CHAPTER 10

ALABASTER ACQUISITION NETWORKS

CHAPTER INTRODUCTION: THE DIFFERENT FORMS OF GYPSUM AT INDUS CIVILIZATION SITES

The mineral gypsum – hydrated calcium sulfate ($CaSO_4 \bullet 2H_2O$), is found in many forms at Indus Civilization sites. Transparent tabular crystals known as selenite have been recovered at Harappa (recall Figure 4.4 C). Gypsum mortar was sometimes used at the site (Vats 1940: 12-13), as well as at Mohenjo-daro (Mackay 1938: 162), for the "pointing" (filling the joints) of brick masonry. At Dholavira, the inlayed lettering of what appears to have been a large signboard was composed of a heated gypsum paste (R.S. Bisht personal communication 2004). Naturally precipitated gypsum has been found encrusting artifacts at Mohenjo-daro (Mackay 1938: 162, 525) and in the soils around Harappa (Amundson and Pendall 1991: 18). The white coating on the exterior of pots in some burials at Harappa, which some believe to be deliberately applied gypsum plaster (Strahan 1991), may actually be natural encrustations. In this chapter, I identify the sources from which residents of Harappa acquired the massive variety of gypsum known as alabaster.

The name "alabaster" has been used to describe ornamental stones of varying chemical compositions. "Oriental" or "Egyptian" alabaster is actually travertine – calcium carbonate ($CaCO_3$) and is sometimes also called "onyx marble" (el-Hiwanni and Loukina 1972; Webster 1958). Recall the small stone ring (Figure 4.7 B) mentioned in Chapter 4 that looks much like the travertine quarried today in the Chagai Hills of Balochistan (Ahmad 1975: 124-128). This is not the type of material that is under examination here. Genuine alabaster is the compact, massive form of gypsum. Gypsum alabaster (hereafter just alabaster) is semi-translucent in thin pieces and has a sugary texture that becomes satiny when polished. Purer varieties are white to pink in color. These qualities, along with the fact that it is a relatively common and easily carved stone (Mohs hardness of 2), made it a popular ornamental material in many areas of the ancient world (Rapp 2002: 123-127). The Indus Civilization was no exception. A wide range of alabaster objects have been found at Indus settlements including large and small rings, whorls, mace-heads, bangles, beads, cubical weights, discs, balls, inlays, pendants, "gamesmen", lattice-screens, plugs, bowls and bottles (see Lahiri 1992 for a site by site listing of alabaster artifacts).

Gale and others (1988) successfully employed a combination of sulfur isotope and strontium isotope analysis to determine the geologic provenience of alabaster artifacts from Mycenaean Greece. Using these same methods, a set of alabaster objects from Harappa is compared to geologic samples from multiple locations in three potential source formations surrounding the Indus Valley. This study is supplemented with isotopic analyses of a small set of artifacts from three other Early Harappan and/or Harappan period sites as well as with the characterization of an unusual type of quartz recovered at Harappa, which may derive from one of the alabaster sources under consideration. Before presenting the details of those studies, I first provide an overview of the forms and contexts in which alabaster is found at the site of Harappa.

Figure 10.1 Alabaster artifacts excavated by the Harappa Archaeological Research Project (1986-2001).

CONTEXT	*Mound AB*	*Mound F*	*Mound ET*	*Mound E*	*Cemetery*	*Sarai*	*Other*	*total*
surface or disturbed	106	9	10	69	1	2	13	*210*
Period 3C	38	46	38	46	8	3	.	*179*
Period 3B	1	.	12	4	1	.	.	*18*
Period 3A	3	.	1	5	.	.	.	*9*
Period 2	3	.	.	.	.	.	.	*3*
Period 1	3	.	.	.	.	.	.	*3*
total	*154*	*55*	*61*	*124*	*10*	*5*	*13*	***422***
objects / debris	81 / 73	24 / 31	31 / 30	54 / 70	3 / 7	0 / 5	7 / 6	200 / 222

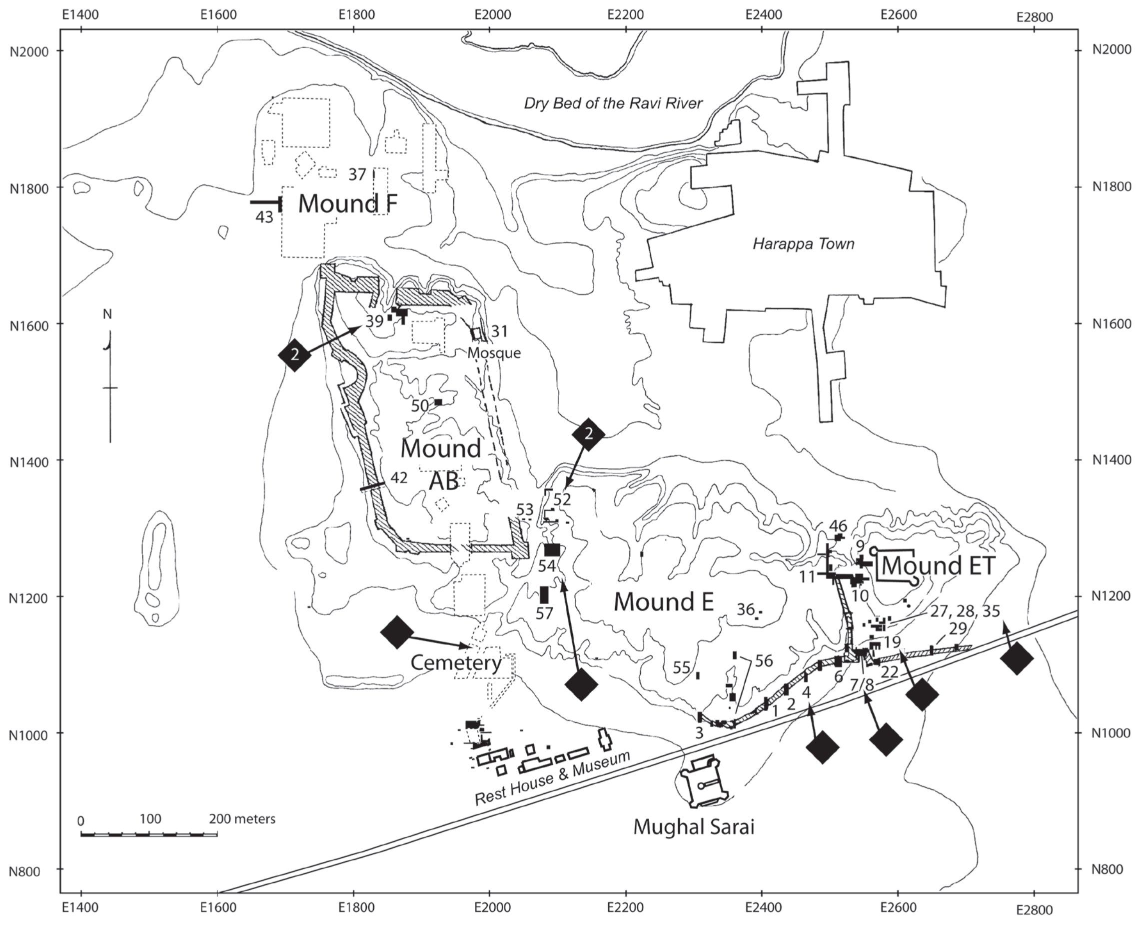


Figure 10.2 Mounds, areas, and trenches (in bold) where alabaster objects or fragments of manufacturing debris have been recovered. Diamond shapes and arrows denotes trenches/areas where "Mari Diamonds" were found.

Figure 10.3 Alabaster debris and non-diagnostic fragments from Harappa.

ALABASTER AT HARAPPA

Alabaster is one of the most abundant of the minor rock and mineral varieties in Harappa's lithic assemblage. To date, 422 artifacts made from this stone have been recovered during excavations by the HARP (Figure 10.1). Numerous other examples were described in the original excavation report (Vats 1940). More than half (n=222) of this material sub-assemblage consists of manufacturing debris or non-diagnostic fragments (Figure 10.3). It is, therefore, reasonable to assume therefore that many or most of the finished alabaster objects recovered at Harappa were crafted at the site itself. An assortment of these artifacts (including several that were analyzed for this study) are displayed in figures 10.4 A through C. Although most alabaster artifacts at Harappa have weathered exteriors, cracks and fractures exposing the interior reveal that the material preferred by Harappans tended to be compact, fine-grained and sugary white. A few fragments (but no artifacts) with a pink cast have also been found.

Alabaster objects and debris fragments have been recovered from all major areas of the site (figures 10.1 and 10.2) and from every chronological phase and sub-phase from Period 1 through Period 3C. Although no examples were found during the very limited excavations of Period 4 and 5 levels, approximately half of the assemblage (n=210) consists of surface finds and so it is possible that some of those artifacts may have originated in Late Harappan strata that were subsequently disturbed by brickrobbers. The great majority (179 of 212 or 85%) of the alabaster artifacts from secure stratified contexts belong to Period 3C. This then is the optimal assemblage with which to examine site-wise synchronic variation in the utilization of alabaster. Next I discuss how that material was distributed across the site during Period

Figure 10.4 An assortment of alabaster artifacts from Harappa. Those noted with artifact numbers were analyzed for this study.

A. Clockwise from top-left: alabaster rings, whorl, ball, bangle fragments, pendent (H94/4999-511), dish fragment, small vessel.

B. Cubical weight made of alabaster from Vats' excavations (#13799).

C. Large alabaster ringstone fragment (H98/7715-9) from Period 3C levels on Mound AB, Trench 42.

3C. Later in this chapter I examine if resident/craftspeople living in different parts of the site at this time used alabaster from the same sources.

In general, there does not appear to have been a great deal of intra-site variation in the use of alabaster as a raw material during Period 3C. Manufacturing debris is found in those levels on every mound at Harappa as well as from the 3C deposits beneath the Mughal era (16th to 18th centuries AD) caravanserai south of Mound E. People residing and working in different areas of the city were basically making or acquiring the same types of alabaster objects. Certain artifacts, such as the cubical weight pictured in Figure 10.4 B and the large ringstone fragment pictured in Figure 10.4 C, are exceptionally rare or unique and thus found only in a few locations. More common items, however, such as beads, inlays and vessels tend to be found in most areas of the site. There is one striking exception. Although fairly common (making up around 18% of finished alabaster artifacts), alabaster bangles have only been found on mounds E-ET, which would indicate that residents of those areas were the only ones producing and/or consuming that particular type of item. This may very well be a diachronic pattern. Even though the alabaster assemblages for periods prior to 3C are significantly smaller (and thus subject to greater sampling bias), during periods 3A and 3B bangles made of this alabaster are also found only on mounds E-ET.

Twenty-nine alabaster artifacts from Harappa were selected for isotopic analysis (Appendix 10.1). This amounts to approximately a seven percent sample of this material sub-assemblage. The set included artifacts from each of Harappa's habitation mounds and each phase and sub-phase between periods 2 and 3C. Most of those chosen (19 of 29) were non-diagnostic manufacturing debris fragments. The remaining ten samples were taken from both common alabaster objects (bangles and vessels) and important varieties of rare ones (a ringstone and a cubical weight). In the following section I discuss the geologic sources to which these artifacts were compared.

POTENTIAL SOURCES OF HARAPPAN ALABASTER

There are extensive deposits of alabaster in several regions surrounding the Indus Basin that would have been directly accessible to Indus Civilization peoples. In this section, I discuss deposits in the three regions that were closest to Harappa – the Salt Range, the Sulaiman Range and Kohat (Figure 10.5). Samples from multiple locations within each of these areas were collected and analyzed for this project. Sources in several other regions are also noted that, although not yet analyzed, are important to be aware of when considering the results of the isotopic studies. Before discussing the potential sources of Harappan alabaster, however, I want to first make it clear that there are certain parts of the Greater Indus region where that material is almost certainly not to be found.

Gypsum occurrences that are not alabaster sources

Gypsum is a mineral precipitate that forms in environmental settings (generally arid ones) in which the evaporation of water takes place (Eckhardt 2001; Warren 1989: 14). Those settings may be terrestrial (such as inland seas or lakes) or marine (typically shallow, marginally restricted oceanic basins). Gypsum is the most common of the sulphate minerals (Deer *et al*. 1992: 615) and occurrences of some kind or another can be found in most parts of the Greater Indus region (Bender 1995b: 264-265; Wadia 1975: 467). The alabaster variety, however, is much less widespread. Just because a large gypsum deposit is reported to occur in a certain area does not necessarily mean that alabaster are also found there. This is a fact that has sometimes not been adequately recognized when considering the potential sources of that material.

Indus Alluvium/Thar Desert

When outlining the raw material resources available to Indus peoples in the Sindh region, Nayanjot Lahiri noted in the section on "Alabaster" that "thick beds of gypsum are abundant in the Indus alluvium" (Lahiri 1992: 24). Although this is indeed so, the gypsum of terrestrial origin that occurs within the alluvium of the Indus Basin is most definitely not of the alabaster variety. Rather, it is either the selenite

Figure 10.5 Regions, sources and sites discussed in this chapter.

or the gypsite (massive but impure gypsum mixed with sand and clay) varieties that are found in thick beds just below the alluvium (Figure 10.6) in areas like Thar Desert. Such deposits are mined today in the Bahawalpur District of Pakistan (Ahmad 1969: 92) and all throughout west-northwestern Rajasthan (Deb 1952; Geological Survey of India 2001b: 68-70; Jacob *et al.* 1952).

Western Sindh

It has been suggested that the Harappans of Mohenjo-daro may have obtained alabaster from the nearby Kirthar Range of western Sindh (Lahiri 1992: 24; Pascoe 1931: 679; Ratnagar 2004: 151). This would not have been possible, however, as it is selenite and veins of fibrous gypsum, rather than massive compact alabaster, which occurs in the Tertiary shales

Figure 10.6 Quaternary gypsite deposit immediately below the desert alluvium, Bikaner district, western Rajasthan.

Figure 10.7 Alabaster lattice fragments on display at the Mohenjo-daro museum.

of this region (Ahmad 1969: 92). The low grade gypsum of the Kirthar Range is mined today for use in the cement industry (Hunting Survey Corporation 1960: 447; Jafry and Ahmad 1991: 28-30) but would have not at all been suitable for carving the types of artifacts being examined in this chapter. In spite of that, raw material of this kind may still have had value to ancient residents of Sindh. For example:

Nineteenth century craftsmen in Sindh used gypsum from deposits in the Kirthar Range for "casting lattices and open work for the tops of doors and windows, and for other purposes [where] the partial admission of air is desirable" (Buist 1852: 229). Interestingly, fragments of stone lattices that are thought to have served the same purpose have been found at Mohenjo-daro (Sahni 1931b: 219). Although those objects appear to have been cut or carved from alabaster blocks, it is difficult to tell for certain if this was so because they have heavily weathered exteriors (Figure 10.7). A closer examination of those artifacts might reveal that they were cast from a gypsum plaster instead. This does not mean that alabaster was not used at Mohenjo-daro. On the contrary, many objects that are clearly made of this variety of gypsum have been recovered at the site. It is highly unlikely, however, that the raw stone used to fashion them came from the Kirthar Range. Dr. Massimo Vidale kindly supplied a single small sample from an alabaster vessel fragment found in the area DK at Mohenjo-daro during the surface surveys by the IsMEO-Aachen University project (Pracchia *et al*. 1985). Analysis of this sample will hopefully allow us to determine what region residents of that site were obtaining that material from.

Gujarat

The Indian state of Gujarat has also been noted as a possible alabaster source for Indus Civilization peoples (Lahiri 1992: 106; Pascoe 1931: 679). Although extensive gypsum deposits do occur in many

Figure 10.8 A mass of selenite crystals from the Little Rann of Kutch, Gujarat.

districts (especially Kutch and Junagadh), a review of the geologic literature indicates that they are not found in the form of alabaster (Desai 1973; Geological Survey of India 2001a: 66-67; Krishnaswamy 1979: 249-250; Sinha 1967: 300-301). Instead it is selenite crystals, such as those that form in the shallow ranns, which occur there (Figure 10.8).

If selenite or gypsite was used to make the mortars, plasters and pastes found at some Indus Civilization sites then those materials could have come from any of the regions discussed above. The alabaster used to make objects like those found at Harappa could not have, however. Next we examine several of the regions where high quality alabaster does occur.

The Salt Range

The Salt Range lies on the northern edge of the Punjab Plain, approximately 225 km away from Harappa at its closest point. Beds of massive alabaster gypsum up to 100 meters thick in some instances are exposed at various places along the base of these mountains (figures 10.9 and 10.10). There has long been a local industry devoted to carving plates and other items from Salt Range alabaster (Wynne 1878: 300; Pascoe 1931: 679; Habib 1986: 13, Map 4B). Geologic samples were acquired from seven sources stretching from the eastern to the western margins of the range (identified with white squares in Figure 10.5). The five easternmost of these deposits occur within the Salt Range Formation (Alam and Khan 1982). Although its precise age has been debated (Gee 1945; Ghosh *et al.* 1951; Shah 1977: 4), today the Salt Range Formation is generally considered to span the late-Precambrian to Cambrian eras (ca. 600 to 500 m.y.a.) (Kazmi 1995c: 66-68; Shah 1980: 8). When referring to deposits associated with this formation I use the term Infra-Cambrian, which denotes the period immediately preceding the Cambrian (Palmer 1977). The two westernmost Salt Range alabaster

Figure 10.9 Massive alabaster gypsum beds at Buri Khel, central Salt Range.

Figure 10.10 Massive alabaster gypsum beds at Saiduwali Nala, western Salt Range (Khassor Range).

deposits sampled for this study (Daud Khel and Saiduwali Nala) are marine in origin and occur in the Sakesar Formation of Eocene age (ca. 55 to 34 m.y.a.) (Kazmi 1995c: 112; Kazmi and Jan 1997: 478).

Alabaster from the Salt Range would have been most directly accessible to Indus Civilization peoples during the Kot Dijian phase (Period 2 at Harappa). In recent years several Kot Dijian sites have been located in the central to eastern part of the range (Dar 2002). The small Kot Dijian/Harappan settlement of Musa Khel (Dani 1971: 32) lies roughly 15 km southeast of the Buri Khel alabaster deposit. Fragments of alabaster were evident on the site's surface along with other lithic materials from the Salt Range including black chert (Chapter 6), limestone and laterite. Small samples for analysis were taken from two such fragments collected by Dr. Syed Baqri of the Pakistan Museum of Natural History during our fieldwork in the area. Alabaster fragments were also observed (and one sampled) on the surface of the Early Harappan Period site of Rehman Dheri (Durrani 1988), which lies just over 30 km southwest of the Saiduwali Nala.

The Sulaiman Range

Two hundred twenty kilometers directly west of Harappa is the north-south running Sulaiman Range. The extensive alabaster deposits located in these mountains (identified with white squares in circles 10.5) are mainly concentrated in the wide southern portion of the range known as the Sulaiman Lobe. Zinda Pir, the easternmost of these southern sources, lies in the Dera Ghazi Khan District of Punjab Province. The alabaster found at this deposit and others nearby is described as gray to grayish white in color (Hussain and Mustafa 1970). The remaining Sulaiman Lobe area deposits are situated in Balochistan proper. The geologist W.T. Blanford visited alabaster occurrences in the vicinity of Dera Bugti and described the material there as "perfectly pure white in color, and quite as well adapted for

Figure 10.11 Massive alabaster gypsum beds at Bahad-ur-Khel, Kohat District, NWFP.

ornamental purposes" (Blanford 1883: 127). Alabaster is also found in the far north of the Sulaiman Range around Drazinda in the NWFP. All of the Sulaiman deposits are marine evaporites that occur within either the Baska or the Domanda formation, which are both of Eocene age (Malkani 2000). Mr. M. Sadiq Maklani of the Geological Survey of Pakistan–Quetta generously provided a set of alabaster samples for isotopic analyses from the ten Sulaiman Range locations identified in Figure 10.5.

The alabaster artifacts found at Harappa could easily have been derived from any of the Sulaiman Range sources. Drazinda, the northernmost of the deposits, lies near the natural route between Early Harappan and Harappan Periods sites on the Gomal Plain like Ghandi Umar Khan (Khan *et al.* 2000) and those of northern Balochistan such as Periano Ghundai (Fairservis 1959: 329). Indus Civilization peoples at sites on the Kachi Plain such as Nausharo (Jarrige 2000) and Judeiro-daro (Flam 1981: 251-53) as well as those living at highland settlements like Dabar Kot (Fairservis 1959: 289) would have been best positioned to access the rich alabaster deposits of Sulaiman lobe region. Although the alabaster found at Zinda Pir does not appear to be the same sugary white variety that was used to make artifacts at Harappa, this source would have nonetheless been the closest and most directly accessible to residents of that site.

Kohat

The Kohat district, NWFP is located directly northwest of the Salt Range. Although the massive gypsum of marine origin that occurs in this region is frequently mixed with clay that gives it a greenish cast, purer beds of white material (Figure 10.11) are often found (Rashid *et al.* 1965: 4-7; Wynne 1875: 45). Samples of relatively pure alabaster from two deposits – Jatta and Bahad-ur-Khel (identified with white triangles in Figure 10.5), were kindly provided by Dr. Syed Baqri of the Pakistan Museum of Natural History in Islamabad. Both of those locations occur within the Jatta Gypsum Formation of early Eocene age (Bender 1995b: 264; Fatmi 1974: 53-54).

It is important to consider alabaster from the Kohat region in a study such as this even though there would have been closer sources of purer material to Harappa. These deposits lie between 40 and 80 km northeast of the series of Early Harappan sites in the Bannu Basin (Khan *et al.* 1991a). Some of this material might conceivably have come to Harappa through interaction with related groups in that region.

Other potential alabaster sources

There are several other regions from which the alabaster recovered at Harappa could have been obtained other than, or in addition to, the three discussed above. Although sources in the areas below have not yet been analyzed, it is important to take into account their locations and geologic contexts when later evaluating the results of the isotopic studies. Because some of those areas are located on or near what would have been the northern fringes of the Indus Civilization, several do not fall within the area of Figure 10.5.

Afghanistan

The presence of the Harappan outpost of Shortughaï (Francfort 1984b) in the far north of Afghanistan (not pictured on Figure 10.5) opens the possibility that alabaster from deposits between that area and the Indus Valley may have been brought to Harappa. One potential source of upper Jurassic age (ca. 160 to 145 m.y.a.) is found in the vicinity of Dudkash in Baghlan Province (ESCAP 1995: 58). This occurrence lies near a major route to northern Afghanistan through the Hindu Kush. Other potential sources are found within Cretaceous formations (ca. 145 to 65 m.y.a.) in the west-northwestern part of the country (Wolfart and Wittekindt 1980: 421) and Eocene-age formations along the eastern border with Pakistan (Ludington *et al*. 2007: Figure 16).

Hazara (NWFP)

Lying less that 100 km northeast of the Early Harappan site of Sarai Khola (Halim 1972) in the Hazara District, NWFP, are beds of white calcareous gypsum 15 to 200 meters thick that occur within the Hazara Formation (Ali *et al*. 1964: 36-37). Although originally correlated with the Infra-Cambrian Salt Range Formation of the Punjab, radiometric dating has indicted that the Hazara Formation, which has undergone low-grade metamorphism, is probably older (Kazmi 1995c: 72). Of all of the uncharacterized alabaster sources, this one is especially important due to the fact that much of the steatite found at Harappa appears to be coming from this region (see Chapter 7).

Jammu and Kashmir

Alabaster deposits in Jammu and Kashmir are especially significant too because, as we shall see in Chapter 12, many of the lead artifacts found at Harappa appear to be coming from these regions. The numerous large deposits of massive "snow white gypsum" that are found across that state are thought to be of Precambrian age (Krishnaswamy 1979: 251-252; Mehta 1957: 61-62; Singh *et al*. 1994). Harappans interacting with Neolithic peoples in the Kashmir Valley (Saar 1992) via the upper Jhelum River valley would have had access to both lead and alabaster in the vicinity of Buniyar (Middlemiss 1929: 3). Similarly, the residents of the Harappan site of Manda (Joshi and Bala 1982) would have been well positioned to exploit the alabaster (Sinha 1967: 298) and lead deposits of Jammu.

Western Himalayas

Southwest of Jammu and Kashmir (not pictured on Figure 10.5) sporadic occurrences of alabaster can be found in the Carboniferous era formations of the western Himalayas (Wadia 1975: 467). In the Kinnaur District of Himachal Pradesh, alabaster occurs in the Lipak Formation (Geological Survey of India 1989a: 29). In the Garhwal region of Uttaranchal, deposits are found in the Krol Formation (Chatterjee 1963b: 227). Although no Harappan sites lie within the Himalayas, some have been discovered in the foothills of that range near Chandigarh (IAR 1985-86: 15) and around Ropar (Sharma 1982).

DETERMINING THE GEOLOGIC PROVENIENCE OF HARAPPAN ALABASTER ARTIFACTS

N.H. Gale and others (1988) successfully employed both sulfur isotope analysis and strontium isotope analysis to characterize gypsum deposits in Greece and to assign a geologic provenience to alabaster artifacts from several Mycenaean sites. The same combination of techniques are used in this study to analyze a group of Harappan alabaster artifacts and compare them to a set of geologic materials from potential sources in Pakistan. To begin this section, I provide the geologic background pertaining to alabaster-bearing marine evaporites, relate how the changing isotopic characteristics of seawater makes studies of this kind possible and discuss what might be expected when samples in sets assembled for this study are analyzed. I then present the results of the isotopic analyses and provenience determinations suggested by them – this is done first for each isotopic system alone and then in combination with one another. In the concluding part of this section I discuss diachronic and synchronic patterns of alabaster source usage at Harappa that are evident based on the results of these studies.

Geologic background – marine evaporites and isotope curves for S and Sr in seawater

The massive beds of alabaster found in the Salt Range, Sulaimans and Kohat are believed to be marine evaporites (Alam and Khan 1982: 3; Bender 1995b: 264). Deposits of this kind form as gypsum precipitates from seawater evaporating in shallow, semi-restricted marine basins (Blatt 1992: 348-350). The alabaster beds of Eocene age that are being considered here would have been originally laid down in the ancient Tethys Sea as it gradually closed between the Indian Subcontinent and the Eurasian Plate beginning around 55 million years ago (Powell 1979: 16). The Infra-Cambrian deposits are perhaps remnants of a similar, but much earlier, process.

The very different ages of the geologic formations under examination here actually facilitates the effort to determine the geologic provenience of alabaster artifacts from Harappa and other Indus Civilization sites. The reason is that the isotopic compositions of certain elements in the waters of the earth's oceans have undergone considerable changes over time. Sedimentary rocks of marine origin (evaporites like alabaster and carbonates like limestone) contain a record of the sulfur and/or strontium isotope characteristics of seawater during the period of time that they formed (Faure and Mensing 2005: 440-441, 833-835). Analysis of marine evaporites and carbonates of different ages from around the world have enabled geologists to construct isotope "curves" that plot the diachronic changes in the compositions of those elements in seawater. Alabaster artifacts can, with reference to either or both isotope curves, be matched to a geologic formation having analogous isotopic characteristics.

In the two sub-sections to follow, I provide short explanations of the sulfur and strontium isotope curves and an outline of how the alabaster source formations under examination here might expected to plot in relation to them.

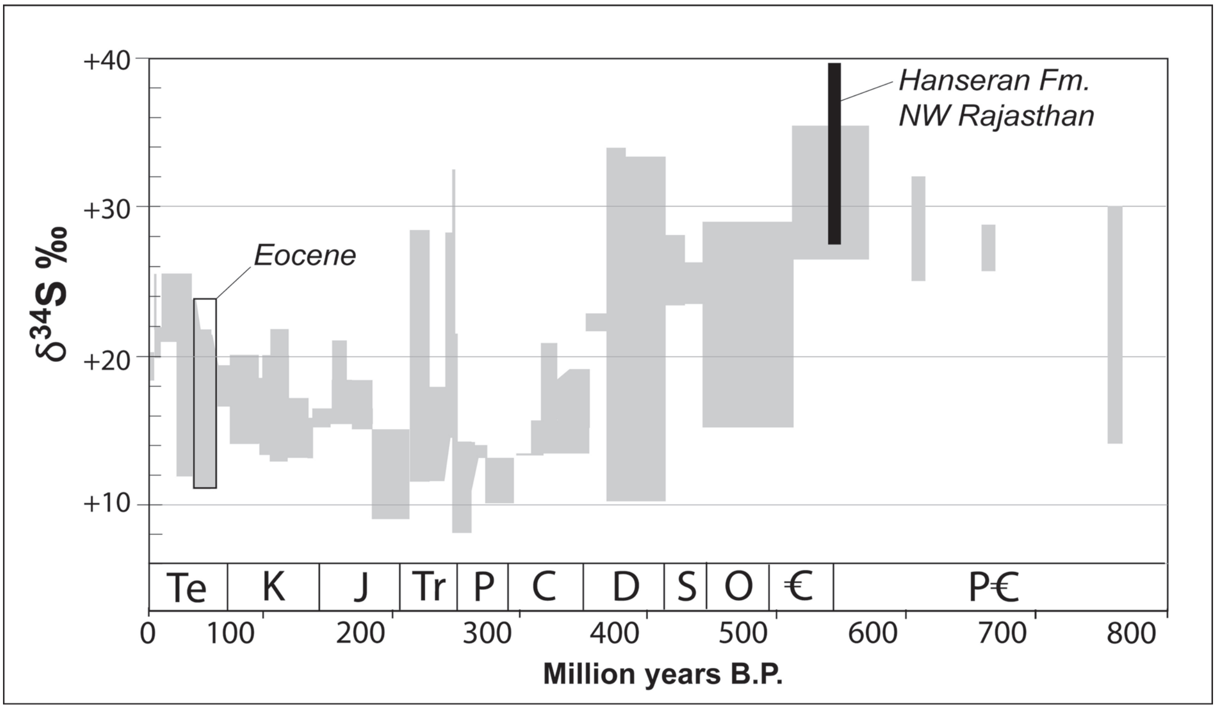


Figure 10.12 Variation in the isotopic composition of sulfur in seawater through time (after Shields *et al*. 2004 and Strauss 1997).

The sulfur curve

The element sulfur (S) has four stable isotopes (^{32}S, ^{33}S, ^{34}S, ^{36}S). The ratio of the two most abundant of these (^{32}S and ^{34}S) in a sample is measured with a mass spectrometer. The results are expressed using the notation $\delta^{34}S$ ‰, which represents the per mil (‰) deviation in the $^{34}S/^{32}S$ ratio measured in the sample compared to that measured in the Canyon Diablo Troilite (CDT) meteorite international standard (Eckhardt 2001: 514). Since sulfur isotopes do not undergo substantial fractionation as gypsum is precipitated, the isotopic composition of that element in an alabaster deposit should be essentially the same as the ancient seawater from which it derived (Faure and Mensing 2005: 833).

The isotopic composition of sulfur in seawater has changed through time and a record of this has gradually been generated through the analysis of marine evaporite sulfate deposits of different ages from around the world (Straus 1997). A representation (the sulfur isotope "curve") of these changes over geologic time can be seen in Figure 10.12. Prior to this study no sulfur isotope analysis had ever been performed on marine evaporites from the three geologic formations under examination here. Nevertheless, based on the sulfur isotope curve we would expect that the Eocene alabaster deposits (and artifacts deriving from them) would have $\delta^{34}S$ ‰ values ranging from approximately +11 to +24 (range noted on Figure 10.12). As for the deposits of Infra-Cambrian age, Harald Strauss and others (2001) analyzed 26 marine sulfate samples from the Hanseran Formation of northern Rajasthan, which is generally considered to be analogous to the Salt Range Formation of the Punjab. This formation was not discussed above because it is located at a minimum at a depth of nearly 300 meters below the surface (Strauss *et al*.'s samples came from drill cores) and therefore could not have been a source of Harappan alabaster. However, Hanseran marine sulfates have $\delta^{34}S$ ‰ values ranging from +27.5 to +39.7 (range noted on Figure 10.12) and so similar values might be expected from Infra-Cambrian Salt Range Formation alabaster deposits and artifacts deriving from them.

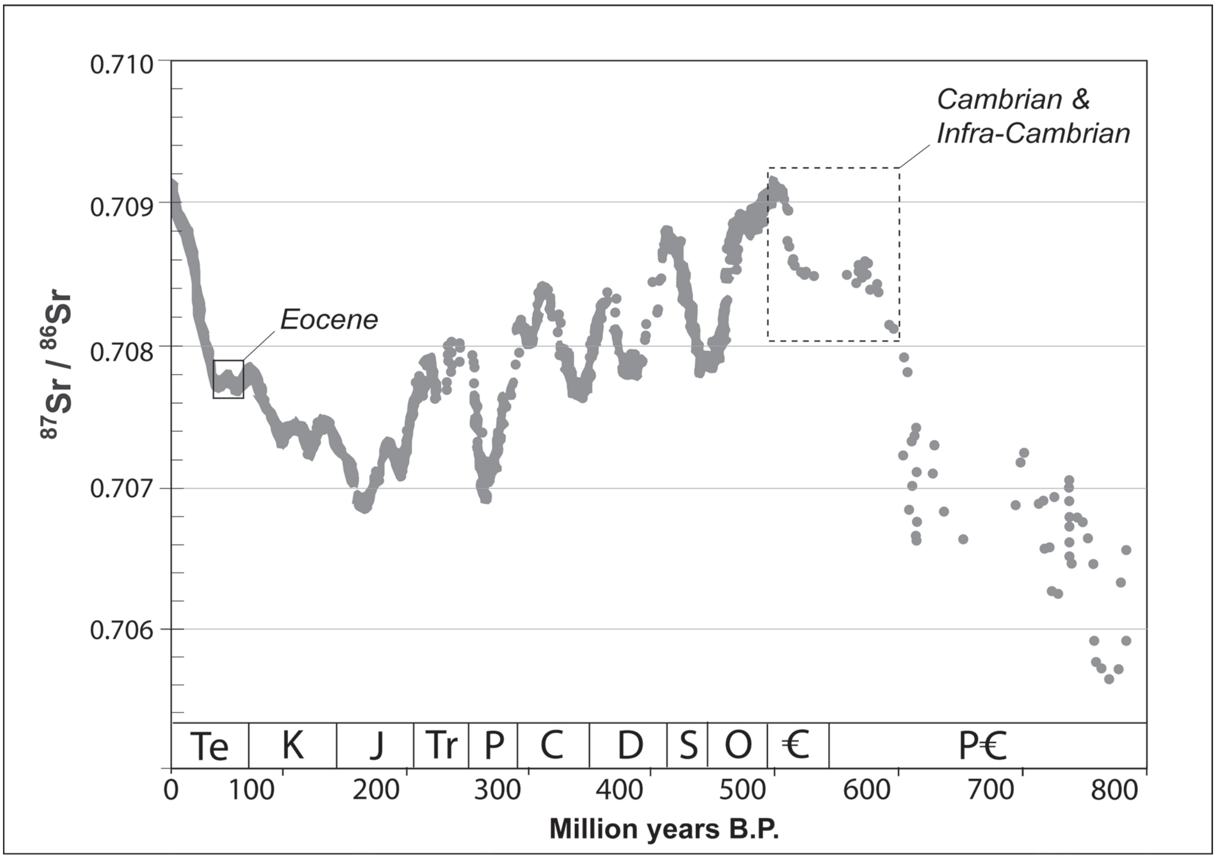


Figure 10.13 Variation in the isotopic composition of strontium in seawater through time (after McArthur *et al*. 2001).

The strontium curve

The element strontium (Sr) also has four stable isotopes (^{84}Sr, ^{86}Sr, ^{87}Sr, ^{88}Sr). In geologic materials ^{87}Sr is augmented over time by the decay of a radioactive isotope of rubidium – ^{87}Rb (Faure and Mensing 2005: 75). However, because the amount of ^{87}Rb in gypsum is extremely low and therefore very little radiogenic ^{87}Sr is generated over time, the overall Sr isotope composition of an alabaster deposit will essentially be the same (barring any later digenetic changes) as the seawater from which it precipitated (Gale *et al*. 1988: 59-60). A mass spectrometer is used to measure the ratio of all the strontium isotopes. The ratio of ^{86}Sr/^{88}Sr, which is constant on the earth, is used to correct the ^{86}Sr/^{87}Sr ratio for instrumental mass bias resulting in the very precise determination of the ^{87}Sr/^{86}Sr ratio (Dr. Joel Blum, *personal communication* 2005).

Like sulfur, the isotopic composition of strontium in seawater has changed through time. A record of the changes has been generated through the analysis of marine carbonates (fossil shells and limestones) of different ages from around the world (Veizer *et al*. 1999). A curve depicting the changing strontium isotope characteristics of seawater through the Phanerozoic (Cambrian Period to present) can be seen in Figure 10.13. Although none of the formations being investigated in this study were previously analyzed, the strontium isotope composition of those marine sulfates should be analogous to carbonates formed during the same periods of time. With reference then to the strontium curve published by McArthur and others (2001), the Eocene period alabaster deposits and artifacts deriving from them would be expected to have ^{87}Sr/^{86}Sr ratios ranging from approximately 0.7076 to 0.7079 (noted on Figure 10.13). The Sr isotope composition of the oceans prior to the Cambrian Period is not well constrained due to the fact that carbonate rocks from that time are scarce and those that do exist have often been altered (Faure and Mensing 2005: 447-448). Geologic samples and artifacts from Infra-Cambrian deposits could have $^{87}Sr/^{86}Sr$ values similar to those of the Cambrian Period – from approximately 0.7080 to 0.7093 (ibid.: Figure 19.6). It is also possible that those deposits might have even higher values. Precambrian marine carbonates in the western Himalayas often have highly radiogenic Sr isotope compositions (from approximately 0.7090 to 0.7323 or even higher) due to isotopic exchange with high $^{87}Sr/^{86}Sr$ silicate rocks during metamorphism (Blum *et al*. 1998; Jacobson *et al*. 2002; Sarkar *et al*. 1996; Singh *et al*. 1998). Precambrian/Infra-Cambrian evaporate deposits of that region may well have been affected in the same way.

Sulfur and strontium isotope analyses of geologic sources and Harappan artifacts

Two sets of alabaster samples were prepared for sulfur and strontium isotope analysis – a set of archaeological samples and a set of geologic source materials. Details regarding the 33 artifacts comprising the archaeological set (Appendix 10.1) were presented in preceding sections. Twenty-nine samples came from Harappa, two from Musa Khel and one each from Rehman Dheri and Mohenjo-daro. Both sulfur and strontium isotope analysis are destructive methods and so some material needed to be removed from each artifact. For this reason two-thirds of the samples were chosen because they were unworked, non-diagnostic alabaster debris fragments. Samples that came from finished objects were taken from an already broken or cracked area. Using a fine tungsten carbide drill the weathered surface of an artifact was burred away from a small circular area approximately 2 mm in diameter. The surface material was discarded and then drilling of the freshly exposed area continued until approximately 50 mg of powder was generated. The powder was then divided and placed into two small polyethylene vials for transport to the laboratory. The full set of 33 artifacts was analyzed for sulfur isotope composition but it was only possible to make Sr isotope determinations on 30 of them.

The geologic set consisted of 46 samples – 24 samples from 12 individual deposits in the Sulaiman Mountains, four from two deposits in Kohat and 18 samples from seven deposits in the Salt Range (Appendix 10.2). All of the sampled locations are identified on Figure 10.5. Approximately 200 mg of material was removed from an unweathered, freshly broken surface on each geologic sample and powdered in an agate mortar. The powder was then divided and placed into two small polyethylene vials for transport to the laboratory. The full set of 46 geologic samples was analyzed for sulfur isotope composition but it was only possible to make Sr isotope determinations on 39 of them.

Sulfur isotope analysis and results

Sulfur isotope analysis of the sample sets was conducted by Dr. Chris Eastoe at the Isotope Geochemistry Laboratory, University of Arizona. Each sample was dissolved in HCl and then a $BaCl_2$ solution was added to precipitate $BaSO_4$, which as then filtered and dried (Isotope Geochemistry Laboratory 2004). Sulfur dioxide gas was extracted from the $BaSO_4$ by combustion with V_2O_5 (Yanagisawa and Sakai 1983) in a Costech elemental analyzer. From that gas $\delta^{34}S$ values were measured a Finnigan Delta PlusXL continuous-flow gas-ratio mass spectrometer. International sulfur standards OGS-1 and NBS123 were used along with several other sulfide and sulfate materials that have been compared between laboratories. Based on repeated use of internal standards the precision was estimated to be ± 0.15 or better (Chris Eastoe personal communication 2004).

The sulfur isotope analysis results for the geologic and archaeological sets are listed in appendices 10.1 and 10.2 and are plotted on Figure 10.14. Samples in the geologic set largely fall where predicted by the

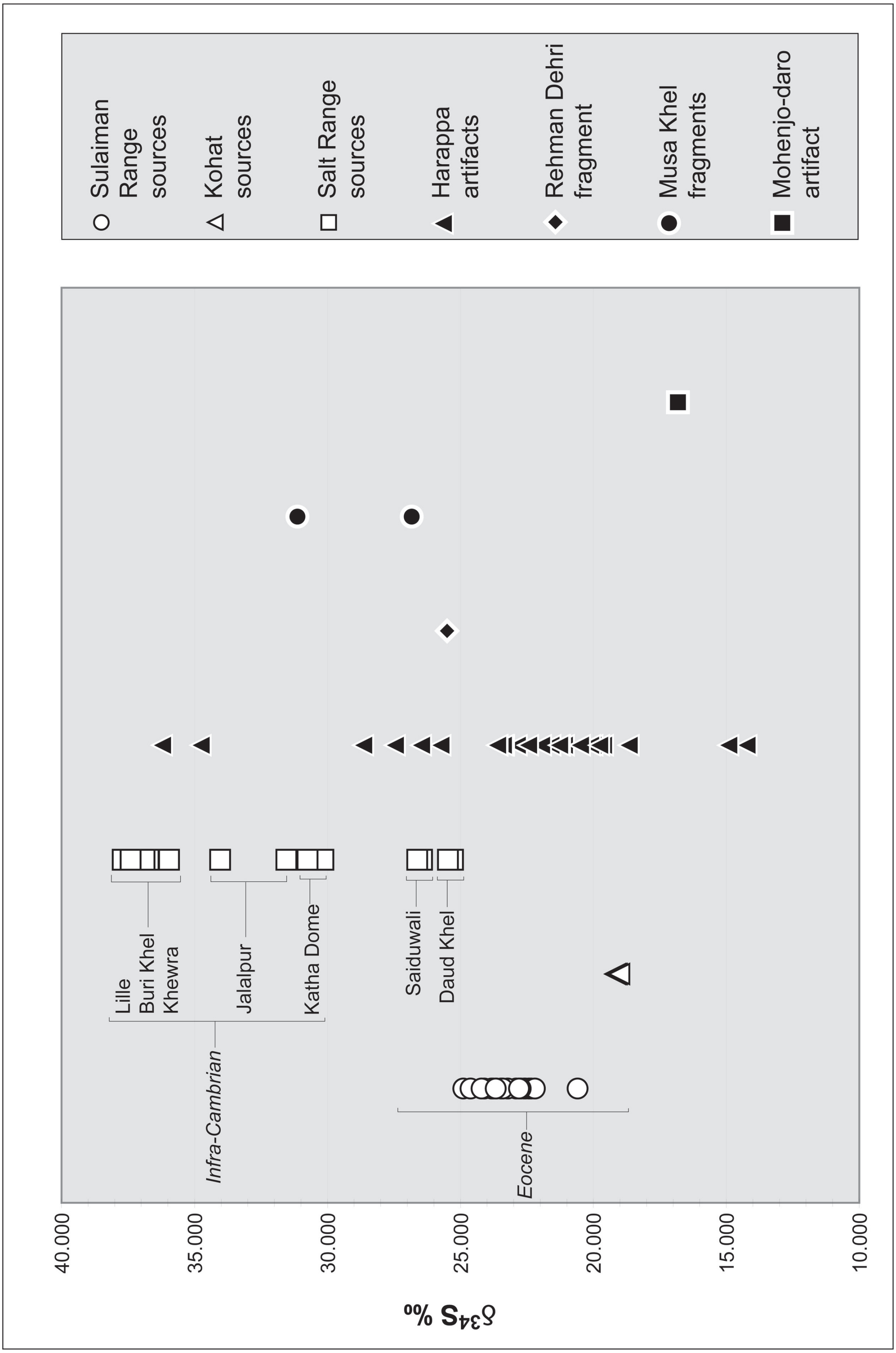


Figure 10.14 Sulfur isotope values for alabaster sources in Pakistan and artifacts from Harappa and three other sites.

sulfur isotope curve for Phanerozoic seawater. The Infra-Cambrian deposits of the Salt Range Formation (noted on the figure) have $\delta^{34}S$ values from +30.15 to +30.69, which is typical of other deposits of that age and places them within the range measured by Strauss and others (2001) for the Hanseran Formation of northern Rajasthan. Most of the Eocene alabaster sources of the Sulaiman Range and Kohat had $\delta^{34}S$ values ranging from +19.02 to +24.89, which would be expected of deposits of that age. The exceptions were the two Eocene deposits of the western part of the Salt Range (Saiduwali and Daud Khel – also noted on the figure), which had slightly higher than expected values (from +25.27 to +26.62).

When archaeological samples are plotted in relation to the geologic sources it appears that alabaster artifacts from Harappa derive from all three regions examined here and as well as, possibly, a fourth unknown source. It seems clear that the two artifacts with the highest $\delta^{34}S$ values came from Infra-Cambrian sources in the eastern part of the Salt Range. Four others are much more closely related sources in the western Salt Range. The two artifacts with $\delta^{34}S$ values below +15.00 would appear to come from an alabaster source other than the three examined here. The bulk of the alabaster artifacts from Harappa, however, have $\delta^{34}S$ values that span the range of variation seen for deposits within the Sulaiman Range and between that region and the Kohat sources. Although some are clearly more analogous to Sulaiman sources than to those in Kohat and vice versa, several plot in an area (approximately +20.00) that falls ambiguously between the two regions.

The artifacts from the other Indus sites plot in both expected and interesting ways. The $\delta^{34}S$ value for the Rehman Dheri fragment not surprisingly falls within the range of the sources closest to that site in the western Salt Range. Although the two fragments analyzed from Musa Khel also plot with Salt Range sources, they appear to probably be from two different deposits. One has a $\delta^{34}S$ ratio value that would indicate that it came from an Eocene source in the western part of the range while the other may have derived from an Infra-Cambrian source farther east. The single sample from Mohenjo-daro does not appear to have come from any of the three regions examined here but may have derived from the same unknown source as the two Harappan samples with the lowest $\delta^{34}S$ values.

Strontium isotope analysis and results

Strontium isotope analysis of the sample sets was conducted by Joel Blum and Andrea Klaue at the Department of Geosciences, University of Michigan–Ann Arbor. Samples were dissolved and strontium was separated from them by cation exchange chromatography following the procedures outlined by Blum and others (1998). $^{87}Sr/^{86}Sr$ ratios were measured on a Finnigan MAT 262 thermal-ionization mass spectrometer (TIMS) and normalized to $^{86}Sr/^{87}Sr$ = 0.1194. Replicate analysis of the NIST SRM-987 standard yielded a value of 0.710250 ±0.000014 (2σ, n= 74). The precision of individual analyses was at least ±0.000 020 (2σ).

The results of strontium isotope analysis of the geologic and archaeological sets are listed in appendices 10.1 and 10.2 and are plotted on Figure 10.15. The various geologic sources examined had $^{87}Sr/^{86}Sr$ values that were, for the most part, within the ranges expected for deposits of those ages with regard to the strontium isotope curve. The Infra-Cambrian alabaster deposits of the Salt Range Formation had ratios from 0.708048 to 709053 – a range comparable to those for late Precambrian to Cambrian formations found elsewhere (highlighted and labeled on Figure 10.13). A single sample of this age from the Jalalpur area had the somewhat high value of 0.710204. Ratios for alabaster occurrences in the Sulaiman Range clustered from 0.707704 to 0.707846 – exactly within the fairly restricted range expected for Eocene marine evaporites (highlighted and labeled on Figure 10.13).

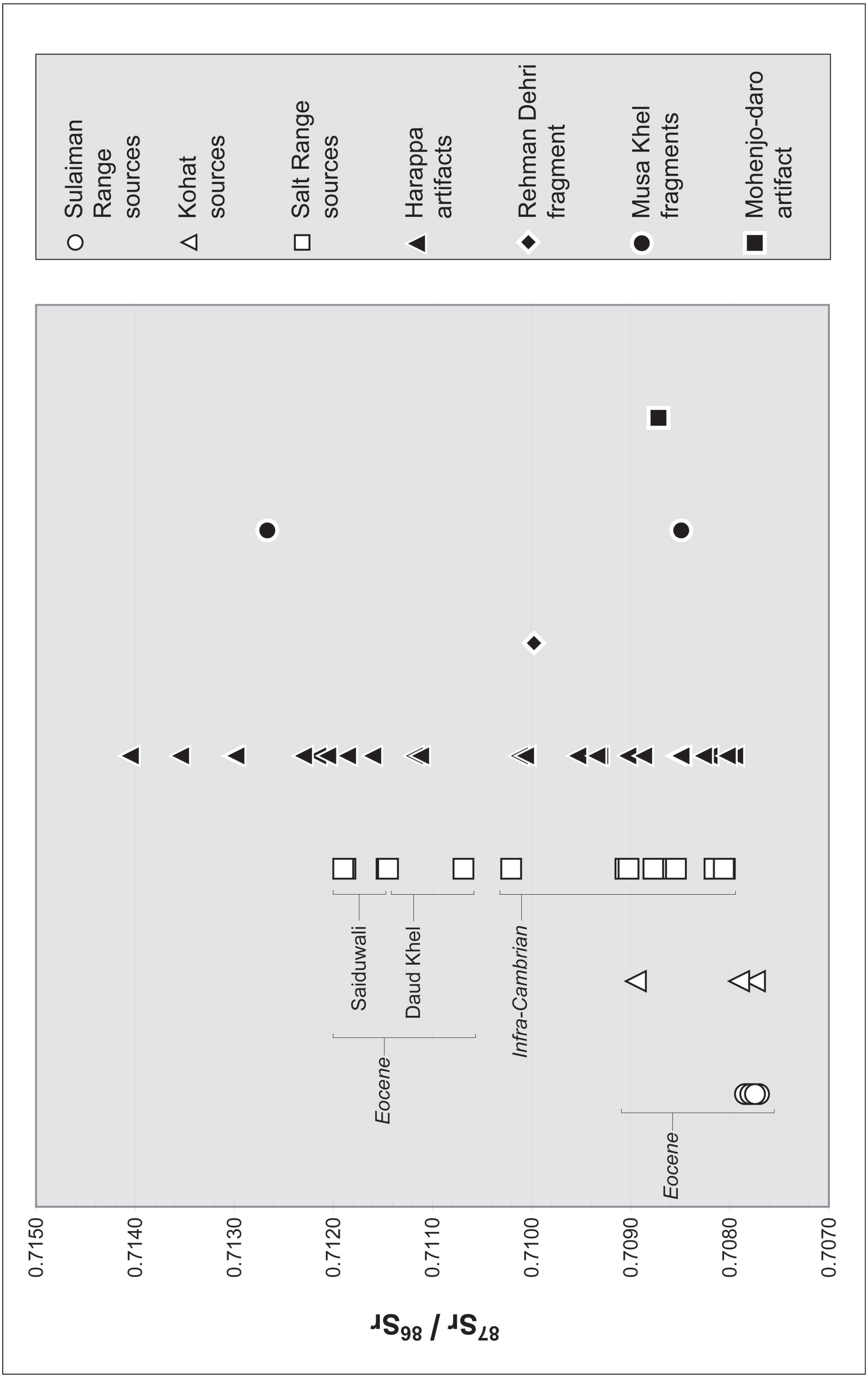


Figure 10.15 Strontium isotope values for alabaster sources in Pakistan and artifacts from Harappa and three other sites.

Eocene deposits in Kohat also plot where predicted with the exception of a single sample from the Jatta deposit that has the slightly higher ratio of 0.708949.

When the alabaster sources of the western Salt Range, Saiduwali and Daud Khel (identified with brackets on Figure 10.15), are compared to the strontium isotope curve it becomes evident that they have unusually high $^{87}Sr/^{86}Sr$ ratios (from 0.710686 to 0.711899), especially for deposits of Eocene age but also for typical marine evaporite of Cambrian/Infra-Cambrian age. These same two deposits likewise had higher than expected sulfur isotope values. It was noted above there are some formations of sedimentary marine rocks in the western Himalayas that, having been metamorphosed together with high $^{87}Sr/^{86}Sr$ silicate rocks, are enriched with highly radiogenic strontium. The alabaster deposits of the western Salt Range do not appear to have been metamorphosed, however. Whatever the cause(s) for their unusually high isotopic values is eventually determined to be, the Eocene alabaster sources of the western Salt Range are quite clearly distinct from both the Infra-Cambrian deposits to their east and those of the same age in the Sulaiman Range and Kohat.

When the strontium isotope ratios of archaeological samples are plotted in relation to the geologic sources the pattern that emerges is very different and seemingly contradictory to the one suggested by the sulfur isotope results. Whereas only six of the 29 samples from Harappa were assigned to Salt Range alabaster sources based on sulfur isotope analysis, 26 samples in the set now fall within or very near the range of variation for Salt Range deposits. The three samples plot higher than any of the geologic sources analyzed here. Due to the single Kohat sample with a high $^{87}Sr/^{86}Sr$ ratio, seven of the archaeological samples are also encompassed within the range of variation for that source region. No samples plot within the very tight strontium isotope range for Eocene deposits in the Sulaiman Range whereas 14 artifacts did when sulfur isotopes were examined.

Artifacts from the other Indus period sites plot in somewhat different ways as well. Although the Rehman Dheri fragment would still be assigned a Salt Range provenience based on its $^{87}Sr/^{86}Sr$ ratio, it now appears more analogous to Infra-Cambrian deposits in the eastern part of that range rather than to the nearest source at Saiduwali. The fragments analyzed from Musa Khel again appear probably to be from two different sources – one from an Infra-Cambrian deposit and one, perhaps, from the Eocene sources (although it has a ratio that is somewhat higher than those measured from Saiduwali or Daud Khel). The vessel fragment from Mohenjo-daro now falls within the range of both Infra-Cambrian deposits of the Salt Range and the Eocene Deposits of Kohat whereas based on sulfur isotopes it seemed to have been unrelated to any of the three geologic sources.

A handful of archaeological samples have $^{87}Sr/^{86}Sr$ ratios that are higher (in some cases significantly higher) than any of the geologic sources analyzed here. The possibility exists that alabaster artifacts may have been post-depositionally altered in a way that affected the isotopic composition of strontium within them. The waters of the rivers draining the Himalayas are known to have elevated levels of radiogenic strontium due to factors relating to the types of rocks eroding in their upper courses (Singh *et al.* 1998; Sarkar *et al.* 1996). A water sample taken from the Ravi River upstream from Harappa had a $^{87}Sr/^{86}Sr$ ratio of 0.729120 (Karim and Veizer 2000). Since the introduction of widespread canal irrigation in the late 19th century and early 20th century the water table has risen significantly in this part of the Punjab as well as farther south in Sindh (Michel 1972). Soil salinity had become tremendous problem in these areas and archaeological sites like Harappa and Mohenjo-daro have suffered considerably as moisture moves to the surface through the mounds and artifacts it contains. Porous materials have become impregnated with salt and, presumably, other dissolved elements in the water. As for alabaster artifacts, great care was taken to get below their weathered surfaces and collect material for analysis from the (hopefully) unaltered interiors. The high $^{87}Sr/^{86}Sr$ ratios exhibited by certain samples may very well be a characteristic of the geologic source(s) – possibly in the western Himalayas (Jammu and Kashmir), they derive from. However, until sources there are analyzed the possibility that alabaster artifacts may have been contaminated by radiogenic strontium from the rivers of the Punjab must be recognized.

Bivariate plotting of the S and Sr analysis data

The seemingly contradictory provenience determinations derived from the sulfur and strontium isotope data might lead one to surmise that either one or both of the methods used were flawed, either in their execution or premise. This is almost certainly not the case, however, as demonstrated by the data resulting from the analyses of the geologic sample set. The isotopic behavior of Phanerozoic seawater is well understood and the assays made here of samples from deposits of marine evaporites of known ages provided values that were, in the great majority of instances, spot on with regard to the expected isotopic compositions predicted by both the sulfur and strontium curves. Exceptions were probably due to as yet not well understood characteristics of particular geologic formations. Any apparent incongruities between how the archaeological set plotted in relation to the isotope curves are no doubt the result of the geochemical properties of the artifacts themselves. It is important bear in mind that each element alone provides only one dimension with which to examine the possible provenience of archaeological alabaster. Considering sulfur and strontium data simultaneously allows a fuller picture of the isotopic variability (or similarity) between geologic formations and artifacts to be generated.

Figure 10.16 is a bivariate plot of the sulfur and strontium isotope data for samples from the geologic and archaeological sets. Strontium values are found on the y-axis and sulfur values on the x-axis. In this new two-dimensional view the three main geologic source regions are even more isotopically distinct from one another than before. The geographically widespread Eocene alabaster deposits of the Sulaiman Range still cluster in a tight a pattern and appear most closely related to sources of the same age in Kohat. Lying in contrast to those deposits and to one another are the two different formations of the Salt Range (circled on Figure 10.16). The high strontium isotope values for Salt Range Eocene alabaster deposits set these clearly apart from all other formations.

The archaeological samples are plotted on Figure 10.16 as black shapes. From this it is evident that at least some of the artifacts from Harappa (triangles) are isotopically analogous, or at least very similar, to the geologic formations examined here. Several fall directly upon or plot within the area encompassed by the geologic sample data points of both the Eocene (Sakesar) and Infra-Cambrian (Salt Range) formations in the Salt Range. Others cluster on and near data points for the Eocene sources in the Sulaiman Range and the Kohat region. Over half of the Harappan samples, however, plot in areas away from these geologic formations. Of those that do, many have high $^{87}Sr/^{86}Sr$ ratios like the Salt Range Sakesar deposits but with slightly lower $\delta^{34}S$ values that cause them to fall in a loose cluster above and to the left of that formation. It is difficult to say if these seemingly similar archaeological fragments actually represent a single source formation or multiple ones. If we use the Infra-Cambrian formation of the Salt Range as a model then it is evident that individual deposits of a single formation can spread widely. Conversely, the isotopic ranges of the geographically widespread Eocene sources of the Sulaimans and Kohat are much more constrained. It is important to point out that only five data points presently exist for the Sakesar Formation deposits, which lie adjacent to this cluster. The possibility exists that future analyses

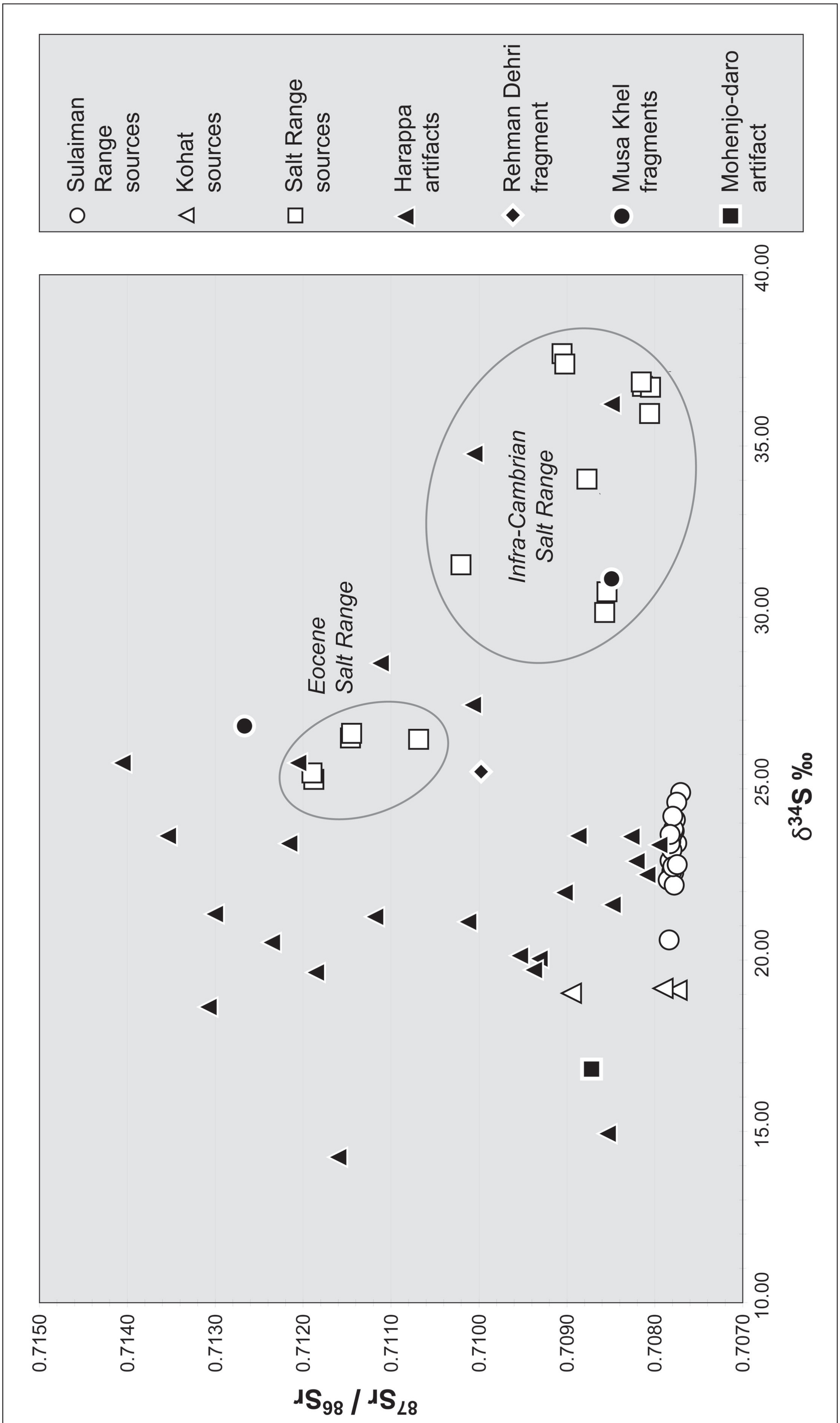


Figure 10.16 Bivariate plot of strontium and sulfur isotope values for alabaster sources in Pakistan and artifacts from Harappa and three other sites.

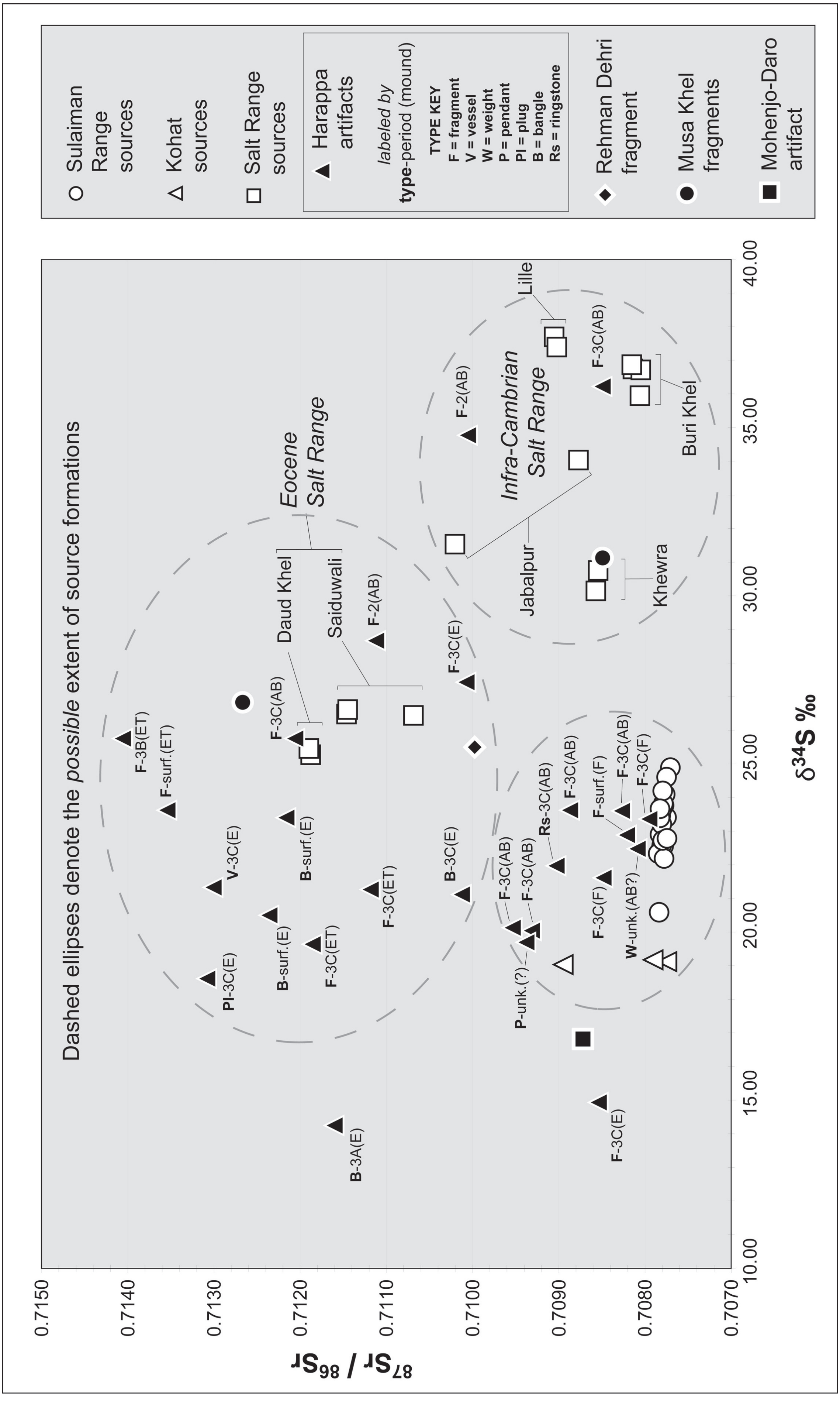


Figure 10.17 Labeled bivariate plot of strontium and sulfur isotope values for alabaster sources in Pakistan and artifacts from Harappa and three other sites.

of geologic source material (from the same deposits and additional ones) might eventually enlarge the isotopic boundaries the Sakesar marine evaporates to encompass some of those ungrouped artifacts. On the other hand, it is also very possible that the raw material for those artifacts may have come from one of the potential sources discussed above that has not yet been analyzed. The most obvious candidates would be those alabaster deposits in parts of the western Himalayas where marine carbonates are known to have similarly high levels of radiogenic strontium.

The way in which the alabaster samples from the other prehistoric sites fall on the bivariate plot is informative. Once again the two fragments from the site of Musa Khel (black circles) appear to be from different Salt Range formations – one clearly comes from an Infra-Cambrian deposit and the other falls quite close to the Eocene age sources. The latter fragment, along with the one from Rehman Dheri (black diamond), provide a good indication of how the isotopic boundaries of Salt Range Eocene alabaster deposits might expand when additional analyses are undertaken of geologic samples from the Sakesar Formation. The alabaster vessel fragment from Mohenjo-daro (black square) along with a single fragment from Harappa stand apart due to their low sulfur and strontium isotope values. Although these two samples could be from a deposit related to the Eocene source formations of the Sulaiman Range or Kohat, they are clearly not from the Salt Range. Certain trade items such as chlorite vessels were brought to Indus cities like Mohenjo-daro from regions far beyond the Indus Valley (Kohl 1975, 1979). It is therefore possible that these alabaster artifacts, and perhaps some others, originated from sources much more distant than the ones discussed in this chapter.

Chronological and spatial interpretation of alabaster provenience determinations

It has been demonstrated that at least some of the alabaster artifacts from Harappa probably came from the geologic sources analyzed for this study. The provenience of other artifacts remains unclear. Nevertheless, much can still be learned about acquisition and use of alabaster at Harappa by examining the patterns derived from the isotopic data in tandem with the temporal and spatial contexts of the archaeological samples.

Figure 10.17 is a version of the bivariate plot of sulfur and strontium isotope data that has been modified to help illustrate some of the points that I discuss in this sub-section. On it, the individual deposits in the Salt Range are noted and archaeological samples from Harappa are labeled with a three part code that denotes artifact type (the type key is on the figure), period and mound of origin. For example, an artifact coded "F-3C(AB)" is an alabaster fragment recovered from Period 3C levels on Mound AB. The dashed ellipses that have been added to the figure represent the possible extent (isotopic boundaries) of geologic sources. These are admittedly speculative and do not represent statically generated confidence intervals. The Infra-Cambrian source area was the only one that was demarcated based on geologic samples alone. The dashed ellipse marking the Eocene Salt Range deposits was drawn to encompass archaeological samples from the sites of Rehman Dheri and Musa Khel, which presumably come from that formation. The Sulaiman-Kohat ellipse is based partly on geologic samples from those regions and partly on archaeological samples that cluster on or nearby them. A final ellipse was drawn to encompass the loose cluster of archaeological samples that plot above and to the left of the Salt Range Eocene deposits.

With reference to Figure 10.17, I begin by examining alabaster source utilization through time. To date only six alabaster artifacts have been recovered from levels earlier than Period 3 at Harappa – three from Period 1 and three from Period 2. Of these, two fragments from Period 2 were analyzed for this study and both appear to have come from Salt Range sources – one from an Eocene deposit and the other from an Infra-Cambrian deposit. Albeit the sample size is very small, the utilization of alabaster from sources north of Harappa is very much in line with the acquisition patterns being observed for other rock and mineral resources during the Early Harappan Period such as grindingstone (Chapter 5), chert (Chapter 6), steatite (Chapter 7) and lead (upcoming - Chapter 12). Note on the figure that there are also alabaster fragments from Period 3C with isotopic values analogous to deposits in the Salt Range. This provides further evidence (along with steatite, vesuvianite-grossular and lead) that Harappans continued to utilize materials from this northern zone well into the urban phase.

Evidence has been presented throughout this book that indicates the emergence of fully urban lifeways at Harappa coincided with an increase in both the number of rock and mineral varieties being brought to the site and the overall number of source regions around the Greater Indus from which such materials were being obtained. This trend towards diversification is yet again apparent with regard to the alabaster acquisition networks in which Harappans were involved during Period 3. Although only a few artifacts coming from periods 3A (n=1) and 3B (n=2) have been analyzed, most of them have isotopic characteristics that clearly set them apart from Salt Range deposits, which suggests that new sources had come into use. Sulfur and strontium isotope data exists for 16 alabaster artifacts from Period 3C levels. It appears from the way these artifacts plot on the figure that, in addition to the two different formations of the Salt Range (discussed above), raw material from at least two other sources (and possibly several more) was being brought to Harappa at this time. One of these new source regions appears to have been the Eocene deposits to the west and northwest of Harappa. Although I have demarcated this cluster with a single ellipse, some of the artifacts in it closely group with Sulaiman Range deposits while others appear more like Kohat material. It is highly probable that the smaller clusters of artifacts within the ellipse represent materials from multiple deposits across these geologically related regions. Another apparent source (or sources) is represented by the widely spaced cluster of artifacts with high $^{87}Sr/^{86}Sr$ ratios labeled "unknown." This is the group that may or may not be related to the Eocene formation of the Salt Range. There are also scattered cases where artifacts seemingly plot away from or between the main clusters. These may represent materials from still other sources or they may just be outliers of either the known or proposed geologic formations. Despite the fact that the geologic provenience of these and many other archaeological samples remains unclear, it is certainly well evident that during Period 3C Harappans were utilizing alabaster from at least three or four different source regions.

Lastly, we turn to synchronic variation of alabaster source usage at Harappa. It was stated toward the beginning of this chapter that, aside from the fact that residents of Mound E were apparently the only ones creating and/or consuming alabaster bangles, there does not appear to have been a great deal of intra-site variation in terms of the utilization of this material during Period 3C. Interesting patterns that seem to suggest otherwise, however, become evident when artifacts from this period are examined in relation to their possible geologic provenience. It would appear that the only Harappans using alabaster from the "unknown" source formation were those living and working on mounds E and ET. Residents of those areas also obtained some of that material from most other available sources with the exception of the Salt Range Infra-Cambrian deposits. People on Mound AB at this time utilized material from both Salt Range formations as well as the Sulaiman-Kohat sources. The Harappans of Mound F appear to have gotten their alabaster exclusively from deposits located in the Sulaiman Range.

Although these results seem to suggest that there might have been genuine differences in alabaster acquisition between peoples dwelling/working in the various habitation at Harappa, caution is advised because of the very small samples sizes involved in this study (only two to five artifacts from each of the major mounds have been analyzed for this period). Many more analyses of artifacts from the different parts of the site will eventually need to be conducted in order to determine if these patterns are valid.

CHARACTERIZATION OF MARI "DIAMONDS" FROM HARAPPA

A number of small (≈ 1 cm) pink-colored quartz crystals have been recovered at Harappa that could potentially provide an added dimension to this study of Harappan alabaster acquisition networks. If not for the highly distinctive bi-pyramidal shape of these artifacts (three examples can be seen in Figure 10.18 A) they would have simply been recorded as examples of common rose quartz. However, crystals of this exact description are known to occur within massive gypsum (Figure 10.18 B) found at certain locations in the Salt Range. The best known occurrences are located on either side of the Indus River at the point where it passes through the Salt Range and onto the Punjab Plain (Punjab Government 1907: 203). Local residents have long been known to search through the gypsum and salt marls of "Diamond Hill" near the village of Mari Indus (Figure 10.18 C) for these unusually shaped quartz crystals, or Mari "Diamonds," which they fashioned into necklaces (Alam and Khan 1982: 8; Wynne 1878: 300). In the site report for Mohenjo-daro, Sir Edwin Pascoe specifically mentions this source in the section outlining possible sources of rock crystal (Pascoe 1931: 678). It is unclear, however, if any quartz artifacts having this unusual shape were ever encountered at Mohenjo-daro or if the pink bi-pyramidal quartz crystals found at Harappa actually came from the Salt Range. Dr. Albert Verchere (cited in Government of the Punjab 1883-84: 18) noted bi-pyramidal quartz crystals in the brecciated gypsum of the Waziristan Hills. In the stone bazaar of Peshawar, I examined examples of similar crystals embedded in a gypsum matrix that were attributed to Afghanistan's Paktia Province, which lies adjacent to Waziristan. Bi-pyramidal crystals called "diamond quartz" are also known from the Karnur area of Tamil Nadu in southern India (Karnath 2000: 251, Figure 10.7a). The nearest occurrences to Harappa, however, are those in the Salt Range. If it could be shown that the Harappan examples are indeed Mari "Diamonds," then that would be an excellent second line of evidence indicating the exploitation of alabaster deposits in that region during the prehistoric period.

In addition to their unusual shape, petrographic studies (Chhibber 1944; Lenk-Chevitch 1955; Holland 1891) have revealed that Mari "Diamonds" from the Salt Range contain minute inclusions of anhydrite – calcium sulfate ($CaSO_4$) – which is basically gypsum without the water component. It is highly unusual to find this mineral within the structure of a crystal and can certainly be taken as indicative of its formation within a gypsum, alabaster or anhydrite deposit. No quartz crystals, bi-pyramidal or otherwise, have ever been reported to occur in either the Balochistan or Kohat alabaster deposits and, as far as I have been able to determine, quartz crystals (of any shape) containing inclusions of anhydrite inclusions do not occur in other geologic environments in South Asia.

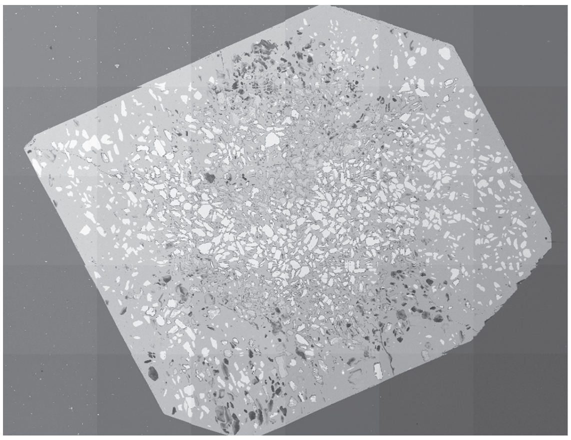
In order to determine if the small pink-colored bi-pyramidal quartz crystals from Harappa are indeed Mari "Diamonds," two examples were selected for characterization using electron microprobe analysis (refer to the section on EMPA in Chapter 3 for details regarding this technique). Back-scattered electron imaging (Figure 10.18 D & E) revealed that both of the crystals examined were filled with inclusions ranging from approximately 20 to 200 μm

Figure 10.18 Mari "Diamonds" – artifacts, sources and analyses

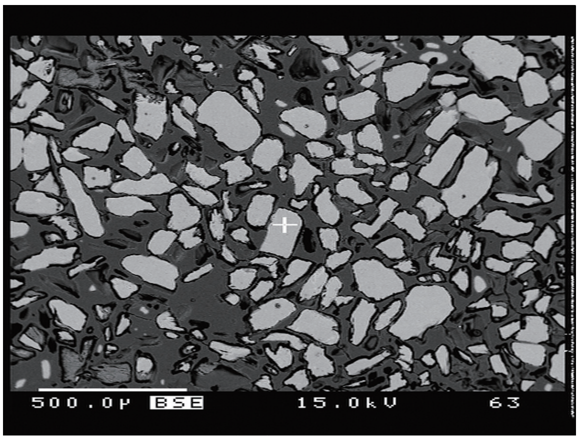
A. Three examples of unusual pink-colored bi-pyramidal quartz crystals recovered at Harappa.

B. Quartz crystals in gypsum-anhydrite matrix from Mari Indus.

C. Gypsum and salt marls at Mari Indus, District Mianwali, Punjab, Pakistan



D. Back scatter electron image of a section of an inclusion-filled Mari "Diamond" from Harappa.



E. Detail of anhydrite inclusions in Mari "Diamond."

(microns) in size. Scans with the microprobe's energy dispersive spectrometer (EDS) indicated that these inclusions were indeed composed of anhydrite. These results strongly support the conclusion that crystals at Harappa with this unique visual appearance are indeed Mari "Diamonds" from the central Salt Range.

To date, ten Mari "Diamonds" have been recovered at Harappa (Appendix 10.3) and none of them appear to have been intentionally modified in any way. It is possible that these examples were transported to the site within the matrix of a piece of raw alabaster and subsequently discarded. Small pieces of pink colored quartz are occasionally found that may represent examples that broke as craftsmen attempted to work them. However, most of these pieces are too fragmentary to determination if they were bi-pyramidal like Mari "Diamonds" and so have not been given that classification until such time as they can be characterized in greater detail using EMPA.

Although few artifacts of this type exist, they have been found across the site from Mound ET in the east to the north side of Mound AB (refer back to Figure 10.2 for locations). One example was found in the Harappa Period dump that covers part of the cemetery area. Most of the Mari "Diamonds" from secure stratigraphic contexts come from Period 3B or 3C levels, although two that may date as early as Period 2 have been found in mixed deposits on Mound AB. The finds from the later levels provide a small but important piece of evidence suggesting that materials from alabaster deposits of the central Salt Range were still being brought to Harappa during the latter half of the urban phase.

CHAPTER CONCLUSION

The combination of sulfur and strontium isotope analysis has proven to be an effective method with which to identify the probable geologic sources of Harappan alabaster artifacts. Even though the provenience of some samples in the archaeological set remains ambiguous and there are several important potential geologic sources left to be characterized, many new insights have been gained into the acquisition and utilization of alabaster in northwestern South Asia during the third millennium BC.

Kot Diji Phase (Period 2) residents of Harappa used alabaster from both the Eocene and Infra-Cambrian age deposits of the Salt Range. They may very well have obtained this material through trade with their Early Harappan contemporaries at sites like Rehman Dheri and Musa Khel, which lie in the vicinity of those mountains and have alabaster fragments on their surfaces isotopically analogous to sources found there. At Musa Khel, as at Harappa, materials from each of the two Salt Range alabaster formations were present. This, taken together with the evidence that black chert identical to that found in Period 2 levels at Harappa may have also been brought to Musa Khel from nearby sources (Chapter 6), suggests that the site was an important gathering place or staging area for rock and mineral resources collected from across this region. Its location near the base of one of the major passes through the Salt Range further strengthens this possibility.

New sources of alabaster began to be used at Harappa as society there and elsewhere in the Indus Valley took on a decidedly urbanized character beginning in Period 3. Exploitation of older sources did not cease however. On the contrary, they continued to be used well into the urban phase as evidenced by the presence through Period 3C of both Salt Range alabaster and Mari "Diamonds." Still, most of the alabaster used by urban phase residents of Harappan seems to have come from either the Eocene deposits west and northwest of the site in the Sulaiman Range and Kohat regions or from the as yet unidentified source(s) characterized by highly radiogenic strontium. That source(s) very likely lies somewhere in the western Himalayas (possibly Jammu and Kashmir) although there is a chance that it could also be related to Eocene deposits in the Salt Range. A few artifacts from Harappa and the vessel fragment from Mohenjo-daro suggest that consumers in the Indus Valley at this time had at least limited access to still other sources.

The results of this study also suggested that some intra-site differences may have existed at Harappa in terms of the acquisition and utilization of alabaster. For example, all alabaster analyzed from Mound F comes from deposits in the Sulaiman Range. Craftspeople on Mound AB also utilized Sulaiman alabaster as well as raw material from both of the Salt Range formations. A slightly different pattern of acquisition and production was left by people residing in the eastern half of the site. Residents of the adjoined mounds E and ET were apparently the only ones at the site producing and consuming alabaster bangles. In addition they seem to have been the sole group with either access to or the desire to work material from the "unknown" alabaster source with unusually high levels of radiogenic strontium. Similar site-wise variations in raw material procurement and/or utilization have been observed between the major mounded areas at Harappa for grindingstone (Chapter 5) as well as for vesuvianite-grossular and "Ernestite" (recall the discussion in Chapter 9).

The amount of alabaster manufacturing debris that is evident at Harappa may not reflect the scale of production there as well as a material like agate does for the bead making industry. The reason is that the waste produced by working a material like agate is generally of little further use and so all or most of it remains in the archaeological record as evidence of that activity. Gypsum, on the other hand, had a very broad range of uses in the ancient world (Levey 1958). Consequently, a large portion of the debris generated during the making of alabaster objects at Harappa may have been collected and used for other purposes that are less detectable archaeologically, thus leaving a much diminished record of production. Even if this was the case, however, the ubiquitous presence of this material across the site and throughout its chronological sequence, when combined with the evidence that multiple sources were at times exploited to meet supply needs, strongly suggests that alabaster working was one of the more important lithic industries at Harappa.

Lastly, although it impossible to know for certain in what sizes Harappans typically transported raw alabaster from the sources identified here, it is stands to reason that the pieces of stone brought to the site for creating objects such as dishes and bowls were significantly larger and heavier than the thin-walled finished products that are found. The best piece of evidence currently available is the large ringstone fragment pictured in Figure 10.4 C, which weighs approximately two kilograms. When that artifact was complete it probably weighed no less than 10 kg. It is therefore possible to state that Harappans (or the people who were supplying them) were capable of transporting raw alabaster of at least that size from certain source areas. With regard to this particular artifact that source appears to have been west of Harappa in the Sulaiman Range. Pab sandstone grindingstones of that size and greater came from the Sulaiman Range (Chapter 5) and so it is not at all surprising that other materials were also transported in bulk sizes from that region.

In the next chapter, I identify and trace the acquisition networks for several distinctive varieties of limestone that were used to make, among other things, the largest type of stone objects found at Harappa – ringstones.