The Important Stone and Metal Resources of Gujarat during the Harappan Period

Randall Law[1]

[1]. Department of Anthropology, University of Wisconsin Madison, USA *(Email: rwlaw@wisc.edu)*

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Abstract: *Many important resources – such as marine shell, pasturage and salt – no doubt induced Early Harappan and Harappan peoples to establish and expand their presence in Gujarat. None, however, were likely as enticing as the region's diverse, beautiful and valuable rocks and minerals. Such resources would have appealed both to their obvious inclination toward self-adornment and their instincts as master crafters and traders. Recently, characterization and geologic provenance studies have been conducted on stone and metal artifacts from the Harappan settlements of Dholavira, Lothal, Gola Dhoro (Bagasra), and Nagwada. These studies include instrumental neutron activation analysis (INAA) of steatite, agate-carnelian, and chert artifacts; Pb isotope analysis of lead and silver items; electron microprobe analysis (EMPA) and variable-pressure scanning electron microscopy (VP-SEM) of items such as seals; and X-ray diffraction (XRD) characterization of numerous objects and raw materials. The results have revealed much about where Harappans in Gujarat acquired rock and mineral resources and how they utilized them.*

Keywords: Harappan Civilization, Gujarat, Saurashtra, Kachchh, Stone and Metal Resources, Source Provenience Analyses, Long-distance Trade

Introduction

In the year 2000, I initiated a large-scale effort to identify the geologic sources from which peoples of the Indus Civilization (ca. 2600 to 1900 BC) acquired rock and mineral resources. Over the next decade, thousands of stone and metal artifacts from more than a dozen Harappan sites were, using a wide range of analytic techniques, directly compared to geologic samples collected from deposits across northwestern South Asia (Law 2005, 2008, 2011). Although this study remains ongoing, a new and detailed picture of resource acquisition and trade during this time period is beginning to emerge. It seems that certain raw materials, such as steatite, chert, agate and, perhaps, copper, were mainly (but not always exclusively) acquired from very specific source areas and then distributed via long-distance trade networks to consumers throughout the Indus Civilization. Underlying this vast inter-regional exchange system were numerous regionally oriented ones. The purpose of this paper is to highlight the important stone and metal resources of the Gujarat region during the Harappan Period

(Figure 1). Ancient Gujarat was the beginning point for several inter-regional raw material trade networks as well as home to an active regional rock and mineral exchange system. I will begin with (and devote a substantial portion of this paper to) the subject of microcrystalline silicates, which were almost certainly one of the region's principal resources.

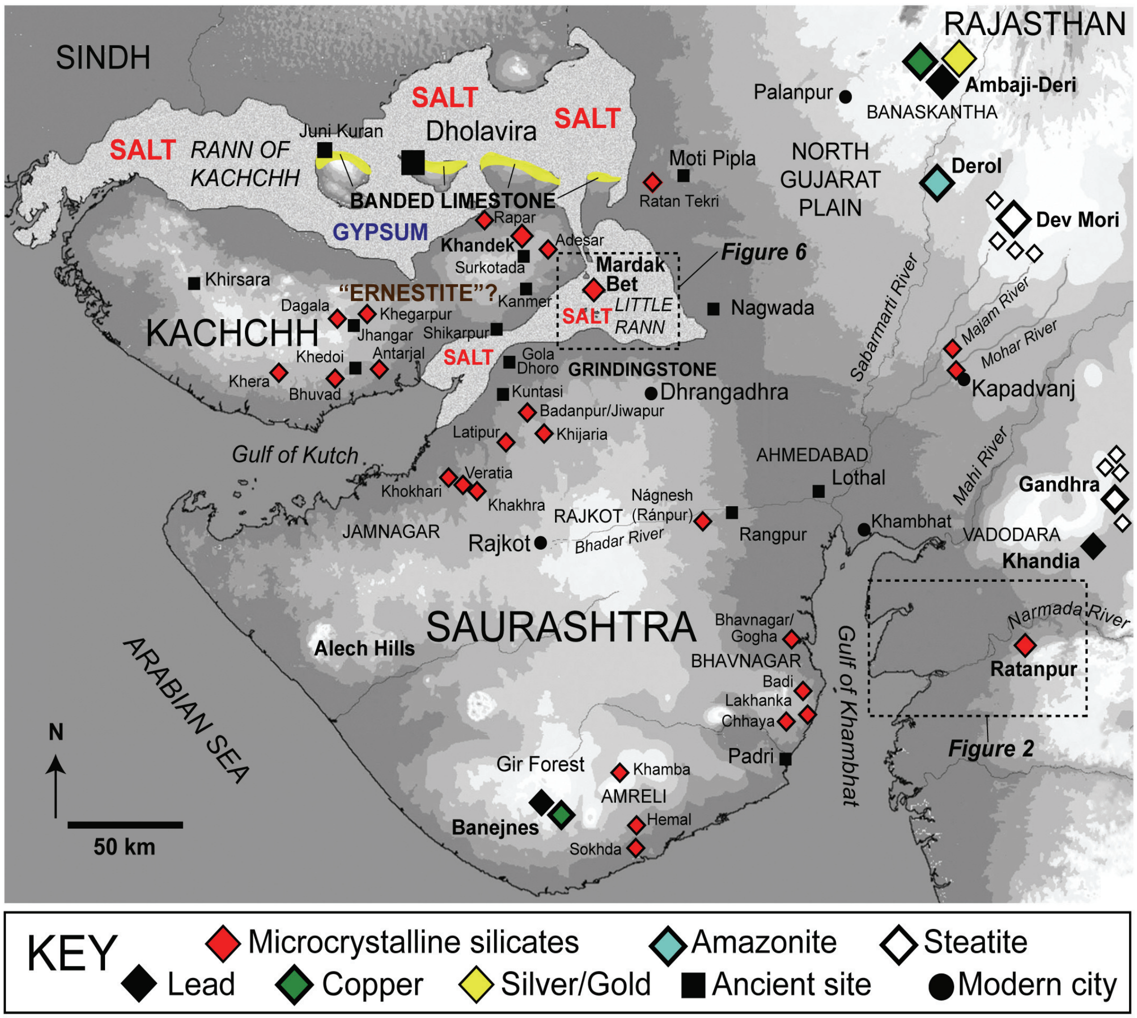

Figure 1: The important stone and metal resources of the Gujarat region during the Harappan Period

Microcrystalline Silicates

Agate, carnelian, chalcedony, chert, flint, jasper, bloodstone, heliotrope, chrysophrase, novaculite, radiolarite, sard and onyx together make up a class of closely related (in many cases mineralogically identical) sedimentary rocks called *microcrystalline silicates*. All are principally composed of microscopic crystals of quartz that formed when silica chemically precipitated out of an aqueous solution (Luedtke 1992: 18). Visually, however, microcrystalline silicates are so highly variable that they defy any absolute classification (Butler 1995). Ask a geologist, mineralogist, gemologist and archaeologist each to define "agate" and you may very well receive four different answers.

There are a number of reasons why the Gujarat region is assumed to have been an important source area, perhaps even the primary source area, for the ornamental varieties of microcrystalline silicates 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 that attracted them to the region in the first place. Secondly, although occurrences of agate and jasper can be found in many parts of South Asia, the extent, diversity and sheer richness of sources in Gujarat is unparalleled. 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 carnelian 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 2) in the eastern part of the state (Allchin 1979; Ball et al. 1881: 506-507; Bose 1908; Francis 1983; Sahni 1948). This review begins there.

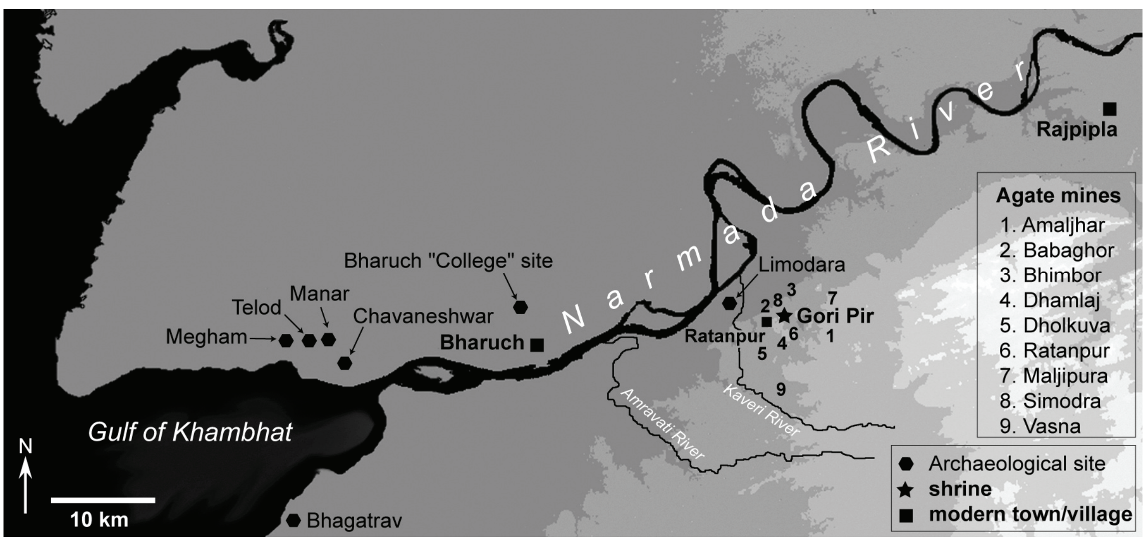

Figure 2: Agate mines and ancient sites in the Ratanpur area, southeastern Gujarat

Eastern Gujarat

Among the low hills around the village of Ratanpur, Bharuch District, Gujarat, there are hundreds of agate mining pits and shafts sunk into the Miocene conglomerate of the Babaguru Formation (Figure 3 A and B). 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 the more geographically appropriate designation (Ball 1886: 238). Mining locations having published geographic coordinates (Chatterjee 1963: 166; Insoll et al. 2004: 1162) are plotted on Figure 2. Trivedi noted (1964: Map 2) most of these localities, as well as around a half dozen others, in his review of the Khambhat bead industry, which to this day consumes tons of Ratanpur agate. 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" (Sahni 1948: 253). I have observed that those nearer to Rajpipla tend to be composed of clear chalcedony.

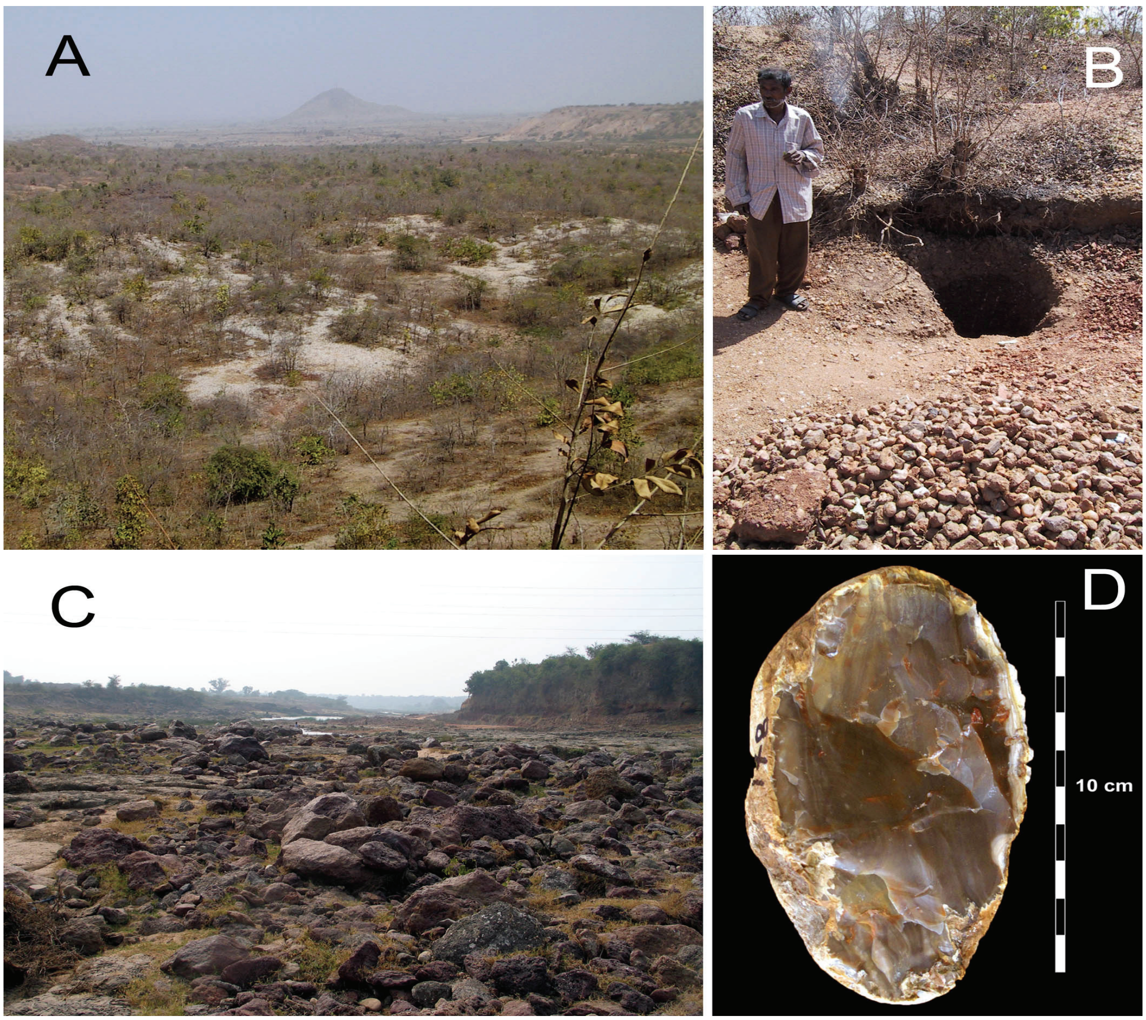

Figure 3: [A] Ratanpur Hills area, Bharuch District, Gujarat. [B] Agate mine shaft sunk into the Miocene conglomerate (Babaguru Formation). [C] Bed of the Mohar River near Kapadvanj. [D] Nodule of Kapadvanj agate.

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.

Approximately 150 km north of the Ratanpur agate deposits, multiple types of microcrystalline silicates (including some that can be heat-treated to produce carnelian) are found in the vicinity of Kapadvanj city (Campbell 1879: 15). Nodules as heavy as ten pounds (≈ 4.5 kg) were reportedly once gathered from the bed of the Mohar River (Figure 3 C), directly adjacent to the city, as well as from the Májam River, some 20 km further north (Campbell 1880: 199-200). I collected agate cobbles at large as 12 cm (Figure 3 D) during a visit to the former location.

Saurashtra

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

Miocene sediments (Figure 4 A) in the vicinity of the towns of Bhavnagar and Gogha in the Bhavnagar District are "agatiferous" and closely related to 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 a fairly good quality, they could have only been used to make very small beads as none of the ones I observed were larger than three centimeters in size (Figure 4 B). 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 "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).

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 (1963: 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.

The Rajkot and Jamnagar districts of northern Saurashtra are especially rich in ornamental microcrystalline silicates. Chatterjee compiled (1963: 167 – from Fedden

1885 and other sources) information on a number of locations (Khijaria, Latipur, Jiwapur, Badanpur, Khakhra, Varatia) at which agate, moss agate and chalcedony is found. Massive, variegated red and yellow jaspers (Figure 4 C and D) occur in amygdaloidal basalts near Khokhari village. Some of this material closely resembles the sorted jasper blocks discovered in storage bins at the Harappan site of Gola Dhoro (Bagasra) (Bhan et. al 2004).

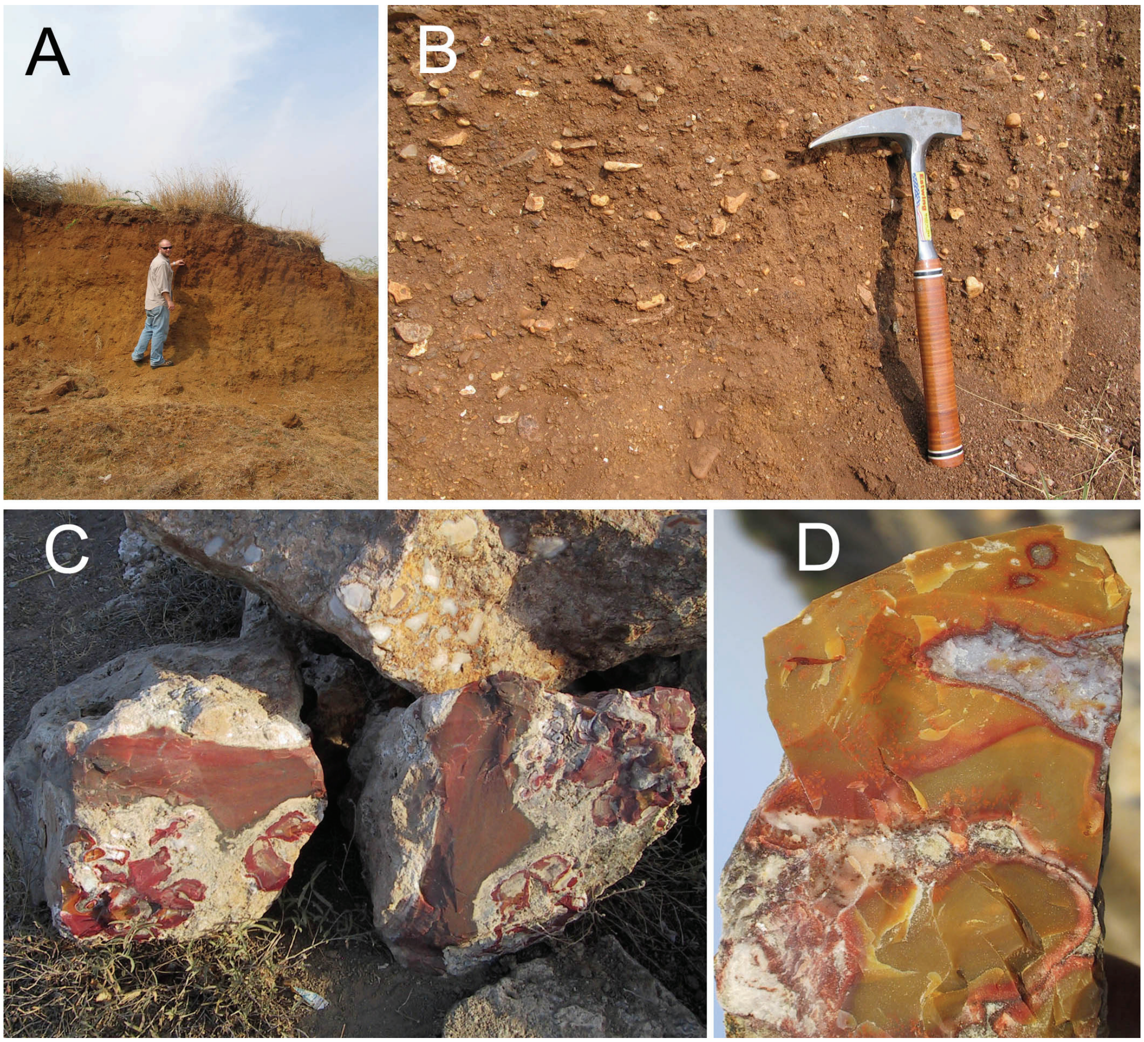

Figure 4: [A] Miocene agate gravel beds near Gogha, Bhavnagar District. [B] Detail of tiny agate nodules in the gravel beds near Gogha. [C & D] Massive, variegated red and yellow jaspers from amygdaloidal basalts occurring near Khokhari village, Jamnagar District, Saurashtra.

Northern Gujarat

The microcrystalline silicate resources 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 Kachchh (Geological Survey of India 2001: 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 several of these sources in central Kachchh and observed only milky white agate-chalcedony (Figure 5 A). Although rarely used for ornamental purposes, this material was an important regional resource for the manufacture of blade tools (approximately half of the blades at Dholavira are made from such stone - *personal observations* 2007-2009). I often encountered white chalcedony blade fragments and cores (Figure 5 B) during my explorations in Kachchh.

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 Ratan Tekri (P. Ajithprasad *personal communication* 2013), Adesar (Geological Survey of India 2001: 47), northwest of Rapar (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). Additional details on the latter two sources mentioned are provided below.

Khandek

The Khandek agate source (Figure 5 C) 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 5 D) 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 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

The agate deposits on the island (bet) of Mardak, in the salt marsh southeast of Kachchh known as the "Little Rann" (Figure 6), 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. A second attempt (this time with Malik and Prof. Kuldeep Bhan of MSU) later that same year just prior to the summer monsoons was successful.

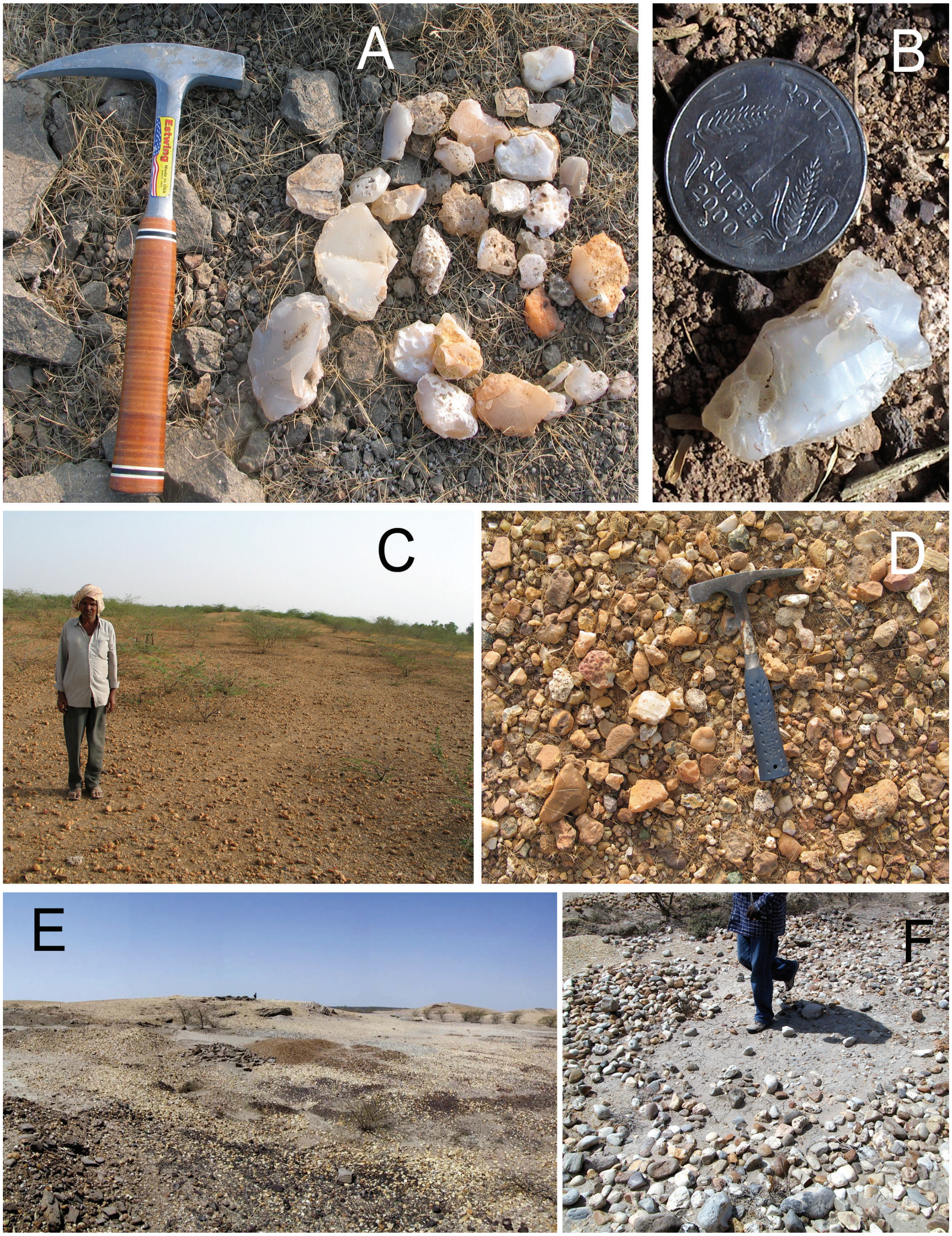

Figure 5: [A] Fragments of milky white agate-chalcedony near Antarjal, central Kachchh District, Gujarat. [B] Spent chalcedony blade core near Bhuj, central Kachchh. [C] With Narsingh Solanki at the Khandek agate beds, eastern Kachchh District. [D] Pavement-like surface of the agate bed at Khandek. [E] Agate beds at “nana” Mardak Bet, Little Rann of Kachchh. [F] Agate nodules flaking and sorting area near "mota" Mardak Bet.

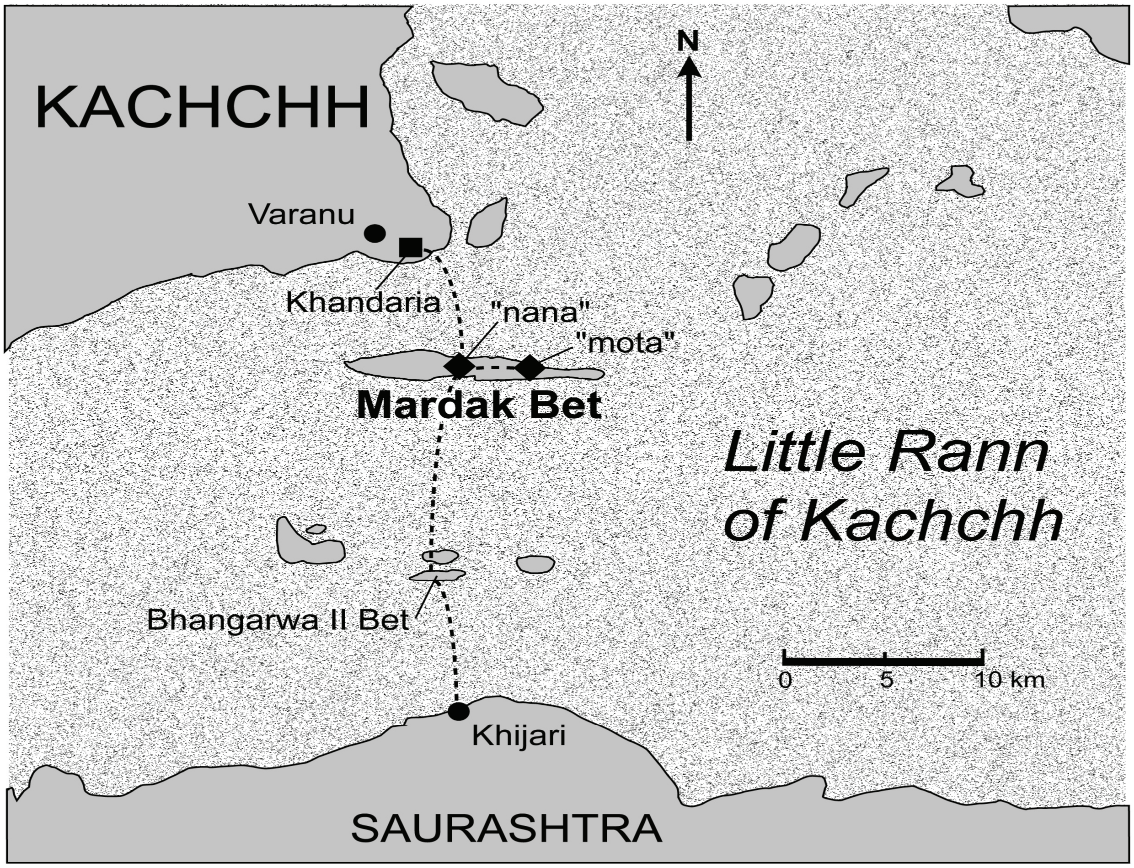

Figure 6: Map of the Little Rann of Kachchh, Gujarat

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 (Figure 5 E), which Arun Malik designated "nana." 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-yellow 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 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 clearly ancient workings in the island's agate beds were identified during our short visits to them. Mining pits and sorting areas (Figure 5 F) 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. 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. I have been informed by R.S. Bisht (*personal communication* 2004) that agate and jasper artifacts composed of material visually identical to that occurring at Mardak Bet are evident at the Harappan site of Khandaria (reported in Bisht 1989: 267), which is located less than 10 km away near the village of Varanu on the northern shore of the Little Rann. The Harappan settlement of Kanmer, where there is also abundant evidence for the manufacture of ornaments using stone that appears to be from this source (*personal observations* 2009), lies 25 km due west.

The Geologic Provenience of Harappan Agate-Carnelian

An effort is ongoing to identify the sources of the various kinds of microcrystalline silicates used by Harappans (Law 2011: Chapter 8; Law et al. 2011). Particular emphasis has been placed on determining the geologic provenience of the red-orange variety of agate commonly known as *carnelian*. While microcrystalline silicates occur across the Gujarat region, there are only a handful of sources from which carnelian (or the variety of brown-yellow agate that can be heat-treated to produce it) of sufficient quality and size necessary to make Harappan-style beads can be obtained. These include the historically important sources of Ratanpur and Kapadvanj in eastern Gujarat and the lesser know occurrences at Khandek and Mardak Bet in Kachchh. It has long been assumed that Harappan agate-carnelian was primarily derived from the Ratanpur area deposits (Allchin and Allchin 1997: 173; Asthana 1993: 274; Biwas 1996: 49; Lal 1997: 163-164; Pascoe 1931: 681; Vidale 2000: 42). However, the occurrences of Kachchh would have been much more accessible to Indus Civilization peoples dwelling in northern Gujarat and, by extension, to Harappan consumers in the Indus Valley proper. In order to determine where this important raw material was acquired, artifacts from seven sites across the Greater Indus region - Harappa in the Punjab, Rakhigarhi in Haryana, Mohenjo-Daro and Chanhu-Daro in Sindh, Nausharo in Balochistan, and Dholavira and Nagwada in Gujarat - were subjected to instrumental neutron activation analysis (INAA) and compared to a database of geologic samples from multiple agate sources in India, Pakistan and Iran.

The results of the analysis confirmed what has long been suspected that carnelian from Gujarat was being distributed to settlements across the Harappan realm. However, all or most of the Gujarati carnelian at each of the sites examined seems to have been derived from one of the sources in Kachchh. Only minor amounts of raw material from the Ratanpur deposits were detected. This does not necessarily mean that Ratanpur was a minor source during the Harappan Period. Larger quantities of raw material from that occurrence might have been transported to a site like Lothal, which is nearer to sources in eastern Gujarat than it is to those in Kachchh. If, as Rao (1979) suggested, Lothal was an important entrepôt on the route between the Indus Civilization and Mesopotamia, then *perhaps* many of the Harappan-style agate-carnelian beads found at contemporaneous sites in the Persian Gulf and Near East were made from Ratanpur stone.

Banded Limestone

Banded limestone is another rock that was transported from its source in Gujarat to Harappan sites deep within the Indus Valley. The particular variety I am referring to occurs in the Pachchham formation - a zone of Jurassic sedimentary rock (Fuersich 2001) exposed on several islands on the southern edge of the Great Rann of Kachchh (see yellow highlighted areas on Figure 1). Dholavira, which is located on Khadir island, was largely constructed of blocks and slabs composed of this distinctive yellow-brown banded, sand-textured limestone (Figure 7 A). The quarry from which much of that material likely came is located three kilometers north of the city. Discarded limestone slabs (Figure 7 B) can be seen among the quarrying debris as can several roughly hewn circular objects (Figure 8 C) that are almost certainly roughouts for pillar bases like those found in the gateways at Dholavira. In 2004, I noted that some of the pillar elements or "ringstones" found at Mohenjo-Daro (Figure 7 D) and Harappa (Figure 7 E) were made from a banded limestone that is visually identical occurring in the Pachchham formation. A geologic provenience study of the ringstones from Harappa and other artifacts that seemed to also be composed of this stone was initiated at that time.

Samples of banded Pachchham formation limestone were collected for analysis from the ancient quarry near Dholavira, as well as from two other locations on Khadir Island and several places near the Harappan site of Juni Kuran (Pramanik 2005) on Pachchham Island (the large landmass in the Great Rann directly west of Khadir). Samples were also obtained from two regions where similar looking banded limestone occurs - the Jaiselmer area of western Rajasthan and the Kirthar Range of western Sindh. These geologic samples, along with a set of banded limestone artifacts from Harappa (including small chips taken from the two ringstones shown in Figure 7 E), were subjected to both INAA and inductively-coupled plasma mass spectrometry (ICP-MS). These studies are detailed in Law and Burton 2006 and Law 2011: Chapter 11. When the results were examined, it was found that most of the artifacts closely matched the Pachchham formation limestone samples, especially those taken from the quarry near Dholavira.

Harappa lies nearly 800 km north-northeast of Dholavira as the crow flies. A journey via the Indus Basin river system would have been considerably longer. The larger of the two ringstones from Harappa pictured in Figure 7 E weighs over 125 kg. The presence of such heavy stone objects so far from their source bears testament to the advanced transportation capabilities of Indus Civilization peoples during the later part of the Harappan Period (ca. 2100 to 1900 BC).

Amazonite

Amazonite (a variety of the feldspar mineral microcline) is easily recognized by its prominent cleavage face in combination with its characteristic white-green to blue-green appearance (Figure 8 A). Early researchers speculated that amazonite artifacts from Mohenjo-daro may have come from the Nilgiris Range of southern India (Pascoe

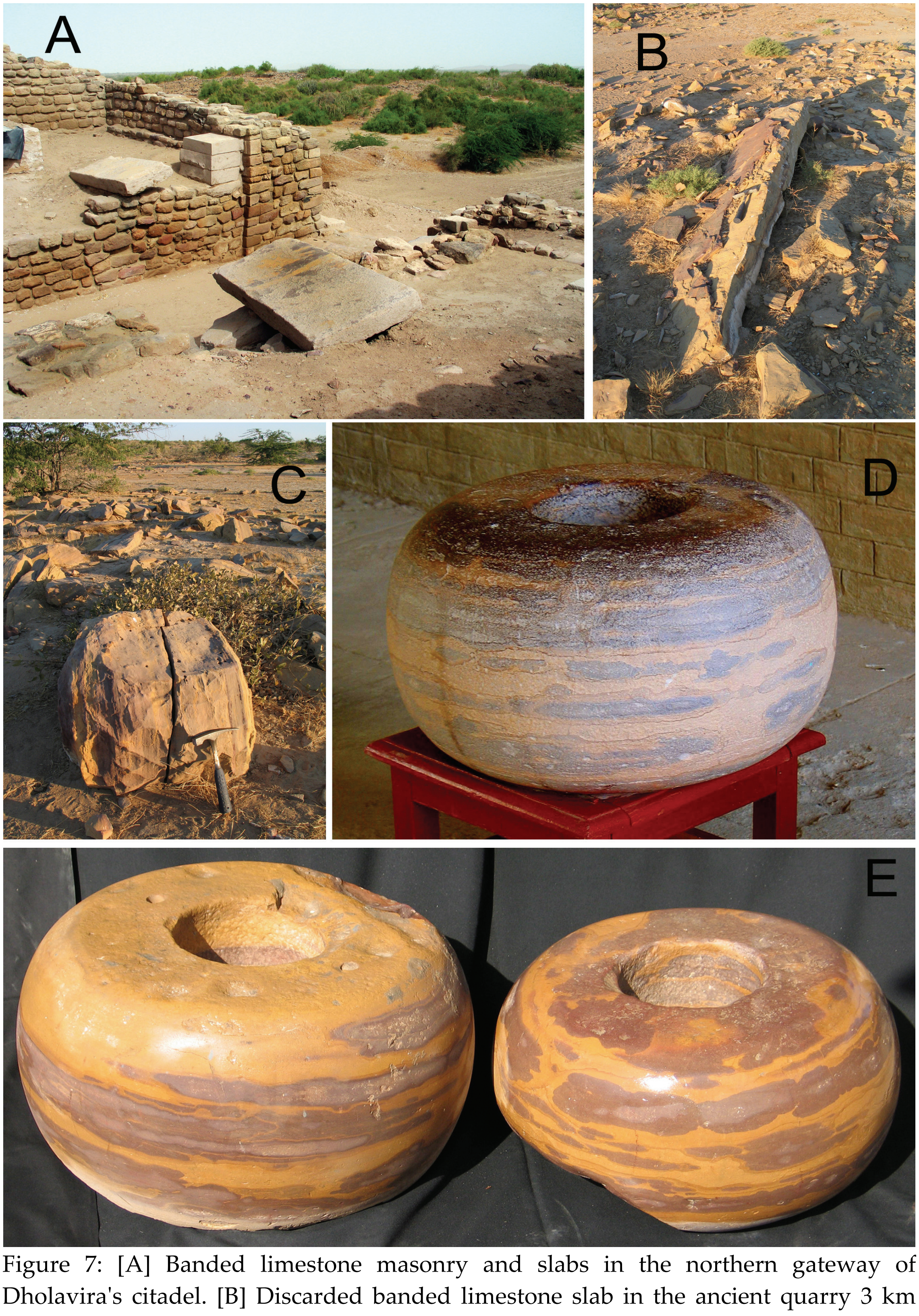

Figure 7: [A] Banded limestone masonry and slabs in the northern gateway of Dholavira's citadel. [B] Discarded banded limestone slab in the ancient quarry 3 km north of Dholavira. [C] Discarded ringstone rough-out at the same quarry. [D] Flat-topped banded limestone ringstone from Mohenjo-daro. [E] Flat-topped banded limestone ringstones Harappa.

1931: 678; Mackay 1938: 500). However, this purported occurrence was long ago shown to probably not exist (Gordon 1936). A significantly closer source lies in northern Gujarat. There, green microcline occurs in granite pegmatites southeast of Palanpur near the village of Derol (Foote 1898: 22) and amazonite pebbles originating from those rocks can be found in the bed of the adjacent Sabarmati River (ibid.: 29). On a loess terrace not far from this location, geologist R.B. Foote reported a prehistoric site at which he recovered chert tools in association with fragments of this stone (Foote 1916: 142-143). Around 125 km southwest of this source lies the Harappan site of Nagwada. Excavators there found chert drills and the abundant remains of amazonite beads in "different stages of manufacture" (Hegde et al. 1988: 58). More recently, I also recorded hundreds of amazonite debris fragments and beads in different stages of manufacture in the assemblage of excavated stone at Dholavira, which is some 260 km due west of Derol. The intensity of amazonite working at these sites (as compared to others I have examined throughout the Greater Indus region) suggests that northern Gujarat might well have been the principal source area for this type of stone during the Harappan Period.

Gypsum

The mineral *gypsum* – hydrated calcium sulfate – occurs in a compact, massive form known as *alabaster* and as transparent crystals known as *selenite*. Alabaster is not found in Gujarat but crusts of selenite (Figure 8 B) form as briny water evaporates in the salt flats (ranns) that surround the island of Kachchh. In a gateway at the Harappan city of Dholavira, the inlayed lettering of what appears to have been a large signboard is composed of a heated gypsum paste (R.S. Bisht *personal communication* 2004). The raw material from which the inlay was created was almost certainly selenite derived from the Great Rann of Kachchh.

"Ernestite"

"Ernestite" is the informal name that Kenoyer and Vidale (1992) gave to the type of rock Harappan bead-makers used to make drill bits (Figure 8 C) for perforating harder types of ornamental stone such as agate-jasper and vesuvianite-grossular garnet. The rock is hard (≈ 7.5 on Mohs hardness scale), fairly dense (its specific gravity ranges from ≈ 2.8 to 3.2) and extremely fine-grained with dark-brown to black patches and/or dendritic veins in a khaki-colored matrix (see examples of raw "Ernestite" from Harappa in Figure 8 D). X-ray diffraction (XRD), electron microprobe analysis (EMPA) and petrographic thin-section analysis have been employed in an effort to determine nature of this material (outlined in Law 2011: Appendix 4.5). Based on these studies, "Ernestite" can be characterized as a extremely indurated *kaolinitic claystone* that was very likely heat-treated. Mineral inclusions in the stone suggest it was formed, in part, from the decomposition volcanic ash. The question now is – Where did "Ernestite" come from?

There is good reason to suspect that the source of "Ernestite" lies somewhere in Kachchh. To begin with, there are kaolinitic clay beds across that region in which

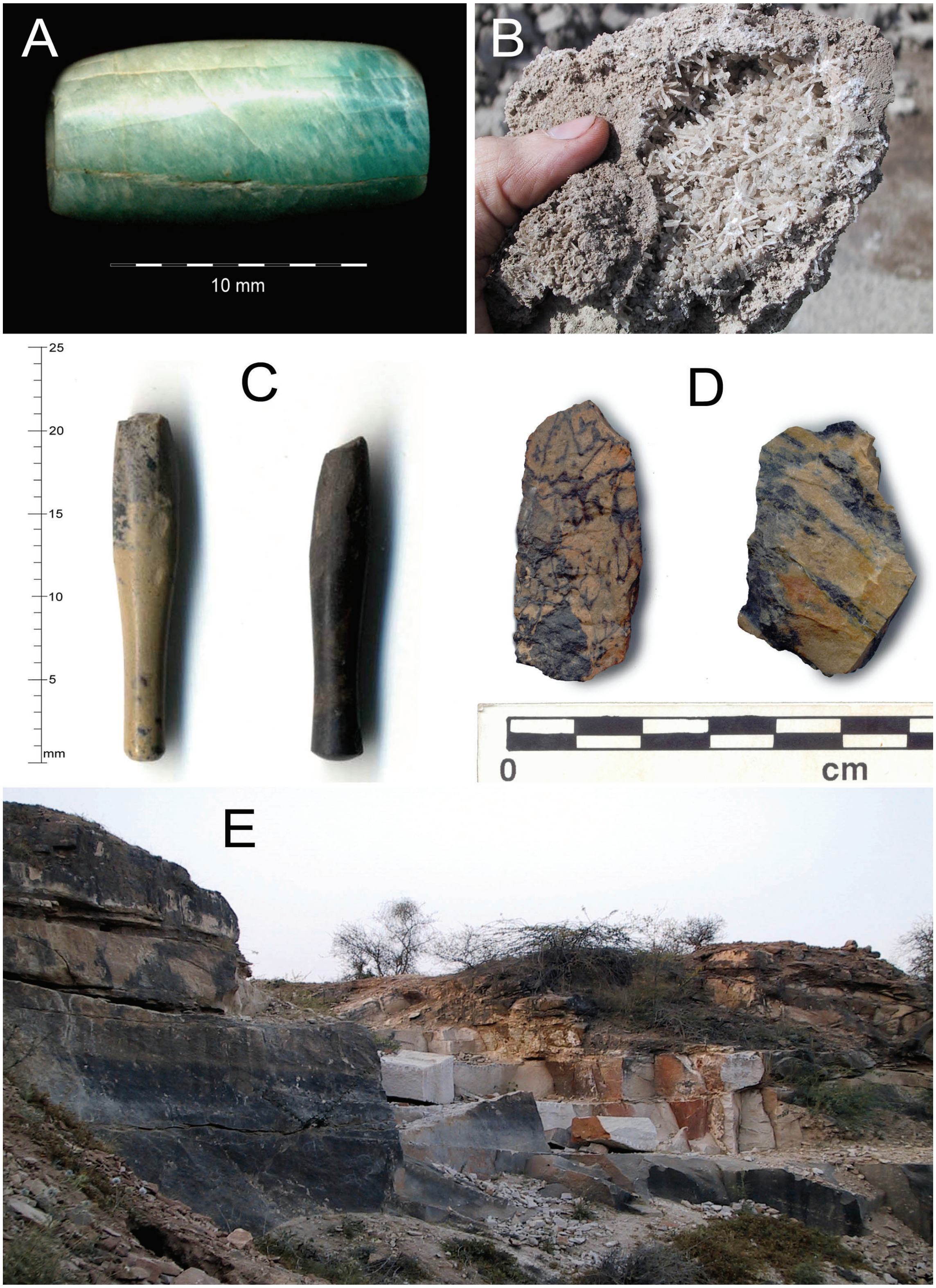

Figure 8: [A] Amazonite bead from Harappa. [B] Mass of selenite gypsum crystals from the Little Rann of Kachchh. [C] Constricted cylindrical drills from Harappa made of "Ernestite". [D] Raw "Ernestite" fragments excavated at Harappa. [E] Dhrangadhra stone quarry, Surendranagar District.

material occurs that is extremely similar to the stone both compositionally and visually. However, although I have visited numerous such occurrences, I have not yet located material that is sufficiently dense or indurated (hardened) to qualify as "Ernestite." Nevertheless, I believe that the source remains to be found in the area due to the fact that drill bits made from this material are, as compared to Harappan sites elsewhere in the Greater Indus region, fairly-to-extremely common finds at sites in Kachchh. Over 1300 hundred "Ernestite" drills bits and fragments of raw material have been recovered at Dholavira (V.N. Prabhakar *personal communication* 2011). Compare that to the 45 bits and debris fragments that have been found in total during the 25 most recent seasons of research at Harappa. Bead-makers at Dholavira clearly had much better access to "Ernestite", which suggests the source was probably located somewhere relatively nearby.

Grindingstone

The large majority of the grindingstones – querns, mortars, mullers and pestles – that I have examined at Harappan sites in Gujarat are composed of a medium-to-coarse-grained light-colored sandstone. Although rock of this general description is found across large areas of Kachchh and northern Saurashtra, most of it is not suitably compact. That is to say, the grains of quartz making it up are apt to loosen and come off when the stone is subjected to pounding or grinding. For this reason, such material would have made poor grindingstone because a sandy grit is apt to end up in your food or whatever else you are processing. However, stone suitable for grinding purposes does occur in the vicinity of Dhrangadhra, in the Surendranagar District of northern Saurashtra. Across that area, a tough, cream-colored sandstone is quarried (Figure 8 E). The name Dhrangadhra means "stone place" and *Dhrangadhra stone* has long been "famous throughout Gujarat" (Imperial Gazetteer of India: 1908: 334-335) as a high-quality material for construction and carving. Although a detailed comparison of this material to artifacts has yet to be undertaken, I and others (such as Yadubirsingh Rawat – *personal communication* 2010) believe it to be the most probably source of grindingstone for Harappans in Gujarat.

Metals

On the whole, Gujarat is not particularly rich in either precious or base metal resources. Trace amounts of gold are found in the ryolite of the Alech Hills of western Saurashtra (Radhakrishna and Curtis 1999: 148) but there is no evidence whatsoever that this occurrence was worked during the 3rd millennium BC. In fact, the occurrence is so trivial that it has not even been exploited in modern times. For these reasons, I did not place a symbol for gold at this location on Figure 1. Small but potentially exploitable copper and/or lead deposits occur near Banejnes in the Gir Forest region of southern Saurashtra (Shekar and Mukul 1969) as well as around Khandia in the Vadodara District of eastern Gujarat (Shah et al. 1985). However, I have conducted lead isotope assays of geologic samples from both of these regions (see Law 2011: Chapter 12) and, thus far, none of the Harappan lead or copper artifacts that I have similarly analyzed have even come close to matching the isotopic characteristics of these sources.

The subject of metal resources in Gujarat would almost end there if not for recent (and still unpublished) findings from Dholavira that point to the exploitation of a source in the far north of the state. The polymetallic (lead, zinc and copper as well as trace silver and gold) deposit at Ambaji-Deri (Figure 9 A & B) literally straddles the Banaskantha District's border with Rajasthan. A zone of old smelting slag (Figure 9 C & D) extends several kilometers across the area. Other polymetallic deposits and old workings, such as those at Zawar, Rajpura and Dariba, are found as one move deeper into southern Rajasthan. However, the lead isotope characteristics of the Ambaji-Deri deposit are

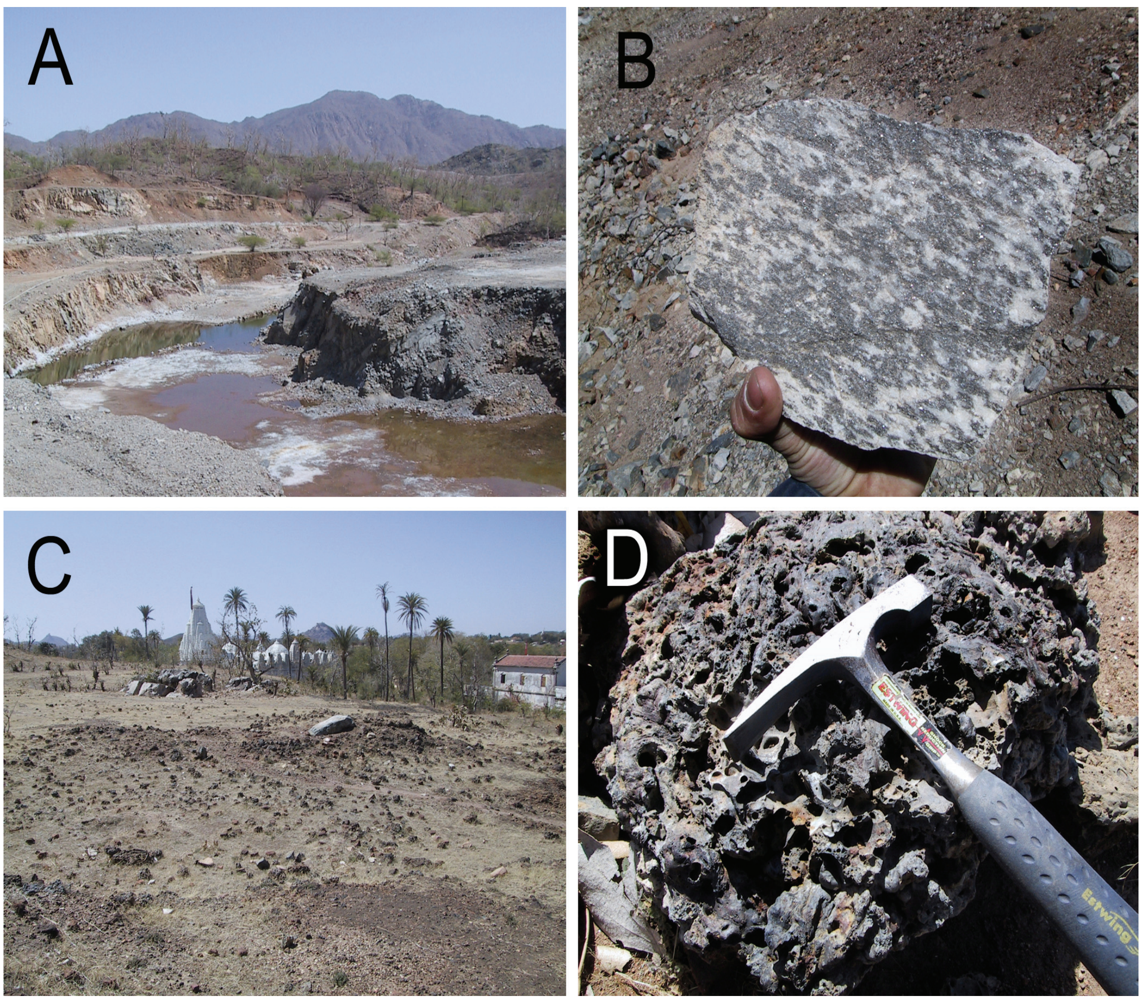

Figure 9: [A] The modern lead-zinc-copper mine at Ambaji, Banaskantha District, northern Gujarat. [B] Galena (lead sulfide) speckled sample taken at that location. [C] Mounds of smelting slags near Ambaji at Kumbariya. [D] Detail of smelting at Kumbariya.

highly distinctive and the analysis of a set of metal objects from Dholavira revealed that a number of artifacts were exact isotopic matches with it. That some amount of lead and copper should have come from this source is not particularly surprising, as it is the nearest such occurrence to that city. Previously, however, the earliest confirmed exploitation of the Ambaji-Deri deposit dated to the 2nd century BC (Shekar 1983). It is now possible to push that date back a further two millennia to the Harappan Period.

The ores of the Ambaji-Deri deposit "are known to contain recoverable quantities of silver and gold" (Radhakrishna and Curtis 1999: 148) and, thus, could have potentially been a source of those precious metals during the Harappan Period. I have not yet analyzed gold objects from any Indus Civilization site and most of the silver artifacts that I have assayed to date – from the sites of Mohenjo-Daro, Allahdino, Dholavira, Rakhigarhi and Nagwada – seem to be made of metal extracted from lead occurrences in southern Balochistan (Law and Burton 2008). However, a single silver bead from Dholavira did have lead isotope characteristics that closely resembled (but did not precisely match) those of the Ambaji-Deri deposit. Future studies of precious metal artifacts at sites in Gujarat may yet confirm it to be a Harappan gold and silver source.

Steatite

Steatite – a rock composed mainly of the mineral talc – was used to create common items, such as disc beads, as well important objects like stamp seals and inscribed tablets. Provenience analyses of artifacts from multiple sites suggests that, for Harappans throughout the Greater Indus region, the primary sources of this stone were located in Khyber-Pakhtunkhwa Province (formerly the NWFP) of modern-day northern Pakistan (see Law 2011: Chapter 7). These studies also, however, revealed that alternate steatite deposits were sometimes exploited. One of those alternate source areas lay in Sarbarkantha District of northeastern Gujarat. Multiple occurrences of steatite, many of which are still mined today, are found in the vicinity of Dev Mori village (Figure 10 A & B). Artifacts composed of stone from this source area have, thus far, been positively identified at the Harappan sites of Dholavira, Nagwada and Gola Dhoro (Bagasra). I recently examined steatite artifacts from Lothal and strongly suspect (but have not yet confirmed) that some of them are also made from Dev Mori steatite. There are other sources in Gujarat that are nearer to Lothal, specifically, those mined near Gandhra (Figure 10 C) in the Panchmahals District. However, the steatite occurring in this area, while perfectly suitable for modern-day applications such as the manufacture of talcum powder (Figure 10 D), is not the same high-quality material Harappans generally utilized.

Salt

Salt was probably one of the most important commodities of Harappan Period Gujarat. This edible rock has been an essential component of civilizations throughout history (Kurlansky 2002) and the Indus Civilization would not have been an exception. The large urbanized populations dwelling on the inland plains of Sindh and the Punjab, as well as the cattle and other herd animals that provided those Harappans with much of their sustenance and wealth, would have required steady, massive supplies of salt. The salt flats or *ranns* (Figure 11 A) adjacent to the island Kachchh would have been an

Figure 10: [A] The Dev Mori steatite mine, Sarbarkantha District. [B] Workers at the Dev Mori mine. [C] Steatite mine near Gandhra, Panchmahals District. [D] Making talc powder from Gandhra steatite.

inexhaustible source. There were, of course, other sources throughout the Greater Indus region, such as the massive rock salt formations of the Salt Range in the northern Punjab and the salt lakes of the Thar Desert. None, however, were as accessible or as easily exploitable (one can gather salt crystals by hand – Figure 11 B) as the ranns of Kachchh. One can imagine watercraft or cattle caravans laden with this "white gold" making their way north from Gujarat toward the cities of the interior plains.

Unfortunately, imagining the Harappan salt trade may be all we are ever able to do. Although evidence of salt production during this period has been unearthed at Padri in southeastern Saurashtra (Shinde et al. 2008), tracking the physical movement of this commodity across the Greater Indus region is likely to remain impossible.

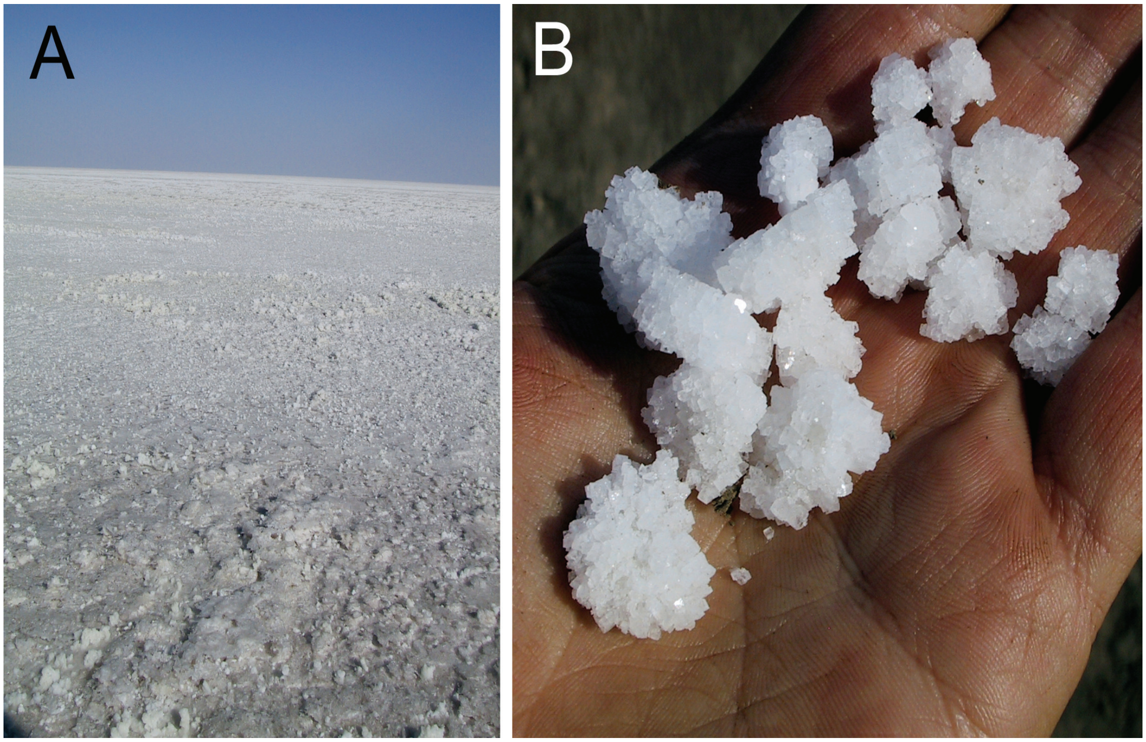

Figure 11: [A] Salt flats of the Great Rann of Kachchh. [B] Salt crystals from the rann

Other Rocks and Minerals

The materials discussed above were by no means the only rock and mineral resources in Gujarat exploited during the Harappan Period, they are just a few of the more important ones. Various igneous rocks (basalt, gabbro), sedimentary rocks (quartzite, sandstone, siltstone, conglomerate, fossiliferous and micritic limestones), clay (kaolinite), ochre minerals (hematite, goethite, limonite) and different types of crystalline quartz (amethyst and rock crystal) are among the other resources occurring in this geologically diverse region that were also utilized at the time. Although most probably moved within local or regional exchange networks, some materials, such as amethyst, were possibly traded to consumers outside of Gujarat.

Summary and Conclusion

Figure 12 is a map showing select Harappan stone and metal exchange networks that originated in Gujarat. Although the routes depicted (as colored lines/arrows) are purely conjectural, the network connection themselves are based on studies in which artifacts from each mapped site were correlated with geologic samples from a source in Gujarat. Agate-carnelian (red lines), mainly from occurrences in Kachchh but also, to a lesser extent, from the Ratanpur deposit, was traded to Harappa, Rakhigarhi,

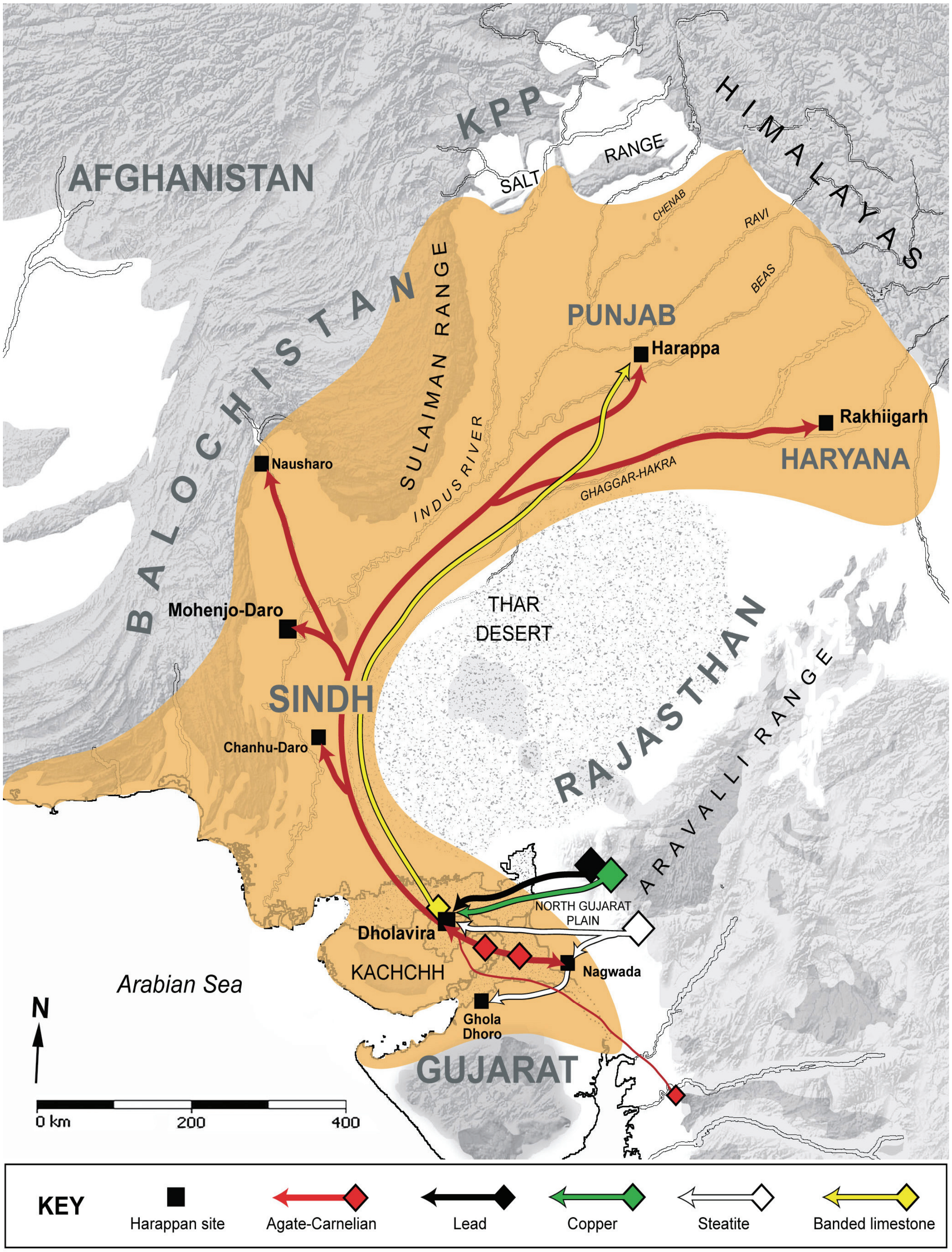

Figure 12: Select Harappan stone and metal exchange networks that originated in Gujarat

Nausharo, Mohenjo-Daro, Chanhu-Daro, Dholavira and Nagwada. Banded limestone (yellow line) from northern Kachchh was carried as far north as Harappa. Lead and copper resources (black and green lines respectively) occurring on the northern fringe of Gujarat were utilized by the residents of Dholavira. Finally, steatite from the northeastern part of the state was used by Harappans at Nagwada, Dholavira and Gola Dhoro (Bagasra). The other materials discussed in this paper were not depicted on Figure 12 as artifact-to-source correlation studies involving them have not yet been conducted. Nevertheless, it is highly likely that they too were moved along the same regional and inter-regional exchange networks. Although geologic provenience studies of these and other Harappan stone and metal resources remain ongoing, important discoveries have already been made.

It is now possible to confirm what has long been suspected – that Harappan beadmakers at sites across the Greater Indus region were utilizing agate-carnelian from sources in Gujarat. Moreover, it was determined that most such stone probably came from occurrences in the eastern Kachchh region rather than, as was widely thought before, the more famous Ratanpur area deposits in the southeastern part of the state. Future analyses of agate-carnelian beadmaking debris from the site of Lothal, which is nearer to Ratanpur, could change this picture, however.

It has also been demonstrated that the Harappans of Gujarat were utilizing a several different kinds of stone and metal (lead, copper, steatite and, quite probably, amazonite) from sources in the north-northeastern part of the state. The question now is – how did they acquire raw materials from these sources? Significantly, there is a 100 km or more gap across between the sources and nearest sites at which Harappans are known to have dwelled. Did Harappans themselves make forays across the plains of northern Gujarat? Or did they acquire these raw materials through trade with some other, non-Harappan intermediary group that had access, either direct or indirect, to resources occurring on the southern fringes of the Aravalli mountains? It is hoped that the joint Spanish-Indian North Gujarat Archaeological Project (NoGAP) currently underway (Madella et al. 2010) will shed light on these problems.

The finding that copper from the Ambaji-Deri deposit was used at Dholavira is highly significant. Lead isotope analyses of the metal objects from that site are incomplete and they remain to be carried out on artifacts from other sites in the region, so it is too soon to say if this was the primary copper source for Harappans in Gujarat. Nevertheless, the fact that we now know that metal from Ambaji-Deri was exploited during this period opens the possibility that it may have been yet another raw material from the Gujarat region that was exported to consumers across the Greater Indus region.

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