in the mud within sight of the island (Figure 8.18). A second attempt (this time with Malik and Dr. Kuldeep Bhan) later that same year just prior to the summer monsoons was successful.

Mardak Bet is a thinly-shaped, east-west oriented island around 12 km in length with a maximum width of about 1.25 km. The agate beds are found in two main areas. The most extensive is located near the island's constricted mid-section, which Malik designated "nana" (Figure 8.19). Another occurs 3 km to the east, around the base of its highest hill (≈ 40 m above the salt flats), which was designated "mota." A wide range of microcrystalline silicates are found at both locations. Brownish-gray agate is by far the most abundant type but nodules of natural carnelian, clear chalcedony and moss agate are not uncommon. Red, green, yellow-brown and variegated jaspers (including bloodstone) are also found. Mardak Bet is the only source visited at which I have encountered a distinctive type of brown and white parallel-banded agate-jasper that was used by beadmakers at both Dholavira (*personal observations* 2007) and Harappa (for an example see Kenoyer 1998: Figure 6.44).

No prehistoric settlements are known to exist on Mardak Bet and no ancient workings in the island's agate beds were identified during our short visits to them. Mining pits and sorting areas (Figure

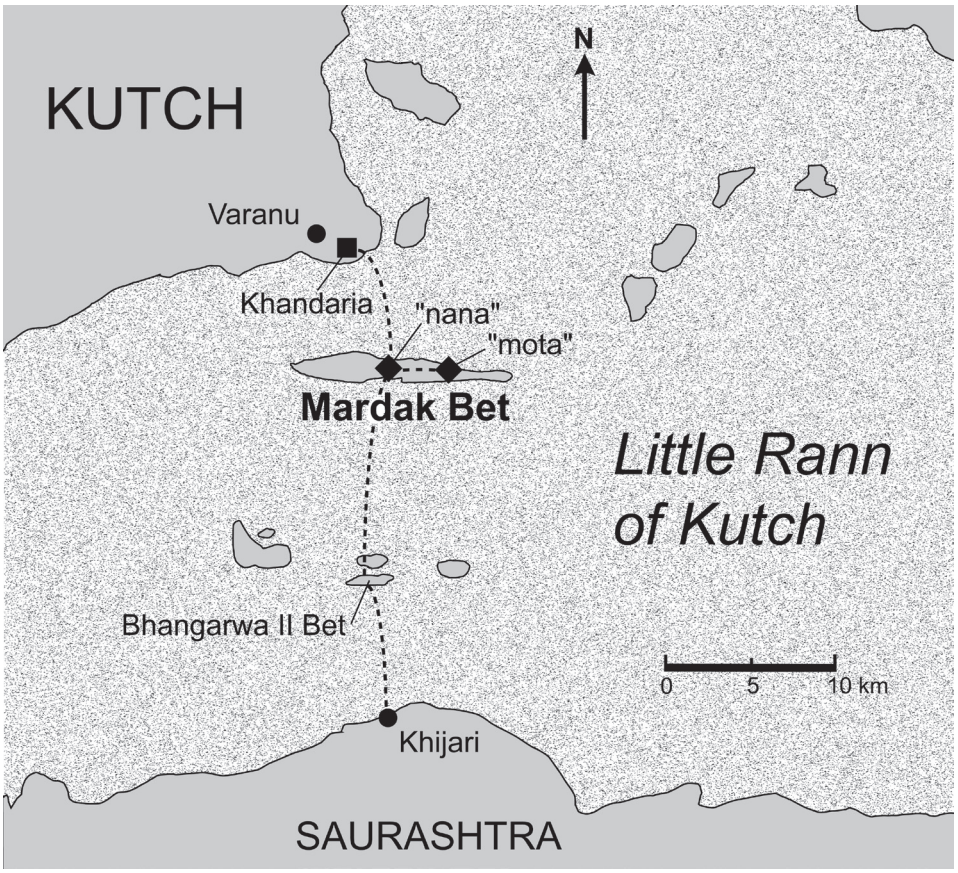


Figure 8.17 Little Rann of Kutch, Gujarat.

Figure 8.18 First attempt to reach Mardak Bet in the Little Rann of Kutch, Gujarat.

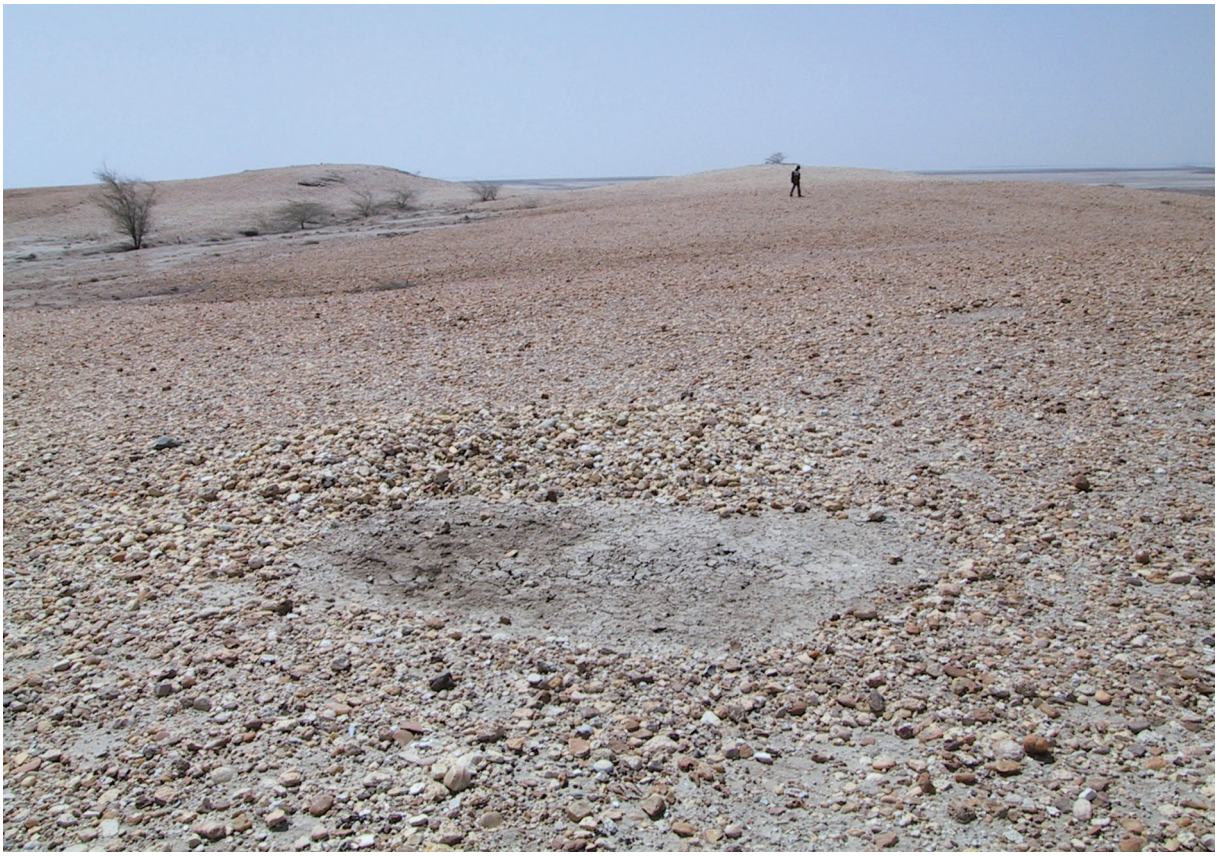


Figure 8.19 Pit in agate bed at “nana” Mardak Bet.

Figure 8.20 Discarded nodules and window flakes at "mota" Mardak Bet.

Figure 8.21 Agate and jasper flakes along with ceramics found on Bhangarwa II Bet, 12 km south of Mardak Bet.

8.20) related to modern extraction activities (Singh 1999: 216; Trivedi 1964: 10-11) have likely obscured any evidence of earlier ones. There are, nonetheless, indications that ancient peoples did exploit these deposits. Numerous agate and jasper flakes, some with a heavy patina suggesting great antiquity, were found on the hillside at "mota" Mardak Bet. Similar flaking debris was also observed 12 km to the south on Bhangarwa II Bet (Figure 8.21). That small island was likely a processing point for raw material obtained at Mardak Bet as there are no agate sources on or nearby it. Finally, I have been informed by R.S. Bisht (*personal communication* 2004) that agate and jasper artifacts visually identical to the material occurring at Mardak Bet (which he has explored firsthand) are evident at the Harappan site of Khandaria (Bisht 1989a: 267), which is located less than 10 km away near the village of Varanu on the northern shore of the Little Rann.

- Eastern Gujarat and Saurashtra

There are a number of other agate occurrences in Gujarat that, even though they were not sampled and/or analyzed for this study, should be noted as potential Harappan sources.

Multiple types of microcrystalline silicates (including some that can be heat-treated to produce carnelian) occur around Kapadvanj, in the eastern part of the state (Campbell 1879: 15), approximately 100 to 110 km northeast of Lothal. Nodules as large as ten pounds (≈ 4.5 kg) were reportedly once gathered near that town as well as from the bed of the Májam River, some twenty kilometers to the north (Campbell 1880: 199-200). Samples were collected from the Kapadvanj source in early 2009 but have not yet been analyzed.

A wide range of microcrystalline silicates, both occurring in and eroded from amygdaloidal basaltic rocks of the Deccan Traps, are found across the Saurashtra Peninsula (also known as Káthiáwár). Below I discuss just a few of the more notable occurrences.

A black and white veined material that was once the "most valued Cambay agate" (Campbell 1880: 200) occurs some 50 km west-southwest of Lothal around Ránpur village in the Ahmedabad District (not to be confused with the site of Rangpur [Rao 1963], which lies 22 km east of that settlement along the Bhadar River). The geographic coordinates provided by Chatterjee (1963a: 166) suggested that the actually source of this stone might be at nearby (5 km east) Nágnesh village where an exposed "bed of sphæroidal felsite, whose nodules have a nucleus of chalcedony" was reported (Fedden 1885: 26). However, during two different trips to that area I failed to locate any gem-quality agate.

Miocene conglomerates (Figure 8.22) in the vicinity of the towns of Bhavnagar and Gogha in the Bhavnagar District are "agatiferous" and closely related to the those of the Ratanpur area (Mohan and Chatterji 1956: 351; Fedden 1885: 110), which lay directly opposite to them across the Gulf of Khambat. Although the agate nodules found here are of excellent quality, they could have only been used to make very small beads as none observed were larger than three centimeters in size (Figure 8.23). Similar conglomerates containing "agate, chalcedony, flint, jasper, etc." are also reported farther south near Lakhanka and between Badi and Chhaya (Gujarat State Gazetteers 1961b: 22). Still further south, in the southern part of the Amreli District (not pictured on Figure 8.6), "milky white chalcedony and agate form geodes in the traps near Khamba, while pebbles of agate and chalcedony are found loose in the nala between Hemal and Sokhda" (Gujarat State Gazetteers 1961a: 17).

The Rajkot and Jamnagar districts of northern Saurashtra are especially rich in ornamental microcrystalline silicates. Chatterjee compiled (1963a: 167 – from Fedden 1885 and other sources) information on a number of locations (Khijaria, Latipur, Jiwapur, Badanpur, Khakhra, Varatia) at

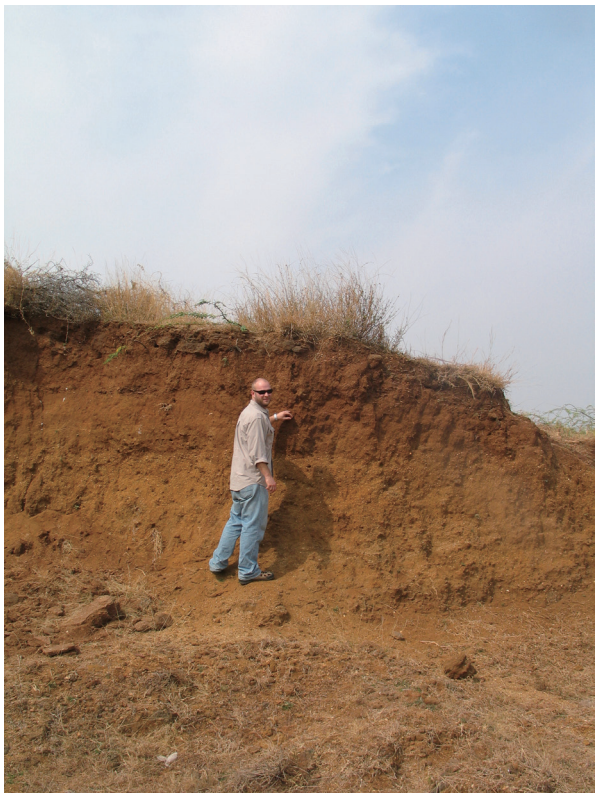


Figure 8.22 Miocene agate gravel beds near Gogha, Bhavnagar District, Gujarat.

Figure 8.23 Detail of tiny agate nodules in the gravel beds near Gogha.

which agate, moss agate and chalcedony occurred, both as loose nodules and in amygdaloidal trap rock. The jasper source near Khokhari village that was highlighted earlier (Figure 8.2) is also located in this region as are numerous ancient settlements including Kuntasi (Dhavalikar 1992) and Gola Dhoro (Bhan *et al*. 2004). Storage bins containing sorted blocks of variegated jasper found at the latter site provide evidence that Harappans were acquiring microcrystalline silicate resources from this region.

Agate deposits elsewhere in South Asia

Gujarat may have been the richest agate source area in South Asia but it was not the only one. In this section, I review other potential sources in the Subcontinent with a particular emphasis on those in and adjacent to Greater Indus region.

- Peninsular, Central and Eastern India

In addition to the agate deposits of Gujarat, P.K. Chatterjee noted, in his *Annotated Index of Indian Mineral Occurrences* (1963a: 165-168), sources in the states of Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Mysore, Orissa, Rajasthan and Uttar Pradesh. There is no need to review all of them in detail here as most are unlikely to have been utilized by Indus Civilization peoples. For example, the varied agate deposits in the Deccan Traps of central Maharashtra (recall Figure 8.3) are important raw material sources for Khambhat lapidaries today (Vidale 2000: 42). Those same occurrences might have even been exploited by the Late Harappan peoples who were dwelling around 80 km from them at Daimabad (Sali 1984). However, they are unlikely to have been utilized to any great extent (if at all) by Indus Civilization beadmakers. To my knowledge there are few (if any) types of ornamental microcrystalline silicates in Maharashtra or elsewhere in Peninsular India that are not also available in Gujarat. There would, therefore, be little reason for Harappans in the Indus Valley proper to bypass source areas like Kutch, Saurashtra or Ratanpur, in order

to obtain agates from that region. They were even less likely to have acquired such materials from still more distant deposits in southern India. The agate occurrences of Central India, being comparatively near the Greater Indus region, would have been much more viable alternate sources for residents of Harappa.

Chatterjee noted (1963a: 168) that "agate, jasper, carnelian, moss [agate] and onyx are common in the beds of the Banas and other rivers" in eastern Rajasthan. In this same general area, Hardie described (1829: 117-119) primary context agate-jasper at Sawah and at Buneerah. Malwa-Rajasthan Tradition Ahar-Banas culture complex (Shinde *et al*. 2005) peoples at settlements like Gilund, Balathal and Ahar would have been in close proximity to these occurrences. Slightly farther to the east, the agate sources of the Sehore-Bhopal region in western Madhya Pradesh (Chatterjee 1963a: 168) may have been among those exploited by beadmakers working at Ujjain during the historic era (Banerjee 1959) and at nearby Kayatha during the Chalcolithic Period (Ansari and Dhavalikar 1971). Harappan-like large storage jars and a cache of 40,000 steatite microbeads (ibid.: 338, 342, Plate 7) recovered in Period 1 (ca. 2000 to 1800 BC) levels at the latter site indicate that people dwelling there had contacts with later phase Indus Tradition peoples. It is not clear if those links extended from Kayatha north-northwest toward Harappan/Late Harappan groups in the Upper Indus Basin/Gangetic Basin region or southwest toward those in Gujarat. What is clear is that trade networks connecting the Malwa Plateau region with the northern Subcontinent (the Ujjain to Taxila route – Eggermont 1966) were firmly in place by the early historic era. The storage jars and steatite beads from Period 1 at Kayatha may represent the initial establishment of those northern networks. This is important for the current discussion because it was around this time that interaction between peoples of the northern and southern reaches of the Greater Indus region diminished (Kenoyer 2005b), thus making the microcrystalline silicate resources of Gujarat unavailable to beadmakers at northern cities like Harappa. The agate deposits of the Malwa Plateau region might have become important new sources for them when this happened.

It is also quite possible that some agate from sources adjacent to the Gangetic Basin, such as those in the Mirzapur and Banda areas (noted on Figure 8.5) of the Vindhya Range (Chatterjee 1963a 168; Kumar 2005: 363; Srivastava *et al*. 1983), ended up at Indus Civilization sites in Haryana or the Punjab. I have recently examined (Law *in preparation*) the stone artifacts from the early levels of Lahuradewa, District Sant Kabir Nagar, Uttar Pradesh (Tewari *et al*. 2006). Those levels are filled with steatite beads that would appear to be Harappan in origin as well as beads and tools evidently made from agate available in the Gangetic region. If the steatite beads were indeed coming from the west then agate from sources in the east could very well have been moving in the opposite direction. This movement might have been even more pronounced during the first half of the second millennium BC, as the Late Harappan demographic center of gravity in the northern part of the Indus world shifted toward the east (Possehl 1997c).

- Northern deposits

Agate deposits located in the mountainous regions north of the Upper Indus Basin are small in size, widely scattered and, in certain instances, extremely remote. Most are associated with volcanic rocks. Two occurrences – one in the Khewra Trap of the eastern Salt Range and the other in the Pir Panjal Trap of western Kashmir, were previously (p. 153) noted as possible sources for the purplish-colored chert/chalcedony found in Early Harappan levels at Harappa. "Small geodes of reddish quartz and chalcedony" were observed (Wynne 1878: 75) in the former formation while "pear-shaped amygdules of chalcedony, reaching to two or three inches in length" were reported (Lydekker 1883: 218) to occur in the latter. In the NWFP, agate nodules derived from with

island-arc volcanics are found in the Dir Kohistan area (Kazmi and Jan 1997: 477). Their appearance has not been described, however. Godwin-Austen reported (1867: 362) that "fine agates and cornelian are to be found in a small ravine" at Kyamgo Traggar, north of Pangong Lake not far from the Tibet-Kashmir border. This occurrence lies over 5100 m above sea level.

It is quite possible that agates from these northern sources found their way into bead workshops at Harappa. In this book, I demonstrate that both Early Harappan and Harappan residents of the site were acquiring other raw materials derived from sources in the Salt Range (chert and alabaster) and western Kashmir (lead and, perhaps, alabaster). The Dir agate source area lies along what may have been a route from the Indus Valley to northern Afghanistan and the Harappan outpost of Shortughaï. Finally, extreme elevation evidently did not impede Northern Neolithic peoples, such as those periodically dwelling at Burzahom in the Kashmir Valley, from crossing the plateau of Tibet during the prehistoric period (Xu 1991). Early Harappans and/or Harappans at settlements in the Himalayan foothills such as Sarai Khola and Manda might have indirectly acquired agates from remote sources like Kyamgo Traggar through interaction with those northern highlanders.

- Sindh and Balochistan

The agate deposits of Sindh and Balochistan, like those in the north, are small and sporadic. A source is reportedly located at Nagar Parker (Kazmi and Jan 1997: 477) in the southeastern corner of Sindh (noted on figures 8.4 and 8.6) near the northern shore of the Great Rann of Kutch. The material found there and its mode of occurrence has not been described but it is quite possibly related to the agate deposits directly to the south on the opposite side of the rann in eastern Kutch. Although no prehistoric sites are reported in the immediate vicinity of Nagar Parker (to my knowledge, no survey has yet been conducted there), toward the west a number of Indus Civilization settlements (Baloch 1973), including Kot Kori (Khan 1979), have been identified in the southern part of Sindh.

In the northern part of the Sindh Kohistan's Laki Range – a north-south running chain of hills that forms part of the western boundary of the Indus Valley, W.T. Blanford first reported (1869: 5-6) "trap" rock that is "slightly amygdaloidal and contains agates." He later identified these thin, weathered beds of basalt and volcanic tuff as distant outliers of the Deccan Traps (1879: 36-37). Unfortunately, like many geologists then and now, Blanford did not see fit to describe in detail the appearance (size or color) of the actual agate nodules/amygdales within them and no description has since been published. Nevertheless, this occurrence should be regarded as an important potential source due of its correlation to the Deccan Traps and because of its close proximity to a number of Early Harappan and Indus Civilization settlements including Amri (≈ 10 km east), Ghazi Shah (≈ 45 km northwest) and Chanhu-daro (≈ 40 km east). Agate beadmaking was a major industry at Chanhu-daro (Mackay 1938: 52; Sher and Vidale 1985) and a few examples of "chalcedony" were among stone tools debris recovered at Amri (Cleland 1977: 84).

Most ornament-quality microcrystalline silicates in areas of Balochistan adjacent to the Indus Valley are red, green and variegated jaspers associated with ophiolite sequences, such as those in the Zhob and Las Bela districts (*personal observations*). Translucent and semi-translucent varieties do sometimes occur, however. Charles Masson noted (1844: 463) that "agates ... are found in the hills east of Kalat" in central Balochistan but he did not describe them. Although some such stones from this area might have found their way down to Indus Tradition peoples at plains sites like Mehrgarh and Nausharo (≈ 100 km to the west-northwest), they probably were not of especially good quality.

Agates occurring in western Balochistan's Chagai District are a different story. Excellent quality

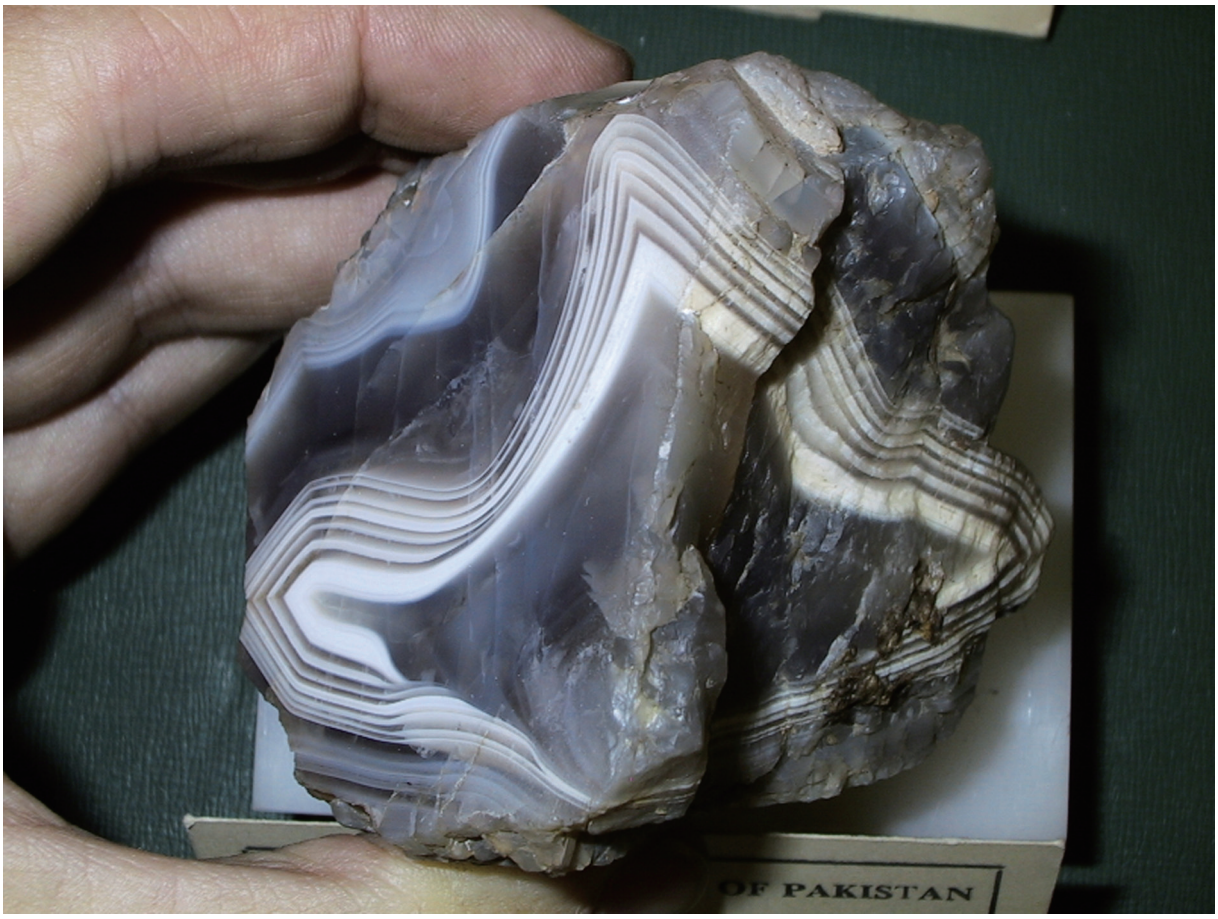


Figure 8.24 Brown and white banded agate from Taftan railway station, Chagai District, Balochistan. GSP-Quetta Museum, Case 41.

examples can be found within and eroding from the andesitic lavas of the region's volcanic formations. Of these agates, Heron [Crookshank] wrote (1954: 131) that "they are as good as the similar stones from Broach [Ratanpur], India, and ... often display novel patterns not found among the Indian stones." An example of one – collected near Taftan railway station and now on display at the Geological Survey of Pakistan's museum in Quetta, can be seen in Figure 8.9. Others are reported at the extinct volcano known as Koh-i-Sultan (Iqbal *et al.* 1993) and in the desert 45 miles (72 km) west of Nokundi (Heron [Crookshank] 1954: 131). These agate sources are particularly important because of their proximity to the rich copper deposits and ancient smelting areas of the Chagai District and the adjacent Gardan Reg region of southwestern Afghanistan (Dales 1992; Vredenburg 1901). Analyses conducted for this study indicate that some copper ore fragments at Harappa likely came from sources located to the west of the Indus Valley (see Chapter 12). If those western sources happened to be in the Chagai District (this is not yet demonstrated but it is a distinct possibility) then agates from the area might have been acquired as well.

Agate deposits beyond the Greater Indus region

In this final section, I provide a brief overview of agate occurrences in Afghanistan, Central Asia, Iran and Arabia – lands outside of the Greater Indus Region with which Harappans had demonstrated contacts (see p. 47).

There is not a great deal of published information regarding the agate occurrences of Afghanistan. In their review of the natural resources of Mundigak – a Bronze Age settlement in the southern part of

that country, Jarrige and Tosi mentioned (1981: 137) that various kinds of microcrystalline silicates "are available in the talus slopes of the Hindu Kush in form of pebbles of different sizes." Closer sources were available to the residents of that site, however. Just 45 km to the southeast, C.L. Griesbach reported (1881: 52, 59) amygdales filled with agate and carnelian in the volcanic trap rock around Kandahar city.

Agate sources in Central Asia, although remote, bear mentioning here because of the clear contacts that Harappans had with BMAC peoples, both in the southern part of that region (Hiebert 1995) and in the Indus Valley (Parpola 2005). Gem quality chalcedony is reportedly found in the Turkestan Range of Uzbekistan (Clarke 1970: 534) and agates are mined today in Tajikistan (Nokleberg *et al*. 2005: 78). Rich deposits also occur in the Irtysh and Pavlador regions of Kazakhstan (Bryksina *et al*. 2001; Yerofeyev and Matsui 1986).

Moving now to sources in Iran, Whitehouse noted (1975: 130) that "nodules of red and orange carnelian erode out of Tertiary sediments" on the Bushehr Peninsula. This occurrence's location adjacent to the Persian Gulf might have made it an important source for consumers in ancient Mesopotamia. However, the "most celebrated Iranian agate localities are in the central and eastern" part of the country (Nazari 2004: 21). Around the Khur area, primary context banded agate nodules occur within tuffaceous andesite (ibid.). Extensive secondary context deposits can be found in Iran's broad salt deserts (dasht) and inland deltas. The explorer Henry Savage Landor marveled (1902: 79) at the "handsome agates" and other colorful stones spread across the wastes of the Dasht-e Lut. Hakemi wrote (1997: 15) that "carnelian is found in considerable quantities in the Lut flood plain." Finally, Tosi noted (1969: 374) that "with regard to cornelian ... numbers of little pebbles of this stone, with a diameter often exceeding 3 cm, may be collected along the dried out beds and ancient branches" of the Helmand River delta near the site of Shahr-i-Sokhta.

Lastly, at al-Ghail, near the northern tip of eastern Arabia's Oman Peninsula, Burkhart Vogt reported (1996: 112) that at outcrops bearing "clear traces of opencast mining and quarrying ... banded agate and carnelian of different varieties and qualities appear in thick veins and are easily accessible." Although it may seem unlikely that raw material from this distant source was shipped all the way to bead workshops in the Indus Valley, Harappans did have a significant presence in this region and so the possibility cannot be completely ruled out. Agate-carnelian occurrences can also be found in central Yeman (Overstreet *et al*. 1985: 319). However, there is no evidence, at present, that Harappan interaction networks in Arabia extended that far to the south.

Section conclucion

There are several reasons why it was necessary to provide a full overview of agate occurrences in the Greater Indus region and beyond even though only three of the deposits discussed above were actually sampled and analyzed. Firstly, it allows the provenience study that follows to be put into perspective. Although the results of this study bode well for future research of this kind, it was important to make clear that they are based on the analysis of only a limited number of potential sources. Secondly, the overview will aid in the interpretation of the study's results. We will see that while most of the agate artifacts analyzed seem to be closely related to the one of the sources in the geologic dataset (described at the beginning of the next section), there are a handful that clearly do not. The possible provenience of those standouts can be better judged now that a broad picture of occurrences has been presented. Lastly, it needed to be shown (insofar as the published information made it possible) that all agate deposits are not the same. Like so many of the other materials examined for this study, the appearance, size and quality of microcrystalline resources vary considerably

from occurrence to occurrence. Just because "agate" is reported at a particular locality does not mean that stone that Harappan beadmakers would have found suitable occurred there.

A GEOLOGIC PROVENIENCE STUDY OF AGATE ARTIFACTS FROM HARAPPA AND FIVE OTHER SITES

In this half of the chapter, I recount how agate artifacts from Harappa and five other Indus Tradition sites were analyzed (using INAA) and compared (using CDA) to samples from three sources in Gujarat and a set of artifacts from the site of Shahr-i-Sokhta that were treated as proxy samples for sources in eastern Iran. The main objective was to evaluate the widely held assumption that Harappan agate primarily came from Gujarat and that the principal sources within that state were the Ratanpur area deposits. Noting the agate occurrences at Mardak Bet and in eastern Kutch, Ratnagar had asked (2004: 146) "did the Harappan inhabitants of Dholavira know of these sources?" This was a good question. Seemingly, those agate occurrences should have been far more accessible to the Harappans of that city than the Ratanpur area deposits, which are located hundreds of kilometers to the southeast (recall Figure 8.6). Although no artifacts from Dholavira were available for this study, it was reasoned that if Gujarat was the principal region from which Indus Civilization peoples obtained agate resources, then it should be possible to indirectly address Ratnagar's question through provenience analyses of artifacts from other Harappan sites in northern Gujarat and the Indus Valley proper. Before detailing and interpreting the results of this study, the selection of source (and proxy source) samples for the geologic dataset are discussed and the agate artifacts that were analyzed are introduced.

Agate source and proxy source samples

For this study, agate samples were collected from the three potential sources in Gujarat – Mardak Bet (source code = GMB, Figure 8.25), Khandek (GKK, Figure 8.26) and Ratanpur (GRTP, Figure 8.27). Although material-wise, each of these secondary context deposits is extremely variable, the samples selected for analysis represent a narrow range of types. Most (but not all) are either natural carnelian or the type of yellowish-brown, iron-impregnated agate that will develop the red-orange hue characteristic of carnelian when heat-treated. Twenty samples from each source were selected (note that only 12 of the 20 from GMB and GKK are actually pictured on figures 8.26 and 8.27 respectively). Earlier I described how agates collected from across a three kilometer-long zone at Ratanpur were treated as coming from a single source. The same will be the case for all samples acquired at GMB (even though the set contains agate from both "nana" and "mota" Mardak Bet) and GKK.

I was unable to visit any agate occurrences other than the three just discussed, which was unfortunate as it would have greatly benefited this study to include samples from a geologic source outside of Gujarat for comparison. A solution to this problem was provided by Dr. Massimo Vidale (l'Istituto Italiano per l'Africa e l'Oriente [IsIAO], Rome) when he generously granted me access to agate manufacturing debris he had collected from the surface of Shahr-i-Sokhta – a Bronze Age urban center in eastern Iran (Tosi 1982). These artifacts, which consisted of chunks of both variegated agate-carnelian and bluish-hued chalcedony (Figure 8.28), were, in all likelihood, derived from known occurrences (described in the previous section) near that site or in the general region. The decision was made to use the debris fragments as proxy samples for a "source" (source code S-i-S) in eastern Iran. It is recognized that the 14 samples selected might not be from the same locality and that some samples, potentially all of them, might not even be from a source in Iran. Nevertheless,

Figure 8.25 Agate samples from Ratanpur, Gujarat (source code = GRTP).

Figure 8.26 Agate samples from Khandek, Gujarat (source code = GKK).

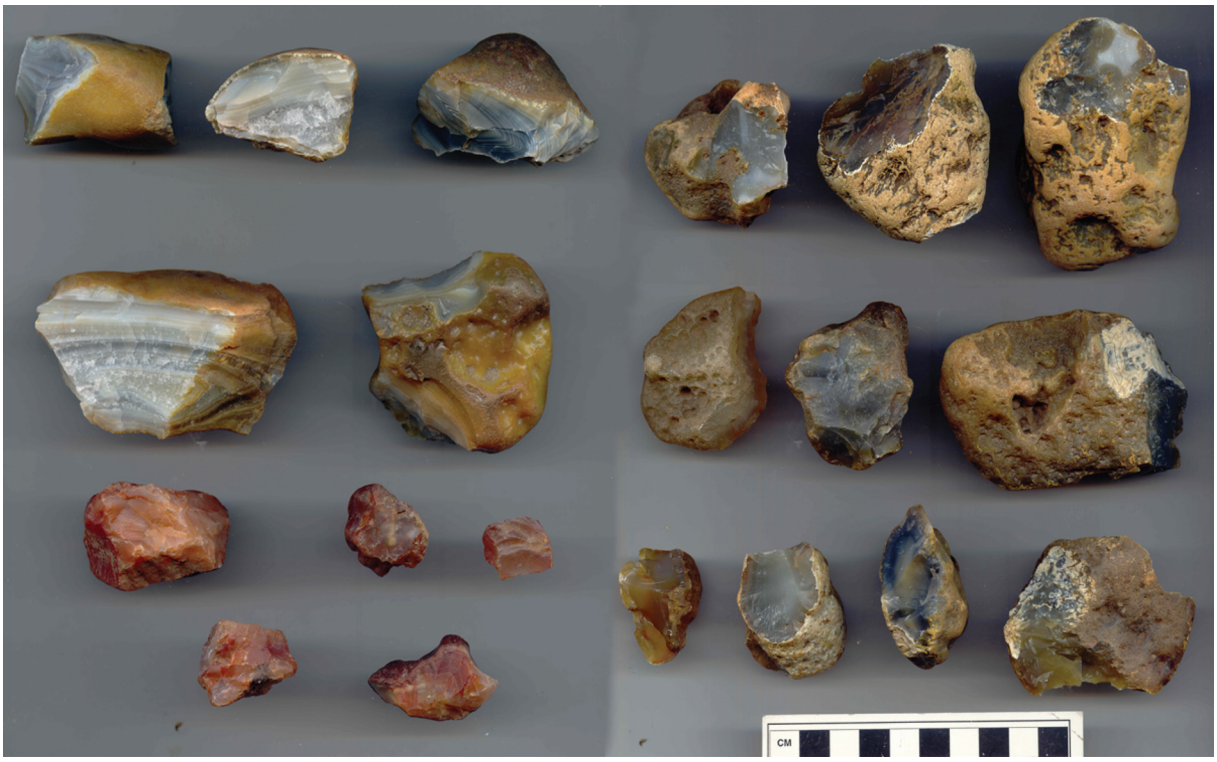


Figure 8.27 Agate samples Ratanpur, Gujarat (source code = GRTP).

Figure 8.28 Archaeological agate fragments from Shahr-i-Sokhta, Iran (source code = S-i-S).

with those qualifications, they were included in the geologic dataset.

Agate artifacts

For this study, 24 agate artifacts from Harappa and 32 from five additional Indus Tradition sites were analyzed and compared to the geologic dataset outline above.

Artifacts from Harappa

The 24 agate artifacts from Harappa that were selected for analysis come from various periods and parts of the site (Figure 8.29). They are numbered AH-1 to AH-24 for this study. Their original HARP numbers and context information are listed in columns two and three of Appendix 8.5. Only 11 of the 24 artifacts were recovered from secure stratified contexts. One comes from Kot Diji Phase levels while the remaining ten come from Harappa Phase levels (three from Period 3B and seven from Period 3C). Nineteen of the 24 artifacts were recovered on mounds E or ET. Of the remaining five, two came from Mound AB and one from a layer of Harappan dump debris in the cemetery area. The exact provenience of two artifacts (AH-1 and AH-2) is unclear. They are agate-chalcedony nodule fragments (Figure 8.30) from pre-HARP excavations that had been stored in the Harappa Museum's Reserve Collection of large stone objects. In fact, these are the two biggest agate artifacts yet recovered at Harappa (AH-1 weighs approximately 0.7 kg and AH-2 weights around 4 kg). Given that they are from the excavations of the 1920s and 30s, it is most probable that they come from Harappa Phase levels either on Mound AB or F.

The set of agate artifacts from Harappa (Figure

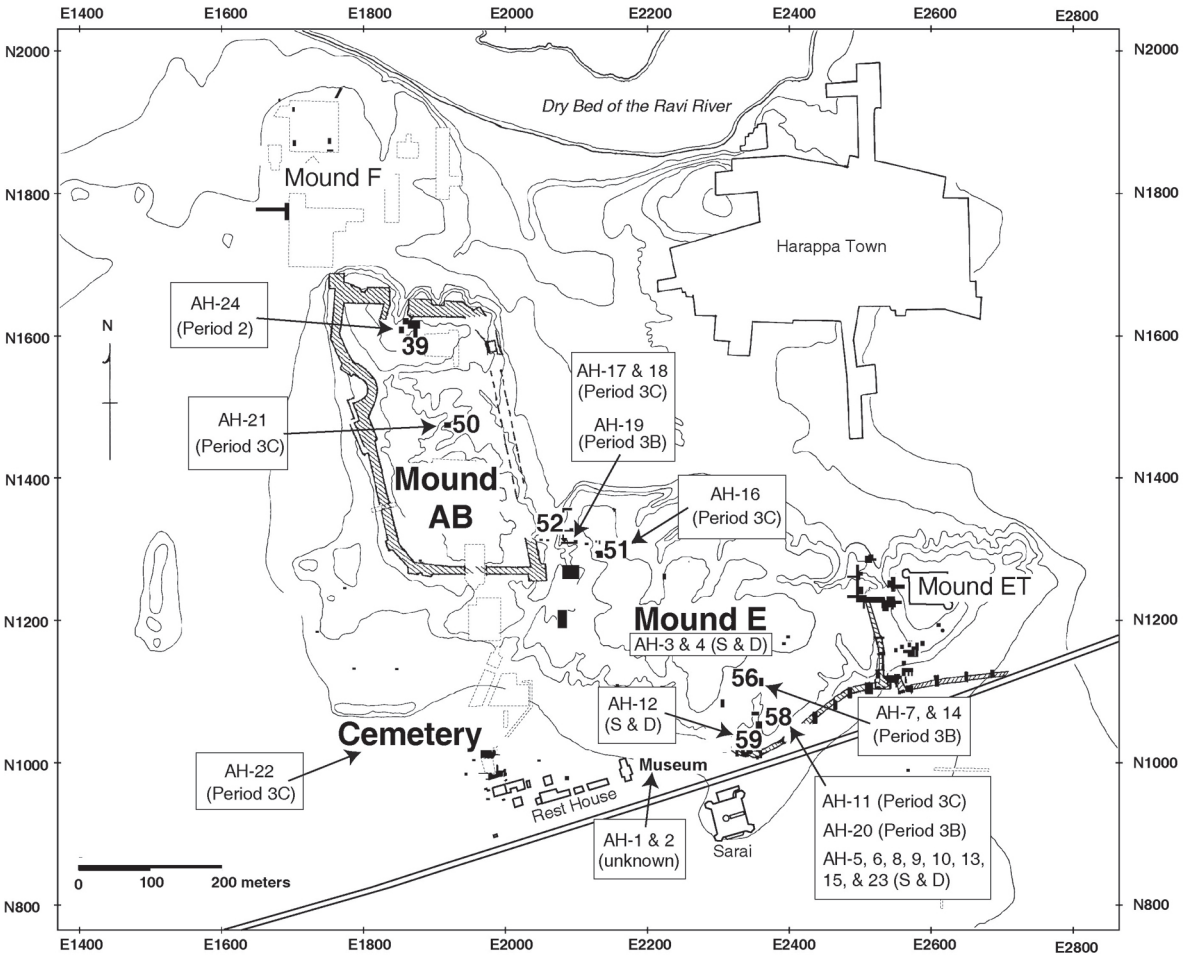


Figure 8.29 Spatial and period-wise distribution of analyzed agate artifacts from Harappa.

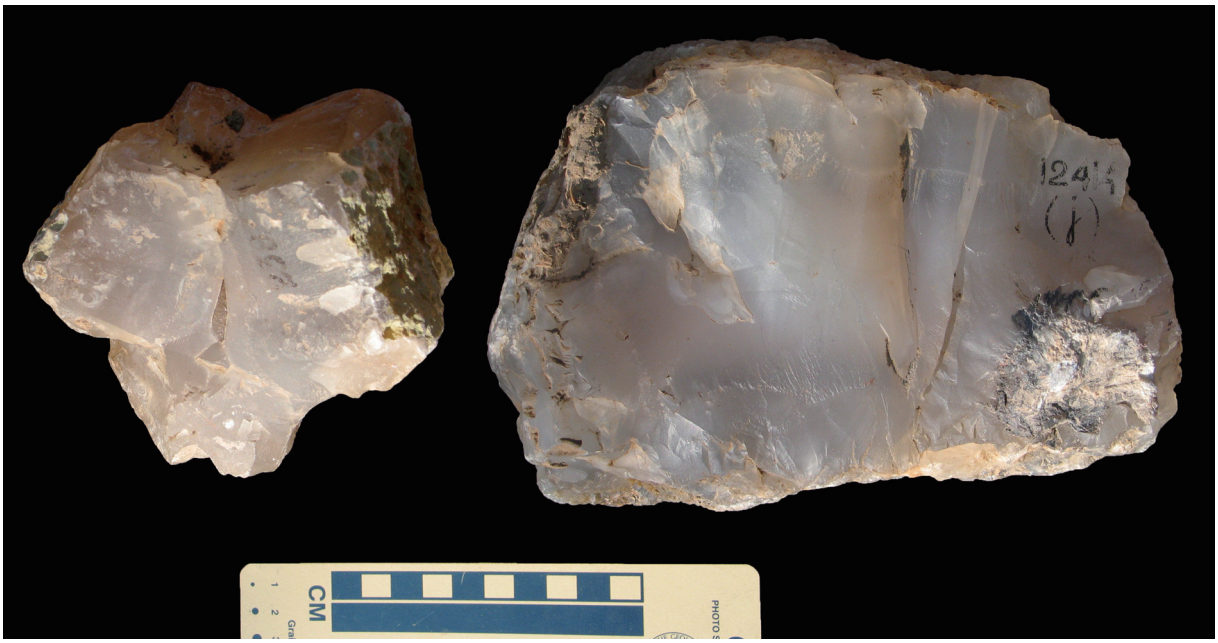


Figure 8.30 Two large agate nodule fragments from previous excavations at Harappa analyzed for this study. Left – HM 2397 (AH-1). Right – HM 12414 (AH-2)

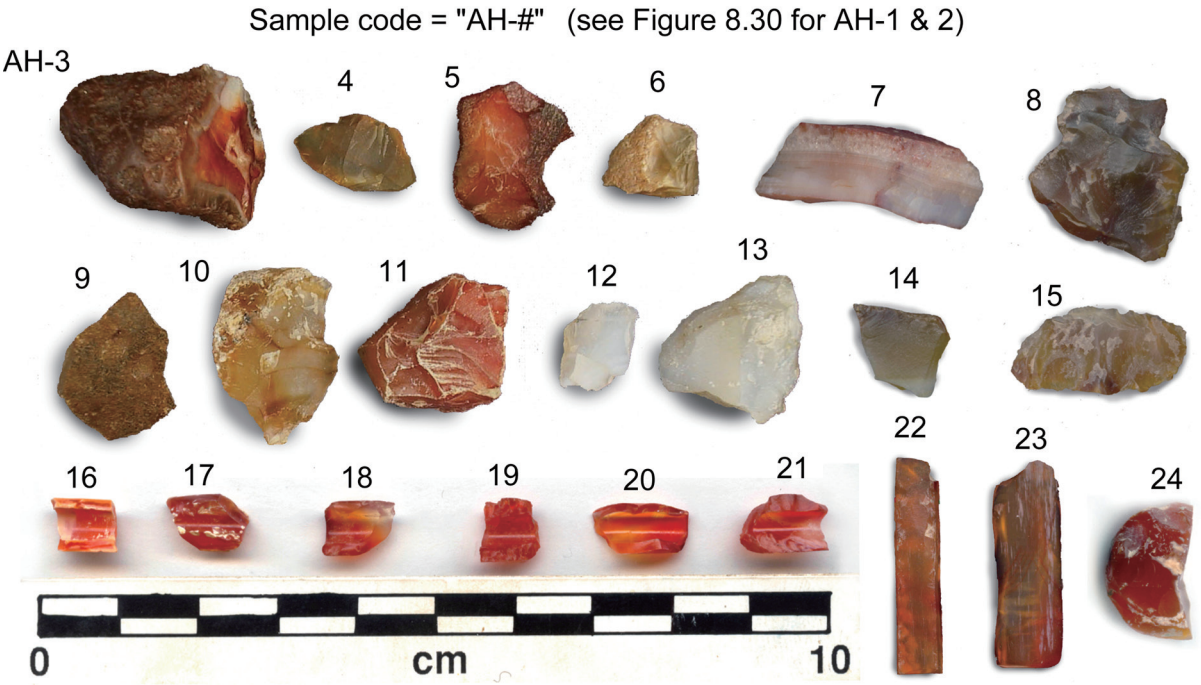


Figure 8.31 The remaining agate artifacts from Harappa analyzed for this study.

8.31) includes thirteen nodule fragments or flakes (AH-3 to AH 15) in addition to the chalcedony nodules just discussed. Examples of carnelian, yellowish-brown agate and semi-translucent chalcedony were selected. I have observed each of these types at all three of the potential sources in Gujarat.

The remaining items in the Harappa agate artifact dataset are all bead fragments. Eight are broken pieces of classic Harappan-style long-barrel carnelian beads (AH-16 to AH 23). A complete example (which was not analyzed) is provided on the figure for comparison. Because this style of bead was only manufactured during the latter half of the Harappa Phase (J. Mark Kenoyer *personal communication* 2007), it is possible to say that the one example (AH-

23) that was recovered from a non-secure context is very likely from either Period 3B or 3C. Importantly, agate-carnelian nodules large enough to make these long beads are rare. The little (≈ 3 cm) carnelian pebbles Tosi described (1969: 374) near Shahr-i-Sokhta would have definitely been too small. Nodules of sufficient size are known mainly to occur in Gujarat at Ratanpur, Kapadvanj and Mardak Bet (Trivedi 1963: 9-11). Although I did not observe any nodules bigger than about 7 cm at Khandek in eastern Kutch, in all likelihood any larger ones that had once been on the surface there were gathered up long ago.

A fragment of a circular-shaped carnelian bead (AH-24) from Period 2 levels on Mound AB rounds out the Harappa agate artifact set.

Artifacts from five other Indus Tradition sites

In addition to the proxy source samples from Shahr-i-Sokhta, Massimo Vidale kindly provided agate debris fragments related to his work on craft activity areas at the sites of Mohenjo-daro (Vidale 1987a) and Chanhu-daro (Sher and Vidale 1985) in Sindh. The seven artifacts from Mohenjo-daro (Figure 8.32 A) were collected from among lapidary debris on the surface of the "Moneer" area and include examples of yellowish-brown agate, banded carnelian and chalcedony. Although it impossible to say with certainty, this debris probably dates to the latter part of the site's Harappa Phase occupation. The seven artifacts from Chanhu-daro (Figure 8.32 B) closely resemble those from Mohenjo-daro and, although they are from the site's surface, also likely date to the Harappa Phase.

Dr. Kuldeep Bhan (Department of Archaeology, Maharaja Sayajirao University, Baroda) generously provided three yellow-brown agate flakes (Figure 8.32

Figure 8.32 Agate artifacts from five Indus Tradition sites analyzed for this study.

C) recovered in Harappan Period levels at Nagwada in northern Gujarat. Importantly, this site is located just east of the Little Rann of Kutch around 60 km from the agate source at Mardak Bet.

Finally, Jean-François and Catherine Jarrige (Centre de Recherches Archéologiques Indus-Balochistan, Asie Centrale et Orientale at the Musée Guimet Paris), graciously provided a set of eight agate fragments (Figure 8.32 D) from the site of Mehrgarh. Seven are plain or banded chalcedony and one is carnelian. All are surface finds from the site's MR2 area, which would date them to Mehrgarh Period III (ca. 4800-3500 BC). The Jarriges also supplied seven broken carnelian beads (Figure 8.32 E) from their excavations at nearby Nausharo. Three come from levels (Period 1C and 1C/1D) around the site's Early Harappan-to-Harappan Phase transition (Jarrige 1993) while four are from Harappan Phase levels (Period III – ca. Period 3B at Harappa). The Mehrgarh and Nausharo artifacts are of particular interest because of those sites' location the foot of the Bolan Pass – a major route into the highlands of Balochistan and beyond to the Helmand Basin. People living there would have been well-placed to acquire agate from sources to the west of the Indus Valley.

Analysis and comparison

The sets of agate artifacts and geologic source samples introduced above were subjected to instrumental neutron activation analysis (INAA) following sample preparation and irradiation procedures outlined in Chapter 3. Out of the data that were returned, ten elements (Al, Co, Cr, Eu, Fe, La, Na, Sb, Sc and V) free of missing values were selected for use in comparisons of the two sets using canonical discriminant analysis (CDA). The measured concentrations of those elements in the source samples and artifacts are listed in the following appendices: GRTP = Appendix 8.1; GMB = Appendix 8.2; GKK = Appendix 8.3; S-i-S = Appendix 8.4; Harappa artifacts = Appendix 8.5; Mehrgarh and Nausharo artifacts = Appendix 8.6; Mohenjo-daro, Chanhu-daro and Nagwada = Appendix 8.7. In Appendix 8.9, the standardized (canonical) discriminant function coefficients for each of the figures in this chapter generated using CDA (figures 8.33 through 8.36) are listed.

First, the GMB, GKK, GRTP source and S-i-S proxy source samples were compared to one another as four sets of grouped cases (Figure 8.33). Good separation between the source-groups resulted. Exactly 85.1% of leave-one-out cross-validated grouped geologic cases were classified correctly. Most of the misclassification (overlap) that occurred was among the three Gujarati agate sources. Only one sample from S-i-S (noted on Figure 8.33) was misclassified as belonging to a Gujarati source (Mardak Bet) when it was cross-validated. That particular fragment – S-i-S_14 (Figure 8.28, *bottom row, fourth from the left*), is a piece of milky, semi-translucent chalcedony that is unlike the other samples (both the variegated agate-carnelians and the bluish-chalcedonies). Overall, however, it can be said that the Iranian agates are quite distinct from the Gujarati sources.

Next, the agate artifacts from Harappa and the five other sites were compared to the grouped geologic sources and plotted as ungrouped cases in relation to them (Figure 8.34). The first predicted group memberships (PGMs) for all of the artifacts are listed in the column labeled *Figure 8.34* in Appendix 8.8. In total, nine of the 56 artifacts had a first PGM in the S-i-S proxy source-group. Each of those nine are labeled on Figure 8.34. Four of them were from Harappa (AH-1, 2, 9 and 20), two were from Chanhu-daro (ACD-3 and 4), two were from Nausharo (ANS-5 and 6) and one was from Mehrgarh (AMR-2). The remaining 47 agate artifacts were assigned a first PGM in one of the three sources in Gujarat. Twenty-six of those had a PGM in the Mardak Bet source-group and 16 had a PGM in the Khandek source-group. Only five agate artifacts had a PGM in the Ratanpur

source-group. Two of these were from Harappa (AH-14 and 22) and one each was from Nagwada (ANG-1), Mehrgarh (AMR-8) and Nausharo (ANS-4).

The results of the initial CDA indicate that majority of the artifacts analyzed from Harappa and the other sites are geochemically more analogous to agate from sources in Gujarat than they are to agate artifacts from Shahr-i-Sokhta, which are presumably from a source(s) in the general vicinity of that site in eastern Iran. Furthermore, the majority of those artifacts predicted to belong to one of the Gujarati sources are more closely related to agate samples from Mardak Bet and Khandek in northern Gujarat than they are to samples from the Ratanpur area in the southeastern part of that state. However, rather than making interpretations based upon these initial results, two additional CDAs were conducted in an effort to 1) achieve better discrimination between the Gujarati sources and the S-i-S group and 2) achieve better discrimination between the three Gujarati sources themselves.

In order to achieve better statistical separation between agate samples from Gujarat and agate artifacts (presumably) from Iran, the cases that make up GMB, GKK and GRTP were combined into a single group that was designated "Gujarati sources." This new source-group was then compared to the S-i-S proxy source-group using CDA. Because only one discrimant score (function) is generated when two groups of cases are compared to one another, it is not possible to make a bivariate plot of the results. An excellent way to display univariate data of this kind is by using a *box plot* (sometimes called a box-and-whisker diagram). For the box plots shown on the next page (Figure 8.35), the two sets of grouped cases ("Gujarati sources" and S-i-S) and the ungrouped cases (agate artifacts from Harappa and the other sites) were plotted on a horizontal axis based on their first (and in this case only) discriminant scores. The distribution of the case data making up each group-source is divided into quartiles with the gray boxed areas depicting the second quartile, which encompasses the middle 50% of the cases. The range demarcated by the "whiskers" that extend from the left and right of the box depict the lower and upper 25% of the case data (the first and third quartiles respectively). The median of the grouped cases is depicted as a line dividing the second quartile box and individual cases that are outliers of the main group of cases are plotted apart as small circles. For more detailed information regarding the generation and utility of box plots see Shennan (1997: 45-46) or Benjamini (1988).

Excellent (although still not perfect) separation between the Gujarati sources group and the S-i-S group was achieved. Precisely 95.9% of leave-one-out cross-validated grouped cases were classified correctly. Proxy source sample S-i-S_14 (the labeled outlier of the S-i-S box plot in Figure 8.35) was again misclassified as belonging to a Gujarati source. Two samples from the Gujarati source-group (GMB-13 and GKK-14) were misclassified as belonging to the S-i-S group. By and large, however, the two source-groups are very distinct from one another as is evident from their box plots on Figure 8.35. Dashed lines were drawn to indicate the upper limit of the Gujarati sources' third quartile and the lower limit of the S-i-S group's first quartile (which does not include the outlier). The artifacts from Harappa and the five other sites are plotted below the box plots of the two source-groups using small vertical bars. A thin line connects each bar to a label on the left side of the plot that indicates the number of the artifact it represents. The PGMs for all of the artifacts are listed in the column labeled *Figure 8.35* in Appendix 8.8. In this CDA, the PGM of eleven artifacts was in the S-i-S group. Each of these is identified on the figure by an asterisk next to its label. They include the exact same nine predicted to belong to the S-i-S group in the previous CDA (Figure 8.34) plus AMD-2 and AH-13.

The results of this CDA once again indicate that the large majority of the artifacts analyzed are more

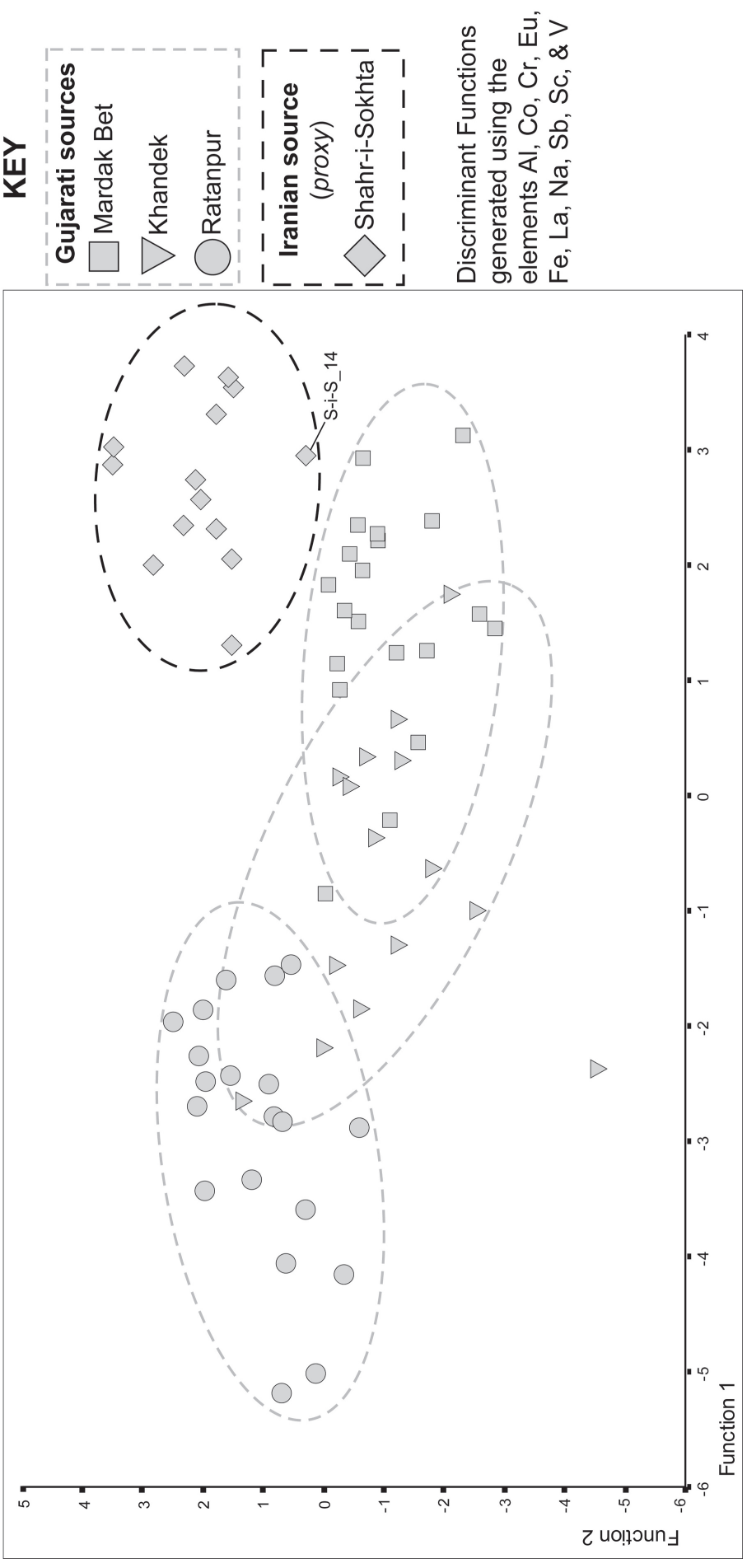


Figure 8.33 CDA comparison of Gujarati and Iranian (proxy) agate sources.

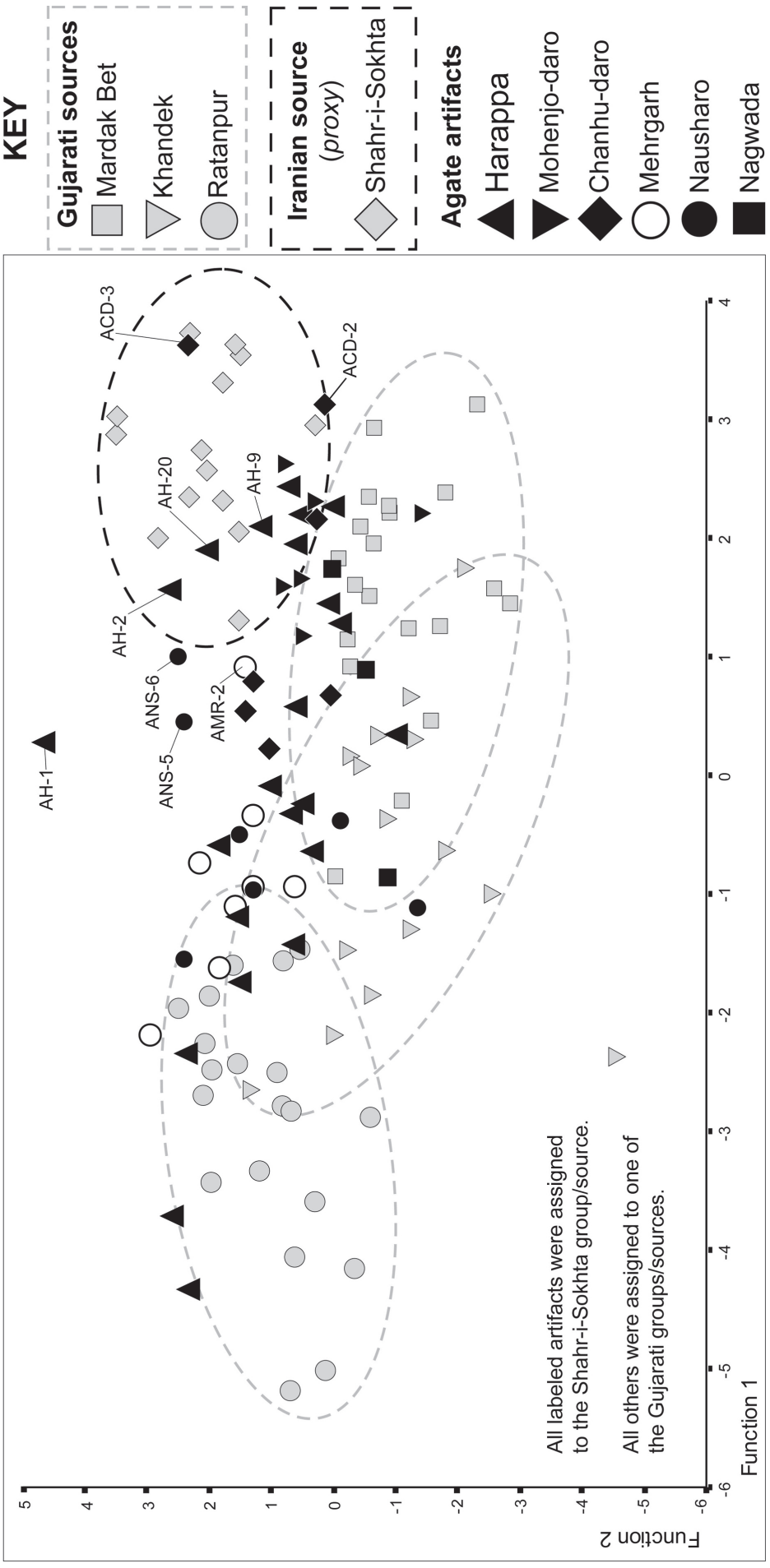


Figure 8.34 CDA comparison of agate artifacts to Gujarati and Iranian agate sources.

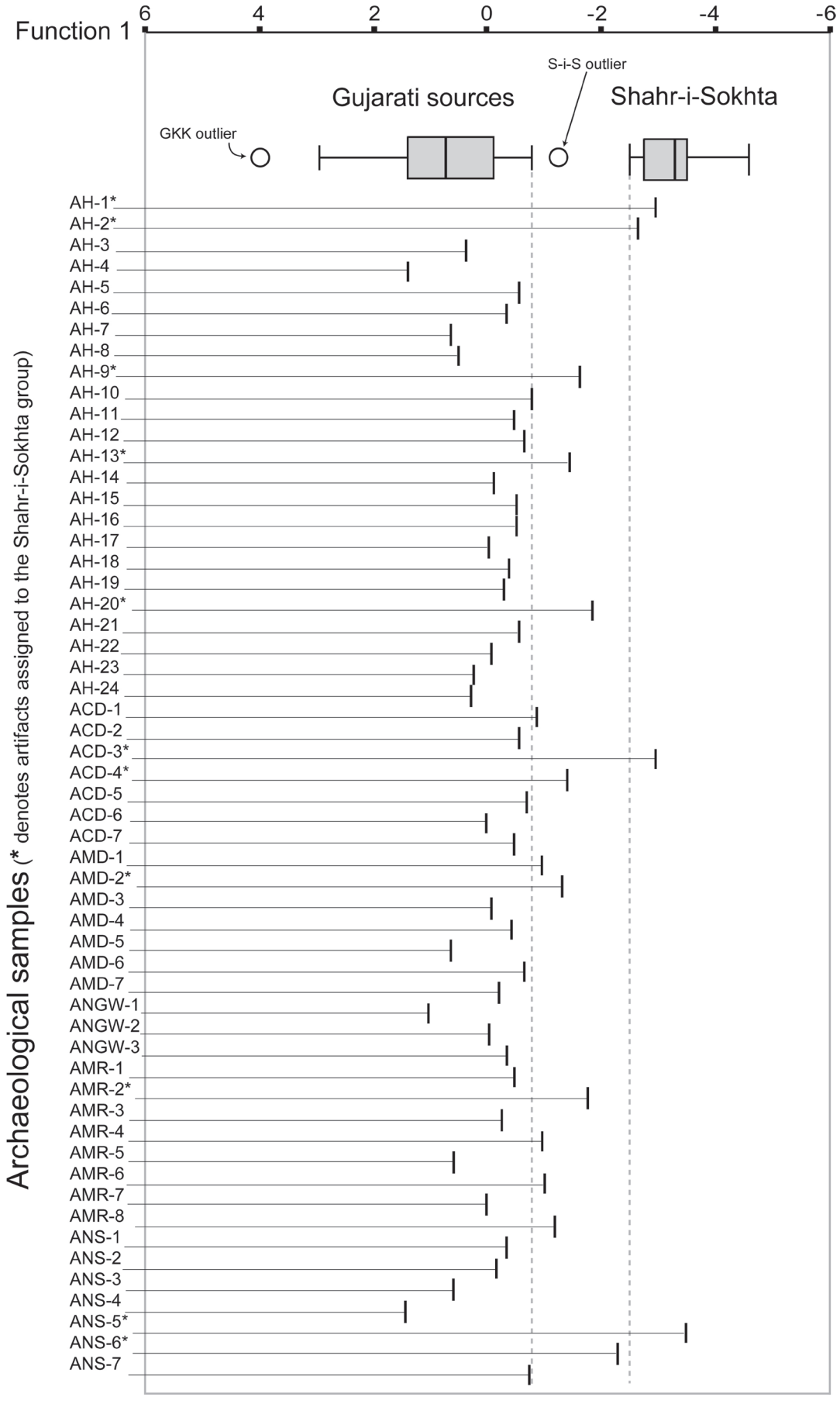


Figure 8.35 Gujarati agate sources compared as one group to the Shahr-i-Sokhta agates. Box plots generated and artifact points plotted using the CDA first discrimant function.

closely related to agate samples from sources in Gujarat than they are to artifacts/proxy source samples from Shahr-i-Sokhta. Note, however, that a number those that were assigned to the Gujarati source-group (AMR-4, 6 and 8, AMD-1 and ACD-1) lie above the upper limit of its third quartile while many of those assigned to S-i-S (AH-9, 13 and 20, ACD-4, AMD-2, AMR-2, ANS-6) plot below the lower limit of its first quartile. Such artifacts could genuinely be outliers of the source-group to which they were assigned. Alternately, they could be misclassified outliers of the opposite source-group. They could (and so could any other artifact in the set regardless of where it plotted) also be from a source not analyzed and simply assigned to the one in the set they more closely resembled.

For the final CDA, the three agate sources in Gujarat (GMB, GKK and GRTP) were compared to one another alone, without the S-i-S proxy source-group (Figure 8.36 A). Although good separation between the three was achieved, it was only slightly better than that for the original CDA (Figure 8.34). Exactly 86.7% of leave-one-out cross-validated grouped cases were classified correctly this time whereas 85.1% were classified correctly when the S-i-S source-group was included in the analysis. This indicates that nearly all of the overlap (misclassification of grouped cases) in the dataset is among Gujarati sources rather than between them and the Iranian artifact/proxy source samples. In this instance, the misclassifications were among the GMB samples (one was predicted to belong to GRTP) and the GRTP samples (one was predicted to belong to GMB and three to GKK).

On Figure 8.36 B, the 45 artifacts that had *not* been predicted to belong to the S-i-S proxy source-group in one of the previous CDAs are plotted as ungrouped cases in relation to the three Gujarati source-groups. The PGMs for each of those are listed in the column that is labeled *Figure 8.36* in Appendix 8.8. In this CDA, 27 artifacts were predicted to belong to GMB, 14 to GKK and four to GRTP. For the most part, these PGM assignments are unchanged from the first CDA (compare them to column labeled *Figure 8.34* in Appendix 8.8). Two artifacts that had been assigned to GMB now had a PGM in GKK and one that had been assigned to GRTP was now predicted to belong in GMB.

The results of this CDA serve to confirm what was evident in the initial one – that the majority of those agate artifacts assigned to a Gujarati source more closely resemble samples collected from Mardak Bet and Khandek than they do samples from Ratanpur. Before commencing with the interpretation of all the results in the next section, it should be noted that there are a number of artifacts that, while assigned to Gujarati sources in the first two CDAs, now plot apart from the three source-groups in Figure 8.36 B suggesting that they are somewhat distinct from them. Dashed ellipses (these and the ones on the other figures in this chapter are visual guides and not any form of confidence interval) have been drawn around the source groups and a few of the more distant outliers have been labeled. These artifacts might merely be outliers of the sources to which they are assigned. However, they could be from a different source in Gujarat or even from a source outside of that region. It is for this reason that caution is advised. The geologic data set that the artifacts are being compared is not necessarily representative of all of the potential sources to which Indus Tradition might have had access. Any interpretation of the results must recognize this element of uncertainty and include the appropriate qualifications.

Interpretation (and qualification) of the results

If the results of this study are taken at face value – i.e., without questioning any of the PGMs made during the CDAs presented above, then the following statements can be made: It appears that Indus Tradition peoples at the sites of Harappa, Mohenjo-

daro, Chanhu-daro, Nausharo, Mehrgarh and Nagwada acquired the majority of their agate from the Gujarat region. Most of it came from sources located in the northern part of that state rather than from the Ratanpur area, as is often assumed. There are some indications that Early Harappans and/or Harappans at all of the sites examined (except for Nagwada) may have also utilized some agate from sources other than the three in Gujarat that were analyzed. Some of those sources were probably located elsewhere in Gujarat while others may have been in regions to the west of the Indus Valley. Although this interpretation is, more or less, the same as that presented in the provisional conclusion for this chapter, there are multiple aspects of it that require qualification.

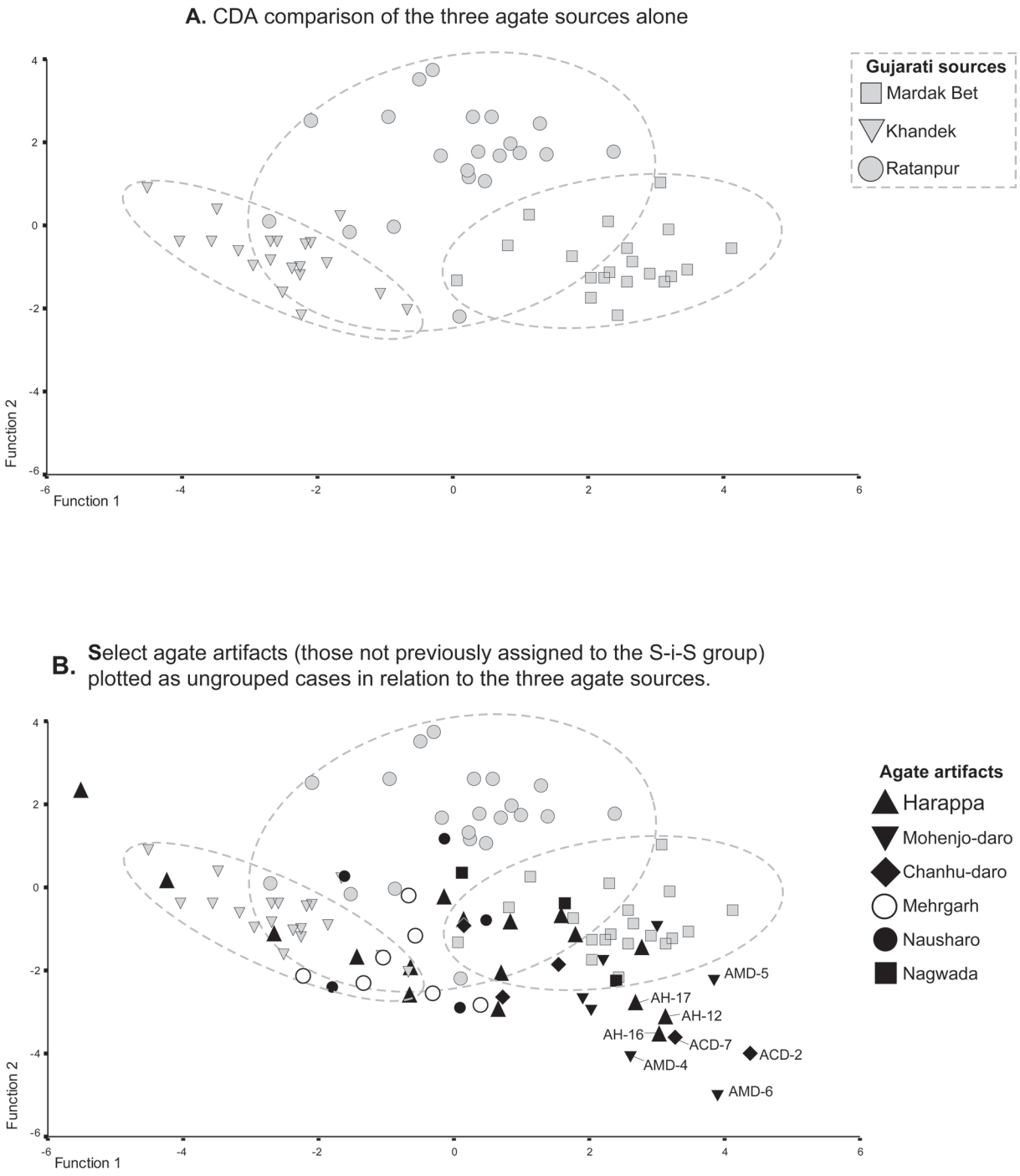
Artifacts from Harappa

First of all, consider the five agate artifacts from Harappa that were predicted in the first and/or second CDAs to belong to the S-i-S proxy source-group. Included among them are the two large agate-chalcedony nodule fragments (AH-1 and 2) pictured in Figure 8.30. These were the only two that actually plotted among the spread of discriminant scores that make up the box plot for S-i-S on Figure 8.35. Assuming that the Shahr-i-Sokhta artifacts did not come from a source in Gujarat (or from a geochemically related source elsewhere in the Deccan Traps) then it is reasonable to assume that the two nodules likewise did not come from that region. I am, however, reluctant to firmly declare that they are from a source in eastern Iran. They are obviously very different in size and appearance from those Tosi described in the vicinity of Shahr-i-Sokhta. They might instead have come from occurrences in southern Afghanistan or western Balochistan. Or they might be from a source in an altogether different region. Still, geochemically, the nodules do resemble the S-i-S artifacts far more than they do the geologic samples from sources in Gujarat. Therefore, it is provisionally concluded that Harappans likely acquired them from an agate occurrence(s) to the west of the Indus Valley, perhaps one in the Helmand Basin region.

The remaining three artifacts from Harappa (AH-9, 13 and 20) that were predicted to belong to the S-i-S source-group plotted in the gap between that group's first quartile and the Gujarati sources group's third quartile. For this reason, I am even more reluctant to than I was with AH-1 and 2 to accept their PGMs; that is, at least not without first making a few qualifying statements. These artifacts could well be outliers of the Gujarat Mardak Bet source that just happened to plot nearer to the centroid of the S-i-S source-group. AH-13 was actually assigned to GMB in the initial CDA (see Appendix 8.8). It is also possible that the three are from unsampled agate deposits in Gujarat (such as those in central Kutch or the ones in the Kapadvanj area) that happen to have trace element characteristics slightly more like those of the source(s) from which the Shahr-i-Sokhta artifacts were acquired (wherever that might be). Furthermore, it should be noted that AH-20 is a fragment of a carnelian long bead. The large-sized iron-impregnated nodules required to make those beads are not, at least to my knowledge, found in regions outside of Gujarat or Central/Peninsular India. There might, of course, be sources of such nodules to the west or north of the Indus Valley that have not been reported or described. For that matter, there also may be agate sources in those regions that have trace element characteristics similar to the ones in the Deccan Traps – the Laki Formation trap of Sindh Kohistan is a strong candidate for being one of these. However, until those other potential sources are better described and analyzed it is impossible to do more speculate. Based on limited geologic dataset that was available for comparison, the best that can be said at present is that AH-9, 13 and 20 *may* have been acquired from a source to the west of the Indus Valley.

With regard to the 19 agate artifacts from

Figure 8.36 CDA comparison of select agate artifacts to three agate sources in Gujarat.



Harappa that were consistently assigned to one of the Gujarati sources, it can be stated that most likely came from a deposit in the northern part of that state (a few possible exceptions – the outliers labeled on Figure 8.36 B, are discussed below). When the three Gujarati sources analyzed were compared only to one another (Figure 8.36), just a single artifact (long bead fragment AH-22) was assigned to the Ratanpur source. Of course, the cross validation success rate for that CDA was 86.7%, which means that some of the artifacts assigned to GMB and GKK might have actually be misassigned outliers of GRTP. On the other hand, AH-22 could just as easily be a misassigned outlier of GMB, which was its second PGM. I favor the latter possibility given the fact that 11 of the 19 agate artifacts were predicted to belong to the GMB source.

One chalcedony fragment (AH-12) and two broken carnelian long beads (AH-16 and 17) from

Harappa are among the handful of agate artifacts (labeled on Figure 8.36 B) that in the third CDA plotted markedly apart from the three Gujarat source-groups. It is possible that some or all of these distinct artifacts are outliers of GMB – the source to which all were assigned. Characterization of additional geologic samples could expand the spread of cases making up that source-group enough to encompass them. On the other hand, the distinctiveness of the artifacts may be an indication that they are from a different source(s). Although that other source(s) could be outside of Gujarat, in the case of the long beads at least, I would argue (for the reason discussed on the preceding page) that it is probably located somewhere within that state. However, until other potential agate sources in Gujarat are sampled and analyzed, the current PGMs of these distinct artifacts will stand.

Artifacts from the five other Indus Tradition sites

The PGMs generated for the artifacts from Nagwada are fairly straightforward. It appears that the Harappans of that site were, not surprisingly, acquiring agate from sources in Gujarat. Two fragments were assigned to the relatively nearby occurrence at Mardak Bet while one was predicted to come from the Ratanpur source. With regard to artifacts analyzed from the four other Indus Tradition sites, a few qualifying remarks are required.

All but one of the Mohenjo-daro artifacts analyzed were predicted to belong to the GMB source. The single fragment (MD-2) from that site that was assigned to the S-i-S group in the second CDA (Figure 8.35) is likely a misassigned GMB outlier. Most of the Chanhu-daro artifacts were also predicted to belong to GMB. Of the two from that site that were assigned to the S-i-S proxy source-group, one (ACD-4) is perhaps a misassigned GMB outlier. The other (ACD-3) is distinct enough (see it plotted on figures 8.34 and 8.35) to suggest that it is probably from a source outside of Gujarat. As was the case with the two large chalcedony nodules from Harappa discussed at the beginning of this section, that source could be in the Helmand Basin region. On the other hand, agate occurs just 40 km west of Chanhu-daro in the trap rock of Sindh Kohistan's Laki Range. If raw material of even marginal quality exists at that location (this is by no means certain) then there is a strong possibility that some of it ended up in the workshops of Chanhu-daro and, for that matter, of Mohenjo-daro and Harappa too. The artifacts from all three of those sites that plotted distinctly apart from the Gujarati sources on Figure 8.36 B might conceivably have come from the Laki Trap. That formation is reportedly a western outlier of the Deccan Traps and so the agate from it might geochemically resemble agate from Gujarat. Or it might not. It is impossible know until samples from that potential source are analyzed.

Most agate artifacts from Mehrgarh and Nausharo were predicted to belong to an occurrence in Gujarat. However, unlike like those from Mohenjo-daro and Chanhu-daro, few were assigned to the Mardak Bet source. ANS-3 was the sole artifact that consistently had a PGM of GMB. AMR-5 and ANS-2 were assigned to that source only in the third CDA. In the first, they had PGMs of GKK and so may be outliers of that source that were subsequently misclassified. If that was the case, then six of the eight artifacts from Mehrgarh and three of the seven from Nausharo may be from GKK. One artifact at each site was assigned to GRTP while one agate fragment from Mehrgarh and two beads from Nausharo were consistently predicted to belong to the S-i-S proxy source-group.

It is curious how the majority of the agate artifacts at Mehrgarh were predicted to belong to the GKK source while most of those at Mohenjo-daro and Chanhu-daro were assigned to GMB. Both of those occurrences are located within 40 km of each other in northern Gujarat. Why would peoples at those distant settlements in Sindh and Balochistan

have almost exclusively utilized raw material from one source over the other? It is quite possible that what appears to be an emphasis on one source is actually the product of a very limited sample. The analysis of a larger number of artifacts from different phases and parts of the sites in question might reveal more heterogeneous patterns of agate source utilization, like that seen at Harappa. Another reason might have to do with the fact that the Mehrgarh artifacts are from an earlier period (ca. 4800-3500 BC) than those of the other Indus Tradition sites examined in this study. Perhaps material from GMB was not being exploited and/or exported during that earlier period. Later, during the Harappan Period (when GMB agate was evidently being used at sites across the Indus Valley), one or two agate artifacts that may be from that source do appear at the nearby site of Nausharo. A final possibility that must be considered is that some or all of the artifacts from Mehrgarh (and possibly Nausharo too) assigned to GKK might not actually be from Gujarat.

Mehrgarh and Nausharo, located as they are at the foot of the Bolan Pass, were the two sites at which I had most expected to see evidence for the utilization of agate from occurrences to the west of the Indus Valley. And, in fact, there are some artifacts (AMR-2, ANS-6 and, in particular, ANS-5) at both that might be from the Helmand Basin region. That many more were predicted to be from sources in Gujarat was not wholly unexpected. After all, residents of Mehrgarh had been acquiring raw materials (lapis lazuli, turquoise and marine shell) from distant regions since that settlement's earliest period (Jarrige 1991b: 41) and Nausharo was a thriving Indus Civilization town (Jarrige 2000). I have, however, doubts about the correctness of the provenience determinations made for many of the artifacts from the former site. It is not only because their PGMs stand in contrast to those of artifacts from Mohenjo-daro and Chanhu-daro (discussed above). It is also because the quality of several artifacts in the group assigned to GKK – in particular the two tiny chalcedony geode fragments (AMR-6 and 7, pictured on 8.32 D), is rather mediocre. Agate of this type occurs at Khandek but it is hard to fathom why someone would have seen fit to transport it approximately 700 km to Mehrgarh when there was much better raw material available at that source and at others in northern Gujarat. It seems more likely that many of the artifacts in question derived from an occurrence nearer to the site, perhaps the one Masson mentioned (1844: 463) "east of Kalat" in central Balochistan or another one like it. There are no published descriptions of agate from that source and until some is collected and analyzed we have no way of knowing if it is geochemically similar to that from GKK. However, if does turn out to be similar then that has important implications. If some or all of the GKK-assigned artifacts from Mehrgarh are actually from an occurrence to the west of the Indus Valley then those at Harappa assigned to that source could be as well. This possibility further underscores the need to regard the results of this study as provisional.

Now that all necessary qualifying remarks have been stated, the conclusions of this study can be presented. The three lines of inquiry outlined in Chapter 1 are not addressed here as the artifacts analyzed from Harappa are not sufficiently representative, either spatially or temporally, to permit this. The results are instead incorporated into the final overview of Harappan rock and mineral acquisition networks in Chapter 13.

CHAPTER CONCLUSION

The results of this study bode well for future research of this kind. Using INAA and CDA, it was possible to differentiate samples from three agate deposits in Gujarat reasonably well. However, a superb degree of discrimination was achieved when those deposits were compared to a set of

artifacts presumably from sources in eastern Iran. This indicates that it is possible, at the very least, to assign a regional provenience to agate artifacts. The results of a recent follow-up study (Law *et al*. 2011) lend further support to this conclusion. Samples from two deposits in Gujarat – the group of Iranian artifacts and a newly sampled source in Thailand (Ban Khao Mogun) – were analyzed at the Missouri University Research Reactor. An excellent 95.1% cross validation success rate was achieved. Most of what little misclassification there was occurred the among the Gujarati sources rather than between them and the other regional source or proxy-source samples. There is then very good reason to expect that when the geologic dataset is further enlarged to include agate from deposits in Sindh, Balochistan, Afghanistan, Arabia, Tibet and Central Asia it will be possible to differentiate them and assign a regional provenience to artifacts. In the meantime, the results of the present study permit the following *provisional* conclusions to be made regarding Indus Tradition agate acquisition networks:

The majority of the agate artifacts from Harappa and the five other Indus Tradition sites examined in this chapter appear to have come from sources in Gujarat. Residents of Harappa were acquiring material from that region by at least the Kot Diji Phase. Although this conclusion is based solely on the analysis of a single carnelian bead fragment (AH-24) from Period 2 levels, that particular artifact is one of the more analogous to geologic samples from the Mardak Bet occurrence (it was consistently assigned to that source and is not among distinct outliers on 8.36 B). Gujarat was evidently the primary agate source area for residents of Harappa during the latter half of the Harappa Phase. All but one of the ten artifacts from the site that are securely attributable to periods 3B and 3C were predicted to belong to a deposit in that region. Significantly, most of the Gujarati agate used at Harappa and the other sites appears to have come from sources in the Kutch region rather than from, as is widely assumed, the Ratanpur area deposits in the southeastern part of the state. As this book was being finalized, data became available from the analysis of agate artifacts from the Indus cites of Dholavira in northern Gujarat and Rakhigarhi in Haryana. Overall, those results were very consistent with the agate acquisition patterns revealed in this chapter.

There are indications that Indus Tradition peoples sometimes utilized agate from regions outside of Gujarat. Four artifacts from Harappa (including a Period 3B bead fragment) as well as a few from Mehrgarh, Nausharo and Chanhu-daro are geochemically more analogous to artifacts from Shahr-i-Sokhta, which could mean that they may have come from the same sources (presumably in the Helmand region) used by residents of that site. Or it might simply indicate that they are from an as of yet unsampled deposit that happens to be more geochemically analogous to Iranian sources than to Gujarati ones. Also, a few of the Gujarat provenience assignments for artifacts from Harappa and the other sites are, in my judgment, tenuous (especially certain ones from Mehrgarh). I believe it likely that those artifacts come from a source(s) to the west of the Indus Valley.

In the next chapter, I examine the acquisition of vesuvianite-grossular garnet – a translucent green-colored rock that has in the past been misidentified as "jade."