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Regional Interaction in the Prehistoric Indus Valley: Initial Results of Rock and Mineral Sourcing Studies at Harappa

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Introduction

The exchange and communication systems that connected distant parts of the Indus Civilization (*c.* 2600 to 1900 BC) and beyond had roots beginning in the early Neolithic period, if not earlier (Jarrige 1991; Kenoyer 1998). In order to better understand the role that such interaction networks and the groups that participated in them, played in the development of the earliest urban state-level society in South Asia, it is first necessary to determine which regions were in contact with one another and to define how these contacts changed through time. Archaeologically, the most precise way to do this is to identify the original sources of the material items that were exchanged between groups from the many different ecosystems comprising the greater Indus Valley region. In this paper I will present preliminary results of source provenance studies of rock and mineral commodities recovered from Harappa, in order to delineate the areas involved in regional interaction and long-distance exchange with that important urban center. Once source areas have been identified, it will be possible to examine how some of those millennia-old interaction networks may have intensified and expanded during the development and existence of the Indus Civilization, while others diminished or disappeared. In the following discussion I will briefly explain the theoretical perspective from which these issues will be considered and outline the methods that are being used to examine them. Two preliminary studies will be summarized: the identification of a broad but pertinent set of rock and mineral types from Harappa and an initial assessment of source areas for an important utilitarian item – stones for grinding purposes. Initial results indicate that a nested series of lithic exchange networks existed from the time of Harappa's earliest occupation. These networks connected the site to multiple source areas from ranging 120 km to more than 700 km away. Perceptible changes in source utilization occurred with regard to grindingstone and chert through Harappa's first three occupational phases in the form of a shift towards more distant source areas.

Examining regional interaction in the prehistoric Indus Valley

Exchange networks connecting distant areas of the greater Indus Valley region clearly existed many millennia before urban societies began to emerge there. One of the necessary preconditions for the emergence of the first urban civilizations was the existence of economic interaction networks between major ecosystems and resource areas in order to ensure a steady supply of certain materials that were essential the development and maintenance of state-level society (Kenoyer 1991: 343-45). Such materials include both subsistence goods and utilitarian items for the general populace and the exotic commodities used by elite groups to define and support their positions of authority. Exchange networks connecting distant and diverse parts of the greater Indus Valley region were in place at least as far back as the 7th millennium BC at Mehrgarh where both lapis lazuli from northern Afghanistan and marine shell from the Arabian Sea coast are found in Period 1 (Jarrige 1991: 41). It was during this early period that networks of interdependent relationships between groups engaged in specialized, but

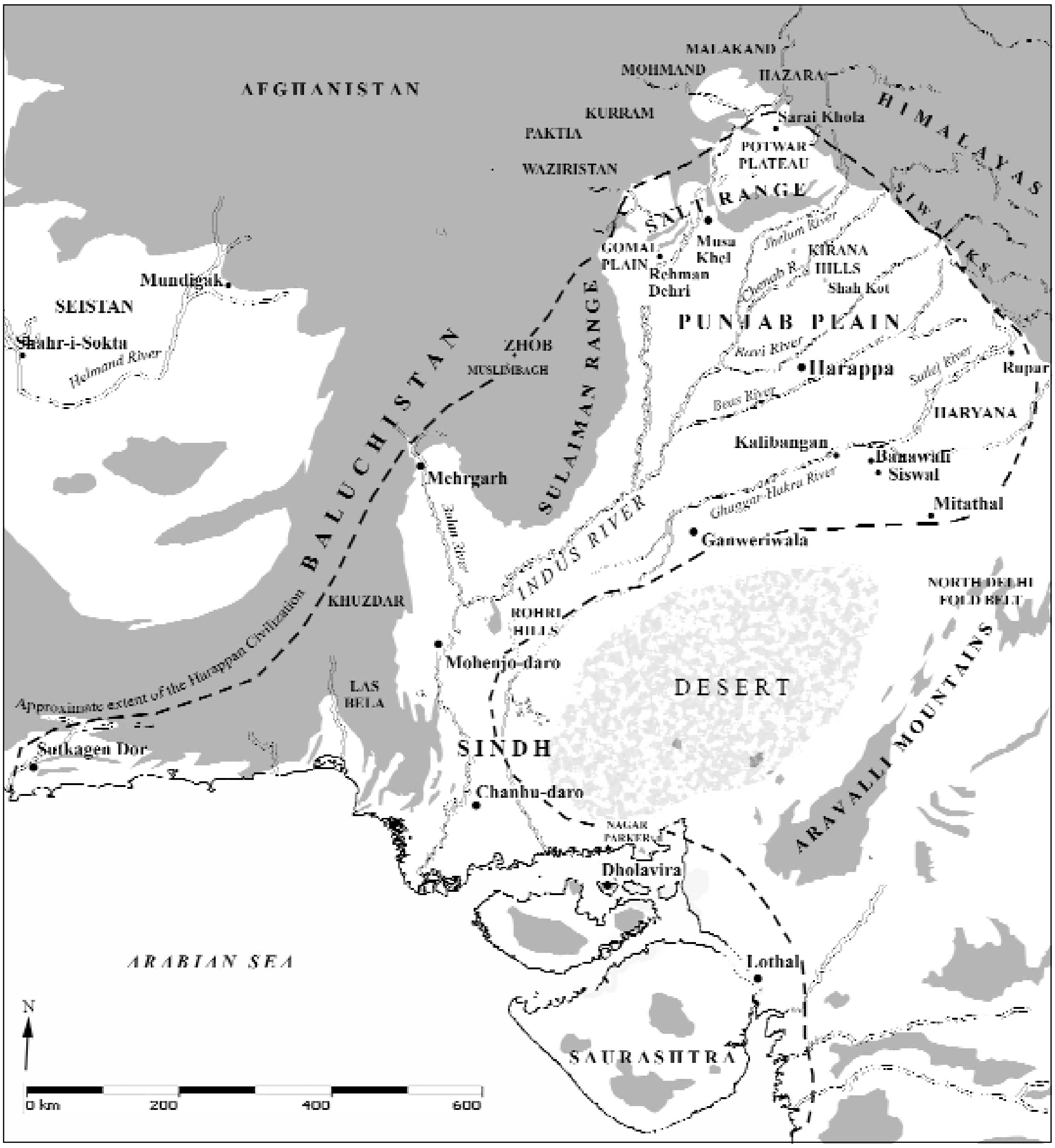

Fig. 1 – Map of sites and regions discussed in this text.

complimentary, activities probably first developed (Kenoyer 1998: 43). The emergence of urbanism in the Indus Valley was largely the result of the intensification and expansion of these long established economic and social links between these interdependent groups. The elite groups that came to rule Indus cities were likely those that controlled access to vital resources such as land, livestock and raw materials (Kenoyer 1995: 213-14) by manipulating these networks-relationships.

How can such networks-relationships be seen archaeologically? Although its causes and origins are regional, "urbanism plays itself out most visibly on the local (town)" level (McIntosh 1999: 68). The various regions/groups involved in the urban transformation of Indus society that began in the early 3rd millennium BC, as well as the links between them, can be identified through the study of non-local material remains at sites that span this important transition period. Likewise, the shifting power networks of an urban settlement's ruling group(s) can be investigated on both a local and regional

Period	Phase	Dates
Period 1	Ravi Phase	> 3300 BC - *c.* 2800 BC
Period 2	Kot Diji (Early Harappa) Phase	*c.* 2800 BC - *c.* 2600 BC
Period 3A	Harappa Phase A	*c.* 2600 BC - *c.* 2450 BC
Period 3B	Harappa Phase B	*c.* 2450 BC - *c.* 2200 BC
Period 3C	Harappa Phase C	*c.* 2200 BC - *c.* 1900 BC
Period 4	Harappa/Late Harappa Transitional	*c.* 1900 BC - *c.* 1800 BC
Period 5	Late Harappa Phase	*c.* 1800 BC? - <1300 BC

Table 1 – Harappa Chronology (after Meadow & Kenoyer 2001).

scale with reference to changing degrees of access to non-local resources that are identifiable in the archaeological record.

The Harappa Archaeological Research Project was initiated so that issues such as these might be examined (Dales & Kenoyer 1993; Meadow & Kenoyer 1997). Since 1986, excavations at Harappa, the second largest urban center of the Indus Civilization, have revealed that a considerable variety of rock and mineral types can be found throughout all periods of the site's long occupation (Table 1). Yet this settlement, founded on an alluvial terrace in the middle of the Punjab plain (Fig. 1), is over 100 km from any significant source of stone.

In the absence of readable texts that explicitly identify resource areas, studies aimed at provenancing the raw material of stone artifacts provide the most conclusive links possible between places where the objects were used and discarded and the areas from which the raw material they are composed of potentially originated. By examining the assemblage of rock and mineral artifacts from each phase and sub-phase of the five-period chronology that has been established at Harappa (Meadow & Kenoyer 2001: 20) a diachronic picture of the avenues of regional interaction that existed during the Early Harappan and Harappan Periods can be reconstructed.

Source Provenance Studies of Rocks and Minerals from Harappa

The goal of this project is to generate a more precise and comprehensive picture of prehistoric regional interaction in the greater Indus Valley, possible by applying geologic sourcing techniques to rock and mineral artifacts. This requires that the economic geology of the site and the region be defined as precisely as possible. What is proposed here is very much like what was done for sites in the Seistan like Mundigak (Jarrige & Tosi 1981) and Shahr-i-Sokta (Costantini & Tosi 1978) except on a much larger scale and with the focus on a single resource category (stone) instead of multiple ones. This investigation of rock and mineral artifacts from Harappa and their potential source areas involves: 1) the utilization of up-to-date geological literature as primary source material; 2) field studies that include the examination of known source formations, collection of raw source materials for analyses, confirmation of alleged sources and identification of previously unknown ones; 3) the correct raw material identification of rock and mineral artifacts and the determination of their potential source areas using systematic comparative methods and/or geochemical analyses.

A wealth of geologic literature exists regarding the rock and mineral resources of South Asia and is used in this investigation as primary source material. The geological surveys of Pakistan and India, as well as many university geology departments in both countries, publish numerous books, journals, guides, conference proceeding, etc. that provide up-to-date and detailed information on rock and mineral resources. The geology of the Subcontinent also attracts scholars from throughout the world who publish their findings in international journals. Many new and far more accurate regional geologic overviews exist (Bender & Raza 1995; Kazmi & Jan 1997) to replace out-dated ones (Brown & Dey 1955). The series of provincial and district gazetteers produced by the government of British India are recognized as remarkable works and valuable sources of information, especially for details such as where regarding where gold washing activities took place, the location of old quarrying sites and the important trade routes of that era. However, these gazetteers, written by non-geologists around the turn of the 19th century, are not always accurate in their identification of materials and sources and definitely should not be considered the most comprehensive accounts available of the mineral resources in the areas they cover. Archaeological studies that have relied heavily upon them, and other outdated or non-primary source material, to delineate resource areas and construct models of access and exchange (e.g. Fentress 1977; Lahiri 1992) have serious limitations because of this.

During 2000-2001, as part of my American Institute of Pakistan Studies and Fulbright supported research, I was able to undertake numerous field excursions within both Pakistan and India for the purpose of studying known rock and mineral source formations, collecting raw samples for comparative studies, and identifying previously unknown material sources. I travelled throughout the Punjab, Baluchistan, Sindh, Rajasthan, Pakistan's Northern Areas, and the Northwest Frontier Province (N.W.F.P.), as well as to areas within the Federally Administered Tribal Areas (F.A.T.A.) – specifically the agencies of North Waziristan, Kurram, Khyber, Malakand, and Mohmand. Among the materials collected for future provenance studies are steatite, serpentine, chlorite, gypsum (alabaster and selenite), lead ore, copper ore, basalt, chert, jasper, grossular garnet, vesuvianite, ochre (hematite, goethite, limonite), rock crystal, and various materials used for grinding purposes.

During the 2000 field season at Harappa a set of 200 samples were selected representing nearly 30 rock and mineral types found at the site. This initial sample set was composed of entirely of rock and mineral manufacturing debris found in surface contexts. With the permission of the Director General of Archaeology and Museums, Government of Pakistan, I was able to use these samples for comparative studies and destructive analyses. Petrographic thin sections of selected samples were prepared and evaluated at the Pakistan Museum of Natural History, Islamabad under the direction of Dr. Syed Baqri, Director of the Earth Sciences Division. X-ray diffraction analyses were performed on selected samples at the University of Peshawar under the direction of Professor Dr. Syed Hamidullah, Director, Centre of Excellence in Geology. During the 2001 field season, permission was given to supplement the original set with approximately 300 additional samples of rock and mineral manufacturing debris from securely dated contexts at Harappa. Among the studies currently in progress on these materials are instrumental neutron activation analyses of steatite, chert, agate, vesuvianite-grossular; studies of lead ore and limestone using inductively plasma coupled mass spectrometry; sulphur and strontium isotope analysis of alabaster, and electron microprobe analyses of numerous materials including basalt and "ernestite" (Kenoyer & Vidale 1992) drill material.

One of the most significant discoveries made during this time was of an important chert source in the Salt Range (Law & Baqri 2001). Most of the chert found at Harappa during Period 3 (2600-1900 BC) is thought to have come from the enormous beds of brown-gray chert found in the Rohri Hills of Sindh (Kenoyer 1995: Figure 6). Indeed, the identification of numerous quarries and knapping areas suggests that chert tools were produced in the Rohri Hills on an industrial scale during the Harappan period (Biagi & Cremaschi 1991). However, prior to 2600 BC other varieties of chert are present at Harappa indicating that alternate sources were utilized during that time. Black chert is one such variety and has been used in the past at Harappa as an indicator that Kot Dijian Period levels had been reached (Dales & Kenoyer 1991). Black cherts are known to occur in Baluchistan (Aubrey *et al.* 1988) and, up until now, material of this type found at Harappa in Kot Dijian levels and in the preceding Ravi Phase (Period 1 – 3300-2800 BC) was thought to have originated from there (Kenoyer pers. comm.). However, at the head of Nammal Gorge in the western Salt Range (Fig. 2) large nodules (up to 75 cm in length) of black to chocolate brown chert occur in the Sakesar limestone. Flaking debris of this material was noted near the mouth of the gorge and as well as 4 km away on the surface of the Kot Diji and Harappan phase site of Musa Khel (Dani 1970-71:32). Comparative studies of this material were conducted with similarly colored cherts from Baluchistan and with archaeological materials at Harappa and in collections at the Museum of Archaeology and Ethnology, University of Peshawar. Based on these comparisons it appears that Sakesar chert may be the same material found in Ravi and Kot Diji levels at Harappa

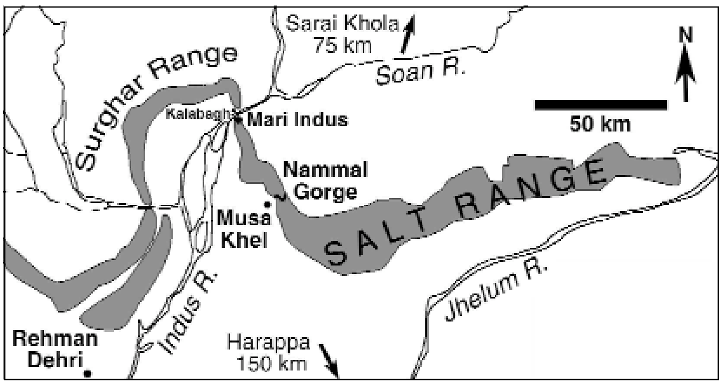

Fig. 2 – Map of the Salt Range.

and other sites of that period on the Gomal Plain such as Rehman Dehri (Law & Baqri 2001). Instrumental neutron activation studies are currently underway to determine if this was indeed the case.

Another important discovery was of the probable source area of several enigmatic quartz crystals that have appeared in Period 3, and possibly Period 2, levels at Harappa. These small (≈ 1 cm), bi-pyramidal, transparent to translucent quartz crystals have a pink cast and appear to be what Pakistani geologists today commonly call "Mari Diamonds" (Alam & Khan 1982: 8). Although they can be sporadically found at a few other locations within the Precambrian gypsum and salt marls of the Salt Range, Mari Diamonds occur in abundance (*ibid.*; pers. observation) in the vicinity of Mari Indus and Kalabagh (Fig. 2). Other occurrences are may exist, however. Bi-pyramidal quartz crystals were noted by Verchere (1860 in Government of the Punjab 1883-84) in the brecciated gypsum of the Waziristan Hills. In the stone bazaar of Peshawar I have examined examples of similar crystals embedded in a gypsum matrix that were attributed to the Paktia region of Afghanistan. Nevertheless, the Salt Range, at 225 km from Harappa, is the closest well document source of these distinctive crystals and further studies may help to support the hypothesis that they came from there. Mari Diamonds are known to contain inclusions of anhydrite (Faruqi 1983: 17) and electron microprobe studies will be conducted to determine if examples from Harappa do as well. Currently underway are strontium and sulfur analyses of alabaster (massive gypsum) fragments from Harappa that should help to determine whether this material originated in the Precambrian deposits of the Salt Range or in Eocene deposits to the west in Baluchistan, the N.W.F.P. and Afghanistan. If some of the alabaster is shown to have originated in the Salt Range then additional support for assigning Mari Diamonds provenance to that formation will be provided.

Identification of rock and mineral samples from Harappa using X-ray diffraction analysis.

The first step in locating rock and mineral source areas is the correct identification of the materials you are trying to source. X-ray diffraction (XRD) analysis is an excellent method with which to identify the major and minor mineral components of a stone sample. This technique has been used effectively before to identify "green" stones from Harappa, Mohenjo-daro and Mehrgarh (Vidale & Bianchetti 1997). Sixty of the original 200 sample set were chosen for analysis and the results are summarized in (Table 2). Please refer to Fig. 1 for the locations of source areas mentioned in this section.

Three samples were composed of *galena*, or lead sulfide, with a secondary component of *stibnite*, or antimony trisulfide. Galena is the most important form of lead ore (Read 1979: 458). Stibnite, also known as "gray antimony" (*ibid*.: 481) is crushed, often with galena, to produce the fine gray powder called "surma" or "kohl" traditionally used in many countries of West and South Asia as a cosmetic (Hardy *et al.* 1998; Siddiqui & Sharp 1993: 396). The nearest sources where galena and stibnite are known to occur together in massive form are found beginning over 700 km to the southwest in the Khuzdar and Las Bela Divisions of Baluchistan (Ahmad 1975).

Seven translucent green stones were analyzed. Five samples were pure *vesuvianite* (idocrase), a silicate of calcium, aluminum, and magnesium. One was *grossular*

Primary Component	Secondary Component	# of samples
Galena	Stibnite	3
Vesuvianite		5
Grossular	Clinochlore	1
Vesuvianite	Grossular	1
Hematite		1
Goethite		1
Gypsum (alabaster)		2
Gypsum (selenite)		2
Mullite	Cristobolite	2
Mullite	Quartz	2
Talc		20
Talc	Quartz	4
Talc	Dolomite	5
Malachite		1
Calcite		1
Sulfur		1
Quartz		2
Quartz	Cristobolite	2
Quartz	Albite	2
Quartz	Tremolite	1
Quartz	Goethite	1

Table 2 – X-ray diffraction analysis of 60 rock and mineral samples from Harappa.

garnet, a calcium aluminum silicate, with a minor component of chlorite that was probably a product of weathering. The final sample was composed of both vesuvianite and grossular, which are structurally similar minerals and often occur in intimate mixtures (Deer *et al.* 1992: 47). The closest vesuvianite, grossular, or vesuvianite-grossular sources to Harappa are 375 km to the northwest in the Malakand and Mohmand agencies of the N.W.F.P (Kazmi & Jan 1997: 286). Another potential source is near the village of Taleri Mohammed Jan, just over 400 km west in southern part of Baluchistan's Zhob District. There, metasomatic alteration of a dolerite dike resulted in the formation of vesuvianite, grossular and clinochore (Bilgrami & Howie 1960).

Two pieces of "ochre" were analyzed. One sample was identified as *hematite*, or iron oxide. The other was identified as *goethite*, a hydrous iron oxide. Both are common mineral pigments (Ahmad *et al.* 1992: 16) and the nearest sources to Harappa would be the ochres mined in the Kirana Hills near Sargodha starting 150 km north (Butt *et al.* 1993: 8; Shah 1973: 10-11; pers. observation).

Four fragments of *gypsum*, hydrated calcium sulfate, were identified. Two of the samples were of the massive variety, commonly called *alabaster*. The other two were *selenite*, a transparent crystalline variety of gypsum. The nearest source to Harappa for gypsum of either variety would be the extensive Precambrian deposits of the Salt Range discussed above (Alam & Khan 1982).

"Ernestite," the stone used by Harappan beadmakers to perforate carnelian and agate more efficiently than chert drills is presently the "mystery" material of this investigation into rocks and minerals from Harappa. Visually it is an extremely fine-grained khaki-colored stone with dark-brown to almost black mottled veins and patches. Findings from Kenoyer and Vidale's (1992: 506-507) preliminary XRD and electron microprobe analyses indicated that "ernestite" was primarily composed of quartz and sillimanite/mullite with hematite and phases of iron/titanium oxide. In order to further refine the characterization of this material four additional "ernestite" samples were analyzed. These were found to be composed largely of the mineral *mullite*, an aluminum silicate and silicon dioxide. Its needle-like structure gives mullite a high mechanical strength (Johnstone & Johnstone 1961: 366) and thus drill bits made from stone containing this mineral would have naturally been very effective. Several rock and mineral types, when heated at temperatures exceeding 1100 to 1200°C (it depends on the material) under normal atmospheric pressure, undergo partial or complete conversion to mullite including those of the sillimanite group (sillimanite, andalusite, kyanite), bauxite, bentonite, spinel, impure kaolins and kaolin-rich rocks such as flint clay or fire clay (Keegan 1998; Johnstone & Johnstone 1961: 366). The silicon dioxide in the samples took two forms: two of the samples showed XRD peaks for *quartz* and two showed peaks for *cristobolite*. Cristobolite is a polymorph of quartz that has undergone solid-state transformation after being heated to temperatures between around 1200° to 1470°C (Sosman 1965: 130-33). Synthetically produced as a refractory material today, mullite is an extremely uncommon mineral in nature and, along with cristobolite, has never been reported to occur in South Asia. The presence of these two high-temperature minerals in the same stone suggests that the "ernestite" was a silicon-rich mullite producing material that was pyrotechnically altered to an extreme degree. This should come as no surprise given the Harappans propensity for heat-treating materials (Miller 1999). Studies are presently underway to determine if this is indeed the case and to identify the composition and source of the original untreated material.

Twenty-nine pieces of steatite manufacturing debris were analyzed and shown to be primarily composed of the mineral *talc*, a hydrous magnesium silicate. Twenty of these samples were pure talc. Four samples contained a component of quartz silica in addition to talc. Five samples showed XRD peaks for *dolomite*, a calcium magnesium carbonate, in addition to talc. Steatite occurs at numerous locations in the mountains surrounding the Indus Valley (Law 2002). The sources reportedly closest to Harappa would be those said to be in the Zhob City-Ft. Sandeman area of Northern Baluchistan, 300 km directly west (Ahmad 1975: 135). However, field checks of these areas in May of 2001 failed confirm the existence of these deposits and it is possible that local chloritized serpentinites were misidentified as steatite. The nearest confirmed steatite sources in Baluchistan are those of the Muslimbagh region in the southern Zhob District. With regard to the five samples containing dolomite, Baluchistan is probably not the source area for these because the parent materials for all of the known steatite deposits in that region are periodititic (igneous ultramafic) rocks rather than sedimentary dolomitic rocks (*pers. observations*). The nearest sources for steatite derived from dolomitic rocks would be over 400 km away in either the Kurram Agency in the F.A.T.A. (Badshah 1983) or the Hazara District of the N.W.F.P (Ali *et al.* 1964: 29-34).

Eleven unidentified minerals collected from Harappa were also analyzed. One sample was identified as *malachite*, or carbonate of copper. Malachite is found in zones where weathering or oxidation of a copper deposit occurs (Read 1979: 252). The closest potential source for malachite would be the copper deposits of North Waziristan (Badshah 1985). One fragment of *calcite*, calcium carbonate, was identified. This extremely common mineral could have originated from any number of regions surrounding the Indus Valley. One sample analyzed was shown to be pure *sulfur*. The closest sulfur sources to Harappa are found along the eastern margins of the Sulaiman Mountains (Ahmad 1969: 159-61). Eight samples analyzed were shown to be primarily composed of *quartz*. One of these was pure quartz of the chalcedony variety. Quartz, of course, is an extremely common mineral and can be found at numerous locations surrounding the Indus Valley. However, the secondary component in the remaining samples may provide a clue as to their origins. Two samples displayed XRD peaks for both quartz silica and cristobolite silica. Cristobolite (see above) is not known to occur naturally in South Asia and so it is therefore thought that this material may possibly be a bi-product of some high-temperature craft activity at Harappa. Two samples contained quartz and *albite*, a sodium aluminum silicate, which is derived from rocks of igneous origin. One sample contained quartz and *tremolite*, a calcium magnesium silicate. Tremolite occurs in both regionally and contact metamorphosed rocks and thus could have been found in the many areas surrounding the Indus Valley where rocks of these types are present. A final sample contained a component of *goethite*. Goethite is used as a mineral pigment and can be found in the Kirana Hills (see above).

Although exact sources cannot be determined through XRD analyses of this kind, the precise mineralogical identifications that they provide do, when used together will the abundant geological literature that exists, allow one to delineate probable source areas. Some materials analyzed (ochre, gypsum, sulfur) could be found in the hills and ranges immediately surrounding the Punjab Plain, while others (steatite, galena-stibnite, vesuvianite-grossular) had to have originated from much more distant sources. Other materials analyzed (quartz, calcite) are far too common to make a determination as to provenance and the material we know as "ernestite" appears perhaps to have been altered by Harappans to such a degree as to obscure the original raw material. Nevertheless, more studies of this kind are needed to better understand the diversity of Harappa's rock and mineral assemblage and to trace the city's connections to raw material source areas.

Type	Period 1	Period 2	Period 3	Period 4/5	All Grindingstone
Delhi Quartzite	0.88% 80.2 g (n=1)	1.35% 583.3 g (n=6)	19.72% 76092.3 g (n=301)	34.85% 988.5 g (n=7)	15.23% 2372.36 kg (n=535)
Fine Gray Sandstone	1.14% 104.3 g (n=2)	4.55% 1962.8 g (n=5)	7.76% 29956.1 g (n=75)	4.69% 133 g (n=2)	14.89% 2318.59 kg (n=171)
Kirana Hills Meta-Quartzite	86.51% 7900.1 g (n=47)	64.11% 27639.1 g (n=156)	2.88% 11108.5 g (n=50)	12.24% 347.2 g (n=2)	3.97% 618.19 kg (n=305)
Pab Sandstone	0.21% 19.2 g (n=1)	11.54% 4975.6 g (n=22)	49.92% 192660 g (n=444)	6.52% 184.9 g (n=2)	34.74% 5410.38 kg (n=783)
Unknown	11.26% 1028.7g (n=9)	18.45% 7954.2 g (n=53)	19.72% 76091.97g (n=314)	41.70% 1182.6g (n=7)	31.17% 4855.36 kg (n=727)

Table 3 – The composition of Harappa's grindingstone assemblage through time (percentage, total weight, and number of samples listed).

A preliminary assessment of Harappa's grindingstone sources.

Stones for grinding purposes (querns/mortars, pestles, whetstones, etc) are among the most common lithic artifacts at Harappa and every excavated fragment has been saved for eventual analysis and identification of specific raw material type. A detailed provenance investigation of grindingstone sources was initiated after preliminary examination during the HARP's 2000 field season indicated that there were several highly distinctive varieties of grindingstone material types present at the site. Although this provenance study is still in progress, interesting patterns relating to grindingstone acquisition have already become apparent.

A sample set containing examples of the various grindingstone material types from Harappa was taken to the Pakistan Museum of Natural History in Islamabad, the Geological Survey of Pakistan-Quetta and the geology departments of the University of Peshawar, University of Baluchistan and Karachi University. The samples were compared with collections at these institutions and evaluated by geologists who were familiar with the materials. The hills and ranges closest to Harappa – the Kirana Hills, Salt Range, the Siwaliks, the Sulaiman Range, the Lower Himalayas of northwest India and various geologic formations in southern Haryana and northern Rajasthan were visited, studied and sampled. A geologic sample set was brought to Harappa and compared directly with excavated materials. All whole and fragmentary querns/mortars and pestles recovered at the site (including those from past excavations stored in the Harappa Museum's reserve collection) were examined at HARP's on site field laboratory. Over 2500 individual pieces were compared with the geologic sample set and assigned a preliminary provenance based on a variety of macroscopic criteria including rock type, color, grain size, patterning, visible inclusions, degree of silicification and toughness. The majority of grindingstones recovered at Harappa are in a fragmentary state. For this reason is was decided that generating percentages of material types present at the site based on weight, rather than by the number of individual fragments, more accurately reflects the degree to which a material source was being utilized.

A basic breakdown (without reference to context or period) of all grindingstones examined in this study can be seen in Table 3 – column 6. Nearly seventy percent (68.8%) of all querns/mortars and pestles at Harappa belong to one of four material types. Pab sandstone, the most common type (34.7%), has a sugary texture and macroscopically grades from solid brown to a highly distinctive gray-white color with small (< 3 mm) regularly spaced brown patches (Shah 1991; Kassi *et al.* 1991). The toughness of this Cretaceous sandstone (Akhtar & Masood 1991: 9) makes it particularly well-suited for grinding and it is still widely used for this purpose in Pakistan today (pers. observations). Although Pab sandstone can also be found in the Las Bela and Khuzdar districts of southern Baluchistan, its most extensive and well-developed occurrence begins 225 km due west of Harappa in the Sulaiman Range. The next most common (15.2%) type of grindingstone at Harappa is a variety of Delhi quartzite found in outliers of the North Delhi Fold Belt located in southern Haryana. Unlike the glassy, highly silicified material that is typical of Delhi quartzite, the quartzite from southern Haryana has a sugary texture and a distinctive gray-pink color that is crisscrossed with thin hematite filled fractures. The northernmost of these outliers is located 389 km southeast of Harappa but is only 29 km south of the site of Harappan period site of Mitathal (Bhan 1969). I have observed this material type on the surface of Mitathal and at several other sites between the source and Harappa including Siswal, Banawali and Kalibangan. The third most common (14.8%) variety of grindingstone at Harappa is an extremely dense, tough and fine-grained gray sandstone that probably derives from one of two regions. Mughal Kot sandstone, found in the northern Sulaiman Range (Shah 1977: 48), is dense and gray and I have observed grindingstones made of this material at Early Harappan and Harappan Period sites on the adjacent Gomal Plain. Fine gray sandstone, eroding from formations in the Siwaliks and Lower Himalayas (Srikantia & Roy 1998), can also be found beginning 350 km east-northeast of Harappa in the beds of Beas, Sutlej and Ghaggar rivers at the point where they meet the plains (pers. observation). The grindingstones on display in the site museum of the Harappan settlement of Rupar (Dutta 1984) are all composed of this material. The final and least abundant overall (3.9%) of the four major grindingstone material types at Harappa is a grey-green mottled, hematite-stained meta-quartzite that derives from a series of Precambrian outcrops called the Kirana Hills (Alam *et al.* 1992), which abruptly emerge out of the Punjab Plain beginning 120 km to the northeast of Harappa at Shah Kot. While meta-quartzite from the Kirana Hills is, in terms of grinding purposes, of decidedly inferior quality (more friable and less homogeneous) as compared to the other three material types, it would have been by far the closest stone of any kind available to the residents of Harappa.

Slightly more than thirty percent (31.7%) of the grindingstones in the assemblage could not be confidently assigned a probable provenance based on macroscopic characteristics alone and so were categorized as "unknown." A great many of these were igneous and metamorphic rocks such as dense black basalt, gabbro, gneiss and diorite that are visually identical to other rocks of the same variety found in numerous regions surrounding the Indus Valley. Many examples of gray or pink granite were examined that could have been from the Tobra boulder beds of the Salt Range (Shah 1980: 12; pers. observation), the Nagar Parker outcrop of southern Sindh (Jafry & Ahmad 1991), outcrops in the Biwani region of southern Haryana (Eby & Kochhar 1990) or several other locations. Likewise, the numerous highly silicified white quartzite cobbles encountered could have come from as near as the Dok Pattan Formation of the Siwaliks (Iqbal 1994; pers. observation) or one of several formations in the North Delhi Fold Belt of the Northern Aravallis (Sinha-Roy *et al.* 1998: 129-140). Chemical composition, isometric dating and/or petrographic studies are planned and may eventually help to resolve the provenance of many of these "unknown" types.

Over 1000 of the grindingstones examined in this study were surface finds or came from disturbed contexts such as brick robber trenches. However, more than 1500 have been recovered from secure, stratified contexts throughout the site's five main periods of occupation (Table 1) and so it is possible examine how acquisition networks for this important utilitarian commodity changed through time (see Chart 1). During Harappa's initial occupation (the Ravi Phase) we see that residents of the then village-size settlement (Kenoyer & Meadow 2000) acquired the vast majority (86.5%) of their stone for grinding purposes from the nearest sources in the Kirana Hills. Although most of the remaining material that has been recovered from this period is of unknown provenance, connections to distant regions both to the west and east are suggested by single examples of Pab sandstone and Delhi quartzite. During the subsequent Kot Diji Phase we see that although the residents of Harappa shared cultural ties with peoples across a broad region extending from northern Sindh to the Potwar Plateau (Mughal 1990), the majority (64.1%) of their grindingstone was still obtained in the Kirana Hills. However, percentages of the other grindingstone types do increase somewhat (Pab sandstone in particular grows to

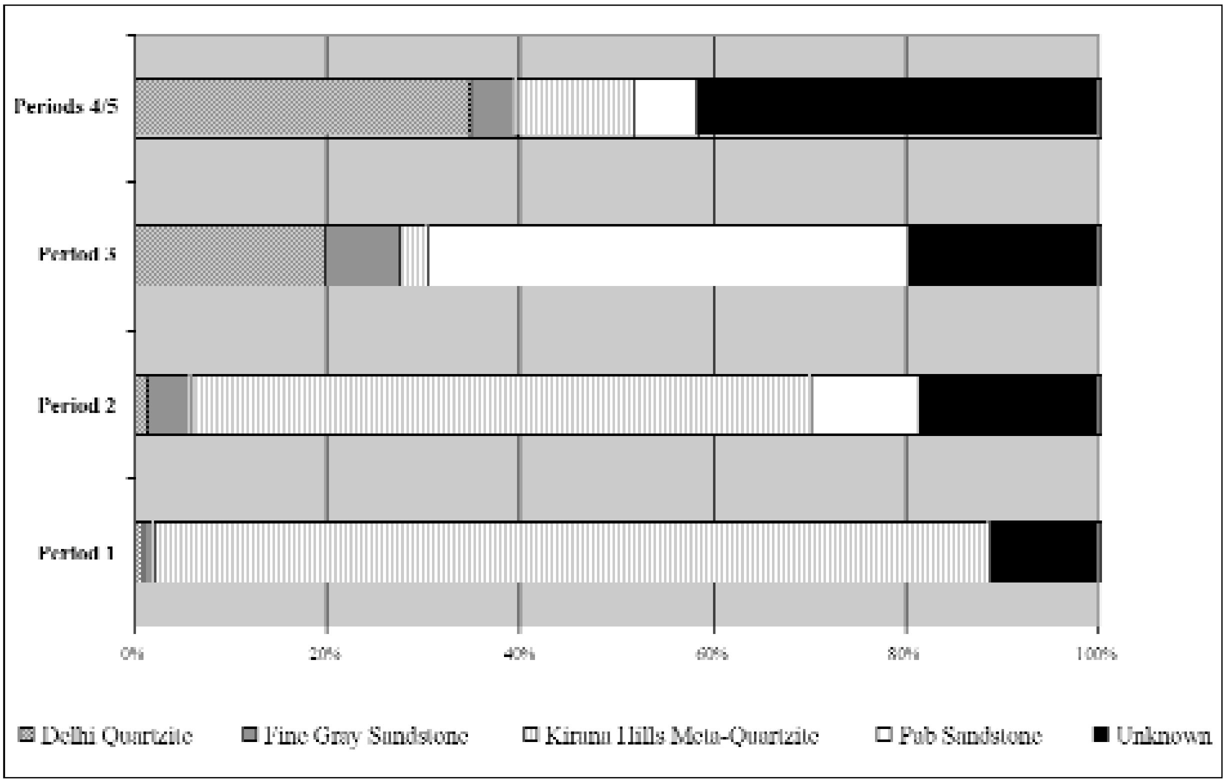

Chart 1 – Changes in the composition of Harappa's Grindingstone Assemblage Trough Time.

comprise 11.5% of the Period 2 assemblage) suggesting that some people living at, or visiting the site, were beginning to expend energy and/or wealth acquiring greater quantities of material from those higher quality but more distant sources. This trend may represent another aspect of the socio-economic development evident during the proto-urban Kot Diji Period at Harappa (Meadow & Kenoyer 1999). By Harappa's fully urban phase (Period 3) it becomes strikingly clear that exchange relationships and transportation networks are fully in place through which heavy, bulky materials like grindingstone can be brought from the higher quality sources located in distant parts of the Indus realm. The Kirana Hills, although located only half as far as the next nearest grindingstone source in the Sulaiman Range, now accounts for only 2.8% of the material from this period. Finally, during the Late Harappan Phase (periods 4 and 5), both Delhi quartzite (34.8%) and "unknown" grindingstone varieties (41.7%) see their highest percentages of any period in the assemblage. While the total number of samples recovered from this phase is admittedly small (n = 20), the apparent change may reflect the general eastward shift of Harappan peoples that occurred during this time (Possehl 1997). The Delhi quartzite source would have been available to the Late Harappans of Haryana and new access to eastern sources in the Gangetic region could account for the increase in "unknown" varieties.

Conclusion

Although the studies above are only two initial steps toward understanding very complex regional processes, they have already provided valuable insights into the various regions that residents of Harappa must have had connections with in order to obtain the different types of rocks and minerals found at the site. The XRD study indicated just how varied and wide ranging those connections might have been. A nested series of lithic exchange networks evidently existed from the time of the site's earliest occupation. The lapis lazuli and agate found in the Ravi Phase (Kenoyer & Meadow 2000) demonstrates that long-distance exchange networks were present for certain types of stone that would have been used to manufacture status items. On the other hand, the grindingstone assemblage for the Ravi and the subsequent Kot Diji Phases indicates a greater emphasis, in contrast to later periods, on sources nearest to Harappa for utilitarian items. Additional confirmation of this pattern may be provided if the black cherts from the Early Harappan levels at the site are indeed found to be from the newly identified source in the Salt Range.

Our knowledge of the interaction networks that connected residents of Harappa with peoples from distant parts of the greater Indus Valley region will become even clearer when studies that are now in progress on materials such as steatite, lead ore, alabaster and chert are completed. With detailed provenance information on multiple categories of stone from each phase at Harappa it will be possible to begin to develop a picture of which regional groups were involved in the processes leading to the development of urban society at Harappa. Future interpretive models focusing on the importance of regional interaction and resources access to the emergence of the Indus Civilization can be made stronger than existing ones by using studies such as these that are based on primary source data and systematic analysis of multiple categories of archaeological material.

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