IMMIGRANT IDENTITY IN THE INDUS CIVILIZATION: A MULTI-SITE ISOTOPIC MORTUARY ANALYSIS

By

BENJAMIN THOMAS VALENTINE

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2013

To Shannon

ACKNOWLEDGMENTS

Truly, I have stood on the shoulders of my betters to reach this point in my career. I could never have completed this dissertation without the unfailing support of my family, friends, and colleagues, both at home and abroad. I am grateful, most of all, for my wife, Shannon Chillingworth. I am humbled by the sacrifices she has made for dreams not her own. I can never repay her for the gifts she has given me, nor will she ever call my debt due. Shannon—thank you.

I am likewise indebted to the scholars and institutions that have facilitated my graduate research these past eight years. Foremost among them is my faculty advisor, John Krigbaum, who took a chance on me, an aspiring researcher with little anthropological training, and welcomed me into the University of Florida (UF) Bone Chemistry Lab. I have worked hard not to fail him, as he has never failed me. Under John Krigbaum's mentorship, I have earned my chance to succeed in academe.

During my time at UF, I have benefited from the efforts of many excellent faculty members, but I am especially grateful to James Davidson, Department of Anthropology and George Kamenov and Jason Curtis, Department of Geological Sciences. They have labored alongside me, in the classroom and laboratory, to ensure my progress. The hours they spent instructing, helping, or just listening to me have directly contributed to the completion of this dissertation.

My research would very likely have been on something else entirely, however, were it not for Jonathan Mark Kenoyer and his co-directors at the Harappa Archaeological Research Project, Richard Meadow and Rita Wright. Jonathan Mark Kenoyer, in particular, has supported my endeavors in Indus Civilization archaeology, offering vital counsel, collaboration, and, when needed, a firm push. His involvement

has been central to my successes thus far, and I cannot overstate how generous he has been.

Likewise, the directors, researchers, and staff of the Archaeological Survey of India have proven foundational to my efforts, and I am forever grateful for the opportunities that they have provided. In particular, I must thank former Director-Generals Guatam Sengupta and K.N. Srivastava as well as Directors R.S. Fonia and Subhra Pramanik. They have opened the door to a world of archaeological scholarship that I am only just beginning to explore. The process of discovery, however, did not always go smoothly, and I frequently needed guidance in unfamiliar terrain. In this regard, I am especially thankful for the tireless efforts of D.V. Sharma and V.N. Prabhakar as they helped clear the path for this lone traveler and wide-eyed researcher. Their dedication to collaborative scholarship is inspiring.

I received equally essential support from the faculties of Deccan College Post-Graduate and Research Institute, Pune and Maharshi Dayanand University, Rohtak. I am truly indebted to Vasant Shinde and Manmohan Kumar for seeing what could come of this research and repeatedly sharing their counsel and assistance. I have also benefited greatly from the expertise and kindness of Veena Mushrif-Tripathy, Pramod Joglekar, Vijay Sathe, Amrita Sarkar Das, and Vivek Dangi who regularly shared their knowledge on matters both scholarly and mundane. Additional assistance was provided by former and present researchers affiliated with Centre for Archaeological Studies and Training, Eastern India, Kolkata as well as Research Institute for Humanity and Nature, Kyoto. I owe particular thanks to Suchira Roychoudhury, Akinori Uesugi, and Toshiki Osada. These and other international scholars have collectively welcomed me into their

academic community, and I am deeply appreciative of their respect for new ideas and new methods within archaeological research.

Lastly, I must acknowledge the financial support received through UF and external granting institutions. Within the university, the Office of Research, Graduate School, College of Liberal Arts and Sciences, Department of Anthropology, and Graduate Student Council have frequently assisted with the indirect costs of this research. Additionally, the American Institute of Indian Studies (AIIS) took me on as a Junior Fellow (2010-2011), during which time I conducted sample collection. Beyond monetary support, the dedication of the officers and staff at AIIS proved invaluable in overcoming the many challenges of field research. I offer my sincere thanks to Philip Lutgendorf, Purnima Mehta, Subir Sarkar, Anil Inamdar, and Mini Raji Kumar for their personal efforts on my behalf. Furthermore, The Wenner-Gren Foundation Dissertation Fieldwork Grant (2011-2012) assisted directly with analytical expenses.

Before embarking on this project, I imagined that research was something that people accomplished by themselves, either wearing a lab coat or writing insightful paragraphs late into the night. I have since learned that the true privilege of scholarship is in working closely with a community of experts, and in bringing their diverse talents to bear on problems that fire the imagination. To all of those above, and to the many more that were not mentioned by name—thank you. Were it not for you, this dissertation would not exist, and my life would be substantially less rich.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

C	carbon
CO_2	carbon dioxide
HARP	Harappa Archaeological Research Project
HBr	hydrobromic acid
HCl	hydrochloric acid
HHC	High Himalayan Crystallines
HNO_3	nitric acid
MC-ICP-MS	multicollector inductively coupled plasma mass spectrometer
NaOCl	sodium hypochlorite (bleach)
O	oxygen
Pb	lead
Sr	strontium
TIMS	thermal ionization mass spectrometer
TRA	time-resolved analysis
VPDB	Vienna Pee Dee Belemnite

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

IMMIGRANT IDENTITY IN THE INDUS CIVILIZATION: A MULTI-SITE ISOTOPIC MORTUARY ANALYSIS

By

Benjamin Thomas Valentine

August 2013

Chair: John Krigbaum
Major: Anthropology

Despite widespread effort within academic, political, and popular arenas to understand the relationships between migration and urbanism, the study of migration in ancient urban contexts remains relatively understudied. This is particularly true for the Indus Civilization, a 3rd millennium BC protohistoric urban society that spanned much of modern day Pakistan and northwest India. Yet migration almost certainly accompanied the sprawling trade networks connecting Indus lowland peoples with the hinterland cultures of the mineral-rich highlands; and the interregional flows of people likely challenged existing social contexts and redefined cultural relationships in a manner that resonates with modern and historical urban settings. Thus the application of isotopic provenience methods to Indus Civilization human remains offers unique insight into the ways that complex societies are entangled with the movement of bodies.

Mortuary samples from the major urban center of Harappa, the eastern frontier town of Farmana, and the post-urban necropolis at Sanauli collectively provide a diachronic perspective on Indus migration. Individual life histories of mobility were gleaned from archaeological tooth enamel using isotopes of strontium, lead, oxygen, and carbon, and when considered within the broader context of mortuary material

culture and South Asian geochemical variation, they suggest that urban era Indus cemetery burials were reserved exclusively for participants in a structured institution of immigration. Although their origins cannot be conclusively determined based on currently available evidence, the isotope data are consistent with birth outside of the alluvial plains including the adjacent resource-rich highlands. Further, intra-individual isotopic data suggest that many individuals, if not all, migrated as children. The implication is that child migration may have happened outside the context of familial residence change.

Additional work is required to verify the ‘all immigrant’ hypothesis, but it is proposed as a framework for future investigations and to demonstrate the need for models of interaction that incorporate the complex social dimensions of the Indus landscape. An institution of fosterage is modeled based on ethnohistoric evidence from the adjacent Hindu Kush mountains. It is proposed that highland and lowland groups could have been economically united through kinship practices that reaffirmed their independent cultural identities.

CHAPTER 1
OBJECTIVES AND OVERVIEW

This dissertation examines the social outcomes of ancient urban migration through the isotopic mortuary analysis of individuals recovered from Indus Civilization cemeteries. Known best from sites in what is now Pakistan and northwest India (Figure 1-1), the Indus Civilization contradicts the familiar narrative of statehood that begins with highly centralized power structures. The 3rd millennium BC urban society was crosscut by heterarchical institutions in a manner that is reminiscent of the increasingly interconnected and decentralized modern world. Situated in a vast landscape estimated between 680,000 km^2 (Kenoyer 1991a) and 1,000,000 km^2 (Jansen 2002), Indus cemeteries provide essential data for understanding the roles of individuals in broader social institutions and the mechanisms that fostered large-scale cultural integration. This study incorporates conventional archaeological data within an isotopic assessment of individual life histories. Isotopes of lead, strontium, oxygen, and carbon in human tooth enamel reveal aspects of past migration, climate, and diet. Further, by sampling multiple teeth from given individuals, it was possible to access life histories spanning birth to early adolescence. The resulting bioarchaeological data sets are used to address three research foci:

- How did early-life migration vary within and between individuals and groups?
- What group identities can be inferred from patterns in the migration data?
- How might intergroup relationships have been enmeshed within the broader social context of the Indus landscape?

Interregional interaction was central to the development and maintenance of the Indus Civilization (Kenoyer 1991a; Kenoyer 1995b) and thus interpretive emphasis for this study is placed on the identification and sourcing of immigrant individuals. Much

effort has been made towards understanding the flow of goods throughout the subcontinent and beyond (Lamberg-Karlovsky 1972; Fairservis 1975; Agrawala and Kumar 1982; Allchin 1984; Gupta 1984; Chakrabarti 1990; Lahiri 1992; Asthana 1993; Hooja 1994; Kenoyer 1997; Law 2008), however, relatively little evidence is available regarding the flow of bodies (Kennedy et al. 1984; Hemphill et al. 1991; Kennedy 2000). Artifactual evidence for trade and culture contact implies the movement of people, but it is a necessarily incomplete picture that leaves open questions regarding the identity and mobility of various social groups. Some models of Indus mobility have been put forward that suggest mobile pastoralists served as intermediaries in interregional trade (Possehl 1979; Mughal 1994b), and Kenoyer (2011a) suggested that far-ranging systems of elite kinship could have promoted interregional alliances and cultural exchange. Nevertheless, a more thorough investigation of Indus mortuary remains using tools of biogeochemistry is needed to refine understandings of how Indus migration and mortuary practices were enmeshed within a complex system of intergroup relationships.

Well-documented Indus burials are scarce and cemetery inhumations even more so (Possehl 2002b). In part this paucity of human remains suggests that formal interments represent individuals associated with a particular segment of society. Even at the large urban period cemeteries known from excavations of Harappa (Wheeler 1947; Sastri 1965; Mughal 1968; Miller 1991; Meadow and Kenoyer 1994), Kalibangan (Sharma 1999), and Farmana (Shinde 2011a), estimates of the number of burials at each site are in the low hundreds. Consequently, the archaeological problem is less about reconstructing demographic profiles and social hierarchies for internally sub-divided mortuary populations, and more about discovering what the inhumed dead had

in common. Pollock (2008) analyzed cemeteries at Mehrgarh, Harappa, Kalibangan, and Lothal, and noted broad similarities in grave goods, burial orientation, and skeletal position at each site except Mehrgarh. The same general pattern holds for the cemeteries at Farmana (Shinde 2011a) and post-urban Sanauli (Prabhakar 2012). Considering that this mode of burial was widespread geographically and temporally but reserved for relatively few individuals, it seems likely that the Indus tradition of cemetery inhumations indexed shared ideological concepts and perpetuated certain relationships between individuals, groups, and institutions.

This research will start to identify potential commonalities of identity in the sampled Indus cemeteries at Farmana, Harappa, and Sanauli. Novel lines of isotopic evidence are used to assess early life patterns of migration among burials for which tooth enamel was available. Lead, strontium, and oxygen isotope data are analyzed to help assess the relative frequency of migration as well as the timing of migration events in an individual's early life history (~14 years). Probable geographic regions of origin are inferred whenever possible by comparison with sediments and fauna from other Indus sites including Allahdino, Balakot, Mehrgarh, and Nausharo. Broader patterns of regional isotopic variation are inferred from the geological literature (e.g., Karim and Veizer 2000; Najman et al. 2000; Clift et al. 2002; Karim and Veizer 2002) and artifact provenience studies (e.g., Law 2008; Hoffman and Miller 2009). Findings suggest that inhumation in formal cemeteries during the Indus urban florescence (ca. 2600-1900 BC) may have been exclusively reserved for individuals who migrated to the area at a young age. This proposed institution of migration appears to have disappeared or transformed in subsequent years given the lower frequency of immigrants in the post-urban mortuary

population and the relatively stochastic nature of the data set. Inferred trends in residential mobility are compared with archaeological mortuary variation including dietary and demographic variables to identify and characterize potential social characteristics of Indus groups. Lastly, a model is developed suggesting how the structure of inter-group relationships both derived from and contributed to broader Indus Civilization social organization.

Previous models of Indus Civilization social organization provide the fundamental underpinning for inferences about the structures and consequences of interregional interaction. Chapter 2 outlines key aspects of Indus society including an overview of factional elite competition for highland resources. Specific attention is paid to the influence of Indus kin groups on trade between peoples of the lowland study sites and adjacent, potentially non-Indus peoples in the highlands, piedmont, or other nearby areas (hereafter referred to simply as highlands) with strategic access to resources not normally found in the alluvial plains. Kinship principles likely shaped group membership throughout Indus society (Kenoyer 1998) and could have provided a means of constructing relatedness between diverse peoples.

Chapter 3 outlines research methods used to generate the isotopic data. Results are then presented in chapters on isotopic variation in the Greater Indus region (Chapter 4), Farmana urban period humans (Chapter 5), Harappa urban period humans (Chapter 6), and Sanauli post-urban humans (Chapter 7). Each chapter includes a site specific review of relevant archaeological context. Chapter 8 synthesizes the data in a multi-site isotopic mortuary analysis and presents a model explaining how the construction of kinship between the inhumed dead and elite groups helped structure

interregional interaction. Chapter 9 concludes by highlighting the key contributions of this research and suggestions for future research. The entire orientation of this research, however, derives from a long history of archaeological approaches to death and migration in ancient societies. The relevant literature is reviewed here to situate the current study within a broader theoretical trajectory.

Mortuary Archaeology

As it is practiced today, mortuary archaeology has moved well beyond the Saxe-Binford paradigm (Saxe 1970; Binford 1971; Saxe 1971) so influential in processual understandings of social structure. Nevertheless, the discipline retains roots in the methods and lessons of that era. Brown (1971) and colleagues rejected the overt emphasis on description and chronology in earlier approaches, emphasizing the utility of mortuary variation for understanding systems of social organization (contra Kroeber 1927). Further, ethnography was transformed from a peripheral source of interpretive inspiration (sensu Ucko 1969) into the essential raw material for comparative analogy (Schuyler 1968). Though strict analogical use of ethnography is fraught with its own problems (Metcalf and Huntington 1991:17-19; Lyman and O'Brien 2001), ethnography regained an important role in the interpretation of past mortuary practices—especially where historical continuity could be established (e.g., Pearson 1982; Dillehay 1995). No ethnographic scenario can be projected wholesale into the past, but broad concepts drawn from ethnographic accounts (such as categories of kinship and personhood) may be relevant to inferences about archaeological societies that demonstrate some measure of structural and historical continuity.

Other important trends have “New Archaeology” origins such as O’Shea’s (1984) emphasis on the redundancy of mortuary variation. Not every distinction in mortuary

style has a corresponding social distinction, nor is every aspect of the mortuary program preserved. In fact, many mortuary practices are invisible in the archaeological record, requiring that archaeologists look for redundancy in the burial program such that correlations between multiple indicators are presumed to convey the most significant social differences (O'Shea 1984:29-30; Weiss-Krejci 2011). Those traits most readily observed by archaeologists such as the quantity and kind of grave goods or the age and sex of the interred may have been irrelevant or subordinate to the primary social distinctions implied by the mortuary program. Archaeologists, therefore, have a greater chance of accurately identifying social distinctions that were observed in life by looking for redundant patterns of differentiation across a full suite of archaeological, biological, and geochemical variables.

A concern with the spatiality of mortuary contexts also has roots in “New Archaeology” (Goldstein 1981). Though limited at first to a representationist perspective in which mortuary variability is interpreted as a reflection of social order (Peebles and Kus 1977; Goldstein 1980; Chapman 1981; Morris 1991), the post-processual critique ushered in a concern for ideology and agency (Hodder 1982; Pearson 1982). Mortuary practices, it was argued, can be strategic means of creating relationships and building affiliations between individuals and institutions (Cannon 1989; Pollock 1991; Gillespie 2001; Joyce 2001). Always, however, those practices are embedded in space—a vital medium of inclusion and exclusion.

Mortuary practices are now increasingly perceived as historically contingent constructions that in turn serve to structure relationships between people, things, and places (Arnold 2002; Charles and Buikstra 2002; Silverman 2002; Hodder 2012). For

example, Arnold (2002) suggested that the evolution, placement, and patterning of mortuary monuments (a “landscape of ancestors”) in the Iron Age of west-central Europe was closely tied to changing perceptions and needs of the living. Tumuli served as material reference points legitimizing territorial claims, and the pattern of their placement in the landscape was structured over time to make various and evolving assertions about the relationships between groups. Linear arrangements of mortuary monuments next to settlements likely guided the approach of outsiders and residents alike, intentionally aligning the social power of the dead with that of local groups. Further, a ritually manipulated alliance between the living and the dead would necessarily have concretized a social distinction between the ritual allies and other, possibly competing groups. Thus, construction of the ritual landscape itself was a means of contention, with socially powerful mortuary landscapes being co-opted over time through the distinct yet structurally related mortuary practices of outsiders. Through such entangled relationships, social landscapes are formed. Importantly, the social qualities of landscapes are not abstracted ephemera. They are inseparable from and constituted by the material interactions of people and things. To describe a mortuary landscape, like any other landscape, is to describe the ways in which bodies and objects, individuals and institutions, come to stand in reference to each other. Always in the process of becoming, mortuary landscapes are constantly being negotiated by differentially empowered (or differentially emplaced) actors who engage differently with the histories of a place (de Certeau 1984; Lefebvre 1991).

Mortuary analysis must consider the spatiality of the subject matter. The locations of burials in relation to each other, of cemeteries to habitations, and of formally

similar cemeteries to each other—all are dimensions of mortuary variation through which past relationships could have been influenced. However, spatiality need not be limited to the physical distances observed by archaeologists. Bodies too are fundamentally spatial in that their histories have the potential to invoke different meanings and different places. The body of an immigrant possesses indexicality (Gell 1998) such that in perceiving an immigrant's non-local origins, one is made mindful of the non-local place. The distant place is made present and the meanings and relationships associated with that place are brought to bear on subsequent interactions. The social significance of such associations is precisely what a mortuary analysis of immigrants must investigate. Redundant patterns and correlations in the archaeological evidence have the potential to demarcate social boundaries and associated group identities that exist only with respect to each other. For archaeological interpretations to have any hope of accuracy, however, they must be grounded in the historical context that shaped the perceptions and motivations of the actors. Through this approach a theory of migration can begin to take shape.

Migration in Archaeology

Migration is relatively under-theorized within archaeology partly because of an intellectual stigma associated with the migration concept. From early on in Anglophone archaeology, cultural types were conflated with ethnic groups such that the changing distributions of material culture were assumed to reflect the changing residence of ethnic groups. Migration was proposed as an *ad hoc* explanation for cultural distributions rather than a process modeled in its own right (Adams et al. 1978). This "black box" approach to migration became less tenable with advances in archaeological science and theory. For example, radiocarbon dating demonstrated that seemingly

abrupt transitions in material culture once attributed to population movements were actually gradual changes over the long term (Trigger 2006:383-384). Positivist approaches of the “New Archaeology” avoided the issue altogether by privileging internal responses to environmental factors as the most probable mechanism of culture change (Renfrew 1972; Renfrew 1973; Moseley 1975; Meacham 1977)

Migration made a limited resurgence by the 1970s in the form of archaeogenetics (Renfrew 2000). Researchers attempted to understand large-scale population movements such as the Austronesian dispersal in Southeast Asia (Bellwood 2004) through a combination of archaeological, linguistic, and eventually molecular data. The notion that groups of linguistically and economically similar migrants could be analyzed as a whole was not entirely dissimilar from previous culture-historical concepts of ethnic groups. However, scholars tried to model specific mechanisms and processes of dispersal as in Ammerman and Cavalli-Sforza’s (1971) demic diffusion of Neolithic agricultural peoples across Europe.

Outside of archaeogenetics, more recent calls for the study of migration as a social process have emphasized the importance of ethnography (Anthony 1990; Anthony 1992). It was argued that ethnographically-based classifications of the different types of migration could help explain past migrations by enabling an explicit focus on variability in the timing, scale, and permanence of migration events (Anthony 1997; Frachetti 2011). Critiqued as direct analogies that ignore the specific contexts of prehistoric migrations (Chapman and Dolukhanov 1992), ethnography was recast by Burmeister (2000) as an investigative starting point from which to make comparisons and test for goodness of fit between theory and archaeological evidence.

Prospects for testing ethnographically-derived models are limited, however, by the often coarse-grained data available to archaeologists (Burmeister 2000). Several methods have been proposed to ameliorate these difficulties, including the application of individual-level data such as those gained from bioarchaeological and biogeochemical methods (Harke 2007), along with the search for redundancy using multiple lines of evidence (Beekman and Christensen 2003). Whatever the methods used to identify migration, explaining migration as a process necessarily requires a multi-scalar approach in which diverse individual- or group-level actions are simultaneously embedded within and helping to construct macro-level conditions (Hakenbeck 2008).

By themselves, biogeochemical provenience data are insufficient for this task. Unless the link between individuals and particular geographic areas is embedded within a model of the social landscape, the movement of groups and individuals devolves into little more than lines connecting regions on a map. The lines that connect regions represent ‘interaction,’ an often poorly defined concept, and in the most limited cases they are reduced to a description of how much information is flowing in which direction. The line might indicate who is migrating, along with their departure point and destination, but it remains a generalized description of macro-level processes. This understanding of migration does not allow for the many articulations between migrants and the world they inhabit. There is little room to discuss how macro-level conditions such as the distribution of raw materials, food-rich environments, and urban marketplaces intersect with micro-level conditions such as the local politics of kinship practices.

One way forward is to apply the visual metaphor of weaving. The weave is similar to Ingold's (2011:63-64) concept of *meshwork* in which the world is composed of limitless intermingled flows of people and things rather than bounded entities in empty space. Likewise, a woven tapestry cannot be made of images and patterns that exist in and of themselves. It is made of the warp and the weft, crossing and contrasting and connecting different places in the weave such that a pattern can emerge in relation to the surrounding threads. Unlike the ephemeral flows of bodies and things in Ingold's meshwork, however, a weave persists. It has history and it holds time in such a way that new threads pull on, intersect with, diverge from, and modify the work that came before. A weave is in many ways evolutionary, and so it is with archaeological cultures. Rather than thinking of bounded groups that exist in and of themselves, groups are defined only in opposition to something else, at the places where the many relationships between people and things are gathered and made material. The diverse flows of people and things come together in ways that are structured by material histories, such that the outcomes are a product of past relationships. Further, perceptions of the past change over time and vary between entities because one's relative position within the weave is constantly evolving.

The infinite extent of the meshwork limits its utility as an analytical tool, but a weave, a product of work, time, and perceptions, can be cut, tangled, or otherwise altered to stop flows in a particular configuration. Such hybridizing actions which condense diverse flows within a new medium (e.g., a body, thing, or institution), overcome the interpretive challenge of limitless meshworks (Strathern 1996). The intersection of diverse flows of peoples and things can be concretized in an act of

creation that draws on different agents with different spatialities and different indexicalities. In this way, and only in this way, can social distinctions be perceived. Groups are not differentiated from each other because they are composed of different people. Groups are differentiated because diverse flows are *gathered* (Ingold 2011:178-179) in hybrid loci that make a tension manifest. They hold a social contrast in place so that it can be considered, referenced, and invoked as a means of distinguishing its constituent flows from each other. Red becomes red at the places where it is altered and hybridized into orange or purple. An ethnic group becomes an ethnic group at the place where its flows of bodies and things are altered by other flows, much like the maintenance of social boundaries modeled by Barth (1969) and Cohen (1974). This meeting of flows, however, is not limited to the decisions of rational actors, and could be, for example, a historical monument that gathers flows from the past and articulates them with the present in unanticipated and variable ways. Similarly, a hybrid person can embody diverse flows--a human born of one culture and raised in another. The constituent flows (diverse ways of life) that meet in a hybrid person may then be rendered as contrasting identities, thus providing one possible means of defining ethnic groups.

A tangled weave captures this process in a way that can be readily visualized and likened to archaeological flows of bodies and things. Different threads laid down at different places and times are gathered together in a tangle. The hybrid locus creates a new visual reference point by which old patterns can be redefined or eliminated and new patterns can emerge. This contrasts with stubbornly implicit diffusionist tendencies in archaeological models of culture contact. Whereas migration is often assumed to lead

to a blending, graduating, and eventual homogenization of distinct cultures, the tangled weave allows for cultural novelty. The hybrid locus creates the reference point by which new groups may be defined. Further, the tangled threads do not pull equally on all aspects of the weave. It is only in proximity to such hybrid gatherings that different regions in the weave can be differentiated from each other. Meanwhile, bodies flowing along more distant threads may barely feel the pull, may barely notice the emerging boundary, and may perceive similarities to, rather than contrasts with the gathered flows. Nor is the ethnic boundary perceived equally by those bodies flowing closest to the tangle. Some of their threads are stretched tight, some loose, and still others hang slack. So it is with a weave of people and things. As people create, they draw on the wider tapestry, gathering diverse actions and objects into a hybrid structure that pulls differently on everyone and everything involved.

By recasting migration as a weave gathered up in places by hybridizing tangles, it becomes possible to discuss the variable perceptions held by the different parties involved, how their social environments and histories constrain the structure of their interaction, how small changes in the social environment might stabilize or destabilize such interactions in the long term, and what the macro-level consequences of interaction might be. For any of this to occur, however, one must return to mortuary analysis as the means of identifying redundancies in mortuary practice indicative of group identities. This analytical process begins in Chapter 2 with a review of Indus Civilization archaeological context.

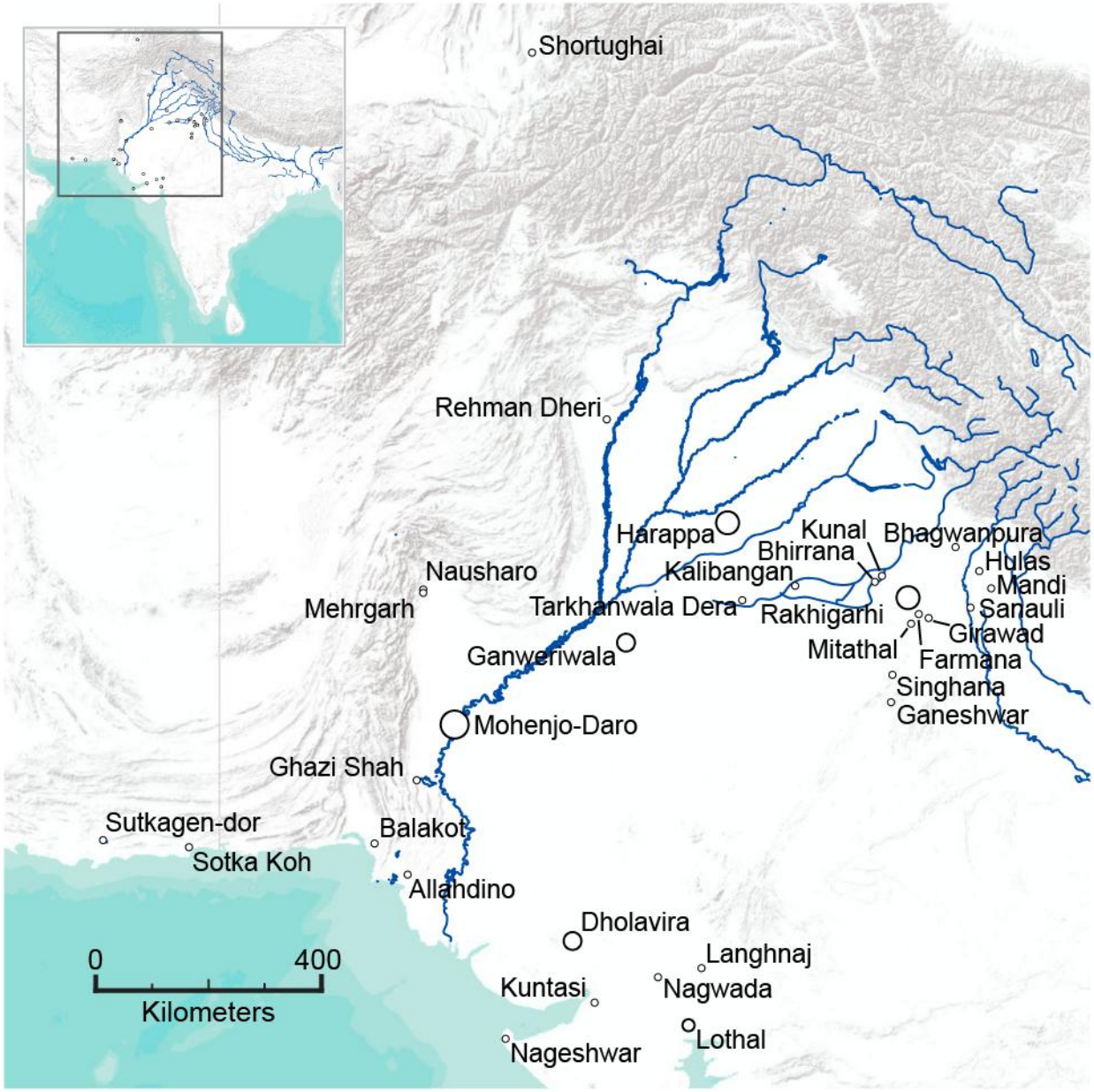

Figure 1-1. Map of study area including sites mentioned in the text.

CHAPTER 2
INDUS CIVILIZATION IN CONTEXT

The term Indus Civilization refers colloquially to the urban zenith of northwestern South Asia during the third millennium BC. Archaeological chronologies tend to convey a more holistic view (Possehl 1977; Kenoyer 1991a; Shaffer 1992), with emphasis on the eight millennia-long development, convergence, and subsequent diversification of various cultural trajectories beginning with foraging lifeways of the early Holocene (ca. 10,000 BC). In either case, the emergence of cities and associated cultural integration across a region covering much of modern-day Pakistan and northwestern India (serves as an important reference point for explaining transformations of social complexity. Indeed, this dissertation is focused primarily on clarifying the nature of interregional relationships coincident with and immediately succeeding the urban climax. An improved understanding of interregional relationships will provide new insights into the transformations of identity associated with this dynamic period of social differentiation and stratification (Kenoyer 1998; Possehl 2002; Wright 2010).

A diverse and relatively dispersed resource base likely played an important role in the development of interregional interaction in the Greater Indus region (Wright 2010:179-180). Indus sites were located primarily on the fertile alluvium of the western Indo-Gangetic plains (Figure 2-1). Frequently situated on doabs, relatively elevated interfluvial regions, settlements were well positioned for agricultural production and riverine transportation. Spaced roughly equidistant from each other, four of the five major cities (Harappa, Mohenjo-Daro, Ganweriwala, and Rakhigarhi) were located at strategic points along the Indus River, its tributaries (the Punjab region), or the Ghaggar-Hakra (Mughal 1994a). Near confluences or mountain passes, residents

would have had unparalleled access to hinterland trade (Kenoyer 1998:43; Law 2006). They depended on trade for a variety of mineral and organic resources available only in the oceans, swamps, and jungles to the south and southeast or the upland regions flanking the Indus Valley to the west, north, and east (Law 2008; Wright 2010:190, 211-212).

Ranges of the Western Fold Belt mark the western highland border, perforated by mountain passes that access Iran and southern Afghanistan (Chakrabarti 1990; Thomas and Knox 1994). The mountains run approximately from north to south before turning to the southwest along the Makran coast. The northern boundary of the Punjab begins at the Potwar Plateau in the northwest and extends eastward along the Himalayan foothills. The Hindu Kush and Karakorum ranges lie further to the north, overlooking the upper Indus drainage. To the east of the Indus Valley, the Ganges River and its major tributary, the Yamuna, demarcate the eastern limit of the Indus Civilization. The now seasonal Ghaggar-Hakra flows south between the glacially-fed Indus and Ganges systems before diverting to the southwest, skirting the northward projecting Aravalli mountains, and disappearing into the Thar Desert. Coastal marshes to the south and southeast characterize the Kutch region where the fifth major city, Dholavira, once had access to maritime routes (Bisht 1989; Kenoyer 1998:53). The Saurashtran peninsula lies beyond the wetlands to the southeast and marks the furthest penetration of Indus sites into southern India. Each hinterland region was exploited for mineral wealth that was traded widely across the Greater Indus Region (Law 2008). Trade was not an equal-opportunity endeavor, however, and elite groups likely competed over access to resources (Kenoyer 2000b).

The presence of elites is well established within the Indus Civilization as it manifests in many aspects of the archaeological record (Kenoyer 1998; Possehl 2002b; Wright 2010). Hierarchy is most strongly inferred from the use and production contexts of various material symbols of ownership and regulation (e.g., Rao 1979; Vidale 1989); likewise, the logistical requirements for the management of agricultural land in a diverse system of intensive food production and the construction and maintenance of expansive civic architecture suggest that certain kinds of people held authority over certain matters (e.g., Bisht 1991; Jansen 1993; Kenoyer 1993, Joshi 2003; Miller 2006b). However, power does not appear to have been concentrated within a central state institution. Instead, diverse groups seemed to coexist within the context of a shared ideology (Miller 1985).

Corporate groups may have sought advantages over each other by gaining preferential access to prestige goods (Kenoyer 1997a). Mineral wealth in particular was scarce in the alluvial plains, necessitating interaction between lowland settlements of the Indus tradition and non-Indus highland peoples through either direct or indirect trade. For example, Law's (2008) extensive provenience study of the mineral assemblage at Harappa indicates far reaching acquisition routes with an emphasis on the adjacent highlands to the north. In many instances, this would have necessitated direct or indirect interaction with Northern Neolithic peoples (Stacul 1992; Stacul 1994; Possehl 1999). Similarly, Indus groups from eastern sites like Farmana and Sanauli may have interacted with peoples of the Rajasthan-Mawal Tradition in the Aravalli Mountains to the south (Agrawala and Kumar 1982; Rizvi 2007).

Many aspects of the development of lowland-highland interactions in different Indus regions remain unclear. Contrary to views expressed by McIntosh (2002; 2008), violence was a fact of life for Indus peoples and was likely structured in some ways by group identity (Robbins Schug et al. 2012). Still, no evidence suggests that interregional interaction between diverse groups was mediated through warfare or conquest to the degree documented in the formation of ancient Egyptian and Mesopotamian states (Akkermans and Schwartz 2003; Wenke 2009; Wright 2010). Relationships between people of different territories appear to have been established and maintained primarily through civilian activities. Interregional exchange provided opportunities for the accumulation of power and was therefore a key motivation for people of different regions to come together (Kenoyer 1998:98-99). The question then becomes how to explain the diverse outcomes of interregional interaction. Importantly, varying degrees of formal similarity in the assemblages at different sites across the Indus region suggest that interaction was neither uniform nor explainable by a single model. It is hoped that the mortuary analysis carried out here will begin to clarify Indus modes of interregional interaction as fundamentally social phenomena, thus moving Indus interaction studies beyond simply the trade of materials towards models that integrate the complexities of the social landscape.

This dissertation will build from the Indus cultural context reviewed in this chapter. First, the Indus culture history is outlined with discussion of the different terminologies applied by various scholars. A review of the evidence for social differentiation is presented, after which the importance of interregional trade is established. Lastly, modes of interregional interaction proposed in the literature are

reviewed. Each subtopic will be addressed with a focus on the peoples of the Greater Indus Valley and the most relevant neighboring groups. External trade and interaction with more distant people are largely eschewed in an effort to deal concisely with the geochemical data.

Culture History

Indus Civilization chronology has been pieced together from a broad range of ceramic types and cultural traits variably expressed in different regions throughout the Greater Indus Valley. After the earliest development of food production in the shadow of the Western Fold Belt at sites like Mehrgarh (Jarrige 1995), the majority of Indus settlement occurred along the channels and tributaries of the Indus and Ghaggar-Hakra river systems (Possehl 1993; Mughal 1997). There is some formal diversity in ceramic assemblages along these rivers and adjoining regions to the south, particularly prior to full urban integration ca. 2600 BC (Joshi 1984; Dales and Kenoyer 1986b; Possehl and Herman 1990; Mughal 1997; Kenoyer 2011b). Nevertheless, Indus ‘types’ are regarded as such because they were either produced by people who participated within the broad cultural milieu out of which urban Indus forms emerged and existed, or they represent the region-specific cultural variations that emerged directly out of the post-urban transformation (Shaffer 1992). A localized continuity of types is apparent in many cases such that gradual cultural transitions typically occur in a given order, but suites of pottery, architecture, food production, and interaction systems cannot be precisely seriated in a single unifying evolutionary sequence. Still, the different cultural sub-groupings can be ordered by their approximate beginnings even if they persist in some places and times alongside supposedly later cultural forms.

In his efforts to deal with the somewhat permeable boundaries of spatial and chronological periodization, Possehl (1977) used the term ‘phase’ to refer to a collective of material culture and associated socio-economic or political activities. For example, patterns of food production or trade are just as important as pottery in defining phases. Phases are grouped together in stages defined by major differences in socio-economic organization. Possehl’s accounting of the Indus Civilization begins around 7000 BC with the appearance of early food-producing communities and ends by 500 BC with phases of the early Iron Age. Possehl (2002b) emphasized that individual phases should be regarded as archaeological constructs that provide a generalized sequence of cultural developments that are highly specific to distinct regional contexts. A phase might persist into the succeeding stage in one region whereas many years earlier it may have disappeared from another region altogether.

Shaffer (1992) used the term phase similarly in his assessment of the Indus Civilization, an adaption of the system Willey and Phillips (1958) originally developed for North American archaeology. Phases are subsumed under eras, roughly comparable to Possehl’s stages, whereas the entire cultural trajectory is defined as a tradition. The contemporaneous cultural complex in the highlands to the west of the lower Indus is classified as the Baluchistan Tradition. Subsequent cultural developments of this region, in particular the Kulli culture area (Franke-Vogt 2000; Franke-Vogt 2005; Wright 2013), maintained a degree of cultural autonomy throughout the Indus urban florescence despite ongoing interaction with the Indus lowlands, but see Possehl (1992b). Other important traditions have been classified by Kenoyer (1991a; 2006) in his elaboration of Shaffer’s scheme, including the Ganga-Vindhya Tradition (incorporating the Ganges

river basin to the east) and the Malwa-Rajasthan Tradition (inclusive of the Ganeshwar-Jodhpura Phase in the Aravalli Mountains to the south of Farmana).

The Indus Tradition chronology as laid out by Shaffer (1992) and Kenoyer (1991a) is broadly similar to Possehl's periodization. However, it explicitly accounts for the Mesolithic and Microlithic Phases of the Foraging Era which began around 10,000 BC and persisted alongside other eras until roughly 2000 BC (Table 2-1). Further, the Indus Tradition ended ca. 1300 BC, although as with all other categories there is substantial chronological variation between regions. Perhaps the most important conceptual contribution of the tradition—era—phase nomenclature is in its nuanced description of the history of settlement on the alluvial plains. Instead of making a simple chronological distinction like the Early and Mature Harappan stages, Shaffer and Kenoyer adopted era names indicative of trends in cultural interaction. The Regionalization, Integration, and Localization Eras suggest the complexity and overall directionality of cultural interaction. Simultaneously, the use of eras resolves the conflicting usage of Harappan in reference to the site itself, the material culture, and the Indus chronology.

Nevertheless, Wright (2010) proposed a useful terminological simplification that will be used as shorthand in places throughout this dissertation. Under Wright's scheme, the cultural trajectory of settlement on the alluvial plains is intuitively divided into Pre-Urban, Urban, and Post-Urban. This straightforward distinction efficiently conveys the aspects of Indus institutional context most relevant to the assessment of social organization that is the focus of this dissertation.

Pre-Urban/Regionalization Era

The Regionalization Era encompasses a multitude of phases, although widespread imprecision within site reports precludes a comprehensive understanding of their spread and duration (Kenoyer 2011b). For example, the Hakra phase as first used by Mughal (1982; 1997) to describe ceramic assemblages along the Ghaggar-Hakra and Ravi river valleys has now been generalized to much of the Greater Indus Region (e.g., Khan et al. 1990; Ajithprasad 2002; Khatri and Acharya 2005; Mallah 2008). In this way, it has become difficult to assess the development of modes of interaction, craft production, and social differentiation at a fine enough scale to begin explaining how Indus urbanism evolved. Nevertheless, broader regional chronologies have been defined, as outlined in Table 2-1.

Signs of incipient urbanism are found in pre-urban material culture from across the Greater Indus Valley. Wright (2010:80) characterized the era as an “age of emerging polities” in which a range of technological and socio-economic changes took hold. It is likely that relatively elaborate social hierarchies began to emerge as implied by the stratified structure in many facets of material culture including settlement size, intra-settlement architectural divisions, craft specialization and standardization, and the early usage of seals and script (Mughal 1990; Khatri and Acharya 1995; Kenoyer and Meadow 1999; Kenoyer 2000; Kenoyer and Meadow 2008). Further, some groups must have exercised increased administrative authority to build and maintain the fortifications and massive platforms known from this time (e.g., Bisht 1991; Kenoyer 1993, Joshi 2003). Lastly, the extensive long-distance trade routes that characterize the urban era have their roots hundreds of years earlier in the systems of exchange established by pre-urban peoples (Law 2008).

Urban/Integration Era

It is widely acknowledged that by ca. 2600 BC the nascent cultural developments of the pre-urban era had intensified, diversified, and spread to the point that Indus society had fundamentally transformed (Shaffer and Lichtenstein 1989; Kenoyer 1998; Ratnagar 2001; Possehl 2002; Wright 2010). Population growth continued to increase and in Wright's (2010) view, settlements conformed to a central place model (sensu Christaller 1966) anchored by five major cities: Mohenjo-Daro, Harappa, Rakhigarhi, Ganweriwala, and Dholavira. Several authors have suggested that these centers served as semi-autonomous cultural and economic foci for the surrounding settlements and that they may best be likened to city-states or peer polities (Joshi 1984; Kenoyer 1997a; Possehl 1997; Smith 1997). The major cities were roughly equidistant from each other in such a way that each likely served as a hub for resource acquisition from adjacent resource-rich highlands (Fentress 1976; Lahiri 1992; Asthana 1993; Possehl 1993; Mughal 1994a; Law 2008). Further, their distinct resource catchments provided unique economic opportunities for the peoples of each area and may have helped to differentiate their political systems from one other.

Despite such differences, people from across the Greater Indus region appear remarkably integrated in their material culture (Figure 2-2A). Whether in the Indus or Ghaggar-Hakra basins or as far south as the Saurashtra peninsula, common ways of living and thinking are apparent from the relative homogeneity in the archaeological record (Miller 1985). Shared traits include, but are not limited to, Harappan Phase ceramic assemblages (Dales and Kenoyer 1986b; Wright 2010:187), the widespread use of Indus script (presently undeciphered) in stamp seals, tablets, and pottery inscriptions (Mahadevan 1977; Frenez and Tosi 2005), a standardized system of

weights and measures (Kenoyer 1998:98), and participation in a complex network of internal and external trade routes (Chakrabarti 1990; Lahiri 1992; Tosi 1993; Kenoyer 1995b; Law 2008).

In short, the Harappan Phase likely correlates to generalized acceptance of a common ideology and participation within the same system of political legitimization. However, incomplete adoption of Harappan culture in some regions suggests variable penetration and acceptance of the Harappan way of life. For example, settlements with Kot Diji assemblages persist into the Harappan phase along the northern edge of the Harappan Phase site distribution (Allchin 1984). Further to the southwest, Kulli sites exhibit only a partial adoption of Harappan material culture (Possehl 1992b; Wright 2013). A similar situation may have existed at the southernmost regions of the Saurashtra peninsula in what Possehl (1992a) labeled the Sorath Harappan. Variable acceptance of Harappan Phase material culture suggests a compelling need to better understand how interaction was structured differently in instances of apparent ideological resistance.

Post-Urban/Localization Era

By ca. 1900 BC, the urban expression of the Indus Civilization went into decline and a process of localized cultural differentiation took place. Cities gradually fell into disrepair, settlements became smaller and more numerous, and much of the population along the Indus River basin dispersed to other regions—especially towards the upper reaches of the Ghaggar-Hakra and the western extent of the Gangetic River system (Wheeler 1968; Possehl 1997; Gangal et al. 2010). Further, the disappearance of seals and inscriptions suggests that Harappan elite groups lost much of their administrative power, concordant with widespread decreases in interregional trade (Kenoyer 2005b).

Many of the integrative behaviors that supported the adoption and perpetuation of the Harappan Phase way of life ceased to operate, effectively setting each region on semi-independent cultural trajectories.

The post-urban phases of the Indus Civilization are less well documented than their antecedents, but they are clearly distinct from and continuous with the preceding urban material culture (Figure 2-2B). The Jhukar Phase emerged along the lower reaches of the Indus River where settlements shrank and became less organized before disappearing altogether over a few hundred years (Mughal 1992; Miller 2005). Similar changes occurred at former Harappan sites in and around the Saurashtra peninsula (e.g., Rao 1985; Dhavalikar 1992), but at many other regional sites there was a general reorganization and transformation rather than a decline (Shaffer and Lichtenstein 1999). In particular, Saurashtran sites (Rangpur Phase) remained viable (Possehl 1997).

The Cemetery H Phase encompasses post-urban variation spanning the upper Indus and Ghaggar-Hakra, reaching as far east as the Ganges-Yamuna doab. From excavations at Harappa (Meadow et al. 2001) and various regional surveys (Stein 1931; Stein 1937; Mughal 1997; Nath 1998; Nath 1999; Dangi 2009), it is clear that people were reorganizing rather than abandoning the area altogether. Though many diagnostic traits of Harappan urbanism had disappeared, it would be inaccurate to characterize this phase as stagnant. For example, Meadow and coworkers (1996) documented a variety of technical advances in craft production during this phase at the site of Harappa. Harappa eventually diminished in size, although perhaps only slightly (Kenoyer 2005b), coincident with regional climatic changes. To that end, settlements gradually shifted

northward and eastward towards regions with more dependable monsoonal precipitation (Kumar 2009; Gangal et al. 2010; Giosan et al. 2012).

Early interpretations suggested that the entire post-urban transformation was the product of conquest and population replacement resulting from the so-called “Aryan invasion” (Wheeler 1968). Though burial traditions at Harappa changed during this time (Vats 1940; Sastri 1965), there is no biological evidence to suggest major phenotypic discontinuities (Hemphill et al. 1991; Kennedy 2000). Instead, recent research suggests that a long period of increasing aridification played a major, but non-deterministic role in the trajectory of the Indus Tradition as a whole (Fuller and Madella 2001; Madella and Fuller 2006; Wright et al. 2008; Giosan et al. 2012). Mid-Holocene monsoonal weakening may have reduced the intensity of flooding and created more productive conditions for floodplain agriculture. In the face of ongoing aridification, however, a threshold was eventually passed by ca. 2000 BC making flood-dependent agriculture unreliable in general—especially so for the lower reaches of the Ghaggar-Hakra basin (Giosan et al. 2012). Regional responses to aridification were most likely variable, but evidence for increasingly diverse cropping regimes including selection for more drought-tolerant plants such as millets suggests that people were actively seeking to cope with environmental change (Weber and Belcher 2003).

Integration Era Social Context

The story of Indus urbanization is in many ways a story of social differentiation. Indus scholars generally agree that the processes driving social differentiation were entangled with the intensification and diversification of production and consumption such that people, groups, and institutions became increasingly interdependent across an increasingly large region (Kenoyer 1998; Possehl 2002b; Wright 2010). Though

integration and intensification across the Indus region was complex and likely cannot be explained by a single factor, the processes when set in motion would have fundamentally altered the economic landscape by creating new opportunities for craft specialists and elite oversight (Morrison 1994). As discussed below, increased conflict over labor and land, resulting from a broad range of specialized modes of food production, would have necessarily resulted in hierarchical relationships of power (Wright 2010). Further, the logistical needs of an urbanized landscape would have contributed to the rise of administrative groups or institutions that would likely have ratcheted up demand for prestige items in their efforts to validate relations of inequality (Kenoyer 1989; Kenoyer 1995a).

Craft Economy

Artifacts made of exotic materials are particularly important indicators of social stratification because they typically represent only a small fraction of any given artifact class. Several authors have argued that Indus consumption was organized along axes of relative value such that a common ideology was promoted by formally similar artifacts, but that status ranking was associated with the rarity of the material and the complexity of the technology used in an object's production (Kenoyer 1992; Vidale 1992; Vidale and Miller 2000). The logic is that exclusivity corresponds with high value, high value items would only have been attainable by elites, elites are a minority, and therefore artifacts made using less accessible materials or technologies should be fewer in number. Wright (2010) found some support for this distribution across artifact classes and sites, suggesting the structure of hierarchies can be glimpsed in detailed artifact classifications. Further, Vidale and Miller (2000) suggested that with the growth of a bureaucratic middle class, ubiquitous artificial materials such as faience offered a

means of expanding the middle tiers in hierarchies of value to accommodate the expanding social strata. Again, some artifact distributions support this idea, but Miller (2008) has suggested that interpretations of past value must also account for factors beyond exclusivity. For example, softer precious stones are nearly unrepresented among bangles. Instead, harder natural materials may have been acquired or artificial ones manufactured so that bangles could provide an auditory experience. No matter how one interprets the spectrum of craft value, however, the wide range of styles in personal dress and ornamentation apparent from inscriptions, figurines, and statuary are suggestive of socio-economic and ethnic differentiation (Kenoyer 1995a).

The various modes of production evident in the Greater Indus Valley are also suggestive of social diversification. Artisans must have dedicated themselves to years of study to acquire the “technical virtuosity” inferred from high-quality Indus crafts (Vidale and Miller 2000). As demonstrated below using examples from Indus bangle production, specialist knowledge was likely seen as proprietary and subject to internal and external administrative controls (Halim and Vidale 1984; Vidale 1989). Further, ethnicities likely emerged at the intersection of production and kinship, with many professions potentially organized by kinship (Kenoyer 1989). For example, hundreds of years of continuity in a cluster of segregated kilns and workshops at Harappa have been interpreted as evidence for kin-structured production of ceramics, relatively free from centralized oversight (Dales and Kenoyer 1990a; Wright 1991). However, certain other crafts were likely subject to administrative control. The production context of stoneware bangles suggests that elites closely regulated the manufacturing process (Halim and Vidale 1984; Vidale 1989). Stoneware bangles were produced in strictly

segregated workshops located only at Harappa and Mohenjo-Daro, and at different stages in the manufacturing process, sealings and inscriptions were applied, presumably as a regulatory measure (Halim and Vidale 1984; Blackman and Vidale 1992). Further, stoneware bangles vanished at the end of the Integration era along with other administrative paraphernalia (e.g., Indus script and stamp seals), suggesting their production was contingent on the social complexity and class distinctions of an urbanized environment.

Most craft production, however, was not as rigidly controlled as stoneware bangles. Evidence suggests a diversity of production contexts, as in the case of shell bangle workshops. At sites such as Balakot, Nageswar, and Kuntasi, production areas appear to have been variously organized at different points on a spectrum between small-scale household operations geared for local consumption and large-scale, elite-run workshops internally segregated by task and oriented towards export (Bhan and Kenoyer 1983; Bhan 1986; Dhavalikar 1992; Vidale 2000). Taken as a whole, the evidence for Indus craft economy suggests a complexity of organization that is difficult to explain without reference to elites or hierarchy.

Food Production

Other aspects of Indus production seem to support similar conclusions. With regard to the diversified, intensified, and specialized forms of food production recognized archaeologically (e.g., Fuller and Madella 2001; Madella 2003; Weber 2003, Miller 2004), conflicting land usage by food producers would likely have required complex (and potentially hierarchical) institutions of mediation (Wright 2010:213). Because large-scale, labor-intensive irrigation is unknown in Indus contexts, water management practices probably did not give rise directly to centralized power structures

(Scarborough 2003). However, evidence for traction (Miller 2004) and extra-household crop processing (Fuller and Madella 2001; Weber 2003) implies that agropastoral land use was organized by diverse groups and institutions (Wright 2010:206. Further, Miller (Miller 1991) suggested that groups with large tracts of corporately owned land would have best been able to cope with the shifting nature of river courses in the Indus plains. Miller (2006b) later emphasized that kin-based groups would have been more effective at allocating and organizing land use given the potential for Indus farmers to easily relocate if pressed too hard by elites. In her model, Miller proposed that land-owning kin groups were another plausible source of social control that could have crosscut power structures predicated on authority over non-kin. Indeed, Kenoyer (1989, 1998) proposed an enduring role for kin groups within urban Indus power structures based on models of the organization of craft production.

Additionally, groups other than kin-structured staple crop agriculturalists would have had competing interests. A variety of Indus crops such as cotton, grapes, dates, and hemp would have required dedicated plots of land and specialist labor (Madella 2003; Weber 2003; Wright 2010). Different groups of pastoralists would also have needed access to pasturage. At Harappa, there is limited zooarchaeological evidence consistent with dairying (Miller 2004). Further, cattle would have been used to pull carts and plows (Wheeler 1947; Miller 2003), while secondary products from cattle and sheep may also have been important (Meadow 1989b; Miller 2004). Sedentary and mobile pastoralists would likely have had different perspectives on land use which could have brought them into conflict with farmers or each other; although sedentary pastoralism and agriculture are known to coexist within ethnographic South Asian kin groups (Miller

2003). Much like with the Indus craft economy, the complex social context of food production probably created conflicts and inequalities necessitating some degree of hierarchical organization.

Infrastructure and Logistics

Whatever the means of production, the process of getting products to consumers created opportunities for intervention by other Indus groups. With respect to fish at Harappa, at least, indirect distribution mechanisms (e.g., 'retail' fishmongers) were more prevalent during the urban era, implying yet another manifestation of specialized labor and possible source of conflict and inequality (Belcher 2003). The transportation of goods may also have opened the door to regulation by elites. In an excavated warehouse at Lothal for example, there were dozens of clay sealings bearing multiple impressions by different seals (Rao 1979). Kenoyer (1998) suggested that they may indicate the regulation of cargo by bureaucratic officials, and further, transported goods may have been subject to taxation as indicated by the frequency and location of classically Harappan chert weights. Specifically, the standardized weights are fewer in number than might be expected if merchants used them for everyday exchanges. Weights also tend to be associated with gates—choke points where taxes on goods could most readily be levied. Even their production might have been subject to elite oversight given that they were predominantly crafted using a specific kind of banded chert from the Rohri Hills in the lower Indus region (Kenoyer 1991).

Perhaps some of the most compelling evidence for hierarchy is in urban architecture. Significant logistical oversight would have been needed to coordinate public works projects such as the foundational mudbrick platforms and extensive system of wells at Mohenjo-Daro (Jansen 1984; Jansen 1993). The platforms were truly

massive and according to Possehl (2002b:103), amounted to 4 million person-days of labor. Also from Mohenjo-Daro comes evidence that the town was laid out according to astrological data (Wanzke 1984), suggesting coordination between different specialists and manual laborers. Elites were not limited to such grand endeavors, however, and may well have organized the care of ubiquitous public drains and sump pits. Wright (2010:238, 242) suggested that extensive sanitation features would have demanded the coordination of maintenance, and if centrally administered, would have required a substantial civic labor force (e.g., Jansen 1993). Even if public sanitation was not centrally administered, those considered fit for such an unpleasant task would almost certainly have been lower status individuals.

Further, the role of urban centers as hubs of Indus life must have conferred a certain prestige on sophisticated urban dwellers. As is often true of cities today, inhabitants of the surrounding rural areas would have been instantly recognizable upon entering the dynamic urban settings of Harappan cities. Social life among urbanites was also stratified as suggested by the spectrum of prosperity apparent in a comparison of urban households (e.g., Jansen 1993). Larger domiciles with more private spaces and improved access to drains almost certainly belonged to relatively prosperous families.

Given the complex patterns of social differentiation considered in the preceding pages, it seems clear that the lived Indus landscape was enmeshed in relations of conflict and control. Where so many diverse interests intersected, some groups must surely have been systematically favored over others; but since the earliest systematic excavations by Vats (1940) and Marshall (1931), archaeologists have noted the lack of grand monuments or elaborate tombs exalting a specific few over the many. Nor is

there evidence for palatial structures or military conquest associated with specific hereditary leaders or groups (Kenoyer 1998:99-100). Whatever the nature of Indus hierarchies, they were not unassailable. They could not withstand the potential backlash caused by such blatant assertions of authority. Present evidence cannot identify the specific groups in Indus hierarchies, but their interactions with each other were almost certainly crosscut by multiple identities and allegiances subject to situational changes and active manipulation. As the ultimate source of food, fertility, and life, land would have conferred authority on those who controlled access to it. But land is also steeped in history and blood. Short of military force, the power derived from land would not have been easily stripped from political rivals. Mineral wealth, however, came from outside the places of kin and forebears. Power born of highland resources was a power from outside their histories and lineages and therefore uniquely accessible to the ambitious and entrepreneurial (Helms 1988; Helms 1993). For this reason, inferences about Indus identity must begin with an understanding of economic exchange.

Trade and Interaction

Indus people maintained extensive internal and external trade routes, transporting all kinds of natural resources by bullock cart and flat-bottomed boat (Miller 2004; Miller 2006a). Trade was driven in part by the reliance of elites on prestige goods as a source of legitimation (Kenoyer 2000). However, the alluvial plains of the Greater Indus Valley are poor in most mineral resources, and a broad variety of raw materials was acquired from highland regions throughout the Indus Tradition for more utilitarian purposes (Law 2008). The demand for non-local resources would have created a powerful incentive for people and groups to compete for preferential access to highland minerals (Kenoyer 2000). The mineral-rich highlands surrounding the Greater Indus

region very often contain multiple sources of any given metal—a fact that might have encouraged competition and prevented any single group from gaining an unchallenged advantage (Kenoyer and Miller 1999).

The strongest artifactual evidence for elite competition comes from the comprehensive assessment of mineral provenience at Harappa conducted by Randall Law (2008), the interpretations of which are briefly reviewed here. Through the application of isotopic and compositional analyses, Law (2008) suggested that at least some raw materials were restricted to certain communities at Harappa. Certain bead-making communities, for example, seem to have had proprietary access to uniquely hardened drill bits made from “Ernestite,” a substance that is variably argued to be an unknown mineral (Kenoyer and Vidale 1992) or a particular kind of heat-treated flint clay (Law 2008:appendix 4.5). In either case, Law suggested the sheer abundance of “Ernestite” at Dholavira implicated a source somewhere in the modern Indian state of Gujarat, far to the south of Harappa. At Harappa, an extremely hard variety of garnet, vesuvianite-grossular, shares a similarly restricted distribution as it probably could be worked only by those with access to “Ernestite” drill bits. The same communities associated with “Ernestite” and vesuvianite-grossular are uniquely associated with alabaster bangle production and exclusive sources of grindingstone, although the sample size is small for the latter two materials. Additionally, Integration Era settlements used Rohri Hills chert almost exclusively despite the prevalence of other sources among pre-urban peoples. According to Law (2008), this might have resulted from an elite faction’s efforts to control the supply of what was the highest quality chert available. Finally, Law suggested that competition to control resources might be underrepresented

at Harappa given that much of the benefit from monopolizing minerals would have derived from trading them to other communities. Therefore patterns of exclusive acquisition might be obscured by patterns of distribution. Thus it cannot be assumed that elites did not compete for access to a particular resource based only on the dataset produced by Law (2008).

Widely available materials such as copper must have created a highly competitive environment for Indus elites and highland suppliers alike. Unlike chert, for which a single source provided an incomparable product, quality copper was available from a variety of regions including Baluchistan and Afghanistan to the west, Oman and possibly Iran via maritime routes, Himalayan deposits to the north, and the Aravalli Mountains to the east (Ahmad 1969; Bazin and Hübner 1969; Nandan et al. 1981; Geological Survey of India 1994; ESCAP 1995; Chakrabarti and Lahiri 1996; Kazmi and Jan 1997; Kenoyer and Miller 1999; Weeks 2004; Peters et al. 2007; Law 2008). The Aravalli deposits are of particular interest for this study as the northernmost mineral-rich sites of the Khetri “Copper Belt” are located fewer than 150km south of Farmana and other eastern Harappan sites. Their importance, however, should not be overstated. Despite a plethora of claims that most Indus copper came from the Khetri deposits (e.g., Sana Ullah 1940; Allchin and Allchin 1982; Agrawala 1984a; Dhavalikar 1997; Kenoyer and Miller 1999), recent work suggests that the Khetri region was one copper source among many (Law 2008; Hoffman and Miller 2009).

Additional analyses are needed to resolve the details of the Indus copper trade, but of primary interest here is that the decision to acquire copper from any given region would have depended very much on the different highland suppliers. One can envision

different Harappan elites ‘shopping around’ for the best bargain. They might have considered factors like the length or reliability of the supply route, the number of ‘middlemen’ involved, whether negotiations would be with many factional producers or a few collective representatives, whether or not other products could be acquired from the same source, whether or not the highland groups had conflicting allegiances to competing Indus elites, and of course the price of the copper itself. Undoubtedly, much effort went into negotiating the most favorable terms, and these would have been subject to change depending on any number of factors. The decisions that were made by all parties surely had wide-ranging repercussions for how each group perceived the other and how their relationships were maintained and changed over time. Trade in copper and other materials must have played an important role in shaping the cultural dynamics between ethnic groups of protohistoric south Asia. If archaeologists are to use exchange as an entry point for explaining process in a region, there must also be a consideration of how exchange was mediated and not just the location of the parties involved. Much more work is needed to firmly establish the myriad source regions and cultural associations involved throughout the Indus region, but inferred relationships of exchange must be modeled to guide ongoing studies of interregional interaction.

Fortunately, there are hints in the archaeological record as to what such relationships may have looked like. Some Harappan settlements appear to have been built as strategic outposts, far away from the alluvial plains, where they would have served as trading posts in the resource-rich hinterlands. Possehl (1980) suggested that Lothal served as a “gateway” settlement in Saurashtra, in part because of his inference that the relatively compact fortifications were constructed according to a single plan.

According to Possehl, Lothal was a base of operations from which traders could acquire goods to ship back to larger urban markets in the north. From comparative statistical analyses of Indus skeletal remains, it was suggested that individuals interred at Lothal were phenotypically intermediate between people buried at alluvial sites and those from Langhnaj, a hunter-gatherer site fewer than 150 km to the north (Possehl and Kennedy 1979; Kennedy et al. 1984). The authors suggested that the relationships between urban traders and hunter-gatherers went beyond material exchange to include significant patterns of gene flow. Economic symbiosis between sedentary agriculturalists and hunter-gatherers is well known from ethnographic accounts of South Asian foragers (Possehl 2002a), and something similar may well have been happening during Indus times. In exchange for providing forest resources, people at Langhnaj may have been compensated with carbohydrate-rich staple crops as suggested by Lukacs and Pal (1993) based on an uncommonly high occurrence of dental caries. If these inferences are correct, it suggests that economic interaction could have been partly shaped by the creation of kin relations. Genetic relatedness does not necessarily correlate with social kinship, but at the very least it is suggestive of cultural interaction at a deeper level than a straightforward extraction of resources by lowland groups from highland regions.

Unfortunately, there is no skeletal record at other outposts to the north and west, but several factors suggest their primary function was to acquire resources from exotic locales. In the northern highlands, archaeologists discovered Shortugai, a small urban era settlement laid out according to typical Harappan designs (Francfort et al. 1989). Further, pottery and beads at the site were skillfully crafted in Harappan styles using

local goods. Various precious materials are abundant in the area including gold, silver, copper, tin, and lapis lazuli, all adjacent to important trade routes (Kohl 1978). Lapis lazuli is limited in distribution, and the residents of Shortugai were probably responsible for the lapis found at Nausharo, Ghazi Shah, Nagwada, and other Indus settlements (Sonawane 1992; Flam 1993; Wright 2010). Based on the above evidence, Wright (2010) suggested that Shortugai was consistent with a trade mission rather than a large-scale migration of settlers.

Outpost settlements like Shortugai were probably structured by the commercial ambitions of Harappan urban dwellers, but they were also variably enmeshed in local ways of life. Their different fates in the post-urban era might indicate a greater or lesser degree of cultural integration with local groups. With the decline of urbanism, Harappan traits at Shortugai were gradually replaced by those of the neighboring Bactria-Margiana Archaeological Complex (BMAC) (Francfort et al. 1989) whereas Sutkagen-dor and Sotka-koh far to the southwest were abandoned altogether (Dales and Lipo 1992). The latter settlements were separated from Harappan sites by those of the Kulli culture which like the BMAC, spread to many formerly Harappan sites in the post-urban era. Kulli people had maintained a variety of independent cultural features in the face of Harappan influence throughout much of the Integration Era, but seemingly grudgingly gave way to a cultural hybridization before their post-urban resurgence (Dales 1976; Franke-Vogt 2000). Perhaps linked by trade in lead (Law 2008), Kulli peoples seem to have had a qualitatively different experience with Harappan traders than many other groups did.

Another group strongly implicated in trade, but relatively less well understood, is the Northern Neolithic people who lived in the highlands, north of Harappa. They probably provided many of the mineral resources used by residents at Harappa and elsewhere (Law 2008), but their means of interaction remains unclear. Perhaps groups at late-occurring Kot Diji settlements, situated between Harappan and Northern Neolithic peoples, facilitated exchange between their neighbors, but this has yet to be tested. The nature of interaction with people of the Ganeshwar-Jodhpura Phase in the northern Aravallis is similarly uncertain. One possible explanation is that nomadic pastoralists served as intermediaries (Possehl 1979; Mughal 1994), but again, there is little direct evidence for this proposal.

In summary, a great deal is unknown about how Harappans interacted with their highland neighbors, but at the very least it would seem that different groups were engaging with each other in different ways. One aspect of highland exchange that is relatively certain is that Harappan involvement was shaped by the interests of competing elite groups (Kenoyer 2000). Further work is needed to ascertain whether or not exchange was carried out directly with highland groups or via intermediaries as this has implications for the politics of identity.

Mortuary Variation

Widespread consistency in the Indus program of inhumation provides another important means of understanding cultural integration in the Great Indus region. With the exception of the formal disposal area at Mehrgarh (Jarrige et al. 1995), urban era cemeteries have many similarities. The mortuary program is strongly normative with little evidence for internal subdivisions. Burials are rectangular or oval and oriented along a north-south axis with the head to the north (Wheeler 1947; Sastri 1965; Mughal

1968; Rao 1973; Rao 1979; Rao 1985; Dales and Kenoyer 1989a; Jarrige et al. 1995; Nath 1998; Nath 1999; Sharma 1999; Trivedi 2009; Shinde 2011a). When included as grave goods, ceramics are most often laid near the head and consist largely of types recovered from habitation deposits. Pottery is sometimes also found at the feet, along the sides, or underneath the body but usually in addition to vessels placed near the head. Further, pottery was sometimes buried first, before the body was lowered into the grave (Dales and Kenoyer 1989a). In most cases, only modest quantities of ceramics were interred although a few graves have more than 40 pots (e.g., Dales and Kenoyer 1989a; Sharma 1999). Apart from the pottery, grave goods are limited to personal ornaments and toilet objects including jewelry and hand mirrors. Bodies generally lay extended and supine, and were occasionally wrapped in shrouds, enclosed in coffins, or sheltered by a brick or clay grave lining. The graves were typically organized in the same way, even in the case of secondary burials and cenotaphs (so-called symbolic burials) that lack some, or all, skeletal elements (Shinde 2011a).

Though few correlations have been observed between different mortuary variables, Kenoyer (2011a) suggested certain structuring principles at Cemetery R-37. For example, males are usually associated with less elaborate graves. Also, shell bangles and certain types of stone pendants tend to be associated with females. A rare deviation from the normative grave type is found in the pot burials at Kalibangan (Sharma 1999). Unlike Cemetery H, the post-urban cemetery at Harappa, the Kalibangan pot burials contain no human remains. Further, they are set apart from the other graves, perhaps indicative of a separate mortuary tradition. Nevertheless, the Kalibangan pot burials are not replicated at other sites, and thus are not suggestive of

significant internal divisions within the Indus mortuary program of inhumations. Indeed, the majority of urban era burials show only modest variation in layout with minor redundancies in aspects of mortuary treatment. The overall impression that emerges is of a specific category of person. The inhumed, perhaps, were perceived largely in terms of a particular group identity, with only secondary importance placed on individual differences.

The collective identity posited for the Indus inhumed is based partly on the scarcity of cemetery inhumations. In fact, formal disposal areas during the urban period are only well documented at Mehrgarh (Jarrige et al. 1995), Harappa (Dales and Kenoyer 1989a; Mughal 1968; Sastri 1965; Wheeler 1947), Kalibangan (Sharma 1999), Lothal (Rao 1973; Rao 1979; Rao 1985), Rakhigarhi (Nath 1998; Nath 1999), Tarkhanewala-Dera (Trivedi 2009), and Farmana (Shinde 2011a). The total number of burials is small, such that excavations at the largest known cemetery (Cemetery R-37 at Harappa) have produced skeletal remains for fewer than 400 individuals (Possehl 2002b:Table 9.4). Instead, the vast majority of Indus people must have received mortuary treatments that did not preserve archaeologically such as cremation, exposure, or immersion. Thus, it is generally agreed that cemetery burial was reserved for members of a particular group, and that cemetery populations do not represent the population at large (Kenoyer 1998:122; Possehl 2002b:171; Wright 2010:263).

There is less consensus, however, on the social identity once held by the inhumed. It is telling that Indus burials have been variously characterized as belonging to the lower (Rao 1979:143, Sharma 1999:14) and upper classes (Kenoyer 1998:122-124) despite overall similarities between cemetery inhumations. Different aspects of the

archaeological and osteological record can be interpreted as evidence of either reverence or disregard, although current evidence may not be able to resolve the issue. The occasional incorporation of particularly well-crafted ornaments and pottery, as is the case for some burials in Cemetery R-37 at Harappa (Kenoyer 1998:122-124), suggests a willingness to invest in mortuary ritual. The osteological data from Harappa (Hemphill et al. 1991, Kennedy 2000) are especially compelling in that they portray relatively healthy, well cared for individuals. Paleopathologies are few, including a moderate prevalence of osteoarthritis in the cervical vertebrae (possibly attributable to biomechanical occupational stresses), and a moderately higher incidence of caries among females. However, the preponderance of data suggests the individuals inhumed at Harappa enjoyed relatively healthy lives with ties to more prosperous social groups. This impression is reinforced by comparison with the disturbed post-urban remains from Area G at Harappa that have a much higher incidence of trauma (Robbins Schug et al. 2012).

Even though urban era inhumations imply relative prosperity, several aspects of the mortuary program are more ambiguous with regard to the status of the inhumed, and they could potentially be interpreted as evidence for disregard. Cemeteries were invariably located hundreds of meters outside the habitation area, and at Harappa, the cemetery was closely associated with a disposal area for more conventional domestic refuse (Dales and Kenoyer 1989a). Further, burials were frequently crosscut by other grave cuts in a haphazard way, and disturbed remains often were casually pushed aside or incorporated into the grave fill rather than reinterred (Wheeler 1947; Dales and Kenoyer 1989a; Shinde 2011a). One possible explanation for the practice could be that

individuals belonging to a separate, and presumably ambivalent, class or group were tasked with digging graves (Kenoyer 1998:122). Another interpretation could be that cemeteries were places to carry out a necessary task without unduly inconveniencing the living, and that the inhumed occupied a middle ground between affiliation and alienation. Neither exceptionally privileged nor disadvantaged, the inhumed might have held a liminal social role on the periphery of high status groups. Unfortunately, the matter likely cannot be resolved until more detailed reports of cemetery excavations are made available.

The challenge for Indus mortuary archaeology is to better understand the social role of the deceased and to model how they could have been enmeshed within a broader cultural context. The problem is daunting, but isotopic bone chemistry methods can contribute to important research questions by beginning to trace the connections between the Indus social environment and the physical landscape. Migration is assessed as a potential mode of interaction between Indus regions, and particular emphasis is placed on the likelihood of highland-lowland mobility as influenced by the needs of competing elites.

Table 2-1. Indus Tradition chronology.[adapted from Kenoyer, J. M. 2011b. Regional Cultures of the Greater Indus Valley: The Ravi and Kot Diji Phase Assemblages of Harappa, Pakistan. *In* Cultural Relations between the Indus and the Iranian Plateau during the Third Millennium BCE. Toshiki Osada and Michael Witzel, eds. Pp. 165-217 (Page 166, Table 1). Cambridge: Department of South Asian Studies, Harvard University.]

Era	Phases	Dates
Foraging	Mesolithic, Microlithic	ca. 10000-2000 BC
Early Food Producing	Mehrgarh	ca. 7000-5000 BC
Regionalization	Hakra, Ravi, Sheri Khan Tarakai, Balakot, Amri, Kot Diji, Nal, Sothi, etc.	ca. 5500-2500 BC
Integration	Harappan	ca. 2600-1900 BC
Localization	Punjab, Jhukar, Rangpur	ca. 1900-1300 BC

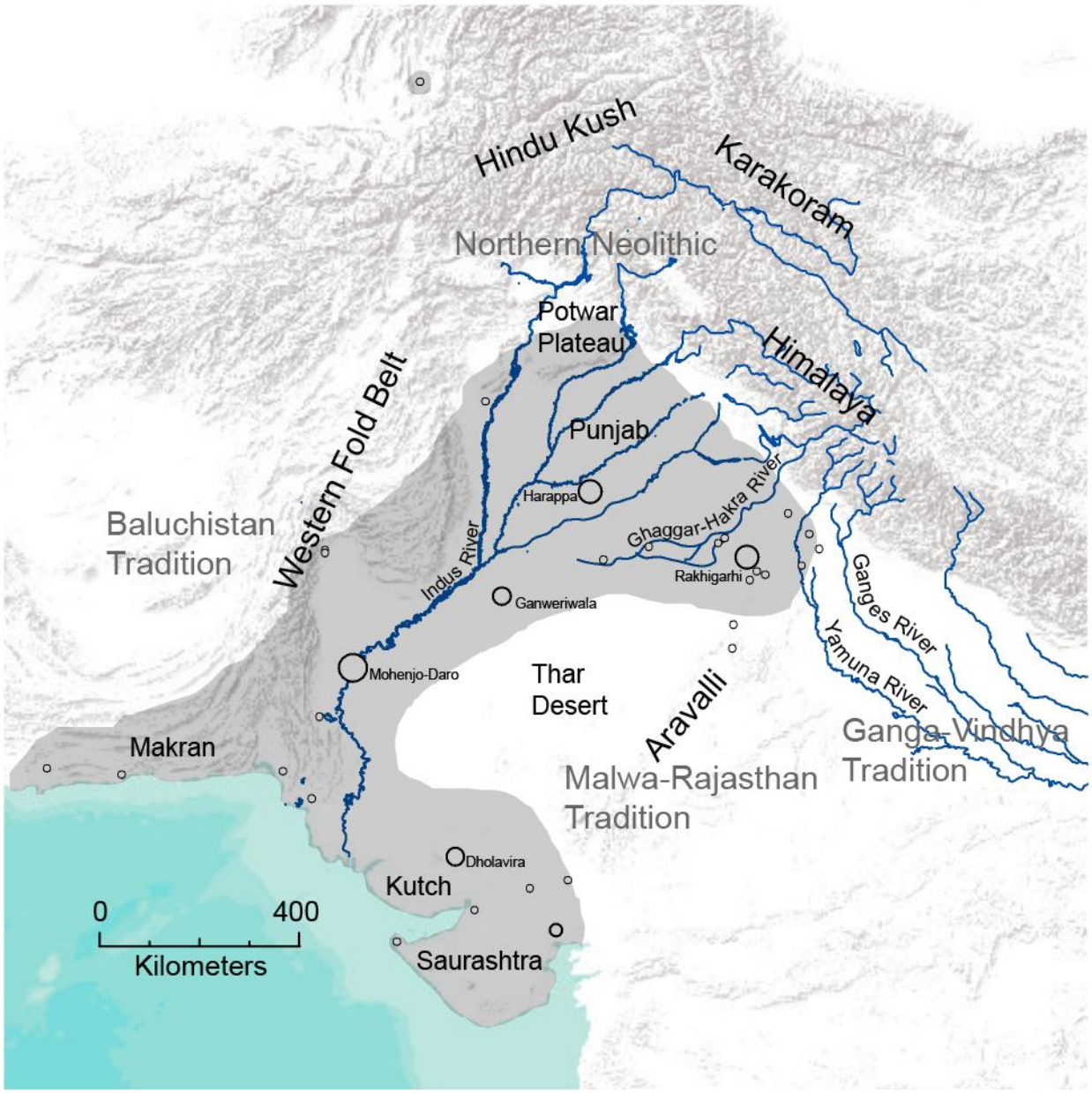

Figure 2-1. Map of the maximum extent of the Indus Tradition culture area including major geographic features and adjacent cultural traditions (in gray). [adapted from Law, R. W. 2008. Inter-Regional Interaction and Urbanism in the Ancient Indus Valley: A Geologic Provenience Study of Harappa's Rock and Mineral Assemblage. PhD dissertation (Page 41, Figure 2.6). University of Wisconsin-Madison]

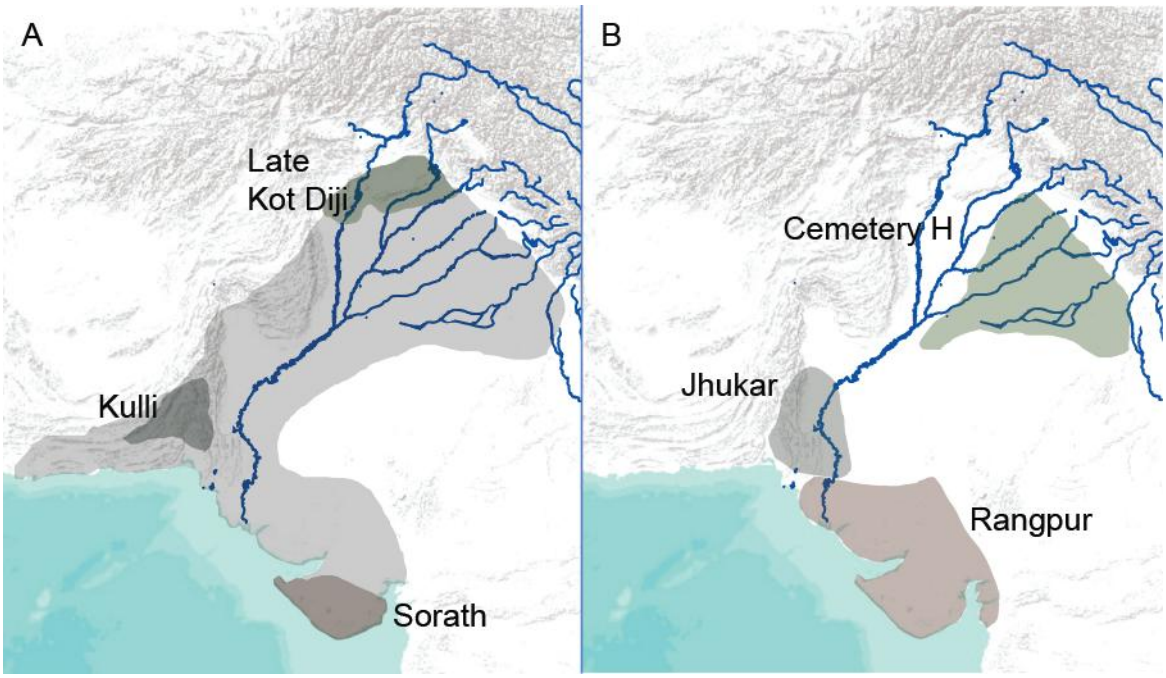

Figure 2-2. Cultural maps of the Indus Tradition. A) Extent of the Harappan Phase during the Integration Era (ca. 2600-1900 BC) including regions with incomplete adoption of Harappan Phase materials. B) Extent of the phases of the Localization Era (ca. 1900-1300 BC). [adapted from Law, R. W. 2008. Inter-Regional Interaction and Urbanism in the Ancient Indus Valley: A Geologic Provenience Study of Harappa's Rock and Mineral Assemblage. PhD dissertation (Page 41, Figure 2.6). University of Wisconsin-Madison]

CHAPTER 3
MATERIALS AND METHODS

Principles of Isotope Analysis

Isotopic data derived from osseous remains provide a proxy measure for the isotopic composition of substances ingested during the life of individual organisms. By understanding how the different isotopes of an element behave in different geochemical environments, archaeologists can infer the likely source or sources for a given element during the period in which the analyzed sample was formed. Differential ingestion or incorporation of various environmental sources can indicate differences in behavior or environmental exposure that are useful for reconstructing certain aspects of individual life histories such as migration (e.g., Dupras and Schwarcz 2001; Bentley et al. 2007; Schroeder et al. 2009; Chenery et al. 2010; Price et al. 2010), diet (e.g., Richards et al. 2000; Ambrose et al. 2003; Krigbaum 2003; Hu et al. 2009; Kinaston et al. 2013), and climate (e.g., Fricke et al. 1995; White et al. 2004b; Daux et al. 2005; Touzeau et al. in press). This mode of archaeological inquiry, like many bioarchaeological methods, has the advantage of associating specific behaviors or environmental conditions with specific individuals, thus improving the chances of identifying and characterizing different sub-groups within a study population. In the aggregate then, trends in isotopic life history data can be used to reconstruct some of the ways regularized behaviors and institutions were entangled with different kinds of social bodies.

Isotopic methods are especially powerful tools for investigating life history in that different skeletal elements represent different periods of exposure depending on their initial formation times and predisposition to turnover. Isotopic data are thereby accessible for discrete periods of early life via tooth enamel apatite and from a relatively

time-averaged period incorporating late life exposure via bone apatite, bone collagen, and tooth dentine. Virtually any other biological substance can be analyzed for isotopic values, but due to their high mineral content, bones and teeth tend to preserve most often in the archaeological record. Consequently, this chapter will focus on the analysis of osteological remains with an emphasis on apatite. Even for osseous materials, however, the post-mortem environment can threaten the integrity of the isotopic values established during life. Therefore, any archaeological isotope study must account for the potentially confounding process of diagenesis.

The following sections outline the geochemical principles underlying the bioarchaeological analysis and interpretation of strontium (Sr), lead (Pb), carbon (C), and oxygen (O) isotopes. Each of these elements is present in bone and tooth mineral, sometimes substituting for calcium in the case of strontium and lead, or as the main components of the carbonate phase (CO_3), which substitutes for the hydroxyl group (OH). Further, biological apatites are dynamic minerals in life as well as death; therefore this chapter will include a brief discussion of osteological formation processes and post-mortem alteration. Lastly, an outline of the research design will address the sampling process, mechanical and chemical sample preparation, and methods of mass spectrometry.

Heavy Stable Isotopes

Two factors make heavy stable isotopes of elements like strontium and lead useful for archaeological provenience studies. First, the isotopes of heavier elements have relatively small mass differences. Consequently, they undergo negligible fractionation during chemical reactions and phase changes; or to put it another way, the isotope ratios of a given heavy element remain the same as they pass from bedrock into

the biosphere and eventually into human bones and teeth. Second, at least one of the isotopes of a given element is the radiogenic daughter isotope of a radioactive parent isotope. In the case of strontium, rubidium (^{87}Rb) decays into ^{87}Sr. For lead, radioactive isotopes of uranium and thorium (^{238}U, ^{235}U, and ^{232}Th) decay into ^{208}Pb, ^{207}Pb, and ^{206}Pb, respectively. Thus, rocks formed at different times have different ratios of isotopes depending on the initial quantity of the parent isotope and the time that has elapsed (Faure and Mensing 2005).

As a result of these two properties, the isotope ratios in an analyzed substance can potentially be matched to the isotope ratios from the geological source. This is complicated, however, when the subject of investigation has acquired geochemical input from multiple sources. This is true of biological samples in the same way that it is true for metallurgical samples. For example, a copper artifact might be made from ingots smelted from different ore bodies, it could be made from recycled metal artifacts of different provenience, or it might be intentionally alloyed with other elements. In all cases, the artifact will have weighted mean isotope ratios determined by the relative contributions from the different geological sources. Likewise, bulk samples of bones and teeth archive the average isotopic input derived from the initial process of mineralization, subsequent regenerative processes, and post-mortem processes of chemical alteration or contamination (Montgomery 2002; Bentley 2006).

Much of the challenge for isotopic provenience work lies in understanding how different sources were averaged and finding appropriate comparative samples that characterize the different geological sources and biogeochemical reservoirs in the study environment. There can be a great deal of isotopic variation within the environment; so

much so, that in many cases it can be difficult to find adjacent geographic regions in which the isotope ranges do not overlap. After all, even different minerals in the same rock can have widely differing isotopic ratios (Fullagar et al. 1971). Further, different plants or even different parts within a single plant can show considerable isotopic variation depending on the depth and extent of roots as well as the relative ability of foliage to capture aeolian particulate (Klaminder et al. 2008; Reynolds et al. 2012). Absolute ranges in rocks or plants, however, are not necessarily the best proxy for the averaged ratios acquired by organisms higher up the food chain.

For one thing, whole rock isotope ratios are not necessarily representative of the values incorporated into the biosphere. Weathering processes preferentially release the soluble fraction of strontium from bedrock and sediments, and it is this biologically available portion that ends up in water, plants, and animals (Sillen et al. 1998; Price et al. 2002). Even leachates of sediments, i.e., weak acid solutions used to extract the most soluble fraction of strontium and lead, can vary considerably within a relatively small area depending on micro-level variations in sediment composition (Capo et al. 1998). Fortunately, this variability is averaged somewhat by plants and to an even greater degree in bones and teeth because of the long-term uptake of strontium from a relatively large catchment area (Burton et al. 1999). Broadly similar principles apply to lead, but it is somewhat less mobile than strontium and undergoes even greater biopurification through trophic processes as relatively little soil lead is taken up by plants (Klaminder et al. 2005). Therefore, lead levels (and consequently isotopic ratios) in animals tend to be more influenced by the ingestion and inhalation of dust than by the lead content of ingested foods (Elias et al. 1982; McBride 1994:337; Kohn et al. 2013).

Indeed, the relatively expansive dietary catchments of animals provide the best estimates of regional isotopic variation for use in provenience studies. Animals living in close proximity to humans should be used whenever possible in the study of human migration as they provide an independent measure of local isotopic ranges (conservatively defined as the mean value ± 2σ) (Price et al. 2002; Evans and Tatham 2004). The most appropriate faunal material varies from context to context, however, such that pigs have been used in the study of prehistoric Germany (Bentley and Knipper 2005) and guinea pig bones for archaeological Peru (Knudson et al. 2004). Some authors suggest that animals with very small territories be used to define isotopic variability (e.g., snails), although this might underestimate the local isotopic ranges of species that have relatively far reaching dietary catchments such as humans (Price et al. 2002).

When faunal samples are unavailable, modern plants, water samples, sediment leachates, and even knowledge of the local lithology can be used to provide estimates of isotopic variability (e.g., Beard and Johnson 2000; Hodell et al. 2004; Bataille and Bowen 2012) . Multiple sample types may best approximate regional variation because no single sample type offers the perfect proxy measure. An accurate estimate of regional isotopic variability may even be obtained from members of the study population that can be independently inferred not to have migrated. For example, when a dataset is highly structured with discretely clustering subsets, the cluster displaying values similar to those of local sediment leachates likely approximates the local dietary catchment.

For all proxy measures, however, there is the potential for disagreement because each has taken up lead and strontium from different sources across a different

geographic area. Furthermore, not all sources contribute equal amounts of strontium or lead to osseous mineral. Sea salt, for example, has a relatively high ratio of strontium to calcium (Sr/Ca) and thus contributes more strontium to bones and teeth than many other foods (Burton and Wright 1995). Given its propensity to be traded across long distances in many archaeological contexts, sea salt can potentially skew the isotopic range displayed by individuals that actually lived and died within the study area (e.g., Wright 2005). Also, lime solutions used by many New World cultures to process maize contribute very large quantities of strontium, effectively obscuring isotopic ratios from the rest of the diet. Even without such unusually rich sources of Sr, a relatively small number of plant food sources will tend to dominate $^{87}Sr/^{86}Sr$ given Sr/Ca differences among dietary items (Burton and Wright 1995). Nevertheless, only the regular consumption of mineral-enriched foods from specific non-local areas is likely to alter isotope ratios in the average diet relative to local values.

In vivo anthropogenic lead contamination must also be considered as certain cultural practices can result in disproportionately high exposure to lead from specific geological sources. In modern contexts, particular kinds of surma, kohl, and other mineral-bearing cosmetics have been linked with elevated blood Pb levels (e.g., Parry and Eaton 1991; Gorospe et al. 2008). Generally speaking, however, the risk of Pb contamination is impacted by multiple factors including hand to mouth activity, inhalation of resuspended soil Pb, and occupational Pb exposure (Gogte et al. 1991; Kadir et al. 2008; Qu et al. 2012; Zahran et al. 2013). In particular, the parental transport of Pb-bearing dust from metallurgical occupations to domestic contexts poses an increased risk of Pb poisoning (Roscoe et al. 1999). Pervasive Pb exposure in archaeological

contexts manifests as “cultural focusing,” the convergence of Pb isotope ratios and a corresponding spike in Pb concentrations across individuals in a population (Montgomery et al. 2005).

Marine aerosols and other kinds of aeolian deposition derived from non-local areas can also significantly influence the heavy isotope ratios of a region (Whipkey et al. 2000; Komárek et al. 2008; Evans et al. 2010). The potential for aeolian influence is particularly important to consider when interpreting lead isotope data from osteological remains given that ingested dust, rather than the food itself, contributes much of the lead in animal tissues (Elias et al 1982; McBride 1994; Kohn et al. 2013). Unfortunately, airborne particulate from industrial activities has swamped the natural background lead, even in remote regions of the globe (Bindler 2011; Klaminder et al. 2011). Modern contaminants like lead in industrial pollution and strontium in fertilizers can affect the isotope ratios of modern samples used to evaluate regional isotope variability (Bentley 2006). Because of globally ubiquitous lead contamination, modern plants and animals should not be used to approximate background values for lead isotopes. Sediment samples taken from lower in the soil profile, however, can be used given the tendency of lead to bind with organic content in the upper levels (Klaminder et al. 2006). In a similar vein, samples exposed to certain fertilizers and other strontium-rich sources should be avoided when estimating natural isotopic variability.

Light Stable Isotopes

In contrast to heavy isotopes, the isotope ratios of lighter elements like carbon and oxygen undergo fractionation when they are involved in physical, chemical, and biological processes. The mass difference between isotopes of light element is relatively large, causing one isotope to be preferentially selected over the other as they undergo

chemical reactions and phase changes. This change in ratios is reported in parts per mil (‰) relative to an international standard (Coplen 1994), and because of the systematic nature of fractionation processes, isotope measurements can be used to make inferences about certain constraining environmental factors. For example, oxygen isotope fractionation is mediated by the temperature of different water sources and evaporation, and varies with respect to related changes in altitude and latitude (Dansgaard 1964). In this way, oxygen isotope values from biological apatites and other carbonate sources reflect climate conditions. Interpreting light stable isotope data is not strictly a matter of determining weighted average values for a range of environmental inputs. One must also account for the fractionation processes of different elements.

Stable oxygen isotopes

The stable isotopes of oxygen relevant for archaeological purposes are ^{18}O and ^{16}O; their ratios in bones and teeth are the end result of a long chain of fractionation processes typically beginning with the evaporation of ocean water from tropical latitudes. Water molecules containing lighter ^{16}O isotopes preferentially evaporate resulting in water vapor with relatively low $\delta^{18}O$. Subsequently, condensation and precipitation favor the heavier ^{18}O isotope such that rainfall has relatively high $\delta^{18}O$ compared to water vapor. This fractionation factor increases at lower temperatures resulting in increased depletion of ^{18}O for water vapor. Further, as the moist air mass moves inland to higher, cooler altitudes, ongoing precipitation or “rainout” leaves the water vapor even more depleted in ^{18}O. Thus, rainfall derived from a given air mass exhibits progressively lower $\delta^{18}O$. Generally speaking, $\delta^{18}O$ for a given air mass and its precipitation decreases with lowered temperature, high precipitation, high latitude, high altitude, and distance from the ocean. Conversely, $\delta^{18}O$ increases with higher

temperatures, low precipitation, low latitude, low altitude, and proximity to the ocean (Bowen and Wilkinson 2002; Gat 1996; Kendall and Coplen 2001). In tropical latitudes, variation in $\delta^{18}O$ is influenced primarily by “rainout”, whereas temperature has a greater influence on seasonality at higher latitudes (Dansgaard 1964; Rozanski et al. 1993). Adding to the complexity, seasonal changes in weather patterns may bring moisture from different regions, causing further differentiation in the isotopic values of intra-annual precipitation (Fricke and O'Neil 1996; Scholl et al. 2009).

Plants and animals acquire water from different sources with potentially different $\delta^{18}O$. For example, rivers originating in the highlands, meteoric water, ground water, and lake or pond water from the same region might all have different $\delta^{18}O$ because their isotopic compositions have evolved under variable regimes of condensation, evaporation, and source mixing. The water management practices of humans are similarly diverse, potentially drawing from multiple environmental sources, storing water in evaporation-prone vessels and reservoirs, or boiling water during cooking (Knudson 2009). Animals also acquire and conserve water using multiple strategies. For example, some animals get the bulk of their water through vegetation whereas others must drink frequently. Isotopic values of the former tend to vary with aridity as $\delta^{18}O$ of leaf water is strongly influenced by processes of evaporative enrichment. In the case of obligate drinkers, however, $\delta^{18}O$ more closely tracks the variability in environmental water sources (Levin et al. 2006).

Once ingested, oxygen isotopes fractionate further as a consequence of metabolic processes. Ultimately, body water $\delta^{18}O$ is the aggregate of isotopic input from drinking water, food, and air modified by fractionation in output through urination,

perspiration, and exhalation. Biological apatites in bones and teeth form in isotopic equilibrium with body water and act as an archive of $\delta^{18}O$, capturing an aggregate measure of complex environmental and physiological fractionation mechanisms (Longinelli 1984; Luz et al. 1984; Luz and Kolodny 1985). Enamel formed during early childhood, in particular, records the isotopic input from breastmilk. An isotopic shift associated with weaning can be observed between early and late forming dentition because breastmilk is derived from body water, a reservoir relatively enriched in ^{18}O compared to environmental sources. The magnitude of the shift has been measured in archaeological populations at approximately 0.7‰ (Wright and Schwarcz 1998), although the shift may be obscured by cultural practices including the consumption of relatively high $\delta^{18}O$ water such as that in boiled foods (Daux et al. 2008).

Because $\delta^{18}O$ also varies geographically, it can be used to provenience osseous remains in much the same way as heavy stable isotopes (e.g., Schwarcz et al. 1993; Dupras and Schwarcz 2001; White et al. 2004b; Prowse et al. 2007; Wright 2012). Geographic comparison is less direct than is the case for strontium and lead, however, because climate and hydrology are less stable than bedrock composition. Therefore, determining an appropriate sample type to represent local $\delta^{18}O$ ranges is more challenging. For one thing, modern samples may not capture the range of past values. Paleoclimate records derived from inorganic carbonates sidestep this problem because they formed under the direct influence of past climate conditions, but they fail to account for fractionation in the biosphere. To facilitate the comparison of biological and inorganic values, several methods have been proposed to predict environmental $\delta^{18}O$ from biogenic $\delta^{18}O$ (e.g., Longinelli 1984; Luz et al. 1984; Levinson et al. 1987; Daux et al.

2008), but they have an error of approximately ±1-3.5‰ 2σ (Pollard et al. 2011). Instead, $\delta^{18}O$ from human bone and enamel can be compared with faunal data following the same logic used for determining local variation in heavy stable isotope ratios. Unfortunately, $\delta^{18}O$ derived from humans and other animals may not be comparable because of variation introduced by cultural behaviors (White et al. 2004a). Therefore comparisons with archaeological fauna should be attempted when possible, but highly structured data sets may offer the best route to identifying immigrants.

Stable carbon isotopes

Stable carbon isotopes ^{13}C and ^{12}C also undergo fractionation in the biosphere prior to being incorporated into bone and tooth enamel. Carbon isotope values in plant tissues show large differences from the value in atmospheric CO_2. Depending on the photosynthetic pathway used, plants differentially discriminate against the heavier ^{13}C isotope as a function of enzymatic differences. Most cool season grasses, trees, and herbs use the Calvin cycle (C_3 plants) and have a mean $\delta^{13}C$ of approximately -28.5‰ (Kohn 2010), whereas warm season grasses, sedges, and some dicotyledons use the Hatch-Slack cycle (C_4 plants) and have a mean $\delta^{13}C$ of -14‰ (O'Leary 1988). Certain arid-adapted succulents and epiphytes employ crassulacean acid metabolism (CAM plants) resulting in intermediate values, although such plants rarely form a major constituent of human diets.

A variety of environmental variables cause small-scale variation (~3-6‰) in C_3 plants, although there is relatively little intraspecific variation in $\delta^{13}C$ among C_4 plants (Tieszen 1991; Brookman and Ambrose 2013). Many such changes result from variation in the partial pressure of CO_2. Plants increasingly discriminate against ^{13}C as intercellular pressure goes up, causing a corresponding decrease in $\delta^{13}C$ (Farquhar et

al. 1982). Increases in pressure can result from decreased irradiance, whereas relatively arid conditions can trigger reduced stomatal conductance, decreasing the partial pressure of CO_2 in some plants. These and other factors show broad geographic and climatic trends such that $\delta^{13}C$ increases slightly with altitude and mean annual temperature while decreasing slightly at higher latitudes (Francey and Farquhar 1982; Farquhar et al. 1989). Lastly, a "canopy effect" of decreased $\delta^{13}C$ in understory environments is caused by the recycling of isotopically lighter CO_2 from decomposing leaf litter (van der Merwe and Medina 1989; van der Merwe and Medina 1991).

In animals, metabolic processes cause further carbon fractionation. The process is not uniform for all carbon-bearing compounds, however, as carbon from the protein portion of diet preferentially contributes to bone collagen, and carbon from the whole diet contributes to bone and tooth apatite. Consequently, isotopic values for the different compartments of bone have different offsets from dietary $\delta^{13}C$. Collagen is isotopically heavier than the food source by ~3.5-6.5‰ while the offset for bone apatite carbonate ranges between ~9 and14‰ (Krueger and Sullivan 1984; Ambrose and Norr 1993; Tieszen and Fagre 1993; Howland et al. 2003; Jim et al. 2004). Notably, the magnitude of the offset between the food source and bone apatite or collagen varies among organisms. For apatite carbonate, for example, herbivorous ungulates are offset by ~12-14‰ (e.g., Cerling and Harris 1999; Balasse 2002) and lab rodents between ~9-11‰ (e.g., DeNiro and Epstein 1978; Jim et al. 2003). The interspecific variation in offset values is important for data interpretation in that the difference in $\delta^{13}C$ between C_3 plants and C_4 plants is only ~14‰ (Passey et al. 2005). Taxonomic differences are partly explained by dietary differences as low meat intake does not allow for the direct

routing of ingested amino acids into protein synthesis and thus leads to fractionation associated with the synthesis of proteins from carbohydrates (Schwarcz 2002). Further, carnivorous diets are high in isotopically light lipids, but diet alone fails to explain the full range of interspecific variation. Differences in digestive physiology likely contribute to the variability; production and absorption of isotopically light methane may well explain lower $\delta^{13}C$ for ruminants (Hedges 2003). The offset for apatite in humans is variably assumed to be as low as 9.5‰ and as high as 12‰—a range that might be partially explained by omnivory and cultural variation in diet (Ambrose and Krigbaum 2003; Harrison and Katzenberg 2003). Finally, modern era industrial emissions of isotopically light CO_2 require that an additional offset of -1.5‰ be applied to archaeological $\delta^{13}C$ to make comparisons with modern data (Friedli et al. 1986). Therefore, an archaeological human with a pure C_4 diet will have higher apatite carbonate values, possibly near 0‰, depending on local values for C_3 and C_4 plants. Isotope ratios from apatite carbonate alone give an approximate sense of C_3 vs. C_4 plant consumption and are most useful in detecting broad relative differences in diet, although dietary inferences are limited without corresponding collagen $\delta^{13}C$. More precise reconstruction of diet from carbon isotopes becomes possible when the organic content of bones has been preserved and apatite carbonate $\delta^{13}C$ can be compared with collagen $\delta^{13}C$ (Kellner and Schoeninger 2007). In ideal circumstances, a variety of faunal specimens in the local food web can also be analyzed to provide constraints on regional isotopic variation.

Osteological Development and Diagenesis

Many tissues can be analyzed for isotopes, but osseous materials tend to be the best preserved in archaeological contexts. Despite their lack of collagen, teeth have developmental and structural qualities that make dental enamel a more suitable choice

for isotopic analysis than bone in many contexts. For one thing, dental enamel forms an incremental record of environmental conditions at the time of mineralization. Mineralization spans several years per tooth in humans, after which the tooth becomes largely impermeable to further chemical exchange. Additionally, different tooth types systematically and predictably mineralize at different chronological ages in childhood. Consequently, any given tooth permanently stores isotopic data from a specific time period of an individual's early life (Table 3-1) (Hillson 1996). Through intertooth sampling then, bone chemistry tools can help reconstruct aspects of early life mobility, diet, and climate that are otherwise difficult to infer. Indeed, the increased interpretive potential of intertooth sampling has increasingly led to explicit intertooth sampling protocols within isotopic research designs (e.g., Wright 2012; Giblin et al. 2013).

Any analysis of early permanent dentition such as first molars must also consider the potential implications of breastfeeding and weaning. As discussed earlier, stable oxygen isotopes demonstrate a trophic shift and can be used to identify the transition to drinking water. Likewise, stable carbon isotopes may indicate the transition to solid foods if the foods used for weaning have an isotopic composition distinct from breast milk (Wright and Schwarcz 1998). Weaning may also be indicated in lead isotope ratios of permanent teeth when prepartum maternal residence is isotopically distinct from postpartum residence (Gulson et al. 2003; Manton et al. 2003). The skeleton acts as a reservoir for lead which may be mobilized along with bone calcium during lactation, although less of the maternal lead burden is released into the blood when the diet is calcium-rich (Gulson et al. 2004). In one study on modern immigrant mothers, breast milk lead accounted for 36-80% of infant blood lead for the first 90 days of life (Gulson

et al. 1998) although Manton and coworkers (2000) found that dust contributed far more to infant blood lead than breast milk. Presumably, a similar process to that described in Gulson et al. (2004) could happen with maternal strontium, but biopurification against strontium in the mammary glands suggests that other sources of strontium would have a greater influence on infant isotopic ratios (Wasserman et al. 1958; Blakely 1989).

Apart from documenting life history, tooth enamel has the additional advantage of resisting diagenetic alteration. Bone mineral is relatively porous and permeable to the labile ionic content of surrounding sediments. By contrast, dental enamel is made of larger crystals arranged in a tighter lattice that resists penetration by diagenetic agents (Driessens and Verbeeck 1990; Budd et al. 2000a; Budd et al. 2000b; Chiaradia et al. 2003). In the case of strontium and lead at least, what little diagenetic alteration occurs seems to be confined to the outermost surface (Budd et al. 1998). Some authors have suggested that successive weak acid pretreatments could recover biogenic strontium isotope ratios from diagenetically altered bone (Sillen 1986; Sillen 1989), but later work suggests that “solubility profiling” is ineffective (Hoppe et al. 2003; Trickett et al. 2003). Thus, dental enamel remains the most reliable material for heavy stable isotope analysis with little preparation required beyond abrasion of the surface enamel. Nevertheless, weak acetic acid pretreatments can help remove weakly adsorbed carbonates, and the fact that different pretreatment protocols yield comparable analyses for strontium and lead (Valentine et al. 2008) suggests that there is no harm in pretreating teeth with weak acetic acid for less than 16 hours.

Given that the source of isotopically analyzed carbon and oxygen for this study was structural carbonate, however, pretreatment was necessary to remove adsorbed

contaminants for light stable isotope analysis. Care must be taken to limit the strength and duration of acetic acid treatment to prevent the dissolution and reprecipitation of structural carbonate (Koch et al. 1997; Garvie-Lok et al. 2004). Apatite phosphate may also be used for stable oxygen isotope analysis and yields systematically related data, but expenses for the preparation of phosphate are significantly greater (Sponheimer and Lee-Thorp 1999; Chenery et al. 2012). The enhanced molecular strength of apatite phosphate and its increased resistance to diagenesis make it particularly appropriate for research on a geological time scale (Bunton et al. 1961; Lecuyer et al. 1999).

Laboratory and Field Methods

Sample collection was guided by a few basic principles. Whenever possible, bulk enamel samples were collected from the first, second, and third molars of human burials to ascertain isotopic life history in three stages: from birth to age three, age three to six, and age eight to twelve. In a few instances when first or second molars were unavailable, teeth with roughly similar mineralization times were sampled instead. For purposes of visual presentation, different tooth types are grouped into cohorts (first, second, and third molar cohorts) based on similar enamel formation times. Incisors are grouped with first molars, whereas canines and premolars are classified as second molars. Further, undomesticated or commensal faunal were selected along with sediments to provide proxy measures for regional variation. Every effort was made to fully document teeth before destructive sampling was undertaken. Unless stated otherwise, photographs or scans were taken and dental impressions were made for all teeth using 3M ESPE Express Vinyl Polysiloxane Impression Material – regular body. Impression material was applied to the tooth crown using a Garant Hand Dispenser, after which the tooth was inverted on a smooth surface until dry.

Once fully documented, approximately 50 mg of tooth enamel spanning cusp tip to cementoenamel junction was collected in one of two ways. Teeth taken from the Harappa Archaeological Research Project were brought to the University of Florida Bone Chemistry Lab and sampled under 10x magnification using a Brassler dental drill with a diamond bit. Teeth collected from the Archaeological Survey of India and Deccan College Post-Graduate and Research Institute were sampled using a rotary tool with a diamond cutting wheel.

Sample collection proceeded in four phases. In 2009, the Harappa Archaeological Research Project provided access to regional fauna and sediments from the following sites: Allahdino (Sus, N=5), Balakot (sediment, N=3), Harappa (Canis, N=3; Sus, N=8), Mehrgarh (Canis, N=2; sediment, N=2), and Nausharo (Equus, N=4; Gazella, N=2). No dental impressions were made during this initial pilot phase.

During the 2010 field season, Farmana human teeth were sampled from 21 individuals (N=37) curated at Deccan College Post-Graduate and Research Institute, Pune, India. Tentative estimates of age and sex were made following Buikstra and Ubelaker (1994), but few reliable identifications could be made given the extremely poor preservation and general scarcity of skeletal elements. Most skeletal remains were still encased in soil, some of which was collected (N=3) for isotopic analysis. Additional sediment samples (N=3) were collected from the site of Sanauli. A clean soil profile was exposed using a shovel and approximately 200 mg of sediment collected from roughly 70 cm below the surface to avoid recent anthropogenic lead bound in the upper levels (Klaminder et al. 2006).

In 2011, human teeth from Sanauli were sampled for 33 individuals (N=67) curated by Archaeological Survey of India at Purana Qila, New Delhi, India. Again, a paucity of skeletal elements hindered accurate estimation of age and sex beyond an adult/sub-adult distinction. Faunal samples (Sus, N=8) were also collected from the Rakhigarhi assemblage curated at Deccan College.

In 2012, an opportunistic sample of teeth from 44 individuals at Harappa (N=51) was collected from the Harappa Archaeological Research Project. Most had been previously sampled for carbon, oxygen, and strontium isotope analysis by Drs. Jonathan Mark Kenoyer and Douglas Price, University of Wisconsin, Madison. No additional documentation was undertaken before sampling. Unpublished age and sex data were made available by Dr. Kenoyer.

At the University of Florida Department of Anthropology Bone Chemistry Lab, the surfaces of all enamel samples were abraded and all dentine was removed using a dental drill. Samples were then ground into powder with an agate mortar and pestle before being pretreated with 2 ml of reagent grade 50% NaOCl solution in a centrifuge tube for 16 hours to remove organic content. The supernate was pipetted out, after which samples were rinsed with 2x distilled water until neutral. The same procedure was then carried out using 0.2N acetic acid to remove adsorbed carbonate. The pretreated samples were finally freeze dried for 72 hours and stored in a desiccator.

At the University of Florida Department of Geological Sciences clean lab facility, approximately 20-30 mg of pretreated enamel powder for each sample was dissolved in pre-cleaned Teflon vials by heating for 24 hours in 8N nitric acid (HNO_3) (optima). The vials were then opened and evaporated to dryness in a laminar flow hood. For each

sediment sample, approximately 100 mg of sediment was leached in pre-cleaned Teflon vials for 2 hours using 4 ml of 0.1N acetic acid. The leachate was pipetted off, the sample evaporated to dryness, an additional 4 ml of 2N HCl added, and the leachate pipetted off once more. Both leachates were evaporated to dryness in preparation for lead and strontium separation. Ion chromatography was then used to separate strontium and lead from single aliquots. Lead was purified using conventional hydrobromic acid (HBr) procedures on Dowex 1X-8 resin, and the washes were collected for further strontium separation as the latter element is not absorbed on the resin. The dried residues were dissolved in 2 ml of 8N nitric acid, producing bromine gas from any residual hydrobromic acid which would otherwise interfere with strontium separation. Once dried, the samples were redissolved in 3.5N nitric acid and loaded onto cation exchange columns packed with strontium-selective crown ether resin (Sr-spec, Eichrom Technologies, Inc.) to separate strontium from other ions, following the procedure by Pin and Bassin (1992).

All samples were analyzed using the mass spectrometry facilities at the University of Florida Department of Geological Sciences. Lead isotopic ratios were measured using a ‘‘Nu-Plasma’’ multiple-collector inductively-coupled-plasma mass spectrometer (MC-ICP-MS) following the thallium-normalization technique of Kamenov and coworkers (2004). The data are reported relative to the following values of NBS 981: $^{206}Pb/^{204}Pb = 16.937 \pm 0.004$ (2σ), $^{207}Pb/^{204}Pb = 15.490 \pm 0.003$ (2σ), and $^{208}Pb/^{204}Pb = 36.695 \pm 0.009$ (2σ).

Pilot strontium data for samples from the 2009 phase were also analyzed by MC-ICP-MS following the time-resolved analysis method of Kamenov et al. (2006). The

long-term reproducibility of the TRA-measured $^{87}Sr/^{86}Sr$ of NBS 987 is 0.710246 ± 0.000030 (2σ). All other samples were analyzed for $^{87}Sr/^{86}Sr$ using a “Micromass Sector 54” thermal ionization mass spectrometer (TIMS). After being loaded on to degassed tungsten filaments, the samples were run at 1.5V for 100 ratios whenever possible, and the resulting data normalized to $^{86}Sr/^{88}Sr$ = 0.1194. The long-term reproducible $^{87}Sr/^{86}Sr$ of NBS-987 is 0.710240 ± 0.000023 (2σ).

All light stable isotope data were measured using a “VG/Micromass PRISM Series II” isotope ratio mass spectrometer with an “Isocarb” common acid bath preparation device. No duplicate samples were prepared for teeth that had already been run by Drs. Kenoyer and Price. All others were reacted in a common acid bath at 90 °C and water was cryogenically removed in a methanol slush. Evolved CO_2 gas was measured online and all isotope results are reported in standard delta notation relative to Vienna Pee Dee Belemnite (VPDB). Analytical precision (1 standard deviation of standards run with samples) is generally better than ±0.1‰ for $\delta^{13}C$ and 0.1‰ for $\delta^{18}O$.

Table 3-1. Approximate crown formation time in years[1]

	Incisor	Canine	Premolar	First Molar	Second Molar	Third Molar
Initial Formation	< 1	< 1	2-6	0	2.5-5	7-11
Crown Completion	3.5 - 5	4-7	5-9	2-4	6-9	10-17

[1] estimated ranges derived from minimum and maximum values in [Hillson, S. 1996. Dental Anthropology (Table 5-1), Cambridge: Cambridge University Press]

CHAPTER 4
GEOCHEMISTRY OF THE GREATER INDUS REGION

Environmental Background

Stretching between the Himalayas and the Arabian Sea, the Indus settlement area is bounded on the west by mountain ranges of the Western Fold Belt and on the east by the Aravallis. The Indo-Gangetic plains derive largely from Quaternary Himalayan detritus overlying and abutting the Indian Shield to the south, thus regional geochemistry can be described primarily in terms of Himalayan geological units. Even sediments of the Makran coast and the Kirthar and Sulaiman Ranges to the west have their ultimate origins in rivers draining the Himalayas. However, the Himalayas are composed of distinct thrust sheets, each with its own lithology, resulting in a geochemically diverse landscape.

Approximately 55 million years of orogeny have dramatically altered the Indian plate and created the vast alluvial plains of the Himalayan peripheral foreland basin in which Indus cities thrived (Kazmi and Jan 1997; Ramakrishnan and Vaidyanadhan 2010). The subduction and subsequent collision of the South Asian subcontinent with the Eurasian plate caused the sequential uplift and exhumation of the major Himalayan units (Figure 4-1). The Trans-Himalaya is northernmost and represents the leading edge of the Eurasian plate. It is composed of several major sub-units including the Hindu Kush and Karakorum Ranges. The Trans-Himalaya is separated from the Indian formations to the south by the Indus-Tsangpo Suture Zone (ITSZ) which channels the upper course of the Indus River. At its western end, the suture diverges around the Kohistan Arc, an ancient island arc sandwiched between Asia and the subcontinent. Running parallel to the Trans-Himalaya along the southern edge of the ITSZ is the

Tibetan Sedimentary Series (TSS) or Tethys Himalaya. To the south and likewise running from east to west are the High Himalayan Crystallines (HHC), the Lesser Himalaya, and the Sub-Himalaya. The latter encompasses various sub-basins of which the Neogene strata are collectively termed the Siwalik Group. All together, the Himalayas have a diverse lithology ranging from continental crust to ophiolites (obducted oceanic crust) and young igneous formations to heavily metamorphosed strata. Different rocks have provided sediments to the foreland basin at different times as various Himalayan units and drainages evolved. Importantly for archaeological research, however, portions of the Indo-Gangetic plains have been partially homogenized as a consequence of complexities of fluvial and aeolian transportation (Tripathi and Rajamani 1999; Tripathi et al. 2007). This results in a relatively large-scale geochemical mosaic conducive to isotopic studies of interregional mobility.

Isotopic Variation—Heavy Isotopes

The Sr and Pb isotope systematics of the major Himalayan units are well characterized, allowing sediment provenience in some cases despite the isotopic overlap between units (Najman et al. 2000; Clift et al. 2002). Further, the different isotope systems are independent of each other and their isotopic ratios need not correlate. Different geological units influence Sr and Pb isotope ratios in biological materials as a function of their solubility and Sr and Pb concentrations. Carbonates, for example, are easily weathered and tend to have high Sr/Ca but low concentrations of Pb. As a result, carbonates have a disproportionate effect on $^{87}Sr/^{86}Sr$ in archaeological tooth enamel. Although much geological data is derived from silicates and therefore not directly comparable with the soluble Sr and Pb archived in enamel, silicate data still indicate relative differences in the biologically available Sr and Pb isotope ratios. Based

on Sr and neodymium (Nd) isotope data, Najman and coworkers proposed that from most radiogenic to least, the isotopic end members contributing to the foreland basin are the Lesser Himalaya, the HHC, the TSS, and geologically young elements of the ITSZ including the Kohistan Arc. Clift et al. (2002) depict similar influences on Pb isotope geochemistry in the Indus basin except their analysis pointed to Asian portions of the Trans-Himalaya rather than the TSS.

Few data are available for Pb isotopes in the Himalayan foreland basin beyond the study of detrital grains by Clift et al. (2002). Nevertheless, the analysis by Clift and coworkers suggests that the Trans-Himalaya and ITSZ are the primary controls on Pb isotope composition in the Indus main channel, whereas the highly radiogenic values of the foreland tributaries (e.g., Chenab, Ravi, Sutlej) are largely derived from the HHC and Lesser Himalaya. The latter two geological units are expected to exert an even greater isotopic influence on Pb in river basins to the east as a function of increased elevation and weathering.

The Sr isotope literature is comparatively rich and includes analyses of the soluble fraction of Sr in river waters and sediments (Figure 4-2) (e.g., Karim and Veizer 2000; Tripathi et al. 2013). Within the Indus basin, $^{87}Sr/^{86}Sr$ data suggest three end members—the HHC, the carbonate-rich Western Fold Belt, and the Kohistan Arc (Pande et al. 1994; Karim 1999; Karim and Veizer 2000). In the upper reaches, the Indus drains mainly the low $^{87}Sr/^{86}Sr$ terrain of the Kohistan Arc and has ratios of ~0.710. The main channel becomes gradually more radiogenic (~0.712) with increased contributions from the HHC. By the middle reaches of the Indus River, however, $^{87}Sr/^{86}Sr$ dips slightly from the influx of high concentration, low $^{87}Sr/^{86}Sr$ waters draining

the Western Fold Belt. The Sr isotope ratios then remain relatively stable (~0.711) through the lower reaches as the main channel is joined by the more radiogenic waters of the foreland tributaries. Significantly for provenience studies, the main Indus channel exhibits lower $^{87}Sr/^{86}Sr$ than most of the foreland tributaries which drain the uniquely radiogenic carbonate terrain of the HHC (Palmer and Edmond 1992). Indeed, Kenoyer and coworkers (2013) estimate high biologically available $^{87}Sr/^{86}Sr$ (~0.720) in the area near Harappa. Ratios taper off gradually to the west and south, whereas higher values are most likely found in the highlands to the north and northeast. The situation is similar for other rivers with headwaters that drain the HHC. The lowland waters of the Yamuna are broadly comparable to those of the radiogenic Indus foreland tributaries (Dalai et al. 2003), whereas the most radiogenic $^{87}Sr/^{86}Sr$ values for any Himalayan river are found in the Ganges where ratios can be as high as 0.741 (Krishnaswami et al. 1992; Chakrapani 2005).

Limited Sr isotope data are also available for sediments and leachates in regions near Farmana and Sanauli (Tripathi et al. 2004; Tripathi et al. 2013). Samples from the semi-arid region between the Yamuna and Ghaggar-Hakra likely approximate the geochemical environment at Farmana, whereas those near the Yamuna, less than 100 km to the east, provide a $^{87}Sr/^{86}Sr$ range estimate for Sanauli. Despite their proximity, the two areas appear to be isotopically distinct. Leachates of Yamuna alluvium have $^{87}Sr/^{86}Sr$ between 0.715 and 0.718, significantly higher than the 0.711-0.716 range exhibited by dust and sand leachates in the Ghaggar-Yamuna interfluve. Bulk sediment analyses confirm that the Yamuna alluvium is more radiogenic, but the most striking comparison is between aeolian sediments of the Ghaggar-Yamuna interfluve and the

Thar Desert fringe near the Aravalli foothills less than 150 km to the south. Samples from the two areas have essentially identical ratios—an unsurprising similarity given their potentially shared origins. Current evidence suggests that aeolian sediments from the lower Indus contribute significantly to the Thar Desert and adjacent terrain (Alizai et al. 2011). These sediments likely retain high concentrations of low $^{87}Sr/^{86}Sr$ as in the lower Indus River, and may therefore swamp the relatively radiogenic ratios derived from local alluvial sources.

Beyond the Himalayan foreland basins, the Indus settlement area extended southward into Saurashtra. Isotopically speaking, the region is not well described, but provisional estimates of low $^{87}Sr/^{86}Sr$ (< 0.710) can be made based on regional lithology (Chamyal et al. 2003). The presence of young volcanic rocks, limestones, and even aeolian sands from the Thar Desert suggests a generally less radiogenic environment, although it is difficult to estimate the more radiogenic contribution from the Precambrian rocks of the adjacent Aravallis.

Isotopic Variation—Light Stable Isotopes

The South Asian hydrological landscape is also conducive to provenience research using stable isotopes of oxygen ($\delta^{18}O$). Summer and winter rains originating in the southern oceans and the Mediterranean, respectively, serve as the primary sources of precipitation in the Indus watershed (Wright et al. 2008). Further, different vapor sources have different $\delta^{18}O$ as exemplified in climatological studies of nearby Oman (Weyhenmeyer et al. 2000; Weyhenmeyer et al. 2002), showing that northern sources range between -4.5 and +1‰ and southern sources vary between -10 and -2‰. Thus, the primacy of summer monsoon precipitation results in relatively low average $\delta^{18}O$ associated with many parts of the subcontinent. By contrast, relatively high $\delta^{18}O$ winter

storms move along the Western Fold Belt and into the western Himalayas (Wright et al 2008). Many regions of the Indus Civilization, including the city of Harappa, relied on both winter and summer rains to support seasonal multi-cropping. It is expected, then, that the relative contributions of summer and winter precipitation will be reflected in $\delta^{18}O$ of archaeological tooth enamel apatites, much as it is today in the waters of the Indus tributaries (Karim and Veizer 2002).

Even in those regions unaffected by Mediterranean precipitation, systematic variation in the summer monsoon creates gradients of $\delta^{18}O$ (Gupta and Deshpande 2005; Lambs et al. 2005). This complicated phenomenon can be explained in part by four factors: isotopically distinct vapor sources, rainout, evaporative effects, and altitude effects. Summer monsoon begins as the annual northward migration of the Intertropical Convergence Zone (ITCZ) creates low pressure systems in the northwestern subcontinent. High pressure oceanic air masses then move onto land, releasing rains that reflect the isotopic composition of the vapor source. For the Indo-Gangetic plains, this primarily means relatively low $\delta^{18}O$ in the Bay of Bengal monsoonal branch. The northwest-travelling air mass becomes gradually more depleted in ^{18}O with greater distance from the ocean because of rainout (Chapter 3). The Bay of Bengal branch alone, however, cannot explain modern variation in South Asian surface waters. The Arabian Sea branch of the summer monsoon has relatively higher $\delta^{18}O$ (~4‰) and contributes measurably to the precipitation budget of Pakistan and Northwest India (Gupta et al. 2005; Sengupta and Sarkar 2006). Further ^{18}O enrichment occurs at local levels depending on evaporation.

Lastly, high altitude drainages channel relatively depleted waters from the Himalayas down to the plains. The headwaters of the Indus (Karim and Veizer 2002), Yamuna (Dalai et al. 2002), and Ganges (Ramesh and Sarin 1992), for example, have lower $\delta^{18}O$ than do lowland channels. By comparison, rain-fed rivers draining the Himalayan foothills should have relatively high $\delta^{18}O$. The most significant rain-fed river in the Greater Indus Valley during the third millennium BC was the Ghaggar-Hakra. At times identified with the perennial glacier-fed Sarasvati of Vedic tradition, this now seasonal river in the Sutlej-Yamuna interfluve is associated with numerous Indus settlements (Mughal 1997; Possehl 2002b). Recent work, however, confirms that it was a perennial monsoon-fed river (Giosan et al. 2012), and as such, would likely have had relatively high $\delta^{18}O$.

The data from modern water sources cannot be compared directly to archaeological tooth enamel, but they still help estimate the relative differences that existed in different regions during the third millennium BC. In particular, studies of South Asian river water provide the most comprehensive $\delta^{18}O$ data set from which to infer variation across the Greater Indus Valley (Figure 4-3). Broadly speaking, the Indus, Ghaggar-Hakra, and Yamuna Rivers represent distinct isotopic regions. The Indus can be further subdivided into the upper reaches, the western tributaries, and the combined region covered by the foreland tributaries and the lower reaches of the main Indus channel. The latter region includes the major urban centers of Harappa and Mohenjo-Daro and can be considered the ‘heartland’ of the Indus Civilization. During the summer months, the lower Indus and foreland tributaries share similar $\delta^{18}O$. Far greater variability in $\delta^{18}O$ is found in the middle and upper Indus because of the countervailing

influences of high altitude and relatively enriched winter rains. For example, the high altitude reaches of the Indus main channel have lower $\delta^{18}O$ compared to the foreland tributaries by as much as 5‰. Conversely, the streams that drain western peaks have $\delta^{18}O$ as much as 8‰ higher than the foreland tributaries—a difference presumably attributable to greater winter precipitation (Karim and Veizer 2002). Similarly high values might also have been found in the far southeastern regions of the Indus Civilization as inferred from modern $\delta^{18}O$ in the Narmada and Tapti rivers draining western India (Lambs et al. 2005).

A more modest increase in $\delta^{18}O$ can be found to the east of the Indus heartland. As it emerges from the Himalayas, for example, the lower reaches of theYamuna main channel exhibit $\delta^{18}O$ ~2-3‰ higher than the foreland tributaries—a difference that may be partly attributable to summer precipitation and the proximity of the Bay of Bengal. Even higher $\delta^{18}O$ may characterize the Ghaggar-Hakra basin given the relatively low-altitude headwaters and increased contribution from the Arabian Sea monsoon. Collectively then, modern river data suggest a complex hydrological environment in which the highest $\delta^{18}O$ is found along the western highlands and southeastern coast, followed by the Ghaggar-Hakra basin (Figure 4-3). The next highest values come from the Yamuna basin, the combined lower Indus-foreland tributary region, and lastly the middle and upper reaches of the Indus excluding those tributaries draining western peaks.

The riverine data suggest certain broad trends in $\delta^{18}O$, but the potential complexities of local hydrology must always be considered. River water tracks the isotopic composition of seasonal precipitation regimes (e.g., Dalai et al. 2002), whereas

variation in regional groundwaters can be even more complex depending on source mixing and evaporative effects (Gupta and Deshpande 2005; Lorenzen et al. 2012). Considering the potential for diverse archaeological water management practices, it is difficult to say which modern data sets best approximate protohistoric $\delta^{18}O$. Large-scale climatic changes in the late Holocene further complicate this matter. Precipitation gradually declined throughout the urban era and into the second millennium BC, but western sources of winter precipitation dwindled more slowly (Wright et al. 2008). It is uncertain how significantly major climate changes might have altered the broad relative differences identified across the region. Nevertheless, spatial patterning in $\delta^{18}O$ is significantly influenced by topography which has remained unchanged since Indus times. Furthermore, river water and tooth enamel samples both represent a spatial and chronological average of environmental water sources, suggesting they may correlate closely despite the complexities of local hydrology.

A final environmental consideration is the pattern of millet consumption (a C_4 crop) as reflected in stable carbon isotope values ($\delta^{13}C$) of tooth enamel. There has been a tendency in the past to emphasize broad regional similarities and large-scale chronological trends in Indus agriculture (e.g., Meadow 1989a; Meadow 1996; Weber 1999). Weber and colleagues (2010), however, recently advocated a departure from a grand narrative in which a predominantly winter-cropping Indus heartland turned to millets during the drier, post-urban era. Instead, they emphasized regional variation in subsistence regimes and called for high-resolution ecological modeling. The view of Weber et al. serves as a reminder that agriculture in general, and millet consumption in particular, cannot be presented as either/or scenarios. Therefore, no simple predictions

can be made for $\delta^{13}C$ at Harappa, Farmana, and Sanauli. Even given the high quality archaeobotanical data recovered from Harappa (Weber 2003), the non-representative nature of Indus mortuary populations precludes straightforward modeling of $\delta^{13}C$.

Towards an Isotopic Baseline

Prior to isotopic mortuary analyses at the primary study sites, sediments and faunal tooth enamel were used to evaluate interregional isotopic differences in the biologically available fraction of strontium, lead, and oxygen. Sample collection included materials from secure chronological contexts at Rakhigarhi, Allahdino, Balakot, Mehrgarh, and Nausharo, as well as the mortuary sites of Farmana, Harappa, and Sanauli. As observed above, there is a general lack of regional data for the biologically available fraction of environmental Pb, however, it is possible to provide estimates for $^{87}Sr/^{86}Sr$ and $\delta^{18}O$. Allahdino and Balakot, for example, are coastal sites near the Indus delta and Makran coast, respectively. Each should reflect relatively less radiogenic contributions from the Western Fold Belt, as well as a potential marine influence on $^{87}Sr/^{86}Sr$ in the form of marine aerosols or through the consumption of marine food resources (Bentley 2006). In such cases, one would expect $^{87}Sr/^{86}Sr$ intermediate between that of the lower Indus (~0.711) and the ocean (~0.709) (McArthur et al. 2012). Mehrgarh and Nausharo, on the other hand, lie near the Bolan River which drains the Western Fold Belt. Therefore, local geochemistry should be consistent with winter storms (relatively high $\delta^{18}O$) and carbonate-rich highlands (~0.708-0.709). Far higher $^{87}Sr/^{86}Sr$ is expected at Harappa and Sanauli (~0.718-0.720) based on their proximity to Himalayan rivers, whereas Rakhigarhi and Farmana should fall somewhere in the middle due to carbonate-rich aeolian contributions from the lower Indus region. Harappa $\delta^{18}O$ should be broadly consistent with that of Allahdino and Balakot to the south,

slightly lower than Sanauli to the east, and even lower than semi-arid Rakhigarhi and Farmana to the southeast.

The above regional estimates of isotopic variability were tested using sediment leachates and tooth enamel from archaeological fauna. All environmental samples taken for this study approximate the biologically available component of local isotope systems, but any proxy for human dietary catchments is problematic. One reason for this is that interspecific differences in diet and drinking water can result in isotopic variation within a given locale. Pigs (*Sus*), dogs (*Canis*), equids (*Equus*) and gazelles (*Gazella*) consume vegetation under different regimes of evapotranspiration – a dietary variable known to affect $\delta^{18}O$ (Kohn et al. 1996; Schoeninger et al. 2000; Sponheimer and Lee-Thorp 2001). Further, obligate drinkers (e.g., pigs, dogs, equids, and humans) tend to have lower $\delta^{18}O$ than browsing animals that receive their water primarily through vegetation they consume (e.g., gazelles). Other complications arise when considering the mobility of fauna or their food sources. The diet of non-domesticated mobile animals may include foods from regions not exploited by nearby humans and could therefore be non-representative of local geochemistry. Even domesticated and commensal animals need not have lived in the same place from birth to death, nor must they have been consumed or disposed of in the same location. Pigs have been shown to have low $^{87}Sr/^{86}Sr$ variation in certain contexts (Bentley and Knipper 2005), but they can have widely varying diet or be transported relatively long distances in other contexts (Hide 2003).

Sediment leachates are similarly imprecise as they represent only a very small portion of a large human dietary catchment. Also, the fraction of Sr and Pb leachable by

methods used in this study may not precisely represent the soluble fraction taken up by biological organisms. For these reasons, any isotopic proxy for local human dietary catchments must necessarily be imprecise, and likely overestimates local ranges.

Results of the Baseline Analyses

The results of the baseline analyses presented in Table 4-1 show considerable interregional isotopic variation. Values of $^{87}Sr/^{86}Sr$ range from 0.70792 to 0.72112 with Sr concentrations from 444 to 1098 ppm. Lead isotope ratios are similarly wide ranging for all three ratios: $^{208}Pb/^{204}Pb$ from 38.371 to 39.511, $^{207}Pb/^{204}Pb$ from 15.655 to 15.823, and $^{206}Pb/^{204}Pb$ from 18.468 to 19.392. Faunal tooth enamel yielded $\delta^{18}O$ of -6.1 to 8.3‰ and $\delta^{13}C$ of -13.3 to 1.6‰. Means and standard deviations are presented on a site-by-site basis in Table 4-2.

As a cost saving measure, MC-ICP-MS was used rather than TIMS for the Sr isotope analysis of environmental samples during the pilot phase of this study. Using TIMS, however, permits the simultaneous determination of Sr concentration. Consequently, no concentration data are available for most environmental samples. Only the subset of environmental samples analyzed using TIMS during the second phase of research are presented in Figure 4-4. No Sr concentrations were determined for sediment leachates as such data are non-representative of the human dietary catchment and irrelevant to archaeological provenience studies. The Sr concentrations for fauna at Harappa and Rakhigarhi appear roughly equivalent with no obvious patterning. Also, there is a clear interregional difference in $^{87}Sr/^{86}Sr$ despite the overlap resulting from two outliers. Mean $^{87}Sr/^{86}Sr$ at Harappa is 0.71865 ± 0.00270 (2σ), distinctly higher than 0.71617 ± 0.00262 (2σ) at Rakhigarhi, $t(19) = 4.12$, $p < 0.001$.

All fauna and sediments are shown in the Pb-Pb plots (Figures 4-4 & 4-5). Both distributions plot along an elongated triangular field suggesting three end members. Farmana and Sanauli plot at the uppermost corner of the triangular distribution, implying a distinct source of Pb in the east. Allahdino, Balakot, Mehrgarh, and Nausharo have the lowest values and are indistinguishable from each other. Therefore the south and west of the Greater Indus Valley likely share a common Pb source. In Figure 4-5, Harappa data are nearly identical to those from southwestern sites, but based on Figure 4-6, it may be that Harappa receives a distinct geochemical contribution from a third end member. Generally speaking, Pb isotope composition is more radiogenic at northeastern sites and less radiogenic in the southwest, but the slight offset in data from Harappa (towards low $^{206}Pb/^{204}Pb$ and moderate $^{207}Pb/^{204}Pb$) suggests that Harappa is influenced by a particular Himalayan lithology that is not strongly represented either in the lower reaches of the Indus River or in the more easterly alluvial plains. Further, the data in Figure 5-3 plot in a broadly similar distribution to the regional lithological units depicted by Clift and coworkers (2002). Unfortunately, the large degree of overlap between the Pb-Pb fields of Clift et al. precludes precise provenience, and only tentative sourcing is possible without additional isotopic analyses of biologically available Pb throughout the Greater Indus region. One possibility is that the low isotope ratios of the lower Indus are derived from the ITSZ, whereas the high ratios at Harappa, Rakhigarhi, Farmana, and Sanauli are derived from the HHC and Lesser Himalaya. At Harappa, the relatively low $^{206}Pb/^{204}Pb$ as compared to sites further east may reflect proportionately greater input from the Lesser Himalaya.

Distributions of $\delta^{18}O$ for faunal tooth enamel at the baseline sites are consistent with the expectations outlined previously (Figure 4-7). Very similar values at Harappa (-3.1‰ ± 2.3 [2σ]) and Allahdino (2.9‰ ± 2.4 [2σ]) show relative homogeneity within the Indus heartland, whereas slightly higher $\delta^{18}O$ is found at Rakhigarhi (-1.8‰ ± 4.5 [2σ]) along the Ghaggar-Hakra catchment ($t(19) = 2.188$, $p = 0.041$). The highest values are found at Mehrgarh (3.0‰) and Nausharo (2.5‰ ± 3.9 [2σ]) as anticipated based on their proximity to the Western Fold Belt drainage. All fauna sampled are obligate drinkers with the exception of two gazelles recovered from Nausharo. The latter two samples show expected ^{18}O enrichment (7.8‰ ± 1.5 [2σ]), and the data are considered separately from the rest of the faunal sample.

Distributions of faunal $\delta^{13}C$ suggest no marked interregional differences, although equids at Nausharo have a very strong C_4 signal (1.0‰ ± 0.8 [2σ]) as one would expect for grazers in an arid environment (Figure 4-8). Further, faunal $\delta^{13}C$ at Allahdino and Harappa exhibit a bimodal distribution that is not explained by interspecific differences. Both pigs and dogs have high and low $\delta^{13}C$, perhaps reflecting differences between wild and domesticated fauna or different provisioning practices. Their differences aside, the majority of faunal $\delta^{13}C$ data suggest a predominantly C_3 diet with slight to moderate contributions from C_4 foods.

Far more geographic patterning is apparent in the heavy isotope ratios (Figure 4-9). The Sr isotope data partition largely as expected, with southwestern sites dominated by low $^{87}Sr/^{86}Sr$ sources, and northern sites influenced by highly radiogenic Himalayan sediments. Slightly less radiogenic values at Farmana and Rakhigarhi may reflect low $^{87}Sr/^{86}Sr$ aeolian contributions from the southern Indus plains. The extremely low

$^{87}Sr/^{86}Sr$ at Mehrgarh and Nausharo is probably controlled by the carbonate-rich Western Fold Belt, and the modest increase in $^{87}Sr/^{86}Sr$ at Allahdino and Balakot likely comes from a combination of terrains: theTrans-Himalaya and HHC sources in the middle and upper reaches of the main Indus channel as well as the foreland tributaries draining the Lesser Himalaya. Whatever the ultimate source, each region has distinct heavy isotopic ranges. Further, the faunal isotopic distributions from Harappa and Rakhigarhi are characterized by a tight cluster with 'satellite' data points. This pattern is consistent with a primarily local dietary catchment supplemented by the long-distance transportation of faunal resources. Consequently, the smaller clusters may represent local dietary catchments more accurately than the inclusive faunal data set. Lastly, sediment leachates and fauna from the same site are broadly consistent, suggesting that both proxies are useful in determining local ranges of isotopic variation in the Greater Indus region.

In summary, analyses of archaeological fauna and sediment leachates support inferences from the literature that the Indo-Gangetic Plains and adjacent areas are geochemically distinct and suitable for archaeological provenience studies. Though much additional work is required, this developing data set appears to be systematically related to proximal sediment sources. Even where environmental data are presently unavailable, this suggests that some constraints can be put on the provenience of individuals who do not precisely match the current comparative data set.

Table 4-1. Baseline samples – results of the analyses

Sample	Site	Leachate/ Taxon	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
AS1	Allahdino	*Sus*	0.70876		38.702	15.674	18.555	-1.5	-10.9
AS2	Allahdino	*Sus*	0.71082		38.840	15.689	18.647	-2.4	-10.8
AS3b	Allahdino	*Sus*	0.70873		39.103	15.705	18.795	-2.6	-11.7
AS4	Allahdino	*Sus*	0.71088		38.945	15.697	18.702	-3.0	-10.7
AS5	Allahdino	*Sus*	0.70870		38.696	15.668	18.565	-4.8	-0.7
BS3a	Balakot	acetic	0.70890		38.950	15.706	18.676		
BS3h	Balakot	HCl	0.70894		38.990	15.704	18.698		
BS5a	Balakot	acetic	0.70888		39.132	15.723	18.785		
BS5h	Balakot	HCl	0.70896		39.146	15.717	18.792		
BS13a	Balakot	acetic	0.70869		39.161	15.727	18.796		
BS13h	Balakot	HCl	0.70883		39.186	15.727	18.810		
F2Sa	Farmana	acetic	0.71553		39.421	15.823	19.339		
F2Sh	Farmana	HCl	0.71565		39.452	15.822	19.341		
F20Sa	Farmana	acetic	0.71559		39.393	15.817	19.297		
F20Sh	Farmana	HCl	0.71565		39.402	15.813	19.307		
F53Sa	Farmana	acetic	0.71554		39.425	15.821	19.339		
F53Sh	Farmana	HCl	0.71594		39.449	15.820	19.343		
HC1	Harappa	*Canis*	0.71828		38.860	15.720	18.687	-2.3	-2.7
HC2	Harappa	*Canis*	0.71797	1098	39.071	15.733	18.874	-3.4	-8.7
HC3	Harappa	*Canis*	0.71828		39.027	15.728	18.762	-3.8	-7.8
HS1	Harappa	*Sus*	0.71913		39.042	15.733	18.779	-2.4	-10.2
HS2	Harappa	*Sus*	0.72112		38.939	15.733	18.684	-1.4	-7.2
HS3	Harappa	*Sus*	0.71796		38.919	15.730	18.718	-3.8	-11.2
HS4	Harappa	*Sus*	0.72084	498	39.087	15.737	18.791	-2.7	-9.3
HS5	Harappa	*Sus*	0.71569	444	38.818	15.741	18.674	-4.1	-1.6

[1] light stable isotope data from [Kenoyer, J. M., T. D. Price, and J. H. Burton 2013. A New Approach to Tracking Connections between the Indus Valley and Mesopotamia: Initial Results of Strontium Isotope Analyses from Harappa and Ur. Journal of Archaeological Science 40(5):2286-2297 (Page 2294, Table 2)]

Table 4-1. Continued

Sample	Site	Leachate/ Taxon	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
HS6	Harappa	*Sus*	0.71855		38.580	15.728	18.468	-4.7	-10.1
HS7	Harappa	*Sus*	0.71795		38.979	15.736	18.796	-3.2	-12.9
HS8	Harappa	*Sus*	0.71908	853	38.955	15.737	18.735	-4.2	-11.5
HA05[1]	Harappa	*Sus*	0.71892	663	39.149	15.749	18.845	-0.7	-7.6
HA06[1]	Harappa	*Sus*	0.71869	837	39.189	15.749	18.858	-3.9	-10.7
MC1	Mehrgarh	*Canis*	0.70815		38.886	15.696	18.659	3.0	-9.9
MC2	Mehrgarh	*Canis*	0.70802		38.814	15.685	18.622		
MS85a	Mehrgarh	acetic	0.70795		39.082	15.708	18.795		
MS85h	Mehrgarh	HCl	0.70803		39.115	15.708	18.798		
MS132a	Mehrgarh	acetic	0.70792		39.023	15.706	18.751		
MS132h	Mehrgarh	HCl	0.70812		39.070	15.707	18.765		
NE1	Nausharo	*Equus*	0.70827		39.105	15.708	18.782	4.0	0.6
NE2	Nausharo	*Equus*	0.70825		38.934	15.697	18.662	2.0	0.8
NE3	Nausharo	*Equus*	0.70821		38.750	15.681	18.638	0.0	1.6
NE4	Nausharo	*Equus*	0.70820		39.051	15.694	18.748	4.1	1.2
NG1	Nausharo	*Gazella*	0.70811		38.888	15.690	18.705	7.3	-7.5
NG2	Nausharo	*Gazella*	0.70816		38.955	15.691	18.699	8.3	-13.2
RS1	Rakhigarhi	*Sus*	0.71574	617	39.054	15.781	18.971	-1.2	-8.8
RS2	Rakhigarhi	*Sus*	0.71585	767	39.188	15.799	19.053	-2.5	-9.7
RS3	Rakhigarhi	*Sus*	0.71568	894	38.996	15.781	18.920	-3.3	-9.4
RS4	Rakhigarhi	*Sus*	0.71471	872	38.815	15.715	18.660	-6.1	-6.8
RS5	Rakhigarhi	*Sus*	0.71903	483	39.070	15.763	18.970	-1.1	-5.9
RS6	Rakhigarhi	*Sus*	0.71702	510	39.020	15.759	18.887	0.7	-9.6
RS7	Rakhigarhi	*Sus*	0.71582	514	39.078	15.765	19.008	-2.0	-6.1
RS8	Rakhigarhi	*Sus*	0.71556	584	38.371	15.655	18.584	0.9	-7.8

[1] light stable isotope data from [Kenoyer, J. M., T. D. Price, and J. H. Burton 2013. A New Approach to Tracking Connections between the Indus Valley and Mesopotamia: Initial Results of Strontium Isotope Analyses from Harappa and Ur. Journal of Archaeological Science 40(5):2286-2297 (Page 2294, Table 2)]

Table 4-1. Continued

Sample	Site	Leachate/ Taxon	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
SXD3a	Sanauli	acetic	0.71762		39.412	15.812	19.333		
SXD3h	Sanauli	HCl	0.71842		39.461	15.820	19.369		
SXD4a	Sanauli	acetic	0.71823		39.444	15.812	19.363		
SXD4h	Sanauli	HCl	0.71967		39.491	15.817	19.381		
SCSa	Sanauli	acetic	0.71752		39.486	15.820	19.392		
SCSh	Sanauli	HCl	0.71900		39.511	15.819	19.390		

[1] light stable isotope data from [Kenoyer, J. M., T. D. Price, and J. H. Burton 2013. A New Approach to Tracking Connections between the Indus Valley and Mesopotamia: Initial Results of Strontium Isotope Analyses from Harappa and Ur. Journal of Archaeological Science 40(5):2286-2297 (Page 2294, Table 2)]

Table 4-2. Baseline samples summary statistics—mean±2σ

Site	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
Allahdino	0.70958±0.00232		38.857±0.344	15.687±0.030	18.653±0.200	-2.9±2.4	-9.0±9.2
Balakot	0.70887±0.00019		39.094±0.197	15.717±0.021	18.760±0.115		
Farmana	0.71565±0.00030		39.423±0.048	15.819±0.007	19.328±0.040		
Harappa	0.71865±0.00270	732±492	38.970±0.318	15.735±0.017	18.744±0.212	-3.1±2.3	-8.6±6.6
Mehrgarh	0.70803±0.00018		38.998±0.241	15.702±0.018	18.731±0.148	3.0	-9.9
Nausharo (*Equus*)	0.70823±0.00006		38.960±0.314	15.695±0.022	18.707±0.137	2.5±3.9	1.0±0.8
Nausharo (*Gazella*)[1]	0.70811±0.00007		38.921±0.094	15.690±0.001	18.702±0.009	7.8±1.5	-10.4±8.2
Rakhigarhi	0.71617±0.00262	655±333	38.949±0.512	15.752±0.092	18.882±0.338	-1.8±4.5	-8.0±3.2
Sanauli	0.71841±0.00165		39.467±0.072	15.816±0.008	19.371±0.044		

[1] very small sample size (n≤3)

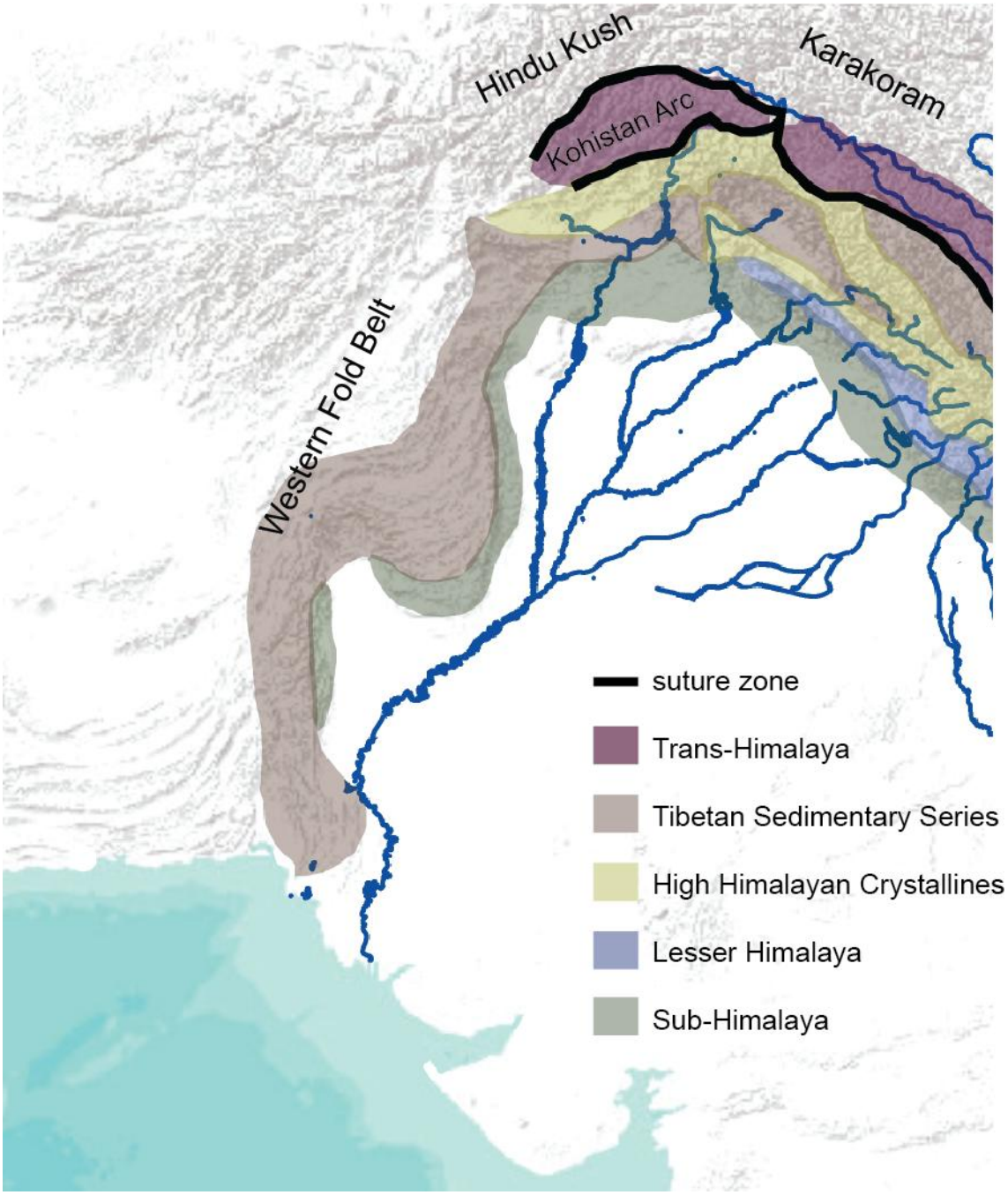

Figure 4-1. Himalayan geology. [adapted from Critelli, S. and Garzanti, E. 1994. Provenance of the Lower Tertiary Murree Redbeds (Hazara-Kashmir Syntaxis, Pakistan) and Initial Rising of the Himalayas. Sedimentary Geology 89(3-4):265-284 (Page 266, Figure 1)]

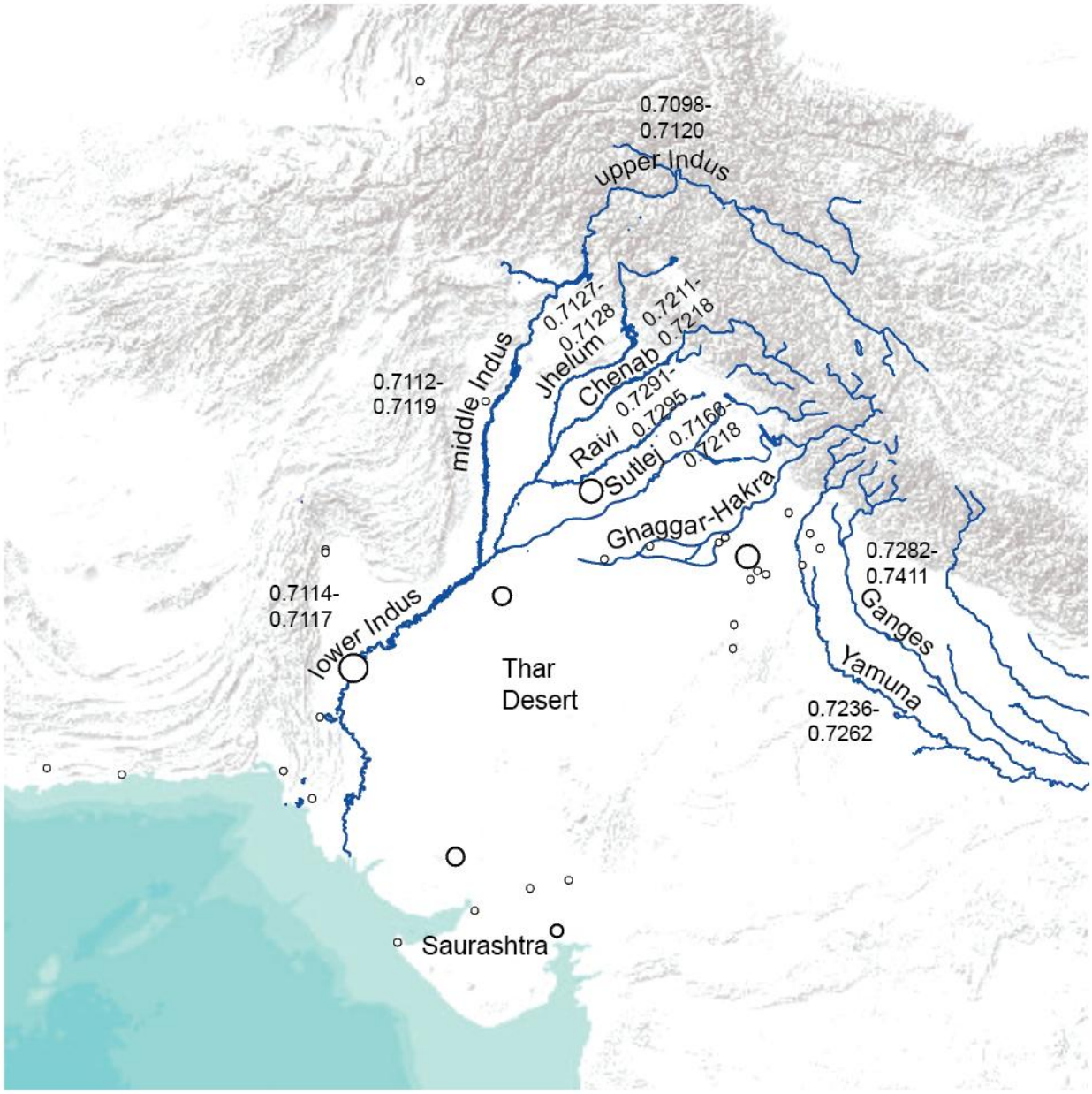

Figure 4-2. Riverine $^{87}Sr/^{86}Sr$ ranges [data from Krishnaswami, S., J. R. Trivedi, M. M. Sarin, R. Ramesh, and K. K. Sharma 1992. Strontium Isotopes and Rubidium in the Ganga-Brahmaputra River System: Weathering in the Himalaya, Fluxes to the Bay of Bengal and Contributions to the Evolution of the Oceanic 87Sr/86Sr. Earth and Planetary Science Letters 109(1-2):243-253 (Page 246, Tables 1 & 2); Pande, K., M. M. Sarin, J. R. Trivedi, S. Krishnaswami, and K. K. Sharma 1994. The Indus River System (India-Pakistan): Major Ion Chemistry, Uranium and Strontium Isotopes. Chemical Geology 116(3-4):245-259 (Page 255, Table 4); Karim, A. and J. Veizer 2000. Weathering Processes in the Indus River Basin: Implications from Riverine Carbon, Sulfur, Oxygen, and Strontium Isotopes. Chemical Geology 170(1-4):153-177 (Page 158-160, Table 1); Dalai, T. K., S. Krishnaswami, and A. Kumar 2003. Sr and 87Sr/86Sr in the Yamuna River System in the Himalaya: Sources,

Fluxes, and Controls on Sr Isotope Composition. Geochimica et Cosmochimica Acta 67(16):2931-2948 (Page 2936-2937, Table 1); Chakrapani, G. J. 2005. Major and Trace Element Geochemistry in Upper Ganga River in the Himalayas, India. Environmental Geology 48(2):189-201 (Page 197, Table 4)]

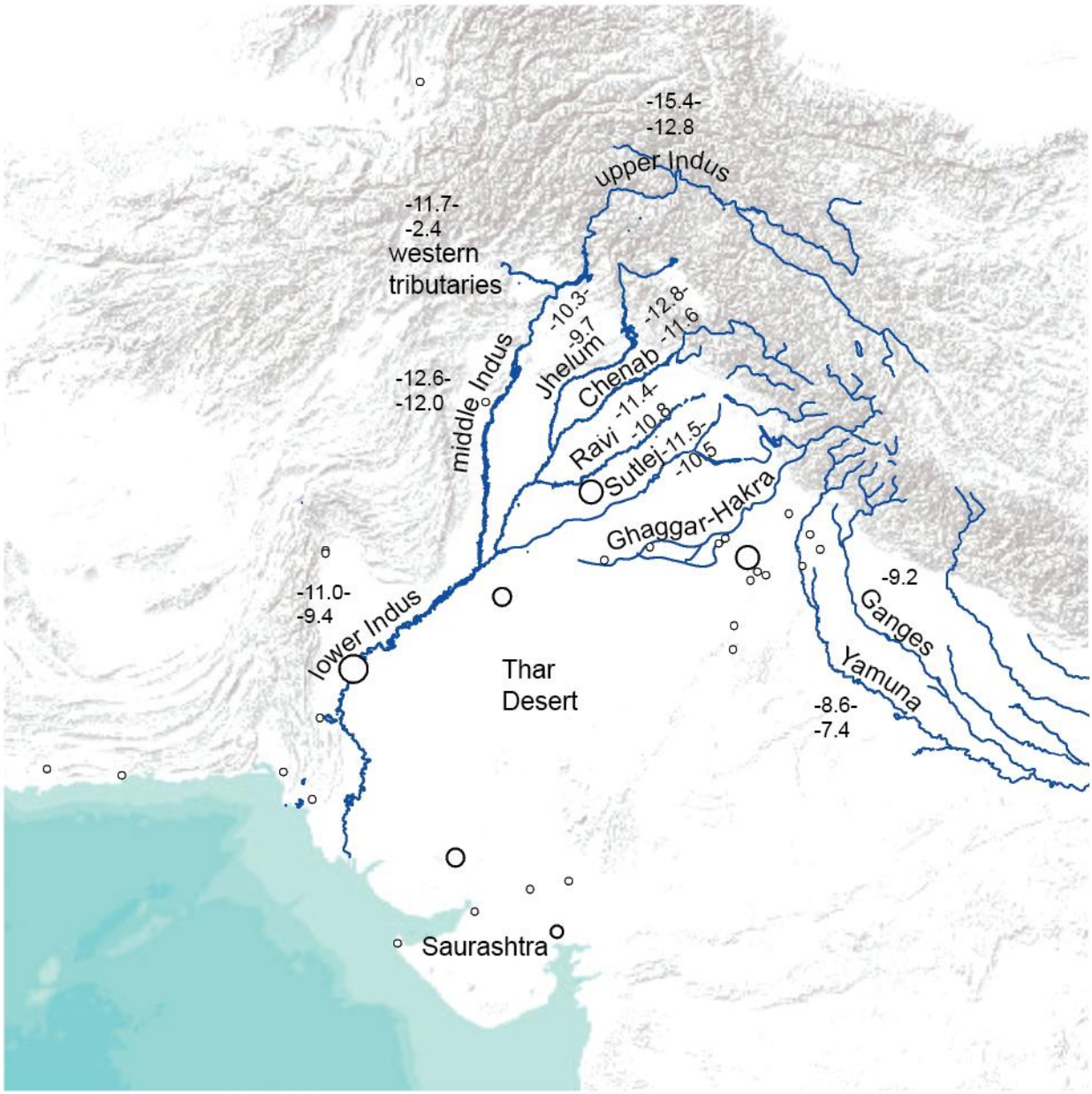

Figure 4-3. Summer riverine $\delta^{18}O$ ranges [data from Ramesh, R. and M. M. Sarin 1992. Stable Isotope Study of the Ganga (Ganges) River System. Journal of Hydrology 139(1-4):49-62 (Page 54-55, Table 1); Dalai, T. K., S. K. Bhattacharya, and S. Krishnaswami 2002. Stable Isotopes in the Source Waters of the Yamuna and its Tributaries: Seasonal and Altitudinal Variations and Relation to Major Cations. Hydrological Processes 16(17):3345-3364 (Page 3350-3351, Table 1); Karim, A. and J. Veizer 2002. Water Balance of the Indus River Basin and Moisture Source in the Karakoram and Western Himalayas: Implications from Hydrogen and Oxygen Isotopes in River Water. Journal of Geophysical Research: Atmospheres 107(D18):4362 (Table 1)]

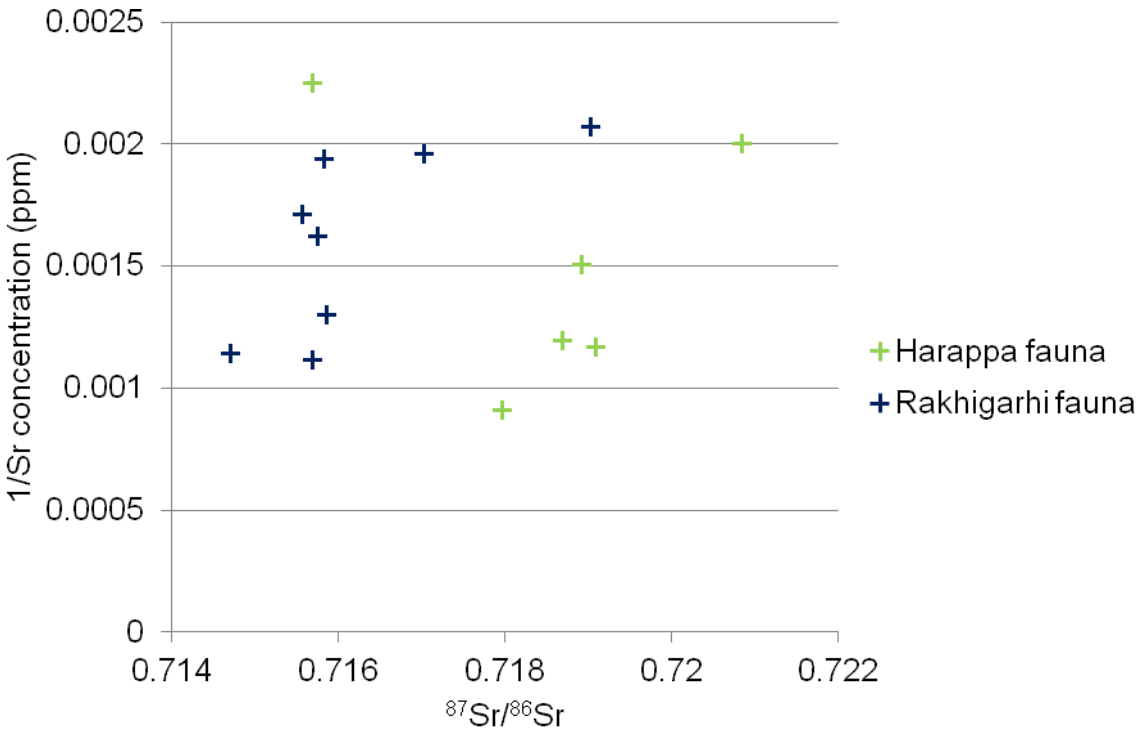

Figure 4-4. Baseline samples in Sr-Sr space—reciprocal of Sr concentration

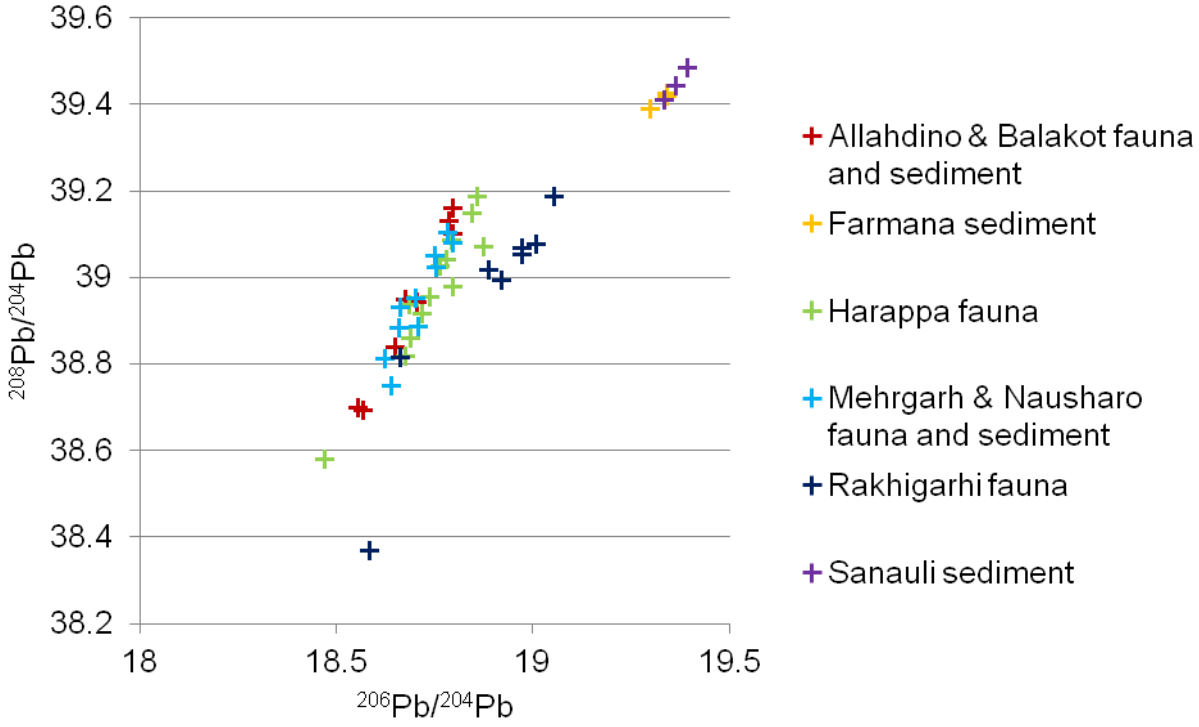

Figure 4-5. Baseline samples in Pb-Pb space—$^{208}Pb/^{204}Pb$

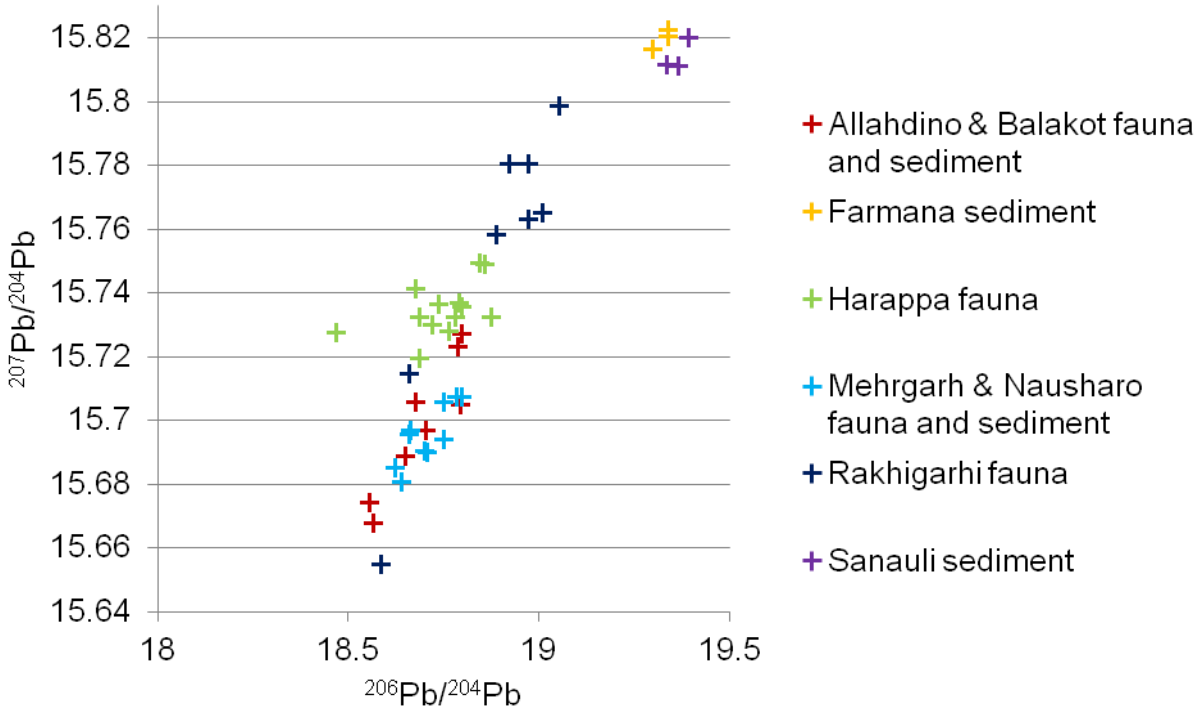

Figure 4-6. Baseline samples in Pb-Pb space—$^{207}Pb/^{204}Pb$

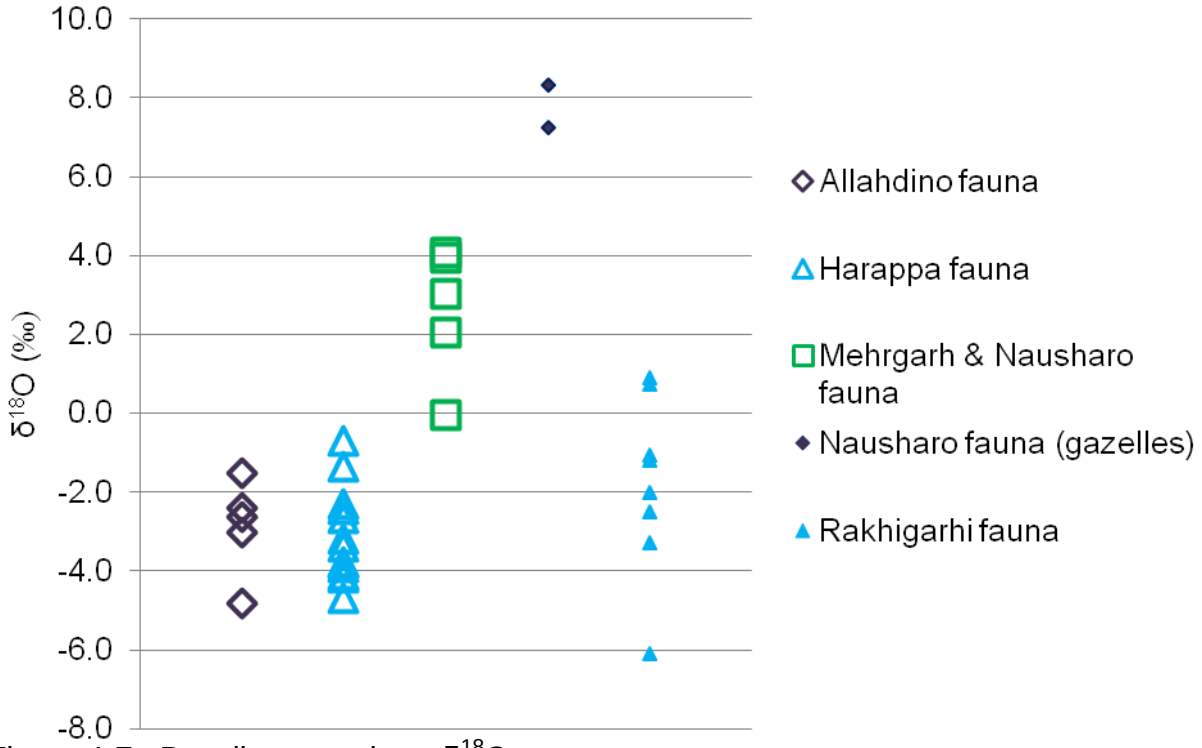

Figure 4-7. Baseline samples—$\delta^{18}O$

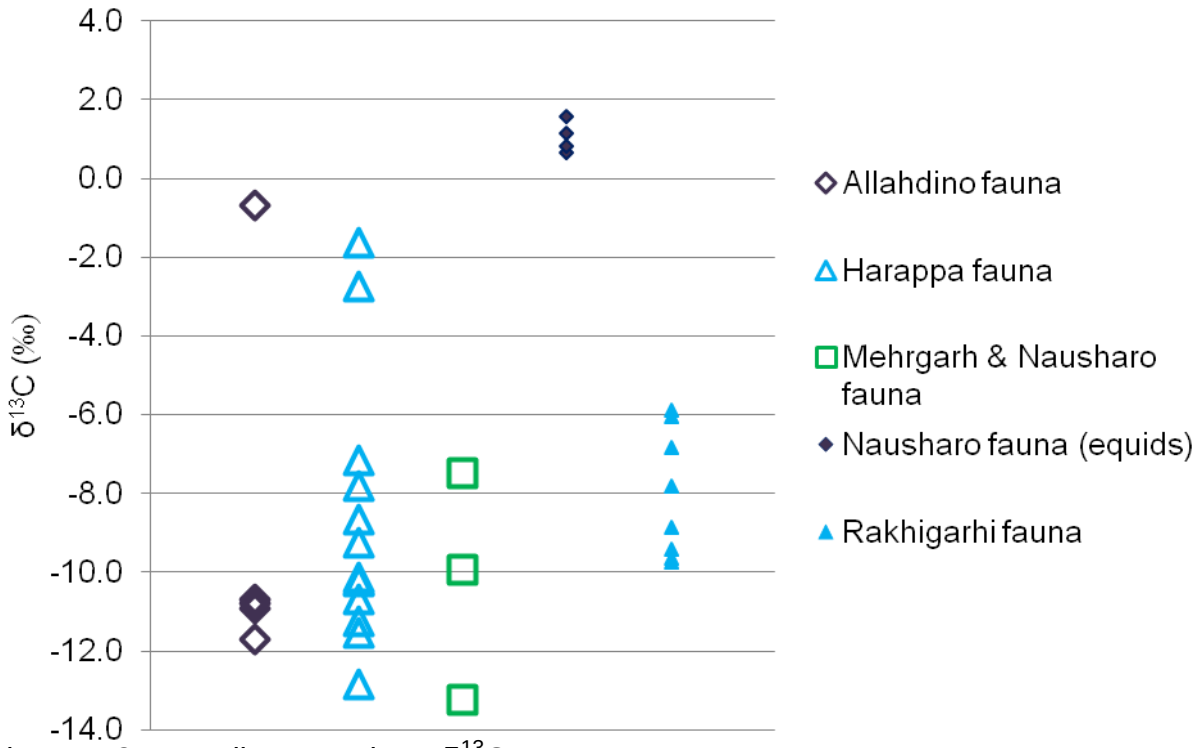

Figure 4-8. Baseline samples—$\delta^{13}C$

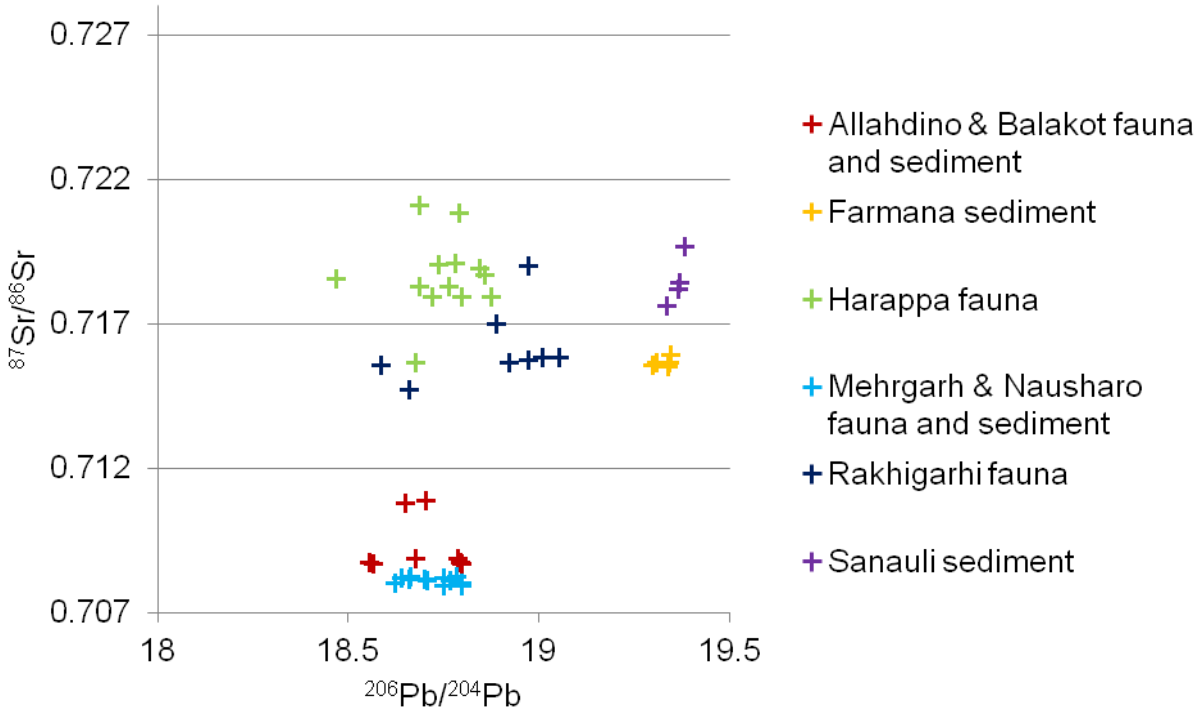

Figure 4-9. Baseline samples in Pb-Sr space—$^{87}Sr/^{86}Sr$

CHAPTER 5
FARMANA

The site of Farmana is located in the modern Indian state of Haryana among the easternmost regions of Indus settlements. The site sits ~30 km off the Chautang River, a now dry tributary of the seasonal Ghaggar River. The site occupied a strategic position between the urban center that is Rakhigarhi and the highlands of the Aravalli Range to the south. The entire region is part of the interfluve between the Indus and Ganges basins, and as such has distinct ecologies and geochemical makeup. The local sediments are largely a product of alluvial deposition through drainage of the Lesser Himalayas to the north and aeolian input from the Thar Desert to the southwest. The Thar Desert is similarly alluvial in nature, but derives primarily from the Indus River, and therefore helps differentiate the southern Ghaggar basin from the northern areas (Thussu 1995).

Archaeologically, the entire region is noteworthy for a high concentration of Indus Civilization sites during the Integration Era (2600-1900 BC), after which declining monsoonal precipitation may have spurred eastward and northward migration towards relatively more wet and stable ecological zones (Giosan et al. 2012). Indus tradition deposits at Farmana date to ca. 2500-2200 BC, suggesting residents lived during a period with ready access to water (Paleo-Labo AMS Dating Group 2011). Their precise water management practices, however, remain uncertain. There is scarce evidence within the Indus Civilization for large-scale irrigation canals and people likely relied on a range of practices including rain-fed or inundated fields supplemented by small-scale extension canals and well or lift irrigation (Miller 2006b). At Farmana, surface collection of several burnt wedge-shaped bricks typically used in well construction hint at the latter

method, but streams and lakes may have contributed to the local water supply as well (Shinde 2011b).

The ecological setting suggests an environment amenable to isotopic comparisons with other contemporary sites. For example, there is nothing to suggest that water sources at Farmana were inordinately exposed to evaporative processes, thereby exhibiting disproportionately high $\delta^{18}O$ relative to that of local precipitation. Further, the scale of variation in geological features is suitable to questions of interregional mobility. Whether immigrants came from the Aravallis, the Thar Desert, the Indus tributaries to the west, the Himalayan piedmont, or the Yamuna and Ganges to the east, there is every reason to expect that their non-local origins will be reflected in geochemical data derived from tooth enamel apatite. Though much future work is needed to fully characterize isotopic variation within the region, the Farmana environment is well suited to archaeological investigation using isotopic methods.

Further, archaeological evidence from three consecutive field seasons of excavation at Farmana (2006-2009) (Shinde et al. 2008a; Shinde et al. 2008b; Shinde et al. 2011a) offers an important comparison against relatively comprehensive archaeological records at major urban centers. Archaeologists increasingly acknowledge that so-called peripheral areas often serve as dynamic cultural frontiers and regions in which individuals of diverse backgrounds are most likely to interact. In a frontier, the social milieu of evolving relationships conditions the processes of acculturation and ethnogenesis relevant to the cultural politics of modern nation-states (Lightfoot et al. 1998; Stein 2002; Naum 2010). Farmana sits near the eastern limit of the Indus Civilization site distribution and as such, is a vital source of data for

understanding how these processes operated in the context of ancient urbanized polities. Given the sites proximity to mineral-rich highlands and sites of other cultural traditions (e.g., Ganeshwar-Jodhpura phase), it can be hypothesized that Farmana served as a kind of outpost in which material (and therefore cultural) exchange regularly took place (Shinde 2011b). The likelihood that people regularly moved materials through Farmana invites a fuller investigation of how people themselves migrated into the site during its occupation. The strontium, lead, carbon, and oxygen isotope values and strontium concentrations presented in this chapter provide compelling evidence for consistently patterned migration among those individuals in the excavated mortuary population with preserved tooth enamel. A review of the archaeological context is needed, however, to better understand the significance of the isotopic data. This chapter summarizes the results of excavation in the habitation area and the cemetery followed by a presentation of the biogeochemical data derived from human tooth enamel.

Habitation Area

The habitation area at Farmana is made up of a single mound spread over 18 ha, a relatively large area given that the vast majority of Integration Era sites are less than 5 ha in size (Possehl 2002b; Shinde 2011b). It is clear from size alone that Farmana must have been viewed as a relatively significant place on the Indus landscape. Unfortunately, active use of the surrounding agricultural lands has destroyed more recent archaeological deposits postdating 2300 BC and may have destroyed additional material in the peripheral portions of the site that could provide a more precise estimate of settlement area. Though modern land use has complicated work on more recent archaeological material at Farmana, excavators have described twelve stratigraphic

layers of anthropogenic deposits that show the culture history of typical Indus traits at the site.

For example, the earliest strata document the use of a round pit feature that likely had a wooden superstructure along with three pots of what Shinde (Shinde 2011c) labeled the Hakra phase. Similar pit structures have been documented at the nearby sites of Bhiranna (Rao et al. 2004), Girawad (Shinde et al. 2011b), and Kunal (Khatri and Acharya 1995) in contexts that suggest they were used for domestic purposes. Shinde (2011c) regarded these founding deposits as Early Harappan, in part because they immediately precede strata containing typical Harappan, or Integration Era, materials and architecture such as a grid layout of buildings composed of mud bricks formed with the characteristic proportions of 1:2:4. Further, Hakra ceramics are known to occur in pre-urban contexts, although the use of the term Hakra requires additional clarification. Shinde's holistic culture history is internally consistent but terminologically complicated by the lack of coordination across the India-Pakistan border. Shaffer's (1992) and Possehl's (2002b) chronologies use Hakra, as exemplified in the work of Mughal (1997), to indicate the pottery phase preceding Kot Diji ceramics of the Early Harappan period in Cholistan. Across the border in the contiguous regions of the Ghaggar basin that include Farmana, variation in Early Harappan ceramic styles has led to the designation Sothi-Siswal. Neither Shaffer's nor Possehl's chronologies regard the Hakra phase as diagnostic of the Early Harappan. In a pointed effort to disentangle the Indus culture history nomenclature, Kenoyer (2011b) suggested that Hakra legitimately refers to the Early Harappan period but that the term has been applied so broadly as to obscure the interregional differences and interactions so critical to understanding the

incipient development of integrated urbanism during the Regionalization Era. Sharing a concern for regional differences, Uesugi (2011b) noted in his alternative chronology of the Farmana ceramic assemblage that there are close similarities between regional styles of pottery and the Sothi-Siswal phase. Though Shinde and Uesugi use different methods and reach different conclusions about Farmana chronology, both observe the persistence of regional ceramic styles alongside the Harappan phase ceramics—pottery commonly associated with urbanization and the Integration Era. Uesugi specifically suggested that no particular trend in the frequencies of Harappan versus non-Harappan types could be observed either vertically or in different excavation areas. However, potential mixing of the strata and incomplete stratigraphic sequences in certain excavation areas as a consequence of modern agricultural activity at Farmana complicates any relative chronology. As a result, statements about the cultural sequence need to be used cautiously and tested through further excavation at undisturbed areas of the site (Kenoyer personal communication). Therefore it is unclear whether Uesugi's interpretation of the horizontal and stratigraphic distribution of pottery types reflects the pre-taphonomic reality.

Despite uncertainties within the Farmana culture history, the different pottery styles identified at the site broadly corroborate the radiocarbon dates in suggesting that the surviving cultural deposits formed over a few hundred years. Harappan and regional styles are found in significant quantities, making it clear that Farmana residents had external interactions at the regional and Greater Indus scales. Harappan pottery is defined in part by its formal similarities to types described at Mohenjo-Daro along the lower Indus Valley (Marshall 1931; Mackay 1938; Dales and Kenoyer 1986a) and

Harappa along the upper Indus Valley (Wheeler 1947; Jenkins 1994). Further, Harappan pottery is thrown entirely using fast wheel rotation and its painted motifs, when present, are distinctive. Non-Harappan pottery consists of styles with a more limited regional distribution and a smaller range of vessel forms. The painted motifs are distinct from those of Harappan ceramics and various technical features including an appliqué ring base and discontinuous striations suggest greater use of hand molding methods (Uesugi 2011b).

A host of artifacts made of exotic materials further attest to Farmana residents' participation in interregional networks (Konasukawa et al. 2011). Beads and bangles are made of a range of locally unavailable materials including marine shell, fired steatite, carnelian, copper, and gold. Administrative technologies such as diagnostic chert weights and typical Indus seals and sealings emphasize the site's incorporation into broader Indus urbanism. Even the ubiquitous triangular terracotta cake implies the use of classic Indus pyrotechnology, and the architectural context is similarly indicative of Integration Era habitation. The rectangular, multi-room, mud brick complexes contain central courtyards and orient along a grid plan of streets—all features of the Integration Era. Interestingly, differences in the quality of architecture may suggest differential access to labor or material by different groups. Certainly the wide variety of local and non-local materials used to craft common forms of jewelry suggests a hierarchy of value consistent with social inequality.

Even the diversity of foodstuffs discovered in the archaeobotanical analyses (Sugiyama 2011; Weber et al. 2011) suggests the possibility that dietary choices may have been guided in part by group affiliation. The overall assemblage of plants revolved

around cereals and pulses and incorporated both summer and winter crops. Rice is absent, but there is combined use of Southwest Asian cereals like barley and wheat with indigenous millets. By dividing the botanical sample into two groups representing upper strata and lower strata, Weber and colleagues inferred a decrease in wheat and barley through time that could have resulted from decreasing winter rains. They also recovered direct evidence for consumption of millets, barley, and gram in dental calculus from a small sample of human teeth.

To summarize, various lines of evidence confirm the fact that Farmana was part of the larger Indus Tradition from the outset, contributing to regional identity in the early phases and eventually integrated into the Harappan Phase by around 2600 BC. Though chronology remains imprecise, very broad trends appear in comparisons of the earliest and latest strata. The first residents likely lived in pit dwellings and used Early Harappan material culture, but those Early Harappan strata are immediately succeeded by typically urban Integration Era architecture suggesting cultural transformation rather than abandonment and resettlement. Additionally, documentation of Early Harappan assemblages across the Greater Indus region shows that the Early Harappan period is the evolutionary forebear of Harappan period urbanism (e.g., Kenoyer and Meadow 2000; Bisht 1997; Nath 1998; Nath 2001). Change at Farmana is not limited to ceramics and architecture, however. Archaeobotanical evidence suggests decreased reliance over time on cereals of Southwest Asian origin such as wheat and barley. This may have resulted from changing patterns of precipitation, such that climatic and dietary changes should register in carbon and oxygen isotope values of human dental enamel.

The diversity of raw materials and foodstuffs at Farmana also suggests possible behavioral elements of social differentiation. This aggregate view of variability at Farmana may actually encompass different lifeways of different social groups, raising the question of how representative the mortuary sample is of the population at large. A clearer understanding of mortuary variability is needed to determine precisely how the bioarchaeological data relate to trends inferred from the habitation area.

Cemetery Area

The Farmana cemetery is located ~900 m northwest of the habitation area, and like the settlement itself, is disturbed by agricultural activity (Shinde 2011a). The excavated area covers less than 1 ha although initial surveys suggest the entire cemetery may cover ~3 ha. It was excavated over two seasons (Shinde et al. 2008b, 2011) after having been accidentally discovered in the 2007-2008 season. The excavators discovered 70 burials, 58 of which were fully excavated by the end of the 2008-2009 field season. The graves were readily identified by their darker backfill, and it is clear that all of the burials were fully surveyed in the excavation area measuring 35x21 m^2.

As at the habitation area, the relative chronology for the cemetery remains problematic. Shinde (2011a) placed the burials into three periods, the Early (2A), Middle (2B), and Late (2C) phases of the Mature Harappan Period (2600-1900 BC), whereas Uesugi (2011a) divided the burials across four sequential phases between ca. 2500-2200 BC (Table 5-1). Further, there is substantial disagreement between the two approaches to seriation of pottery resulting in incompatible chronologies. Problematically, the burials at Farmana cannot be linked stratigraphically or across space because the overlying strata that would show where the burial pits are located

were removed by later agricultural activity. This makes it impossible to determine their precise chronological relationships. The widely different results from the two attempts at periodization suggest that pottery is not necessarily the best way to seriate the graves except at a very broad level of earlier and later (Kenoyer personal communication). For this reason, the isotopic mortuary analysis of Farmana will treat the mortuary sample as a single chronological population.

Unfortunately, similar logic precludes the reliable use of biological sex in the mortuary analysis. Preservation of the Farmana skeletal remains was extremely poor, resulting in highly friable material that retains few reliable osteological indicators of sex. Osteological assessment of the material using the methods of Buikstra and Ubelaker (1994) was followed with only a handful of cranial traits scored for any given individual. Many diagnostic regions were represented by sections of bone that were fractured, deformed, heavily eroded or otherwise damaged through generally poor preservation. A more thorough analysis was performed by the Deccan College Post-Graduate and Research Institute Biological Anthropology Lab that resulted in different sex assignments (Table 5-1) (Mushrif-Tripathy personal communication). Given the poor sample preservation and high inter-observer error, the most conservative approach is to ignore biological sex as a category in the Farmana mortuary analysis. The relatively better preservation of tooth enamel, however, aided in age estimations. Distinctions between adults and sub-adults were made for all sampled individuals, and conservative sub-adult biological age ranges can be inferred based on enamel formation times and tooth eruption sequences (Table 5-1) (Hillson 1996; Reid and Dean 2006). Though the sample size is modest, the lack of individuals younger than two years old suggests that

infants were not included in the program of inhumation. Because not all skeletal elements exposed by the excavators were preserved for curation, photographic documentation of all 58 burials provides an additional, albeit less precise, line of evidence suggesting that infants were not buried in the Farmana cemetery (Shinde et al. 2008b; Shinde 2011a).

Inhumations are surprisingly scarce throughout the Indus Civilization and formal cemeteries even more so. As is the case for most Integration Era cemetery-based inhumations, the Farmana graves are rectangular pits oriented around a north-south axis (Shinde 2011a). The basic burial program remained the same throughout the life of the cemetery and included many of the elements common to most Integration Era cemeteries. Skeletal remains are deposited in primary and secondary contexts with the cranium towards the north end of the grave, abutting a variable number of ceramic vessels. Primary inhumations lie extended and supine and sometimes are adorned with a small number of personal ornaments or other seemingly minor artifacts. Not all burials contain skeletal remains, but most such symbolic burials or cenotaphs contain ceramics arranged in similar ways. Lastly, a few graves have an additional clay lining. The intermittent use of containment features such as wooden coffins and clay or brick linings has been noted at other Integration Era cemeteries like that of Harappa (Dales and Kenoyer 1989a). In short, the Farmana burials seem to conform to a broader tradition of Integration Era mortuary practice that was consistently reserved for a minority of the population.

Mortuary variation for each burial is discussed in detail by Shinde (2011a), and therefore only a summary of the differences in mortuary treatment at Farmana is

presented here. The quantity of ceramics is broadly comparable to that of other sites with an average of 7 pots per burial and a maximum of 27. Five burials had more than 21 pots and twelve burials had no pots, although it is not always clear whether or not pots were removed or destroyed through post-depositional activity. Further, the majority of burials have mixed ceramic assemblages consisting of Harappan and regional non-Harappan types. Only six burials have exclusively non-Harappan types, and ten burials have exclusively Harappan types. Within the isotopic mortuary sample, these include burials 52, 66, and 67 for non-Harappan vessels and burials 18, 20, and 23 for Harappan vessels (Table 5-2). Harappan types are distinguished by the exclusive use of fast wheel rotation, distinct forms, more finely tempered and levigated clay and flat bottoms. By contrast, non-Harappan ceramics are generally more variable in terms of production methods including a greater variety of surface treatments and burnishing techniques. A handful of burials contain painted non-Harappan vessels, including burials 39 and 65 in the isotopic mortuary sample. There is no obvious structure in terms of pottery within the mortuary sample as burials containing predominantly Harappan or non-Harappan types both exhibit variation in skeletal age, orientation, presence or absence of clay linings, and personal ornamentation. The overall impression is that mortuary variation was randomly distributed within a culturally prescribed spectrum.

For example, some burial pits are lined in clay, including burials 26, 52, 53, 54, 58, 62, 64, and 67 (Table 5-1). The orientation of the pit varies slightly around a NNW-SSE axis with a few oriented along a NE-SW axis including burials 20 and 65. Some burials contain additional items like jewelry made of shell, copper, or semi-precious

stones, but no single burial is particularly ostentatious (Table 5-2). Within the osteological sample, beads of semi-precious stones or steatite are associated with burials 1, 3, 14, 20, 26, 41, 47, 50A, and 65. Some individuals, including both adults and subadults, are adorned with one or more copper bangles (burials 5, 20, 41, 50B and 52), and four individuals (adult and subadult) are wearing shell bangles (burials 3, 20, 50B, and 65). Burial 20, one of the more heavily ornamented individuals, also has copper bangles, a copper earring, and the aforementioned microsteatite beads. Lastly, burials 14, 32, and 34 are associated with bone and shell tools.

There may be an association between the quantity of items and grave orientation. Three total burials are oriented along a NE-SW axis, and one of these, burial 20, is well adorned in jewelry. Burial 65 has no jewelry but does have 22 pots, a fairly large number for the Farmana assemblage. Burial 22, which is not represented in the osteological sample, is also oriented NE-SW but has only ten pots and a bivalve shell. These three individuals are all above average in terms of the quantity of grave goods, and atypical grave orientation may have been exploited to accentuate their differences from other individuals. However, with only three data points and the presence of more elaborate burials among the conventionally oriented graves, this trend remains inconclusive. In general then, there is relatively little systematic differentiation among the Farmana burials. Certainly there is variability, but it does not appear to be consistently patterned across multiple media in a way that indicates groups of individuals are qualitatively distinct from each other. The overall impression from the mortuary program is that individuals are inhumed largely on the basis of their similarities with less concern for their differences.

Finally, the distribution of burials is somewhat haphazard with five instances of crosscutting and overlapping grave shafts. This tendency has been observed at Harappa, leading Kenoyer (1998) to suggest that those who dug the burial pits belonged to a separate ethnic group or otherwise did not identify with the deceased. The modern grave backfill is starkly visible against the surrounding soil, which supports the idea that there was a general disregard for older burials, although the visual contrast may have been less apparent more than four millennia ago. Nevertheless, given the similarities with Harappa, the spatial disorganization and crosscutting suggests that inhumation was a relatively short-term affair with little emphasis on enduring commemoration. The situation at Farmana is consistent with the possibility that the inhumed constituted a different kind of person who inspired little deference among those responsible for carrying out the mortuary program.

In summary, the mortuary program at Farmana indicates a degree of social distance between the dead and the living and relatively less distance between those who were inhumed. Whatever their individual differences, the inhumed were treated as a socially distinct group that required a specific and extremely uncommon form of mortuary treatment. Further, the mortuary variability fails to show a consistent and repeated pattern of differentiation within the mortuary population as a whole. Though some of the dead (or those who mourned them) might have held positions of relative prestige, the differences between individual inhumations appear subordinate to the overall impression of similarity. Taken together, the mortuary context is consistent with the possibility that the act of inhumation referenced a shared and in some ways socially distinct group identity that had been lived by the deceased.

Results of the Analyses

Isotopic data and Sr concentrations resulting from the analyses are presented in Table 5-3. Values of $^{87}Sr/^{86}Sr$ range from 0.71529 to 0.72038 with Sr concentrations from 246 to 1388 ppm. Lead isotope ratios also exhibit heterogeneity with $^{208}Pb/^{204}Pb$ from 36.279 to 39.431, $^{207}Pb/^{204}Pb$ from 15.572 to 15.823, and $^{206}Pb/^{204}Pb$ from 16.506 to 19.311. Tooth enamel yielded $\delta^{18}O$ of -5.0 to -2.1‰ and $\delta^{13}C$ of -12.0 to -6.8‰. Means and standard deviations are presented for each tooth cohort in Table 5-4.

Only isotope ratios of Sr and Pb were obtained for the acid leachates of sediment samples as Sr concentrations and light stable isotope values from soils are irrelevant to the objectives of this dissertation. Recall from Chapter 3 that the only available faunal material at the time of sample collection was from the Rakhigarhi material curated at Deccan College Post-Graduate and Research Institute. Therefore the eight analyzed samples of pig enamel are more representative of the geochemistry in the dietary catchment of Rakhigarhi located ~30 km northwest of Farmana. Regardless, the faunal and leachate data are quite similar and together constitute the available proxy for local isotope values at Farmana.

During human tooth enamel sampling, some samples were taken from deciduous or incompletely mineralized teeth (burials 5, 15, and 52) to assess the likelihood of diagenesis relative to fully mineralized enamel from permanent dentition. Because of visual or quantitative observations, the data from these samples were disregarded. Note that human enamel samples from burials 5 and 52 are from deciduous dentition. The enamel structure of deciduous teeth is known to be less regular with larger crystals than that of permanent dentition and presumably more susceptible to diagenesis. Because of the very high Sr concentration and the close overlap between sample 5 and the

sediment leachates, this sample is regarded as contaminated and is disregarded in the subsequent presentation and discussion of data. Even though sample 52 does not have similar values to the sediment leachates, the possibility remains that an unquantifiable degree of diagenetic alteration has occurred and so the data from this burial are also rejected. Sample 15 was an extremely thin slice of incipiently mineralized cusp tips, and it was observed to begin dissolution in the 0.1N acetic acid solution used for pretreatment. Therefore it is assumed that the natural pH of the burial environment could also have contributed to alteration of isotopic values. Consequently, data from sample 15 are also rejected.

The data from sample 39 must also be disregarded because of indeterminate molar position. At the time of sampling, it was anticipated that if there were any meaningful differences in isotope values across teeth for the same individual then it was most likely to occur in later childhood, just prior to full mineralization of the third molar. However, given the interpretive significance of differences in first and second molar isotope values, the data from sample 39 must be excluded from this analysis. They may still be relevant to other research questions, but they cannot resolve the patterns of early childhood migration that turned out to be so significant to this isotopic mortuary analysis.

Lastly, light stable isotope values for samples 18-3 and 67-2 could not be obtained because of small sample size. After the removal of dentine in preparation for pretreatment and analysis, the remaining amount of enamel was smaller than initially apparent on visual inspection. Given the priority of heavy isotope data over light isotope data for studies of mobility and the larger sample size requirements for heavy isotope

analysis, it was decided to use the entire sample for Sr and Pb isotope analysis to maximize the likelihood of acquiring useful data.

Strontium isotope data are first presented in comparison with 1/Sr concentration following the method of Montgomery and coworkers (2007) (Figure 5-1). Even where Sr isotope ratios for a given region are very similar because they are heavily influenced by a single environmental source, concentration data can be used to infer location along an environmental Sr mixing line between two sources. The data in Figure 5-1 likely indicate a relatively radiogenic endmember with low Sr concentration and a high concentration endmember with low $^{87}Sr/^{86}Sr$. The dataset appears unstructured with regard to tooth type as first, second, and third molar cohorts have similar values.

Unlike the Sr isotope data, the Pb data show much more pronounced systematic variation by tooth type (Figures 5-2 & 5-3). There may also be a simple mixing system at work between a less radiogenic source and a more radiogenic source. The striking pattern, however, is the clustering of first molar values away from second and third molar values. There is also fairly good correlation between third molar values and the approximate intersection of Farmana sediment leachates and Rakhigarhi faunal enamel.

Oxygen isotope values show a clear trend based on tooth type (Figure 5-4). First molar mean $\delta^{18}O$ (-2.7‰ ± 1.2 [2σ]) is higher than that of second (-3.5‰ ± 1.4 [2σ]) ($t(18) = 2.618$, $p = 0.017$) or third molars (-3.7‰ ± 1.5 [2σ]) ($t(17) = 3.019$, $p = 0.008$), whereas no significant difference exists between second and third molar cohorts. A change in water source for the individuals in the study samples occurred largely between first and second molar mineralization times. Because tooth enamel formation

times are standardized across populations with a species, this means the change in fluid uptake occurred around the chronological age of three.

Carbon isotope values differ from those of Pb and O in that they do not change significantly with age (Figure 5-5). There is a fair amount of variation in the relative contribution of C_3 and C_4 foods at the population level ($\delta^{13}C$ range = 4.7‰), but this variation is not systematically correlated with tooth type. The means for first, second, and third molars are -10.1‰ ± 2.3 (2σ), -10.1‰ ± 1.7 (2σ), and -10.1‰ ± 2.6 (2σ) respectively. In other words, there is variation in the diets of individuals, but the relative contribution of C_3 and C_4 foods is not a factor of life history.

Lastly, plotting isotope ratios of Pb against those of Sr increases the discriminatory power of the two isotope systems and shows the differences within and between tooth types more clearly (Figure 5-6). Figure 5-6 shows a clustering of third molar values near the intersection of Farmana sediment leachates and Rakhigarhi faunal enamel. Second molar data substantially overlap with third molar data but have a slightly greater range, therefore indicating a small contribution of environmental Pb and Sr from less radiogenic sources early in the mineralization process. First molar data plot apart from other tooth types.

The isotope data clearly detail a change in environmental sources of Pb and O through time. In general, there is a convergence through time towards the sediment leachate and faunal isotope values suggesting that most individuals shared a common geochemical environment (i.e., Farmana) by late childhood. Most of the change seems to occur within an environment of fairly homogenous Sr sources, although some individuals are exposed to fairly radiogenic strontium sources throughout childhood.

There is very little change in $\delta^{13}C$ by tooth type suggesting that, throughout childhood, individuals consumed similar types of food with respect to C_3 and C_4 vegetation. The isotope data will be interpreted with regard to human behavior in Chapter 8 at which point all isotopic and mortuary data will be synthesized.

Table 5-1. Chronology, demographic data, and mortuary treatment at Farmana

Burial No.	Period[1]	Phase[2]	Sex[3]	Sex[4]	Age	Burial Type	Harappan Pot Qty.	Non-Harappan Pot Qty.	Orientation	Clay Lining
1		4		M	adult	primary	23		N-S	absent
2			F	F	adult	primary			NW-SE	absent
3		4			subadult	secondary	3		N-S	absent
5					2-6	secondary			NW-SE	absent
6		2	F	F	adult	secondary	15	1	NW-SE	absent
8	2C	2		M	adult	primary	2	4	NW-SE	absent
10	2C	2		F	adult	primary	3	6	NW-SE	absent
11	2C	3		M	adult	primary	3	1	NW-SE	absent
14	2B		F	M	adult	primary			NW-SE	absent
15	2C				2-4	secondary	1	1	NW-SE	absent
18	2C	4	F	F	adult	primary	7		N-S	absent
20	2C	1	F	F	adult	primary	2		NE-SW	absent
23	2B	3			12-18	primary	9		N-S	absent
25	2C	4		M	adult	secondary	8	8	N-S	absent
26	2C	4	F	F	adult	primary	1	1	NW-SE	present
28	2A	1			subadult	primary	8		N-S	absent
32	2A	3		F	adult	primary	21	5	NW-SE	absent
34	2C	4		M	adult	secondary	1	8	N-S	absent
39A	2B	2		F	adult	secondary	10	6	N-S	absent
39B	2B	2		M	adult	secondary	10	6	N-S	absent
41	2C	4			5-9	primary	1	7	N-S	absent
45	2B				12-18	primary			NW-SE	absent
47	2C				5-9	secondary			NW-SE	absent
48	2B	3		M	adult	primary	1	9	NW-SE	absent
50A	2B	2		M	adult	primary	6	15	N-S	absent

[1] Shinde 2011a [2] Uesugi 2011a [3] Author's assessment [4] Mushrif-Tripathy personal communication

Table 5-1. Continued

Burial No.	Period[1]	Phase[2]	Sex[3]	Sex[4]	Age	Burial Type	Harappan Pot Qty.	Non-Harappan Pot Qty.	Orientation	Clay Lining
50B	2B	2		F	adult	primary	4	1	NW-SE	absent
52	2C				2-6	secondary		6	NW-SE	present
53	2C	4		F	adult	primary	3	7	NW-SE	present
54	2B	2	M	M	adult	primary	3	3	NW-SE	present
58	2B				adult	secondary			N-S	present
62	2C	3			9-14	primary	2	6	N-S	present
64	2C	1		M	adult	primary	12	1	NW-SE	present
65	2C	2			adult	primary	2	20	NE-SW	absent
66	2C		M	M	adult	secondary		1	N-S	absent
67	2C		F	M	adult	primary		1	NW-SE	present

[1] Shinde 2011a [2] Uesugi 2011a [3] Author's assessment [4] Mushrif-Tripathy personal communication

Table 5-2. Mortuary elaboration at Farmana

Burial No.	Pottery Qty.	Copper Bangles	Shell Bangles	Semi-Precious Beads	Steatite Ornaments	Other Items
1	23			3 carnelian, 2 copper	30 disc beads	
2						
3			1	1 agate		
5		2				
6	16					
8	6					
10						
11	4					
14				1 agate		2 bone tools
15	2					
18	7					
20	2	5	3		microbeads	1 copper earring
23	9					
25						
26	2			1 agate		
28						
32						1 shell spoon
34						3 bone tools
39A	16					
39B	16					
41	8	1		1 jasper		
45						
47				1 carnelian		
48						
50A					microbeads	

Table 5-2. Continued

Burial No.	Pottery Qty.	Copper Bangles	Shell Bangles	Semi-Precious Beads	Steatite Ornaments	Other Items
50B		1	3			
52	6	2				
53						
54	6					
58						
62	8					
64						
65	22		1	3 carnelian		
66	1					
67	1					

Table 5-3. Farmana mortuary sample—results of the analyses

Sample No.	Burial	Tooth	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
F2-1	2	LM_1	0.71529	1167	38.623	15.734	18.553	-3.9	-11.2
F2-2	2	LM_2	0.71529	1260	39.351	15.805	19.197	-4.5	-11.2
F2-3	2	LM_3	0.71541	1163	39.401	15.809	19.222	-5.0	-10.7
F5-d1[1]	5	Rdm[1]	0.71557	1206	39.431	15.818	19.311	-4.1	-10.0
F6-1	6	LM_1	0.71582	704	38.871	15.727	18.725	-3.3	-8.3
F6-2	6	LM_2	0.71584	778	39.200	15.775	19.118	-3.5	-9.5
F6-3	6	LM_3	0.71581	881	39.286	15.796	19.171	-3.7	-11.2
F11-2	11	LM_2	0.71581	881	39.351	15.803	19.233	-3.6	-10.9
F11-3	11	LM_3	0.71583	857	39.413	15.814	19.293	-3.4	-9.1
F14-1	14	RM^1	0.71551	1030	38.842	15.723	18.750	-2.4	-9.6
F14-2	14	LM^2	0.71549	971	39.315	15.786	19.218	-2.6	-8.8
F14-3	14	RM^3	0.71560	1072	39.211	15.783	19.195	-2.8	-10.6
F15-2[1]	15	RM^2	0.71574	1336	39.296	15.796	19.195	-2.3	-9.3
F18-1	18	LM^1	0.71589	758	38.133	15.679	18.166	-2.1	-9.4
F18-2	18	LM_2	0.71587	739	38.929	15.753	18.908	-2.6	-9.9
F18-3	18	RM_3	0.71578	702	39.044	15.766	19.028	[3]	[3]
F20-1	20	RM^1	0.71572	626	37.950	15.673	18.037	-2.3	-10.6
F20-3	20	RM^3	0.71571	630	39.041	15.775	19.020	-4.0	-10.4
F23-1	23	RM_1	0.71592	788	38.546	15.700	18.502	-2.6	-10.4
F23-2	23	RM_2	0.71584	984	38.871	15.741	18.842	-2.9	-9.9
F23-3	23	RM_3	0.71579	816	39.150	15.775	19.090	-3.6	-10.7

[1] enamel is deciduous or poorly mineralized [2] indeterminate molar position [3] insufficient sample for analysis

Table 5-3. Continued

Sample No.	Burial	Tooth	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
F26-2	26	RM^2	0.71589	542	39.387	15.801	19.896	-4.1	-10.3
F26-3	26	RM^3	0.71600	595	39.184	15.777	19.172	-3.6	-7.3
F39B-1/2[2]	39B	$RM_{1/2}$	0.71586	1061	39.249	15.785	19.192	-3.1	-6.8
F41-1	41	RM^1	0.71576	983	36.279	15.572	16.506	-3.1	-10.4
F45-p3	45	RP^3	0.71756	504	39.190	15.782	19.086	-4.5	-11.4
F47-p4	47	RP^4	0.71588	1388	39.148	15.773	19.075	-4.0	-10.4
F52-d2[1]	52	Rdm_2	0.71577	1016	38.252	15.705	18.315	-3.2	-9.8
F54-1	54	RM_1	0.71620	828	39.161	15.765	19.100	-4.9	-10.6
F58-2	58	RM_2	0.71570	933	38.975	15.744	18.903	-3.1	-9.1
F62-1	62	LM^1	0.71572	991	38.027	15.687	18.137	-2.7	-9.6
F62-3	62	LM^3	0.71590	820	39.280	15.797	19.204	-2.8	-9.3
F65-1	65	RM_1	0.71578	855	38.899	15.727	18.776	-2.3	-12.0
F65-2	65	RM_2	0.71588	814	39.086	15.757	19.010	-3.1	-9.6
F66-3	66	RM^3	0.71704	605	39.200	15.766	19.160	-4.7	-10.2
F67-2	67	LM^2	0.71975	342	39.228	15.798	19.299	[3]	[3]
F67-3	67	LM_3	0.72038	246	38.814	15.738	19.013	-3.0	-11.9

[1] enamel is deciduous or poorly mineralized [2] indeterminate molar position [3] insufficient sample for analysis

Table 5-4. Farmana mortuary sample summary statistics--mean±2σ

Cohort	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/204Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
All	0.71607±0.00210	861±515	38.935±1.189	15.757±0.100	18.908±1.104	-3.3±1.6	-10.0±2.3
1st molar	0.71571±0.00042	865±366	38.486±0.789	15.706±0.049	18.456±0.602	-2.7±1.2	-10.1±2.3
2nd molar	0.71623±0.00247	845±600	39.170±0.347	15.776±0.047	19.149±0.551	-3.5±1.4	-10.1±1.7
3rd molar	0.71630±0.00283	762±500	39.184±0.346	15.781±0.044	19.142±0.184	-3.7±1.5	-10.1±2.6

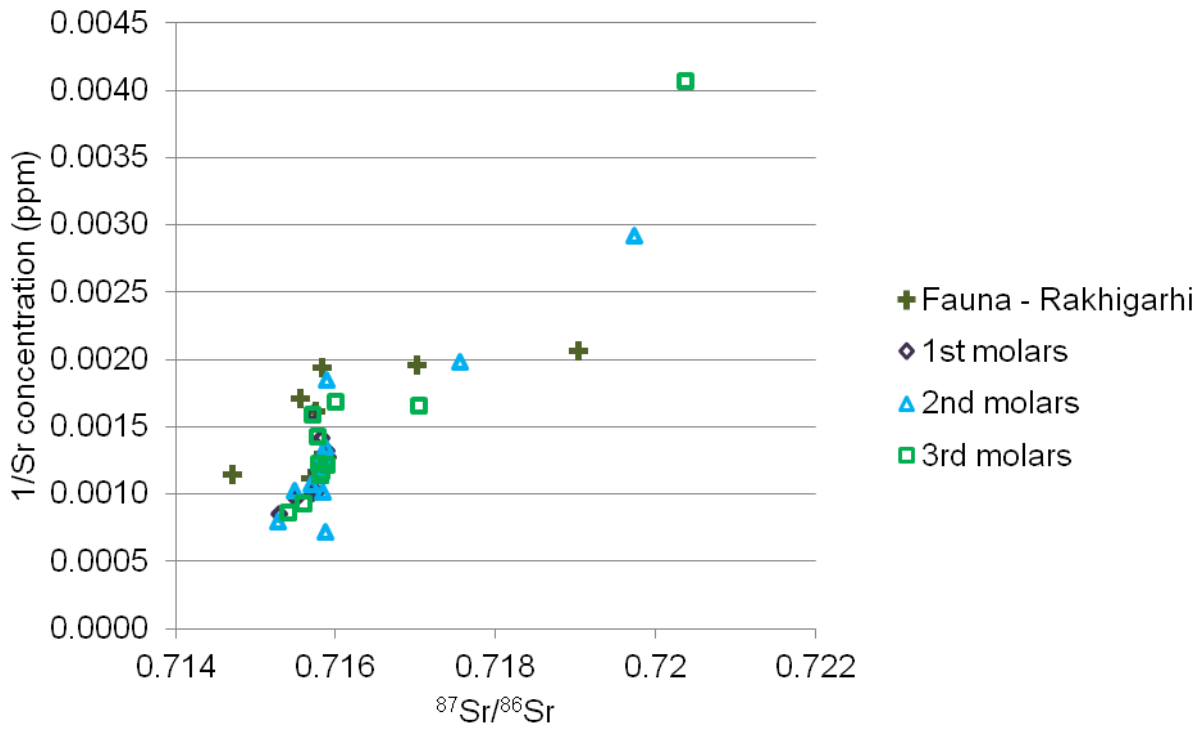

Figure 5-1. Farmana samples in Sr-Sr space—reciprocal of Sr concentration

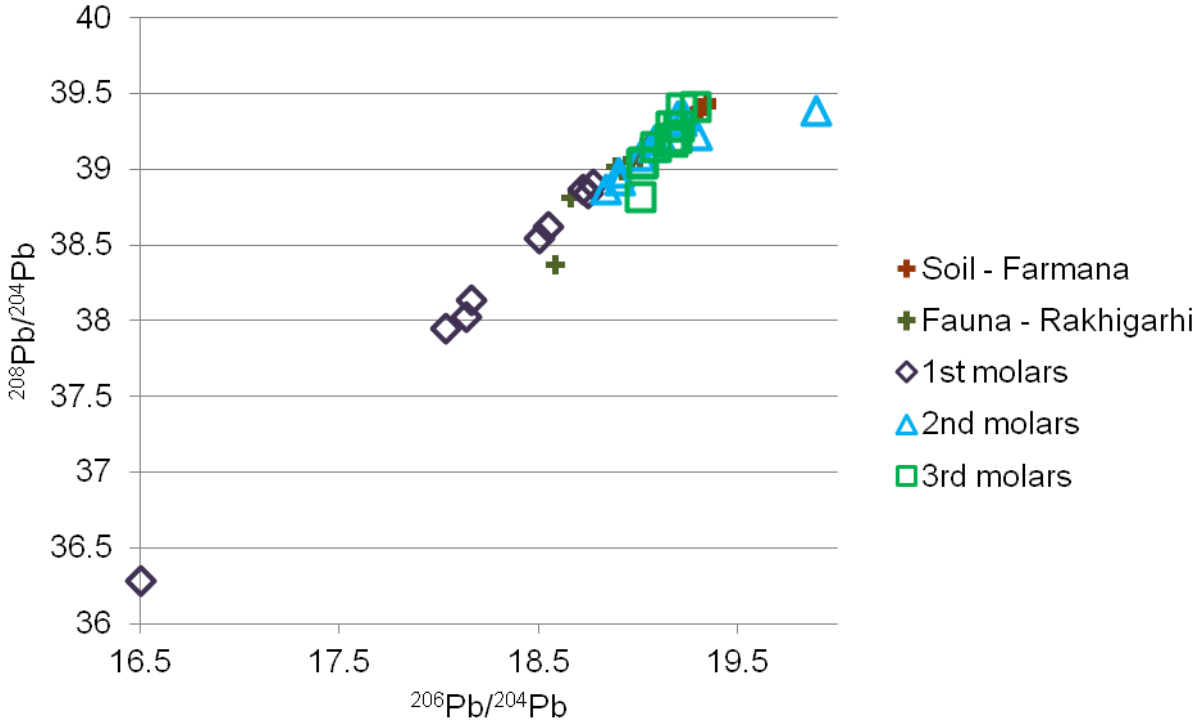

Figure 5-2. Farmana samples in Pb-Pb space—$^{208}Pb/^{204}Pb$

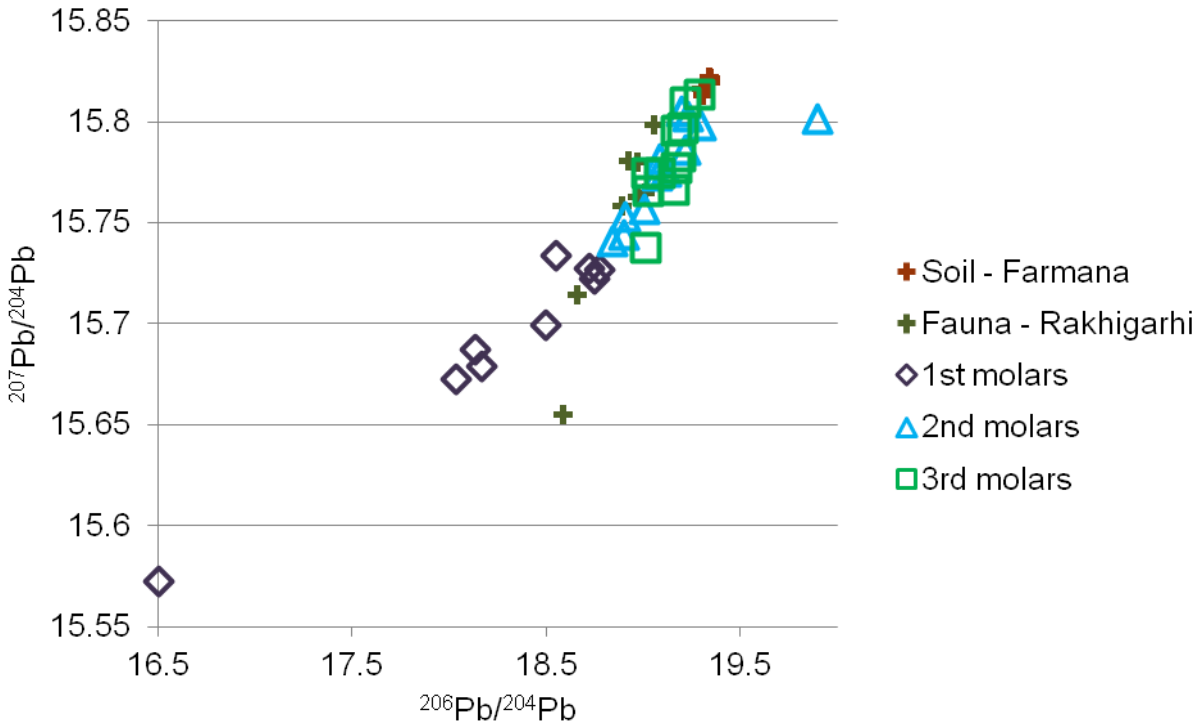

Figure 5-3. Farmana samples in Pb-Pb space—$^{207}Pb/^{204}Pb$

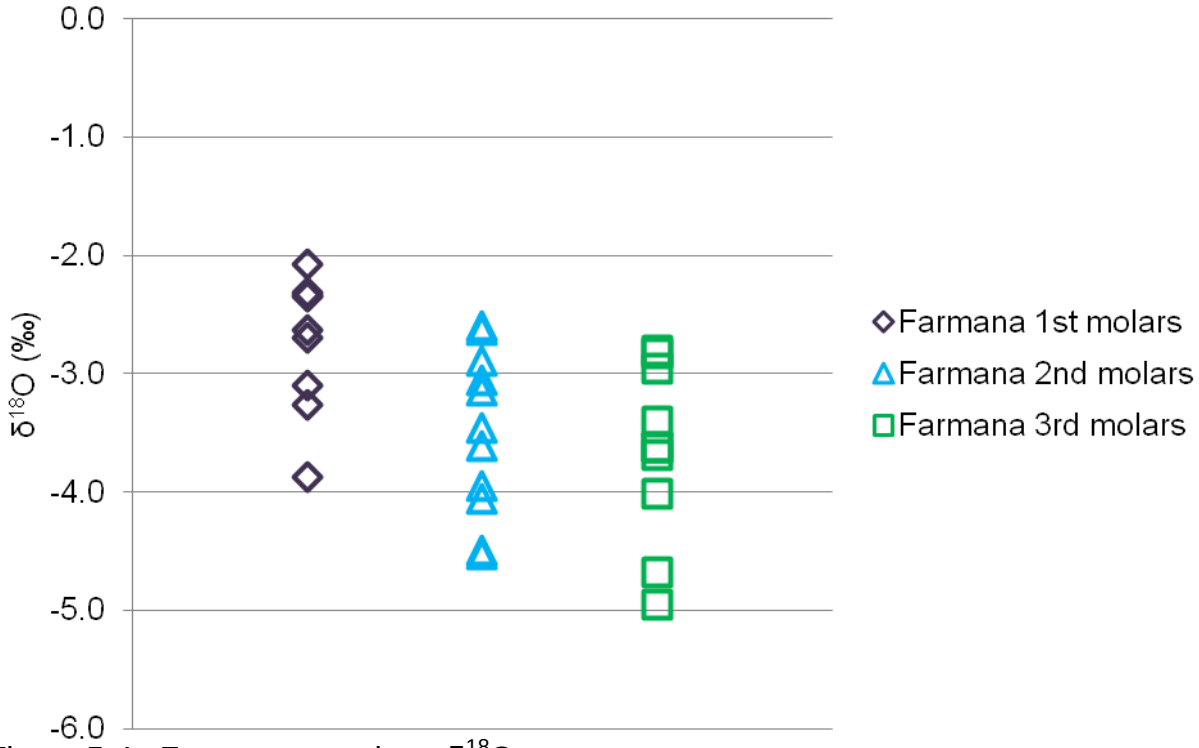

Figure 5-4. Farmana samples—$\delta^{18}O$

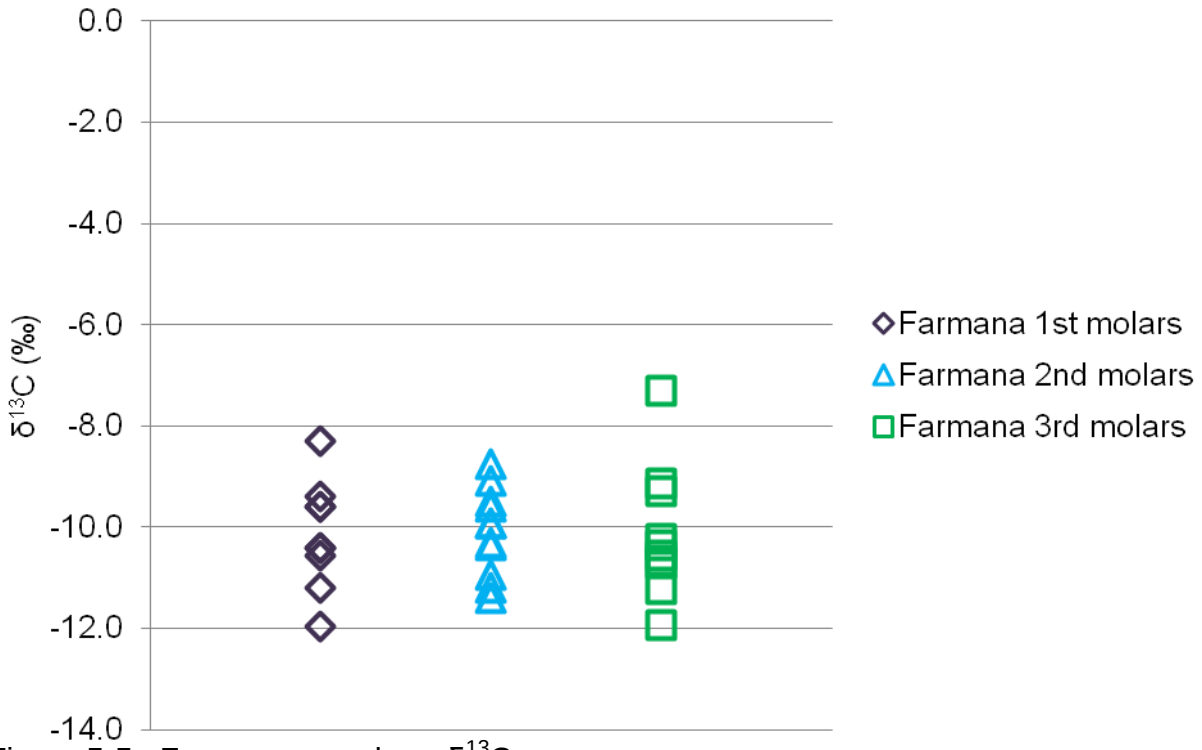

Figure 5-5. Farmana samples—$\delta^{13}C$

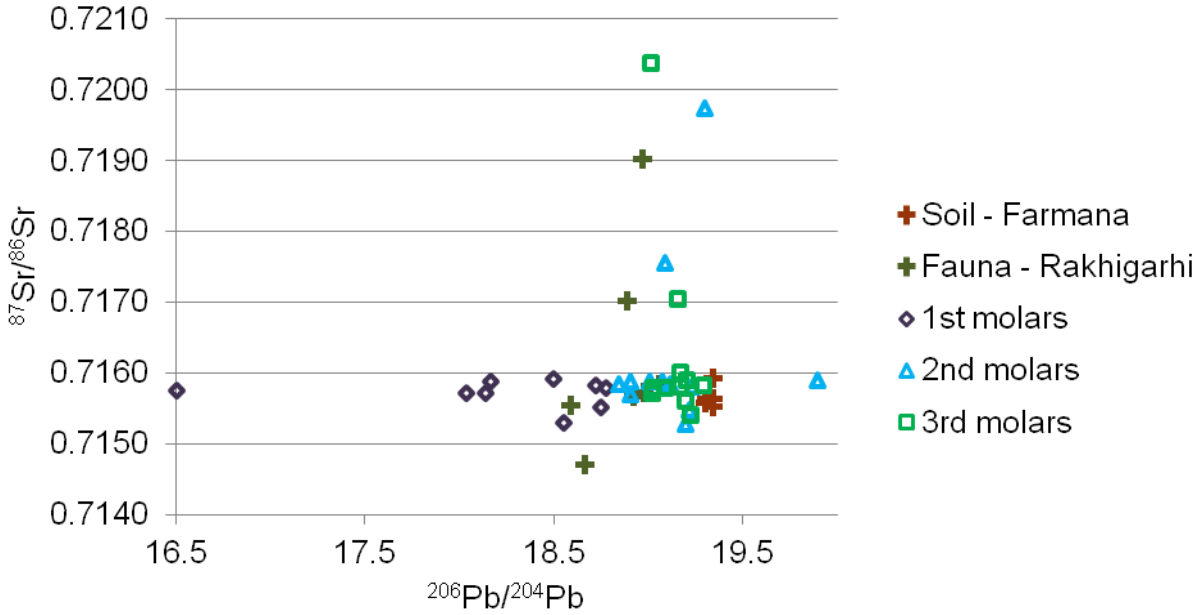

Figure 5-6. Farmana samples in Pb-Sr space—$^{87}Sr/^{86}Sr$

CHAPTER 6
HARAPPA

Harappa was a major urban center situated ~8 km from the Ravi River in the Punjab of present-day Pakistan. It is uniquely well studied among Indus sites, and a wealth of data resulting from decades of excavation has strongly influenced how the entire Indus Civilization is viewed. Rediscovered by antiquarian Charles Masson in 1829 (Masson 1844), the first systematic excavations did not take place until the 1920s and 1930s—decades after large swaths of the uppermost strata had been looted for bricks used in railroad construction (Possehl 2002b). Nevertheless, excavations under the Archaeological Survey of India (Sahni 1921; Sahni 1926; Sahni 1927; Vats 1933; Vats 1935; Vats 1936; Wheeler 1947) and Department of Archaeology and Museums, Government of Pakistan (Mughal 1968) revealed much of the habitation mounds, fortifications, and cemetery areas. More recent collaborative ventures between the Pakistani agency and United States archaeologists (Dales and Kenoyer 1986b; Dales and Kenoyer 1987; Dales and Kenoyer 1988; Dales and Kenoyer 1989b; Dales and Kenoyer 1990b; Meadow and Kenoyer 1992; Meadow and Kenoyer 1993; Meadow et al. 1994; Meadow et al. 1995; Meadow et al. 1996; Meadow et al. 1997; Meadow et al. 1998; Meadow et al. 1999; Meadow et al. 2001) have provided the most comprehensive dataset from any Indus site using modern methods of excavation and chronometric dating. Many of the interpretations of Indus social organization presented in Chapter 2 are derived in large part from the Harappa literature and will not be revisited here. Instead, the first part of this chapter emphasizes site-specific culture history and mortuary variability as they pertain to individual life histories and broader social contexts.

Habitation Area

The protohistory of Harappa is divided into five periods represented by six distinct archaeological phases (Table 6-1). The earliest levels pre-date many diagnostic traits of Indus urbanism (e.g., wheel-thrown pottery and baked brick architecture), but the limited excavations of these strata suggest important continuities between the small Ravi Phase village and the large city that it was to become. For example, symbols etched in sherds may represent incipient Indus script (Kenoyer and Meadow 1996; Meadow and Kenoyer 2008). Likewise, many of the long-distance trade routes that later proved integral to the development and maintenance of Indus urbanism were already in place at this time, providing exotic raw materials for the local production of prestige goods (Kenoyer and Meadow 1999; Kenoyer and Meadow 2000; Kenoyer 2005a; Law 2008).

Excavations of the relatively expanded Kot Diji levels (~25 ha) revealed a trend of increasing complexity (Kenoyer 1998). Harappans had access to greater quantities and varieties of imported goods which may have been regulated through the increased use of script, stamp seals, chert weights and perimeter walls (Meadow and Kenoyer 2001; Meadow and Kenoyer 2005; Meadow and Kenoyer 2008). The settlement began to take on much of its eventual urban character during this time, being clearly divided into separate walled mounds using mud bricks with standardized proportions. Importantly, Period 2 levels did not exist in a cultural vacuum. Many of the architectural developments from Harappa were mirrored at other Regionalization Era sites including Kalibangan (Joshi 2003), Dholavira (Bisht 1991), Rehman Dheri (Durrani 1988; Durrani et al. 1995), and Kunal (Khatri and Acharya 1995), whereas Kot Diji ceramics are found

at sites spanning ~1000 km northeast-southwest along the Indus River Valley (Law 2008).

By 2600 BC, the Kot Dijian way of life had gradually transformed into a fully urbanized existence represented by three sub-phases. Much of the diagnostic suite of Indus material culture is present throughout Periods 3A, 3B, and 3C, but interpretations of the Harappa Phase cannot be reduced to a single trajectory of growth or decay. Instead, urban development was variable and fluctuated through time (Meadow and Kenoyer 2005). During Period 3A, Kot Dijian revetments were replaced and elaborated on using baked bricks, while settlement remained largely confined to the existing boundaries of Mounds AB and E. Further, civic architecture deteriorated in some regions of Mound E, suggesting a measure of stagnation before the urban renewal of Period 3B (Kenoyer 1991b). Eventually, crumbling structures were repaired and new habitation mounds were founded. One of the new mounds, Mound ET, has been characterized as a “suburb” of Mound E (Kenoyer 1998: 55), in part because the two areas shared their perimeter wall and a city gate (Meadow and Kenoyer 1997). Mound F, on the other hand, had its own wall and became the site for new large-scale civic projects including the so-called “granary” (Vats 1940; Fentress 1984; Meadow and Kenoyer 2008).

Period 3C strata are the best studied levels at Harappa and serve as a primary reference for the normative mode of Indus urbanism – so much so that Kenoyer (personal communication) suggested that the widely and variously used term “Mature Harappan” be confined to Period 3C. Arguably the best known trait of this sub-phase is the pointed base goblet, a mass-produced ceramic that is ubiquitous within Period 3C

deposits (Meadow and Kenoyer 2001). The presence of these and other diagnostic finds show that the Mature Harappan settlement was at its largest, extending beneath the present-day city and beyond the southernmost gate (Meadow and Kenoyer 1993) to cover an area of ~150 ha (Dales and Kenoyer 1989a). Though growing in size, not all areas were equally prosperous. Mound E fell into disrepair once more, whereas evidence suggests the inhabitants of Mounds AB and F were relatively affluent (Meadow and Kenoyer 2005).

Coincident with the post-urban regional demographic shift discussed in Chapter 2, Period 4 at Harappa marks the beginning of a process of profound cultural transformation (Kenoyer 2005b). Strictly speaking, habitation at Harappa between ca. 1900 and 1700 BC retained certain urban qualities, but many of the traits associated with the fully integrated and spatially expansive Indus Civilization phenomenon (e.g., Indus script, chert weights, stamp seals) disappeared. Subsistence practices also changed during this time as wheat production declined and summer crops became increasingly common (Weber 2003). There were even technological innovations in bead drilling (and possibly in glass-making)—perhaps to compensate for the loss of various crafts as exchange networks deteriorated (Kenoyer 2005b). By ca 1700 BC, however, the unique styles and motifs of the Cemetery H Phase replaced the Harappa Phase as the predominant archaeological culture. Through much of this transformation, Harappa remained a vibrant population center, and the settled area may have covered ~100 ha during Period 5 before its decline sometime prior to 1300 BC.

To summarize, the cultural trajectory at Harappa is not readily described by a single generalized trend. Instead, different habitation areas seem to ebb and flow at

different times and only at the most general level can the Harappan site history be reduced to a ‘rise’ and ‘fall.’ For that reason, models of Harappan social variation must account for diverse groups with differing perspectives and possible conflicts. At the same time, cultural phases were widely shared and cultural transitions were gradual rather than abrupt, suggesting that diversity was accommodated within a common ideological system. Future high-resolution analyses of intra-site patterning (akin to the mineral provenience study by Law (2008) are needed to better understand the social dynamics in this complex system of interdependence.

The dietary catchments at Harappa may have been similarly complex, and variability in the food supply or certain technological practices could potentially impact individuals’ exposure to lead, strontium, oxygen, and carbon. For example, the transportation of food from regions with distinct isotopic compositions could alter consumer isotopic values relative to local fauna and sediment leachates. Marine foods are one possible source as the remains of marine fish have been documented at Harappa (Belcher 1991; Belcher 2003). The evidence is extremely limited, however, suggesting that neither marine fish nor the salt used for their preservation were significant sources of dietary Sr. Likewise, there is little evidence for widespread anthropogenic Pb input in the form of smelting with the exception of a single large slag (Kenoyer personal communication). Finished goods such as bronze vessels were a more plausible cause of technological Pb exposure. Makeup may also have included Pb as suggested by Law’s (2008) analysis of a small rod-like artifact of granulated material found in a burial of Cemetery R-37. Galena crystals were identified within the rod which may have been a solidified cosmetic similar to surma or kohl. Another small jar that

contained black residue and was found in habitation contexts had levels of Pb detectable by ICP-MS, whereas seven other jars and sherds yielded no conclusive evidence for Pb. The possibility of Pb exposure via makeup remains an open question given the possibility of Pb contamination associated with modern surma use as discussed in Chapter 3. It may be, however, that cosmetics were predominantly carbon based products as proposed by Mackay (1938). Whatever the case, any impact on Pb isotope ratios in humans with access to the bustling markets of Harappa may be characterized by high inter-individual variation, as the Pb fraction in metal wares and other products at the site has widely varying provenience (Law 2008; Hoffman and Miller 2009).

Water management practices at Harappa may have been similarly varied. Different water sources could have been exploited by different people at different times, each source having potentially distinct $\delta^{18}O$. The glacially-fed Ravi River may have flowed closer to the site during its protohistoric habitation and theoretically could have supplied residents with potable water (Pendall and Amundson 1990). Its waters are derived from snow and ice melt at high altitudes and should therefore yield relatively low $\delta^{18}O$ compared to lowland precipitation. A large culturally sterile depression at the center of the site might also have served as a rain-fed reservoir (Kenoyer 1998: 59). Harappans relying on an uncovered reservoir would have relatively high $\delta^{18}O$ because of evaporative effects, whereas those drawing groundwater from wells might have intermediate values given the potential for mixing of river water and precipitation along with a reduction in evaporation. Only eight wells have been discovered at Harappa to date, however, so the exact nature of urban water consumption remains uncertain. In

general, it is surmised that Harappan cultural practices impacted the isotopic composition of human tooth enamel, but no specific inferences can be made on the basis of archaeological evidence.

Cemetery Area

Cemetery R-37, the urban era cemetery, is located ~200 m south of the habitation area on a low rise. The area served simultaneously as a cemetery and disposal area for Harappan Phase debris (Dales and Kenoyer 1991). Five radiocarbon dates from charcoal in good context corroborate the relative date, putting the period of active use from ca. 2550-2030 BC (Meadow and Kenoyer 1994). Cemetery excavations occurred at different times under different directors, and no comprehensive publication on the burials and their contents has been published. Reports by Vats (1940), Wheeler (1947), Mughal (1968), Dales and Kenoyer (1989a, 1991), and Meadow and Kenoyer (1994) lack sufficient detail for a detailed consideration of mortuary variability. Only a cursory analysis is possible pending the comprehensive cemetery report by the Harappa Archaeological Research Project, but the available data are summarized below for those burials with relatively complete descriptions (Table 6-2). Table 6-2 is a non-representative sample as many burials were more fully described precisely because of their unique features.

Problems aside, the excavators at Cemetery R-37 confirmed a strongly normative mode of burial (Vats 1940; Wheeler 1947; Sastri 1965; Mughal 1968; Dales and Kenoyer 1991; Kenoyer 1998). Nearly all burials are extended and supine with the head to the north, and pottery is most often, but not exclusively, located at the head of the grave. Pottery vessels included with individuals number between one and fifty per grave, and occasionally are placed alongside the feet, sides of the body, or underneath

the body. Non-pottery grave goods were generally limited to personal ornaments and toilet objects and included rings, earrings, and bangles of copper or shell, numerous beads of semi-precious stone or steatite, shell spoons, and copper mirrors. Also, conical stone pendants and shell bangles are confined largely, but not exclusively, to women.

Overall, Harappa has some of the richest graves known from the Indus Tradition, but the graves remain relatively modest and do not contain grave wealth beyond what individuals could have adorned themselves with at one time. The body itself was occasionally interred in a wooden coffin or wrapped in a shroud, and a great many were disturbed in antiquity. Wheeler (1947) observed that eighteen burials crosscut earlier burials, and eight of those were crosscut themselves, a tendency confirmed by subsequent excavations (Dales and Kenoyer 1991). Most of the burials in good condition are confined to a relatively undisturbed east-west ridge, whereas fragmentary remains are frequently found along the eroding slopes of the site or in the backfill of grave shafts.

Contrary to the relative homogeneity in mortuary treatment, osteological analysis suggests certain gender-based distinctions. For example, frequencies of caries and enamel hypoplasias suggest women likely had poorer childhood nutrition and increased access to cariogenic foods (Hemphill et al. 1991). Also, principal component analysis for comparisons of metric and non-metric craniodental traits suggests that males and females derive from genetically distinct populations (Hemphill et al. 1991). Because the urban and post-urban female populations retain closer genetic affinity to each other than do the urban and post-urban males, this gender difference has been interpreted as evidence for matrilocality (Kennedy 2000).

Lastly, the isotopic sample represents a relatively small fraction of all excavated burials, and as such, may not be representative of the larger mortuary population (Table 6-3). The present sample (n=51) comes from 40 features excavated in the 1987, 1988, and 1994 field seasons of the Harappa Archaeological Research Project (HARP). Samples include one or more teeth from 17 primary burials in various states of preservation, a single secondary burial, and the remainder from disturbed contexts.

Results of the Analyses

Isotopic values and Sr concentrations resulting from the analyses are presented in Table 6-3. Values of $^{87}Sr/^{86}Sr$ show a considerable range, from 0.71113 to 0.72802, with relatively modest Sr concentrations ranging between 137 and 642 ppm. Lead isotope ratios also exhibit heterogeneity with $^{208}Pb/^{204}Pb$ from 38.013 to 39.377, $^{207}Pb/^{204}Pb$ from 15.650 to 15.770, and $^{206}Pb/^{204}Pb$ from 18.054 to 19.220. Tooth enamel yielded $\delta^{18}O$ of -7.8 to -2.8‰ and $\delta^{13}C$ of -14.0 to -8.7‰. Means and standard deviations are presented for each tooth cohort in Table 6-4.

As was the case for certain faunal teeth in the Harappa sample (Chapter 4), many human teeth were also analyzed for $^{87}Sr/^{86}Sr$ previously on a Nu Plasma HR – a high-resolution multi-collector, double-focusing, plasma-source mass spectrometer (MC-ICP-MS) at the University of Illinois-Urbana-Champaign. Standard deviation for $^{87}Sr/^{86}Sr$ was generally better than ±0.00001 (Kenoyer et al. 2013), providing precision comparable to that of the TIMS used in the University of Florida Department of Geological Sciences (Chapter 3). Whenever possible, previously sampled teeth were re-run using the TIMS (n=35) to maintain an internally consistent dataset and verify the MC-ICP-MS results. Further, repeat analysis on the TIMS was the most cost-efficient way to acquire both $^{87}Sr/^{86}Sr$ and Sr concentrations without consuming additional

sample beyond the amount required for Pb column chemistry. Except for two pairs of analyses with an absolute difference greater than 0.001, the TIMS results corroborate the MC-ICP-MS data. After excluding burials H87/85 74a and H88/161 170, the mean absolute difference between MC-ICP-MS and TIMS analyses is 0.00018 ± 0.00032 (2σ). Inter-laboratory differences might reflect variation in analytical procedures or sample preparation, or they might reflect real biological variation. Any given bulk enamel sample has a unique composition of appositional growth layers that mineralized at different times in that individual's life. Isotopic differences between samples taken from different parts of a tooth crown might reflect the different geochemical environments experienced by an individual in life. Caution is advised when comparing datasets from study regions having relatively little isotopic variability without first reviewing differences in laboratory methods. Regardless, the magnitude of $^{87}Sr/^{86}Sr$ differences reported here is largely irrelevant to a study of interregional migration given the diverse geochemical environments of the Greater Indus Valley. Therefore, the more complete TIMS dataset is shown in Table 6-3, and it serves as the basis for subsequent figures and interpretations. Isotopic data from burials H87/85 74a and H88/161 170 are excluded as the discrepancy in $^{87}Sr/^{86}Sr$ casts doubt on their provenience. Likewise, burials H87/85 49d.1, H88/185 186, and H88/206 208a are disregarded because the tooth position could not be determined. Lastly, data from premolars and canines are graphically presented as second molars and data from anterior dentition are classified as first molars because of their similar enamel mineralization times.

A plot of $^{87}Sr/^{86}Sr$ against the reciprocal of Sr concentration is presented in Figure 6-1. Overlaid fields indicate the range of values for males and females. There is

substantial variation in the dataset, which appears to be controlled by at least three end members. Individuals appear to fall on one of two mixing lines between the local range, estimated from faunal samples, and either a more radiogenic low concentration source(s) or a less radiogenic source(s) of roughly similar Sr concentration. Male and female distributions overlap but are not coterminous. Males predominantly plot along the less radiogenic mixing line, whereas females plot on both. There is no clear segregation by tooth type, although first molars may be excluded from the local range estimated from the intersection of faunal and human data.

Pb isotope ratios display similar evidence for mixing lines and segregation by sex (Figures 6-2 & 6-3). The variation is most apparent in the $^{207}Pb/^{204}Pb$ data presented in Figure 6-3. The triangular distribution of data suggests a geochemical environment controlled by three end members. As with $^{87}Sr/^{86}Sr$, males and females have overlapping but non-identical distributions in Pb-Pb space. Data from males, females, and fauna converge near one end of the distribution, suggesting the bulk of the data fall on mixing lines between the local or near-local environment and one or more end-members. The data are relatively homogenous with respect to tooth type, except that first molars seem to plot outside of the local range. Some first molar data points are similar to faunal values, but they remain distinct from the tightest and slightly more radiogenic cluster of human and faunal values.

Oxygen isotope variation also appears to correlate with sex and tooth type, although extremely small sample sizes preclude any statistical comparison with male and female third molars. There is minimal change in $\delta^{18}O$ across tooth types for the entire population, but male and female sub-groups appear to show inverse trends over

developmental time (Figure 6-4). The difference between mean $\delta^{18}O$ for female and male first molars is not statistically significant, but a qualitative assessment suggests that female second molar $\delta^{18}O$ increases relative to first molars. The decrease between male first molar mean $\delta^{18}O$ (-4.4‰ ± 2.0 [2σ]) and second molar mean $\delta^{18}O$ (-5.4‰ ± 1.2 [2σ]) is significant ($t(13) = 2.522$, $p = 0.025$), thereby indicating a change in water source around two or three years of age.

No such trends are visible in $\delta^{13}C$, although there is substantial variability in the data set (Figure 6-5). While there were certainly inter-individual differences in diet, it does not appear to have been structured by age or sex. All sub-samples have mean $\delta^{13}C$ near 12‰ with a range of ~5‰.

Lastly, Pb and Sr isotope systems are combined in Figure 6-6. As shown in the preceding heavy isotope plots, the data are structured by age and sex. Male and female distributions are different from one another, but they converge with the faunal data at a point not well defined by a single end member. The increased resolution afforded by multiple isotope systems suggests a possible fourth end member with relatively radiogenic Pb isotope ratios and moderate values of $^{87}Sr/^{86}Sr$. Additionally, first molars plot outside of the presumably local environment indicated at the human-faunal convergence.

As with the Farmana data set, the isotope data demonstrate changing environmental inputs over developmental time. Isotope ratios of Pb and Sr in conjunction with Sr concentrations suggest that individuals of all ages were exposed to a diverse and complex geochemical environment, but that first molars archived non-local Sr and Pb inputs exclusively. Oxygen isotope values are similarly structured by

tooth type, suggesting a change in water sources around three years of age. Further, males and females tended to be exposed to different geochemical environments. Only $\delta^{13}C$ shows no strong correlation with age or sex. There is, however, a wide range of $\delta^{13}C$ values suggesting substantial heterogeneity in diet between individuals.

Table 6-1. Chronology at Harappa[1]

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

[1] [adapted from Meadow, R. H., and J. M. Kenoyer 2001. Recent Discoveries and Highlights from Excavations at Harappa: 1998-2000. Indo-Koko-Kenkyu [Indian Archaeological Studies] 22:19-36]

Table 6-2. Select demographic data and mortuary elaboration at Harappa[1]

Burial No.	MNI	Age	Sex	Orientation	Position	Pottery Qty.	Ornaments	Other Items
H779a-f, H783[2]	7	4 adults	3F/1M	N-S	supine			
H782[2]	1			N-S	supine			2 faunal ribs
H793[2]	1	adult	M	N-S	left side		steatite discs	
H793/A[2]	1	adult	M	N-S	prone			
H793/B[2]	1	adult	M	N-S	right side			
H794[2]	1	adult	M	N-S	right side		steatite discs	faunal rib
H795/A & B[2]	1	adult	F	N-S	right side			
H798[2]	6	3 adults	3M	N-S				
H798/A[2]	1	adult	F	N-S	supine			
H798/B[2]	1	subadult		N-S				
H799[2]	1			N-S	left side			
H800, H800/A & B[2]	1			N-S	supine			faunal rib
H801/A[2]	1	adult	F	N-S	supine			faunal rib
H801/B[2]	2	subadult	M					2 faunal bones
H803[2]	1			NNE-SSW	right side			faunal bone
H804[2]	1	adult	F	N-S	right side		steatite discs, shell bangle	
H805/A[2]	1			N-S	prone			
H806[2]	2	adult	M	N-S	supine			faunal ribs
H808[2]	1			N-S	supine		2 gold & carnelian beads	

[1] incomplete descriptions of material culture [2] from Vats 1940 [3] from Wheeler 1947

Table 6-2. Continued

Burial No.	MNI	Age	Sex	Orientation	Position	Pottery Qty.	Ornaments	Other Items
H814[2]	2			N-S	supine			
H816, H816/A[2]	2	adult	F	SE-NW	prone			
H817[2]	1	adult	F	N-S	supine			avian bones, lamp
H818[2]	1	adult	M	N-S	supine			
H820[2]	3	3 adults	2F/1M	N-S	left side			
1[3]	1	adult	M	N-S	supine	21	steatite disc	chert flake
2[3]	1	adult	F	N-S	supine	21	steatite disc	copper mirror
3[3]	1					21		
4[3]	1					0		
5[3]	1	adult	F	N-S	supine	37	copper ring, 3 shell rings	coffin
6[3]	1					3		faunal bones
7[3]	1					3		
8[3]	1					2		1 faunal bone
9[3]	1					15		
10[3]	1	adult	M	N-S		2		brick lining

[1] incomplete descriptions of material culture [2] from Vats 1940 [3] from Wheeler 1947

Table 6-3. Harappa mortuary sample—results of the analyses

Sample No.	Burial	Tooth	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
H18a-1_1	H87/ 25 18a	LM_1	0.71485	390	38.013	15.683	18.054	-5.4	-11.7
H34a-2_1	H87/ 40 34a	LM_2	0.71459	284	38.905	15.714	18.723	-5.1	-12.3
H34a2-1_1	H87/ 40 34a.2	RM_1	0.71360	246	38.865	15.728	18.658	-3.5	-12.9
H34b1-1_1	H87/ 40-89 34b.1	RM_1	0.71236	370	38.867	15.723	18.662	-2.8	-11.2
H49b1-3	H87/ 71 49b1	RM_3	0.71343	358	38.672	15.681	18.566	-5.4	-13.1
H49c-1_1	H87/ 71 49c	M_1	0.71585	209	38.822	15.717	18.670	-6.0	-11.8
H49c-3	H87/ 71 49c	M_3	0.71828	290	39.030	15.735	18.814	-4.0	-11.9
H49ha-i	H87/ 72 49h	LI_1	0.71321	321	38.863	15.721	18.736	-5.6	-11.9
H49ha-c_1	H87/ 72 49h	LC	0.71741	366	39.033	15.732	18.794	-5.9	-11.7
H49hb-1	H87/ 72 49h	M_1	0.71754	358	38.894	15.724	18.715	-5.1	-11.3
H49hc-3_1	H87/ 72 49h	M_3	0.72090	177	39.114	15.738	18.836	-4.6	-11.3
H49b-1_1	H87/ 72 49b	RM^1	0.71415	345	38.700	15.683	18.531	-4.8	-12.7
H49d1-m_{12}	H87/ 85 49d1	M	0.71389	334	38.654	15.684	18.526	-4.6	-12.5
H49ga-2_1	H87/ 85 49g	LM_2	0.71922	404	38.746	15.712	18.565	-4.0	-10.9
H49gb-2_1	H87/ 85 49g	LM_2	0.72190	238	39.066	15.736	18.825	-4.3	-12.1
H49hc-2_1	H87/ 85 49h	RM_2	0.71760	388	39.081	15.743	18.868	-5.1	-11.4
H74a-2_1	H87/ 85 74a	RM_2	0.71528	642	38.530	15.696	18.393	-5.6	-12.6
H80a-2	H87/ 91 80a	RM^2	0.71659	481	38.821	15.727	18.724	-5.0	-11.8
H81a-3	H87/ 92 81a	LM^3	0.71817	457	38.684	15.713	18.498	-5.1	-10.1
H126a-3	H87/ 108 126a	RM^3	0.71880	467	39.095	15.742	18.856	-4.7	-12.3

$_1$ light stable isotope data from [Kenoyer, J. M., T. D. Price, and J. H. Burton 2013. A New Approach to Tracking Connections between the Indus Valley and Mesopotamia: Initial Results of Strontium Isotope Analyses from Harappa and Ur. Journal of Archaeological Science 40(5):2286-2297 (Page 2294, Table 2)] $_2$ indeterminate molar position

Table 6-3. Continued

Sample No.	Burial	Tooth	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
H128a-1	H87/ 116 128a	LM_1	0.71305	320	38.731	15.687	18.621	-5.3	-12.7
H147a-1[1]	H87/ 136 147a	LM_1	0.71272	323	38.802	15.700	18.648	-4.9	-12.6
H152a-1[1]	H87/ 141 152a	LM^1	0.71962	205	38.721	15.708	18.559	-4.2	-12.5
H156a-1[1]	H87/ 145 156a	LM_1	0.71853	372	38.515	15.705	18.405	-4.2	-10.8
H203a-2[1]	H87/ 200 203a	RM_2	0.71691	256	39.377	15.768	19.099	-4.5	-9.8
H127a-1[1]	H88/ 114 127a	LM_1	0.71230	469	38.699	15.700	18.545	-5.2	-12.3
H147a-1[1]	H88/ 130 147a	LM_2	0.71202	422	39.007	15.725	18.793	-6.0	-12.3
H170-2/3[12]	H88/ 161 170	$LM_{2/3}$	0.71738	297	39.367	15.753	19.220	-4.2	-8.8
H121-p3[1]	H88/ 162 121	RP^3	0.72123	265	39.046	15.735	18.804	-3.5	-12.3
H133a10-2[1]	H88/ 173 133a.10	LM_2	0.71930	338	38.767	15.709	18.608	-5.4	-11.1
H126b2a-1[1]	H88/ 174 126b.2	RM^1	0.71546	232	38.846	15.705	18.658	-5.3	-11.8
H126b2b-3	H88/ 174 126b.2	RM^3	0.71543	235	39.043	15.730	18.798	-6.3	-12.3
H170a17a-1	H88/ 180 170a.17	LM^1	0.71367	315	38.857	15.701	18.665	-5.3	-13.2
H170a17b-3	H88/ 180 170a.17	LM^3	0.71286	318	39.000	15.719	18.778	-7.0	-13.1
H185c1-2[1]	H88/ 191 185c.1	RM^2	0.72707	167	39.054	15.748	18.901	-4.0	-11.4
H185f-1[1]	H88/ 191 185f	LM_1	0.72802	137	38.827	15.770	18.845	-4.1	-12.7
H196a-2[1]	H88/ 194 196a	LM_2	0.71275	235	38.935	15.713	18.724	-4.9	-11.4
H200a-2	H88/ 198 200a	LM^2	0.71980	295	38.656	15.690	18.559	-2.8	-12.6
H204a-1	H88/ 201 204a	RM_1	0.71951	367	38.878	15.710	18.697	-4.4	-11.4

[1] light stable isotope data from [Kenoyer, J. M., T. D. Price, and J. H. Burton 2013. A New Approach to Tracking Connections between the Indus Valley and Mesopotamia: Initial Results of Strontium Isotope Analyses from Harappa and Ur. Journal of Archaeological Science 40(5):2286-2297 (Page 2294, Table 2)] [2] indeterminate molar position

Table 6-3. Continued

Sample No.	Burial	Tooth	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
H208a-mx$_{12}$	H88/ 206 208a	M	0.71842	314	38.972	15.730	18.779	-3.9	-11.3
H208a-my$_{12}$	H88/ 206 208a	M	0.72128	239	39.035	15.744	18.839	-4.7	-11.6
H219a-1$_1$	H88/ 216 219a	LM^1	0.71896	264	39.167	15.751	18.980	-4.1	-8.7
H220a-2$_1$	H88/ 217 220a	LM$_2$	0.71300	430	38.737	15.689	18.576	-6.1	-11.7
H4b-2$_1$	H88/ 439 4b	LM$_2$	0.71258	340	38.753	15.710	18.604	-5.9	-12.3
H5#2-2	H94/ 243 5#2	LM^2	0.71113	557	38.625	15.678	18.612	-5.2	-12.0
H27-2$_1$	H94/ 243 27	LM$_2$	0.71604	411	38.934	15.735	18.856	-3.8	-12.3
H7-1$_1$	H94/ 245 7	LM$_1$	0.71475	309	38.613	15.697	18.536	-4.9	-12.6
H17-1$_1$	H94/ 250 17	RM$_1$	0.71480	358	38.744	15.694	18.604	-4.6	-12.8
H18-1$_1$	H94/ 253 18	LM$_1$	0.71274	353	38.149	15.650	18.530	-4.0	-12.5
H18-2$_1$	H94/ 253 18	LM$_2$	0.71248	360	38.172	15.650	18.535	-7.8	-14.0

$_1$ light stable isotope data from [Kenoyer, J. M., T. D. Price, and J. H. Burton 2013. A New Approach to Tracking Connections between the Indus Valley and Mesopotamia: Initial Results of Strontium Isotope Analyses from Harappa and Ur. Journal of Archaeological Science 40(5):2286-2297 (Page 2294, Table 2)] $_2$ indeterminate molar position

Table 6-4. Harappa mortuary sample summary statistics--mean±2σ

Cohort	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
1st molar: all	0.71509±0.005	320±145	38.705±0.566	15.706±0.046	18.593±0.382	-4.7±1.6	-11.9±2.1
1st molar: female	0.71605±0.005	311±182	38.677±0.618	15.705±0.041	18.549±0.489	-4.9±1.3	-11.7±2.5
1st molar: male	0.71385±0.004	333±85	38.741±0.531	15.706±0.055	18.650±0.138	-4.4±2.0	-12.2±1.4
2nd molar: all	0.71653±0.009	321±180	38.989±0.349	15.728±0.043	18.796±0.289	-5.0±1.7	-11.7±1.5
2nd molar: female[1]	0.72167±0.011	272±251	39.018±0.146	15.740±0.015	18.861±0.076	-4.0±0.5	-11.9±0.9
2nd molar: male	0.71461±0.005	340±149	38.979±0.407	15.724±0.048	18.772±0.328	-5.4±1.2	-11.6±1.7
3rd molar: all[1]	0.71821±0.005	234±113	39.062±0.091	15.734±0.008	18.816±0.038	-5.0±2.3	-11.8±1.0
3rd molar: female[1]	0.71686±0.004	263±78	39.037±0.019	15.732±0.007	18.806±0.022	-5.1±3.2	-12.1±0.7
3rd molar: male[1]	0.72090	177	39.114	15.738	18.836	-4.6	-11.3

[1] very small sample (n≤3)

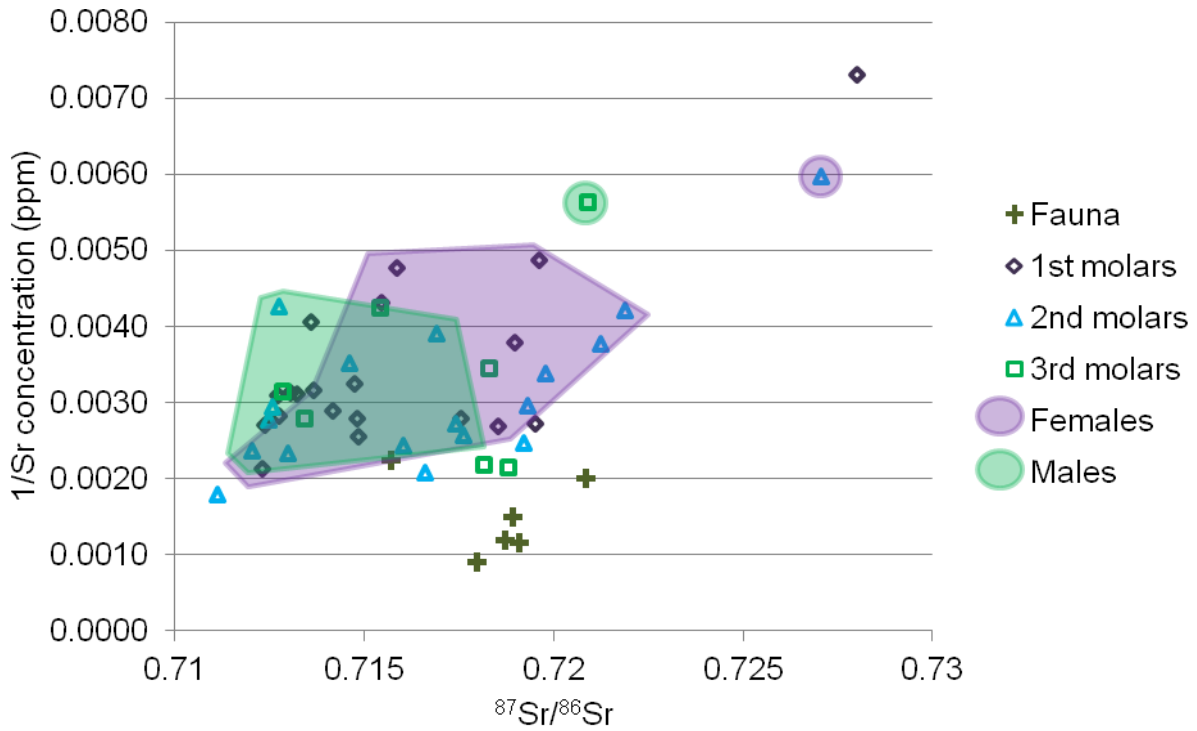

Figure 6-1. Harappa samples in Sr-Sr space by sex—reciprocal of Sr concentration

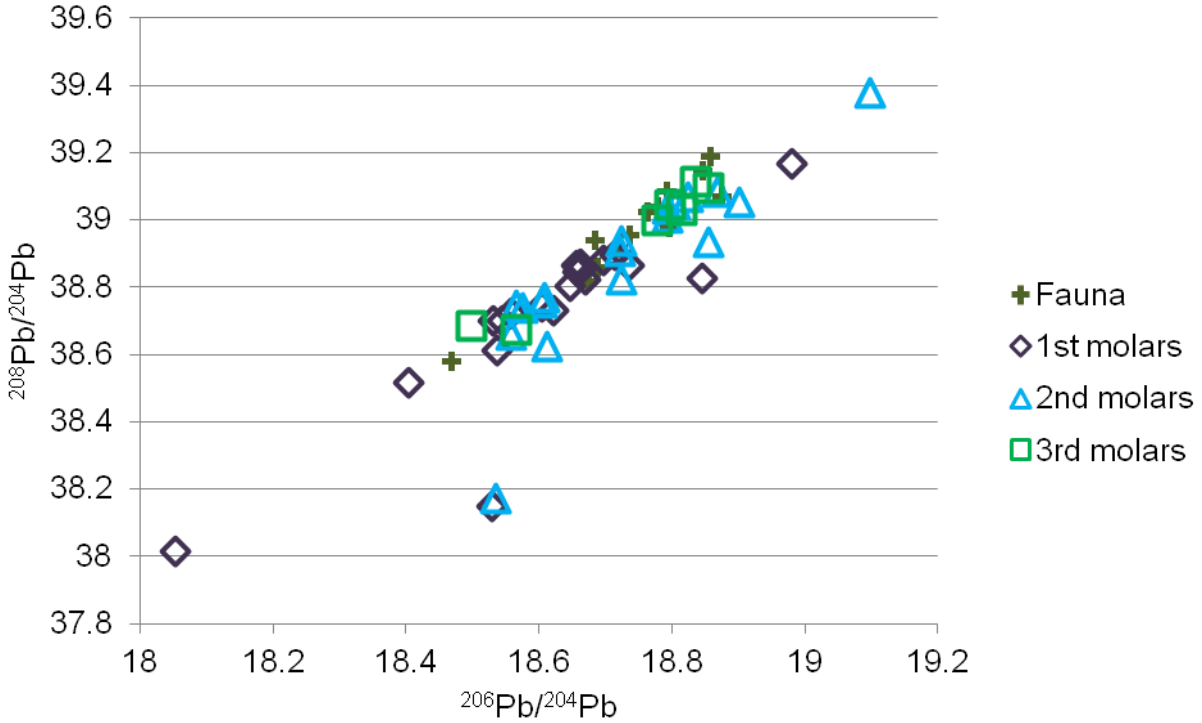

Figure 6-2. Harappa samples in Pb-Pb space—$^{208}Pb/^{204}Pb$

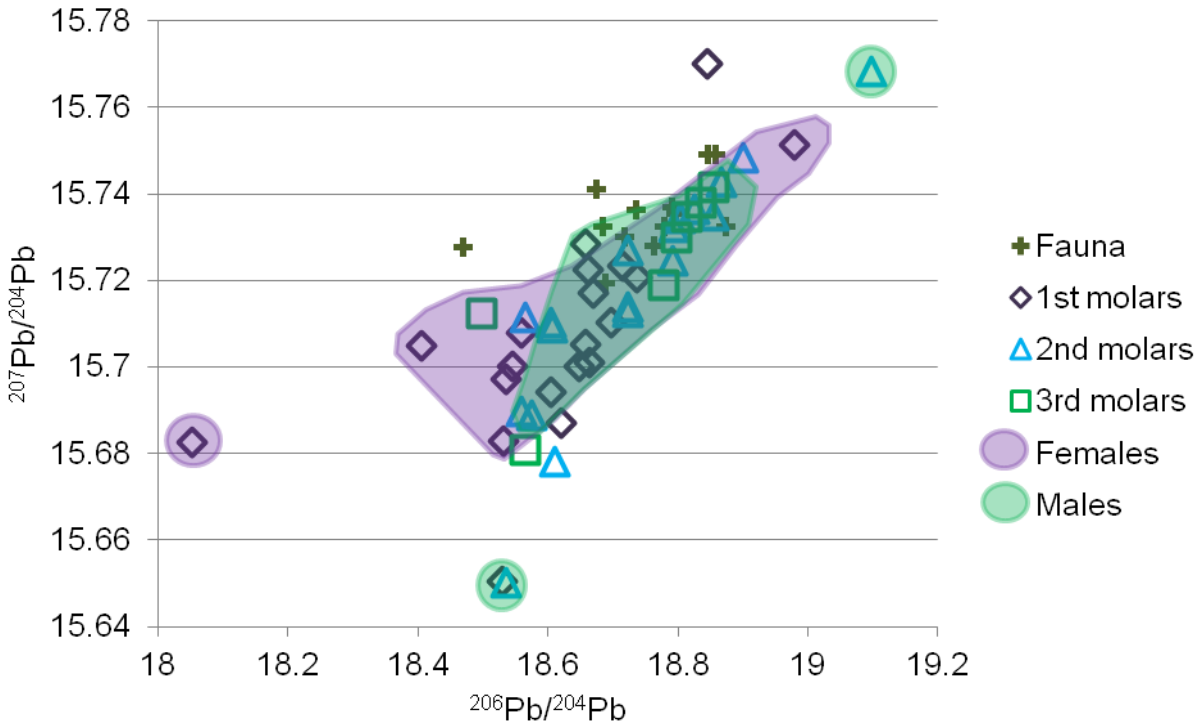

Figure 6-3. Harappa samples in Pb-Pb space by sex—$^{207}Pb/^{204}Pb$

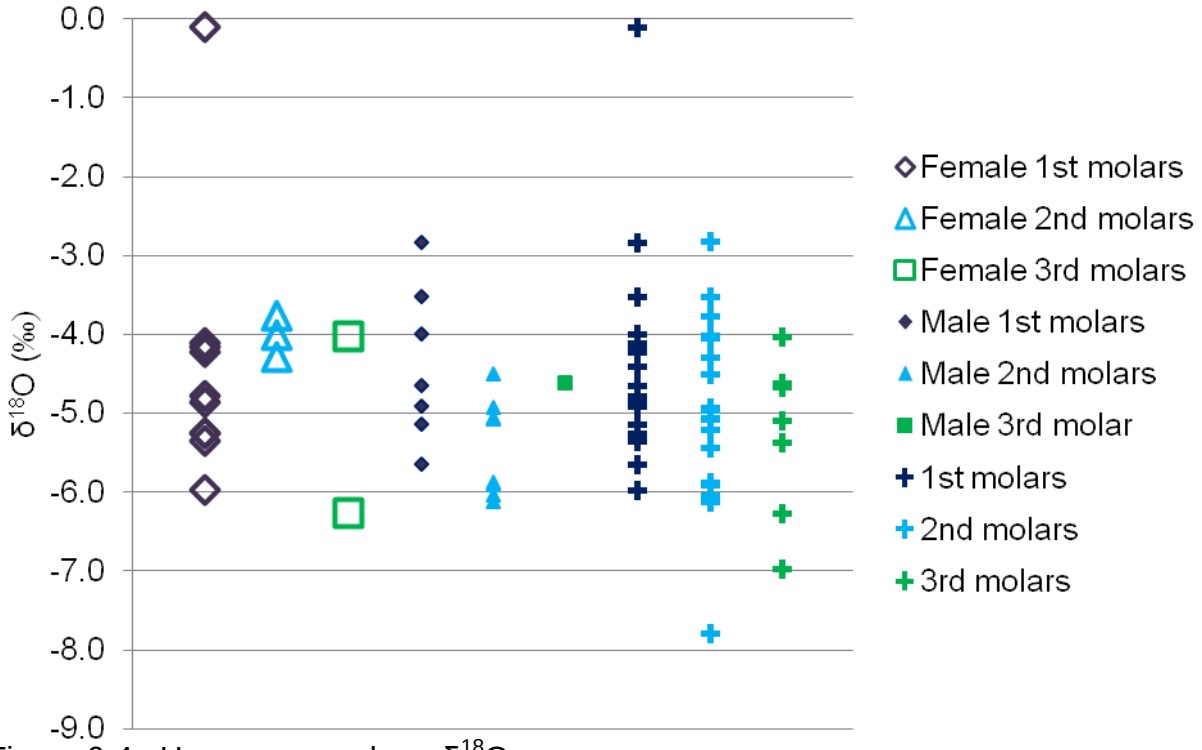

Figure 6-4. Harappa samples—$\delta^{18}O$

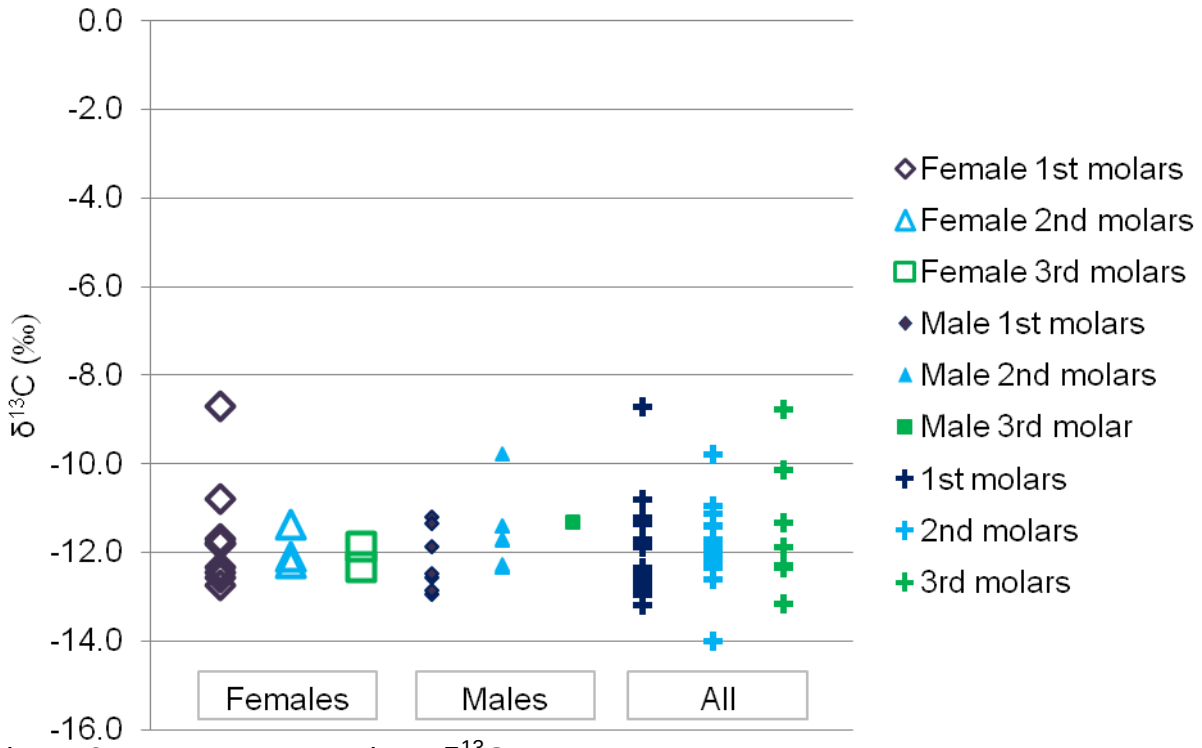

Figure 6-5. Harappa samples—$\delta^{13}C$

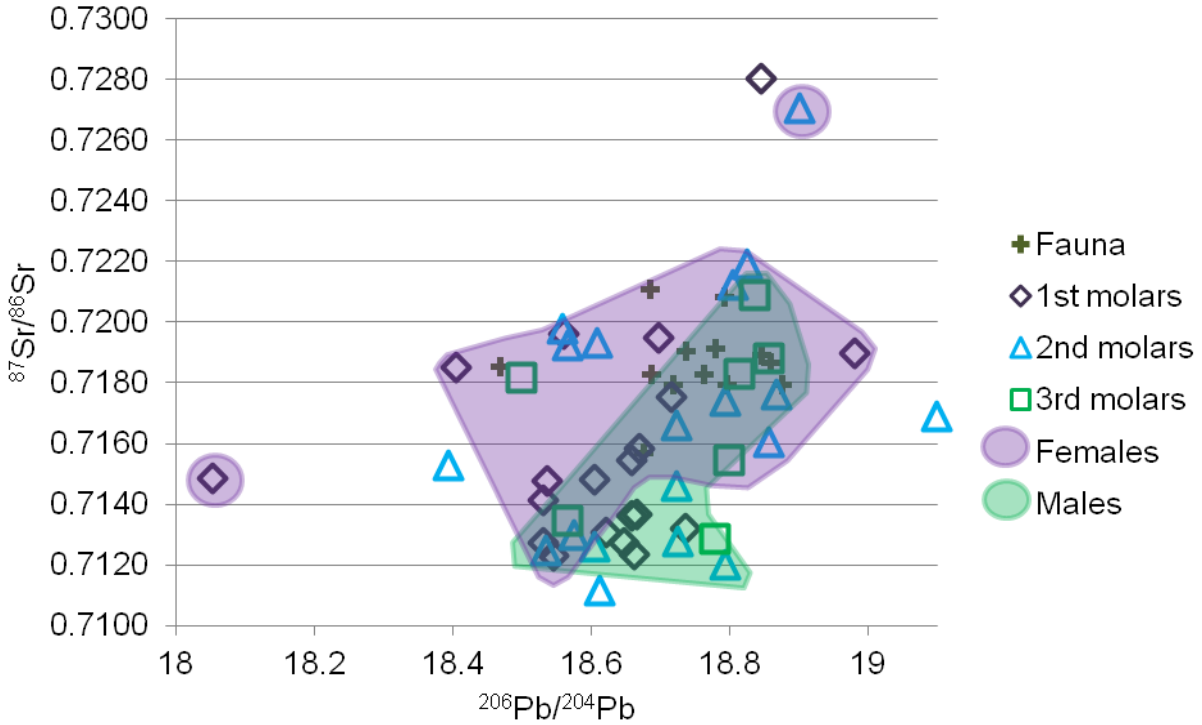

Figure 6-6. Harappa samples in Pb-Sr space by sex—$^{87}Sr/^{86}Sr$

CHAPTER 7
SANAULI

Localization Era Mortuary Treatment

Localization Era cemeteries are even less well documented than those of the Integration Era, thus the mortuary site of Sanauli provides one of the few available opportunities for a diachronic isotopic perspective on mobility within the Indus Civilization. Sanauli is the only known Localization Era cemetery apart from Cemetery H and Area G at Harappa, but the disturbed remains from Area G demonstrates little continuity with broader Indus mortuary practices (Vats 1940). The formalized inhumations of Cemetery H provide the best contemporaneous parallel for mortuary practices at Sanauli. Excavated by M. S. Vats between 1928-1934 (1940) and Sir Mortimer Wheeler in 1946 (1947), 26 inhumations were discovered in the lower levels (Stratum II) of Cemetery H which were immediately overlain by secondary “pot burials” in the uppermost levels (Stratum I) (Gupta et al. 1962). Archaeologists have variously emphasized the similarities of Stratum II inhumations with those of Cemetery R-37 (Kenoyer 1998: 174-175) as well as the dissimilarities (Wright 2011: 266).

Though no exhaustive descriptions of Cemetery H burials have been published, Vats’ summary treatment of Stratum II inhumations (1940: 220-240) depicts a mortuary program that is broadly similar to that of the urban era. Some individuals are buried in a flexed posture, but others have the extended supine position known from urban era cemeteries. Likewise, the same broad functional classes of pottery are present at Cemetery H (e.g., dish-on-stand). Though pottery was sometimes deposited at the feet, at other times it was placed near the head and occasionally buried below the body as frequently occurred at urban cemeteries. Other parallels can be seen in the relatively

modest display of grave wealth which is limited primarily to pottery and a few personal ornaments.

Cemetery H burials are differentiated from those of the urban era by the inclusion of some faunal remains and diverse grave orientations, but the relatively greater variability of post-urban mortuary practices does not appear to be strongly patterned based on Vats' (1940) selective description. The lack of redundancy in mortuary traits implies that the different mortuary treatments are best regarded as variations on a common theme. For example, demographic categories like age and sex are not consistently associated with any particular burial practices, and spatial variables such as grave orientation show no obvious correlation with other mortuary traits. The provisional conclusion, then, is that the post-urban program of inhumations dealt primarily with those aspects of identity shared by the deceased rather than those that differentiated them from each other. Indeed, a similar inference was made in the preceding chapters for urban era inhumations, suggesting that the general criteria for inhumation in a cemetery may have remained the same even when affiliations with specific social institutions or cultures changed. One possibility to consider is that migration or a social identity contingent on residence change was a prerequisite for inclusion in the highly restrictive program of Indus cemetery inhumations.

The Sanauli Cemetery

Located between the Yamuna and Hindon Rivers in what today is western Uttar Pradesh, Sanauli is one of the few well-documented post-urban mortuary sites of the Indus Tradition. D.V. Sharma led excavations from 2005-2006 and discovered 94 burials and 22 additional associated features across a 1565 m^2 area. The full extent of the site is unclear, but local residents report finding further archaeological materials in

the surrounding fields, suggesting the site could be much larger (Prabhakar 2012). No associated habitation area has been discovered yet, but Indus inhabitants likely would have enjoyed relatively reliable agricultural production compared to people living in more arid regions of the Indo-Gangetic divide. Modern precipitation gradients and lithostratigraphic transects for this ecologically transitional region suggest that summer precipitation declined steeply in areas to the west and south (Saini and Mujtaba 2012), allowing Sanauli residents to conceivably grow more drought-susceptible cereals like wheat, barley, and rice. Further, modern topographical observations suggest the site may have been adjacent to an ox-bow lake, a now dry remnant of the Yamuna that is presently located ~7 km to the west (Prabhakar 2012). In fact, local ecologies were probably important influences in the redistribution and transformation of Indus settlements across the subcontinent during the post-urban era, and no uniform statements can be made about post-urban agricultural production and social organization (Weber et al. 2010; Wright and Schuldenrein 2008). Unfortunately, such post-urban heterogeneity coupled with the lack of habitation data permit only the most tenuous speculations on the broader socio-economic conditions at the site. It might even be the case that Sanauli was a stand-alone necropolis used by multiple communities in the area. Modern residential and agricultural land-use, however, might be concealing the habitation area at the site.

Domestic context aside, the mortuary material culture at Sanauli has much in common with other post-urban Indus sites. Though some specific types are unique to the site, much of the ceramic corpus consists of well-fired, wheel-made red ware in forms known from other post-urban sites including Bhagwanpura, Hulas, Mitathal,

Mandi, and Cemetery H at Harappa (Sharma et al. 2005, 2007; Prabhakar 2012). area reliable chronology is unavailable, however, V.N. Prabhakar (2012) used a modified version of the classification system advocated by Dales and Kenoyer (1986a) and estimated that the cemetery was active during the first half of the 2nd millennium BC. Unfortunately, disturbed topsoil makes stratigraphic comparison unreliable. Multiple phases of burial activity are apparent, though not precisely defined, suggesting relatively long-term use of the site (Prabhakar personal communication). Lastly, the presence of multiple gold grave goods further supports a post-urban chronology because the precious metal is only rarely found in urban era mortuary contexts.

Primary Burials and the Osteological Sample

Though Sanauli can provide vital insight into post-urban Indus life, any interpretation of the mortuary program must be preceded by a discussion of bone preservation. The vicissitudes of monsoon weather and extensive disturbance over the millennia have heavily impacted the cemetery. The skeletal remains in particular have been damaged, and even the most complete skeletons are missing various elements. In many instances, only highly fragmentary crania or long bones remain. Robust elements of the legs and pelvis are particularly well represented, and this bias can give the impression of secondary mortuary activity. In each case, however, the preservation can be attributed to disturbances such as modern agricultural activity or crosscutting burials (Prabhakar personal communication). The latter disturbances appear to be a common feature of the broader Indus mortuary program and at Cemetery R-37, at least, have resulted in numerous skeletal fragments either isolated or in grave shaft backfill (Dales and Kenoyer 1989a). Several recorded features at Sanauli are little more than small

piles of human or faunal bone fragments, and they are perhaps best interpreted as an unintentional byproduct of repeated digging.

However, secondary mortuary activity may best explain some aspects of the skeletal record. It was noted that the tibia of burial 21 is longer than the associated femur and one clavicle of burial 37 is shorter and more robust than the other (Sharma et al. 2007; Prabhakar 2012). Attributed to pathology and occupational stress, these are nevertheless very unusual conditions and it is difficult to rule out either a technical error or the possibility that the skeletons were misassembled during secondary mortuary treatment. Given the limited information available, however, the most conservative approach for this analysis is to follow the classification of Prabhakar and assume all but four of the burials are primary inhumations. The remaining four burials are “symbolic” and are discussed below.

Pooled demographic data from the osteological field analysis and my own assessment of the isotopic sample suggest the mortuary population is likely not a representative cross section of a breeding population (Table 7-1). Adults are nearly twice as prevalent relative to sub-adults among the 35 individuals for whom age estimation was possible. This inversion of the mortality profile commonly found in stable archaeological populations suggests either that the majority of sub-adult skeletons were not preserved, or more plausibly, that sub-adults were less frequently inhumed in the cemetery. No such bias appears to have existed based on sex, however, as males and females are present in nearly equal proportions. Also, observations from the field analysis suggest that females are relatively robust and of slightly greater stature than males. Though sample sizes are small, this finding could suggest genetic distance

between the sexes, i.e., males and females derived from different populations, as has been inferred at Harappa from biodistance studies (Hemphill et al. 1991; Kennedy 2000).

The relatively small number of sub-adults suggests the mortuary population was structured by cultural practices, but there is little correlation between demographic variables and particular mortuary treatments (Table 7-1). One possible exception, however, is the inclusion of beads. Out of 13 burials with beads, six are associated with sub-adults, three are associated with adults, three are from burials with no age estimate, and one comes from a double burial containing the remains of one adult and one partial skeleton with no age estimate. In fact, the richest burial in the cemetery is a sub-adult adorned with four gold bangles and elaborate gold and copper bead necklaces. One possible explanation for the observed distribution of wealth items such as beads is that burial was an expensive process reserved for more prominent kin. Wealthier families, however, may have been able to bury younger individuals as readily as adults, leading to a higher proportion of sub-adults buried with beads. Nevertheless, this remains speculative and mortuary samples at other sites are needed to confirm the trend.

The substantial majority of burials at Sanauli is less elaborate and conforms to the typical Indus pattern—extended and supine skeletal remains oriented in a northerly direction with pottery near the head and modest grave wealth, if any. The local expression of the mortuary program varies across a range of traits, most of which are known from other cemetery sites. For example, burials are oriented around a NW-SE axis, as is the case for Farmana, instead of the N-S trend observed at Cemetery R-37.

Four inhumations (16, 18, 25, and 73) deviate furthest from the N-S axis and orient nearly west to east, although this alignment does not appear to be associated with any other mortuary trait in particular. Like grave orientation, associated ceramics vary in ways that are similar to other Indus cemeteries. Pots were sometimes interred at a level lower than the body (n=5), suggesting a multistep inhumation process like that known from Cemetery R-37 (Dales and Kenoyer 1991). Pots were also sometimes placed underneath the pelvic area, along the sides, or at the feet rather than just near the head (n=19). No obvious correlation is discernible between these alternative modes of pottery placement and other mortuary variables, although comparisons are limited by the highly disturbed skeletal sample and the nature of the ceramic analysis. No discussion is presented here on the proportions of Harappan vs. non-Harappan ceramics, as was the case in Chapter 5, because the Sanauli reports (Sharma et al. 2007; Prabhakar 2012) make no systematic burial-specific distinction between pots of the Indus Tradition (e.g., Cemetery H or Punjab phase) and pots made in regional styles.

Symbolic Burials

The most unusual burials at Sanauli are the so-called “symbolic” burials (14, 28, 106, and 116). The symbolic burials clearly constitute a distinct class, although a spectrum of continuity with other burials in terms of their overall orientation, pottery forms, and pottery distribution might suggest a hybridization of mortuary practices. Further, intermediate burial forms might indicate interregional interaction between local residents and non-locals with diverse cultural affiliations. Unfortunately, skeletal material is absent—having been substituted for by several unique ceramic types and various ritual objects. Burial 14 contains 18 vessels, three of which are a type of vase found nowhere else in the Sanauli assemblage. In place of a skeleton, a copper sheath lies

across a dish-on-stand, and situated amongst the pots at the head of the burial with blade pointing skyward is a copper “antenna” sword with its diagnostic flanged hilt. Such swords are known from archaeological caches of copper artifacts including celts, weapons, anthropomorphs and other items that collectively are referred to as copper hoards. They are most often found in and around the Ganga-Yamuna doab, but they have been recovered from many parts of India—usually as isolated finds without associated context (Lal 1951; Gupta 1989). Excavations at Sapai, however, have shown them to be contemporaneous with Ochre Colored Pottery (OCP), an archaeological complex of the 2nd millennium BC variously deemed a distinct archaeological culture or a regional manifestation of the post-urban Indus Tradition (Lal 1972; Dikshit 1979; Singh 2008:216-218). In either case, the antenna sword of burial 14 suggests that Sanauli residents occupied a culturally diverse landscape.

A mix of novel and ‘typical’ traits suggests that symbolic burials constitute a distinct mortuary type expressed partly in terms of the normative mode of inhumation. For example, burial 28 consists of 28 copper anthropomorphs laid out in the shape of a violin and bounded by a copper strip. The composite copper display is directly adjacent to two dishes-on-stands of a unique type that nevertheless seem to reference the way that a dish-on-stand supports the pelvis in some extended burials. Burial 106 invokes both the violin-shaped display of burial 28 and the copper sheath of burial 14. No ceramics are present, but multiple rows of steatite inlays outline a violin-shape with a circular “head” along an E-W orientation. A copper sheath lies in the center of the inlays, and the entire display is flanked by a mud-brick wall to the north which could possibly be one wall of a burial chamber. Two such walls are present at the northern corners of

burial 116 which is made up of 15 ceramic vessels adjacent to a copper display. A bowl sits in the middle of a violin-shaped display made from approximately 600 faience beads. Though highly disturbed, burials 66 and 73 further support the idea of a hybrid mortuary program. Both contain fragmentary skeletal remains and are laid out in a manner comparable to other inhumations, but they also contain copper items like those of the symbolic burials. Burial 66 includes a display of six copper anthropomorphs arranged similarly to those of burial 28, and burial 73 has a copper sheath.

Collectively, the symbolic burials and burials 28 and 73 suggest that participation in the Sanauli mortuary program was not subject to the same ideological controls that have been inferred for urban era cemeteries based on their relative homogeneity (Pollock 2008). At least some residents had leeway to hybridize different modes of burial, such that they were very likely aware of the diverse challenges and opportunities in a variable social landscape. Hybridized burials may have been one medium by which interregional relationships between OCP-producing peoples and other post-urban groups were negotiated. Further, migration may have been structured by the interactions between OCP sites from the east and south and other post-urban Indus sites to the north and west. No tooth enamel was recovered from the hybridized burials, but evidence for interaction along these lines may still be observable in the broader isotopic sample.

Results of the Analyses

Isotopic data and Sr concentrations are presented in Table 7-2. Values of $^{87}Sr/^{86}Sr$ range from 0.71254 to 0.72714 with Sr concentrations from 93 to 359 ppm. Lead isotope ratios also exhibit heterogeneity with $^{208}Pb/^{204}Pb$ from 38.156 to 39.478, $^{207}Pb/^{204}Pb$ from 15.677 to 15.827, and $^{206}Pb/^{204}Pb$ from 18.227 to 19.439. Tooth

enamel yielded $\delta^{18}O$ of -6.6 to -1.7‰ and $\delta^{13}C$ of -13.5 to -4.4‰. Means and standard deviations are presented for each tooth cohort in Table 7-3.

No faunal teeth were available at the time of sampling, and sediment leachates serve as the only proxy for local environmental variability of Sr and Pb isotope ratios. The results of all analyses are given, but data from deciduous teeth (burials 36, 67, 74B, 95, and 99) are excluded from subsequent figures and interpretations because deciduous enamel is presumed to be more susceptible to diagenetic alteration. Data from burials 34, 55, and an individual of unknown burial number are similarly excluded because of their indeterminate molar position.

A plot of Sr ratios against the reciprocal of Sr concentration is presented in Figure 7-1. Unlike the Farmana sample, the Sanauli distribution suggests a random scatter rather than a distinct mixing line between two endmembers. This could mean that the geochemical environment was relatively homogenized with respect to Sr isotopes. On the one hand, variability is substantial but does not seem to be represented by a simple mixing line. On the other hand, high inter-individual variation in Sr concentration caused by dietary differences might obscure a linear trend between a more radiogenic low concentration source and a less radiogenic high concentration source.

The Pb isotope data, however, show a clear linear trend (Figures 7-2 & 7-3). The patterning suggests that individuals at Sanauli were exposed to environmental sources with diverse Pb isotope ratios, although the range of values cannot be used to infer geographic distance without additional baseline analyses. The data may indicate a two component mixing system controlled by a more radiogenic and a less radiogenic

source. Further, local soil ratios cluster at one end of the distribution, whereas the full range of ratios is represented by all three tooth types.

Oxygen isotope values show a clear trend based on tooth type (Figure 7-4). The first molar mean $\delta^{18}O$ (-4.1‰ ± 1.8 [2σ]) is not significantly higher than that of second molars (-0.4‰ ± 1.6 [2σ]), but is significantly higher than the third molar mean $\delta^{18}O$ (-4.9‰ ± 1.3 [2σ]) ($t(34) = 2.867$, $p = 0.007$). The shift was ongoing or not yet begun at the time of second molar mineralization, suggesting a change in water source typically occurred late in the mineralization process at ~5 years of age.

Carbon isotope values differ from $\delta^{18}O$ in that the mean values remain stable across developmental time (Figure 7-5). Mean $\delta^{13}C$ for first molars is -12.1‰ ± 1.5 (2σ), for second molars is -11.8‰ ± 1.4 (2σ), and for third molars is -12.1‰ ± 1.0 (2σ). Further, there is relatively less intra-population variation in the consumption of C_3 vs. C_4 foods compared to Farmana ($\delta^{13}C$ range = 3.9‰). In other words, there is some variation in the diets of individuals, but the relative contribution of C_3 and C_4 foods is not systematically associated with particular stages in life.

Lastly, plotting isotope ratios of Pb against those of Sr shows a more complicated pattern of variability than suggested by either isotope system alone (Figure 7-6). Figure 7-6 confirms that environmental sources of Sr and Pb are not systematically related to developmental stages as is apparent for individuals at Farmana and Harappa. The only possible exception is that the overall range in third molar data is slightly less than that for first and second molars, which could indicate fewer sources of environmental Sr and Pb in late childhood. Overall, the data cluster most tightly near the soil values, suggesting most samples were formed under exposure to the local environment. Lastly,

at least three linear distributions radiate from the large cluster of ‘local’ values, suggesting at least three additional sources of exposure to environmental Sr and Pb.

The heavy isotope data suggest that most individuals shared a common geochemical environment independent of their age. Further, the fan-shaped distribution of data points seems to radiate away from locally available sediment leachates towards less radiogenic Pb and more radiogenic Sr. Nevertheless, a substantial portion of the dataset can likely only be explained by additional exposure to one of at least three different geochemical environments. Unlike the heavy isotope data, however, $\delta^{18}O$ correlates with tooth type, suggesting most individuals experienced a shift in water sources around age five. Lastly, there is very little change in $\delta^{13}C$ by tooth type suggesting that the same range of foods underlies isotopic exposure throughout childhood. Further syntheses and interpretations are given in the following chapters.

Table 7-1. Demographic data and mortuary elaboration at Sanauli

Burial	Age	Sex	Orientation	Pottery Qty.	Beads	Bangles	Other Items
2	3-4	-	NW-SE	2	1 agate		
4	adult	F	NW-SE	-		2 copper	
18	adult	F	W-E	-	8		
20	adult	-	NW-SE	-			
21	adult	F	NW-SE	2			
22	8-12	-	NW-SE	2			
23	adult	M	NW-SE	5	2 carnelian		
25	adult	F	W-E	2			
27A	adult	M	NW-SE	6	1 steatite, 1 agate		
36	4-5	-	NW-SE	-	5		
37	adult	M	NW-SE	-	1		
38	adult	M	NW-SE	-			
42	adult	M	NW-SE	9			1 gold caplet
44A	2 adults	-	NW-SE	4			
48	1-3	-	NW-SE	-	2 agate	2 copper	
49	adult	M	NW-SE	-			
57	adult	M	NW-SE	-			
60	adult	M	NW-SE	2			
61	12-15	-	NW-SE	-			
67	1-2	-	NW-SE	2	5		
69	3 adults	F/M/-	NW-SE	25			
71	5-9	-	NW-SE	-			
74	adult/1-3	F/-	NW-SE				
80	12-15	-	NW-SE	-			
85	adult	F	NW-SE	10			
93	6-7	-	NW-SE	5	5	2 copper	

Table 7-1. Continued

Burial	Age	Sex	Orientation	Pottery Qty.	Beads	Bangles	Other Items
95	2-4	-	NW-SE	6	8 carnelian	4 gold	gold & copper necklaces
97	adult	-	NW-SE	-			
98	adult	F	NW-SE	1			
99	4-5	-	NW-SE	3			
112	adult	-	NW-SE	1			

Table 7-2. Sanauli mortuary sample—results of the analyses

Sample No.	Burial	Tooth	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
SYC-1	YC1/2 hearth	RM_1	0.72078	180	39.317	15.798	19.259	-4.7	-11.8
SYC-2	YC1/2 hearth	RM_2	0.72042	217	39.310	15.792	19.265	-5.9	-11.6
SU3-1/2[1]	unknown 3	$RM^{1/2}$	0.72064	155	39.261	15.799	19.115	-4.7	-12.7
S20-p4	20	LP^4	0.72714	171	39.079	15.781	19.166	-3.6	-13.3
S20-3	20	LM^3	0.72213	211	38.913	15.748	18.917	-4.8	-12.4
S22-1	22	RM^1	0.71709	254	39.387	15.807	19.312	-4.1	-11.1
S22-2	22	RM^2	0.71693	295	39.298	15.793	19.228	-3.9	-11.1
S25-1	25	LM_1	0.71938	203	39.435	15.816	19.353	-4.1	-10.3
S25-2	25	LM_2	0.71957	234	39.329	15.812	19.248	-3.9	-11.5
S25-3	25	LM_3	0.71984	208	39.291	15.793	19.225	-4.1	-12.2
S29-p3	29	LP_3	0.71962	215	39.169	15.763	19.250	-3.1	-11.5
S34-1/2[1]	34	$RM^{1/2}$	0.71984	195	39.282	15.784	19.232	-4.9	-11.6
S36-d2[2]	36	LdM_2	0.71881	193	39.296	15.787	19.221	-4.0	-11.9
S36-1	36	RM_1	0.71876	219	39.444	15.813	19.346	-4.4	-11.9
S37-1	37	LM_1	0.72182	93	38.971	15.750	19.025	-3.7	-11.6
S37-2	37	LM_2	0.72216	98	39.284	15.798	19.205	-4.0	-10.5
S37-3	37	LM_3	0.72213	126	39.330	15.803	19.227	-4.9	-11.4
S38-1	38	RM_1	0.71925	157	38.883	15.730	18.985	-4.5	-13.3
S38-2	38	RM_2	0.71906	208	39.401	15.801	19.290	-5.0	-12.7
S44A-1	44A	RM_1	0.71923	133	39.274	15.779	19.211	-4.6	-12.6
S44A-2	44A	RM_2	0.71900	174	39.356	15.797	19.267	-5.4	-12.1
S44A-3	44A	RM_3	0.71891	156	38.589	15.677	18.752	-5.3	-11.7
S44B-1	44B	LM_1	0.72164	127	39.145	15.776	19.008	-4.1	-12.8
S44B-2	44B	LM_2	0.72119	209	39.171	15.773	19.073	-4.5	-11.6
S44B-3	44B	LM_3	0.72175	170	39.111	15.775	18.992	-5.0	-11.3

[1] indeterminate molar position [2] enamel is deciduous or poorly mineralized

Table 7-2. Continued

Sample No.	Burial	Tooth	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
S44C-1	44C	RM^1	0.71757	181	39.302	15.786	19.237	-4.6	-12.3
S44C-2	44C	RM^2	0.71762	245	39.375	15.807	19.316	-5.2	-11.3
S49-2	49	RM_2	0.72101	158	39.347	15.802	19.287	-4.1	-12.2
S54-1	54	LM_1	0.71894	189	39.026	15.747	19.016	-3.3	-11.6
S54-2	54	RM^2	0.71807	198	39.379	15.805	19.294	-4.4	-10.3
S55-1/2[1]	55	$LM_{1/2}$	0.71254	236	38.882	15.716	18.902	-2.7	-4.4
S58-i2	58	LI^2	0.71863	141	38.156	15.725	18.227	-5.4	-12.5
S61-1	61	RM^1	0.71866	191	39.318	15.827	19.439	-3.3	-12.6
S61-2	61	RM^2	0.71851	203	39.255	15.791	19.216	-5.3	-12.8
S61-3	61	RM^3	0.71895	241	39.387	15.801	19.294	-6.6	-11.8
S67-d2[2]	67	RdM_2	0.72209	158	39.405	15.808	19.330	-4.3	-12.4
S69A-1	69A	LM^1	0.71983	225	39.089	15.770	19.075	-4.3	-12.1
S69A-2	69A	LM^2	0.71950	300	39.095	15.764	19.095	-4.4	-11.6
S69A-3	69A	LM^3	0.71899	312	39.293	15.787	19.222	-4.7	-11.9
S69B-1	69B	LM^1	0.71816	226	39.314	15.792	19.346	-1.7	-11.3
S69C-2	69C	LM^2	0.71953	254	38.755	15.721	18.805	-4.0	-11.8
S69C-3	69C	LM^3	0.71909	233	39.244	15.780	19.196	-4.7	-12.0
S71-1	71	LM^1	0.71974	167	39.313	15.791	19.230	-2.5	-12.1
S71-2	71	LM^2	0.71978	183	39.251	15.786	19.187	-4.1	-11.7
S74A-1	74A	LM_1	0.71900	160	39.378	15.801	19.289	-3.6	-13.5
S74A-2	74A	LM_2	0.71910	183	39.351	15.800	19.261	-2.5	-12.5
S74A-3	74A	LM_3	0.72005	164	39.292	15.787	19.191	-4.7	-11.8
S74B-d2[2]	74B	RdM^2	0.71893	101	39.110	15.765	19.059	-3.9	-12.7
S80-1	80	RM_1	0.71940	206	39.334	15.791	19.254	-5.6	-12.8
S80-2	80	RM_2	0.71991	278	39.365	15.803	19.257	-4.6	-11.8

[1] indeterminate molar position [2] enamel is deciduous or poorly mineralized

Table 7-2. Continued

Sample No.	Burial	Tooth	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
S80-3	80	RM^3	0.71875	264	39.444	15.817	19.357	-5.1	-12.9
S85-1	85	LM_1	0.72133	179	39.180	15.787	19.068	-3.7	-11.4
S85-2	85	LM_2	0.72069	213	39.005	15.727	19.122	-4.1	-11.8
S93-1	93	LM_1	0.71953	198	39.345	15.798	19.269	-3.4	-11.9
S95-d2[2]	95	RdM^2	0.71933	153	39.373	15.801	19.293	-4.3	-11.5
S97-1	97	LM_1	0.71905	182	39.064	15.754	19.130	-4.3	-12.8
S97-2	97	LM_2	0.71946	200	39.003	15.747	19.016	-5.0	-12.4
S97-3	97	LM_3	0.71940	180	38.891	15.732	18.966	-4.6	-12.4
S98-1	98	LM_1	0.72021	163	39.372	15.804	19.275	-3.7	-13.1
S98-2	98	LM_2	0.72048	243	39.277	15.794	19.200	-4.0	-12.1
S98-3	98	LM_3	0.72137	217	39.362	15.801	19.259	-4.0	-12.7
S99-d2[2]	99	LdM_2	0.71990	136	39.229	15.790	19.172	-4.4	-11.2
S99-1	99	LM_1	0.72008	178	39.314	15.796	19.237	-4.9	-11.5
S112-1	112	LM_1	0.71846	300	39.478	15.827	19.377	-5.1	-12.3
S112-2	112	RM_2	0.71858	290	39.472	15.824	19.369	-5.0	-12.0
S112-3	112	LM_3	0.71962	359	39.421	15.821	19.316	-4.9	-12.8

[1] indeterminate molar position [2] enamel is deciduous or poorly mineralized

Table 7-3. Sanauli mortuary sample summary statistics—mean±2σ

Cohort	$^{87}Sr/^{86}Sr$	Sr ppm	$^{208}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{206}Pb/^{204}Pb$	$\delta^{18}O$	$\delta^{13}C$
All	0.71965±0.00351	200±105	39.221±0.450	15.784±0.060	19.176±0.366	-4.3±1.6	-11.9±2.3
1st molar1	0.71941±0.00238	185±88	39.210±0.558	15.785±0.056	19.172±0.488	-4.1±1.8	-12.1±1.5
2nd molar	0.71988±0.00403	217±97	39.242±0.336	15.786±0.053	19.201±0.244	-4.4±1.6	-11.8±1.4
3rd molar	0.72008±0.00260	218±130	39.197±0.508	15.779±0.079	19.147±0.363	-4.9±1.3	-12.1±1.0

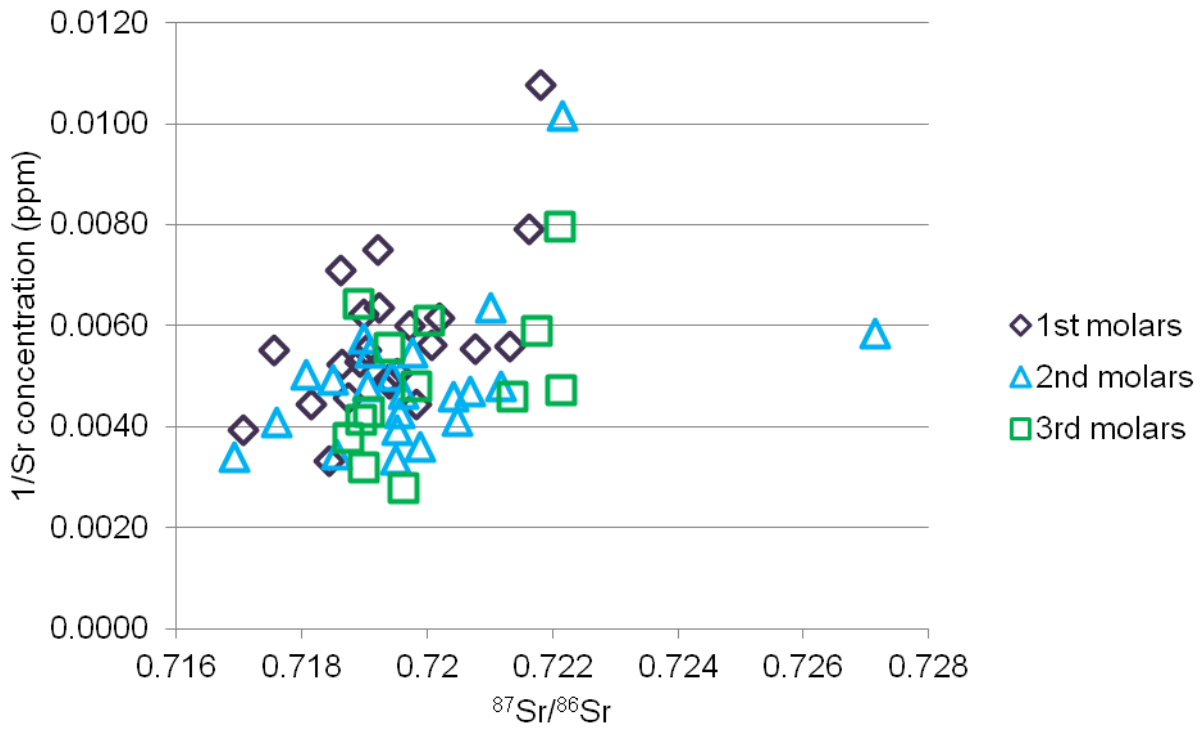

Figure 7-1. Sanauli samples in Sr-Sr space—reciprocal of Sr concentration

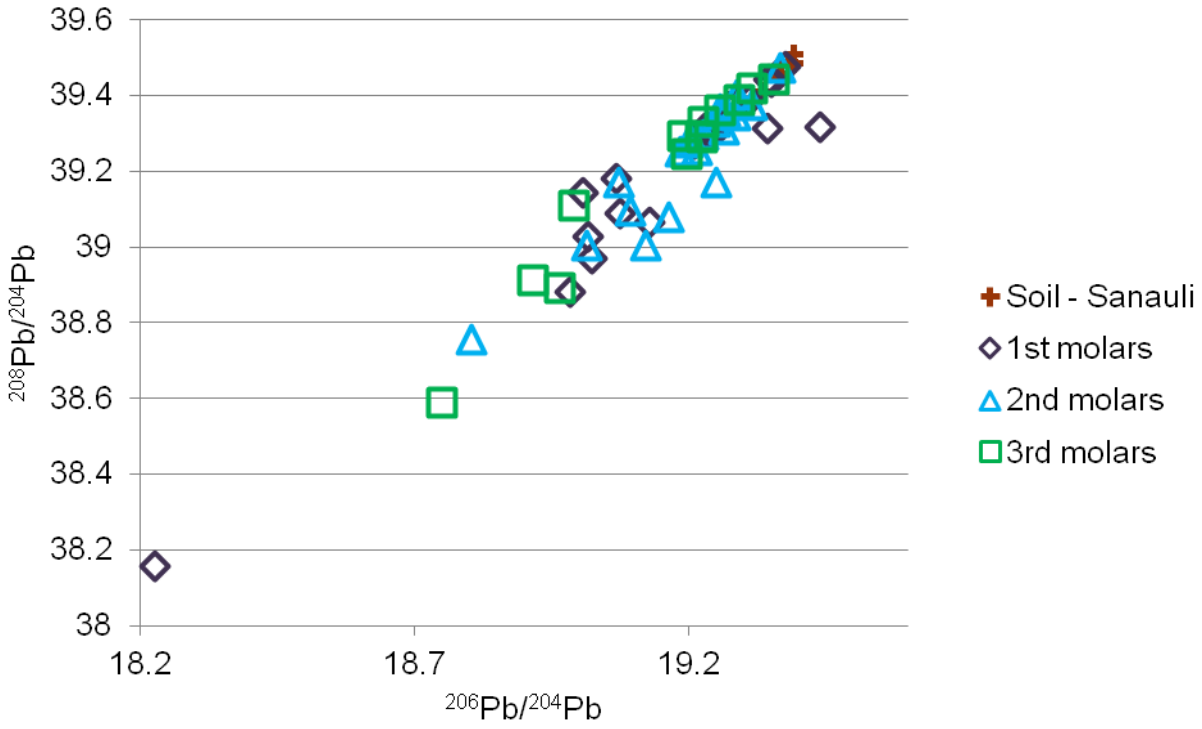

Figure 7-2. Sanauli samples in Pb-Pb space—$^{208}Pb/^{204}Pb$

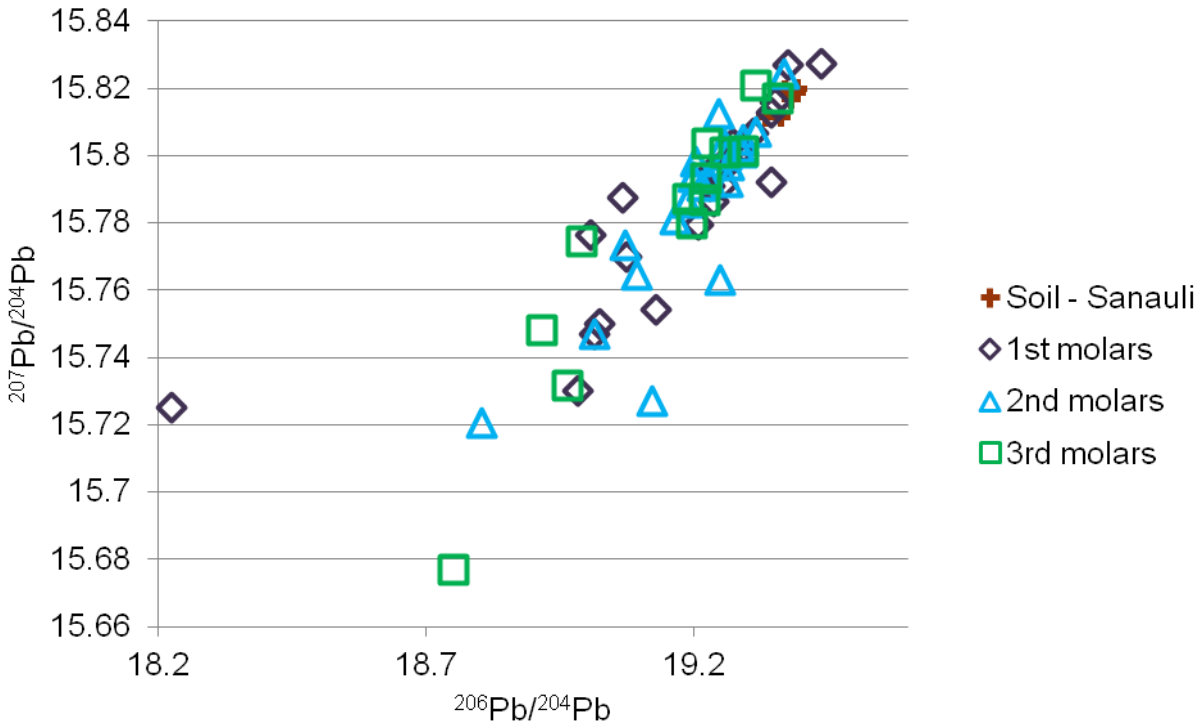

Figure 7-3. Sanauli samples in Pb-Pb space—$^{207}Pb/^{204}Pb$

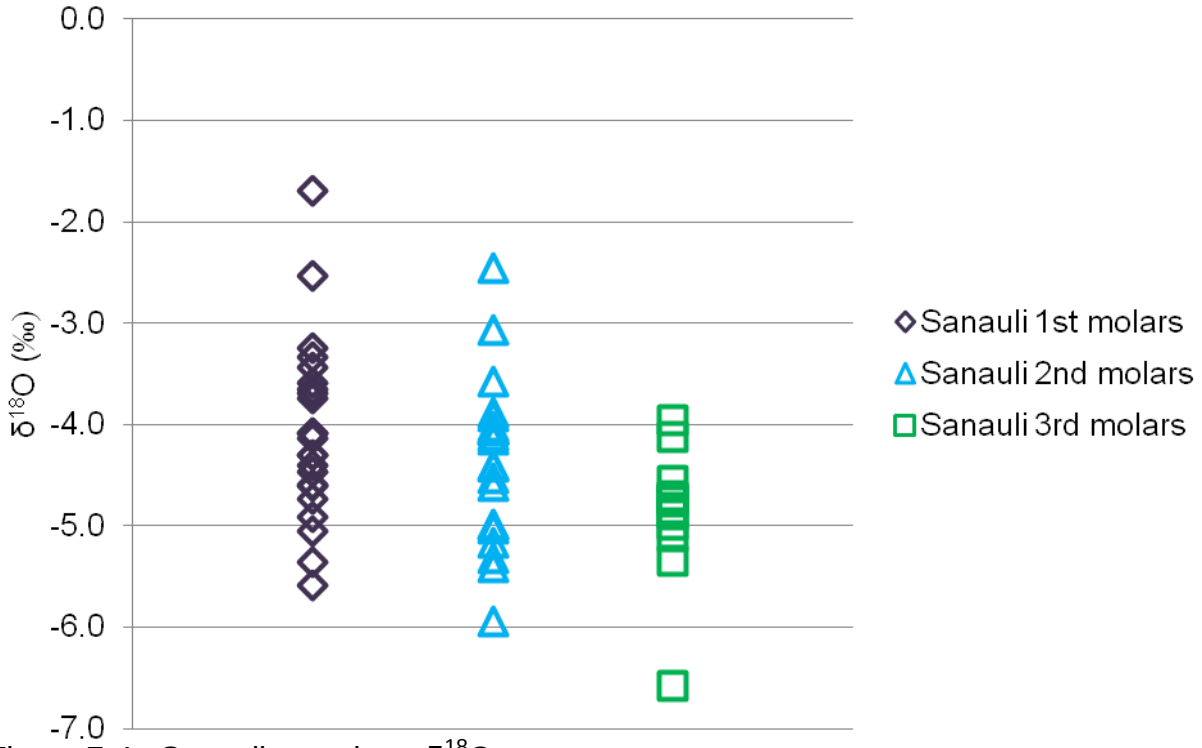

Figure 7-4. Sanauli samples—$\delta^{18}O$

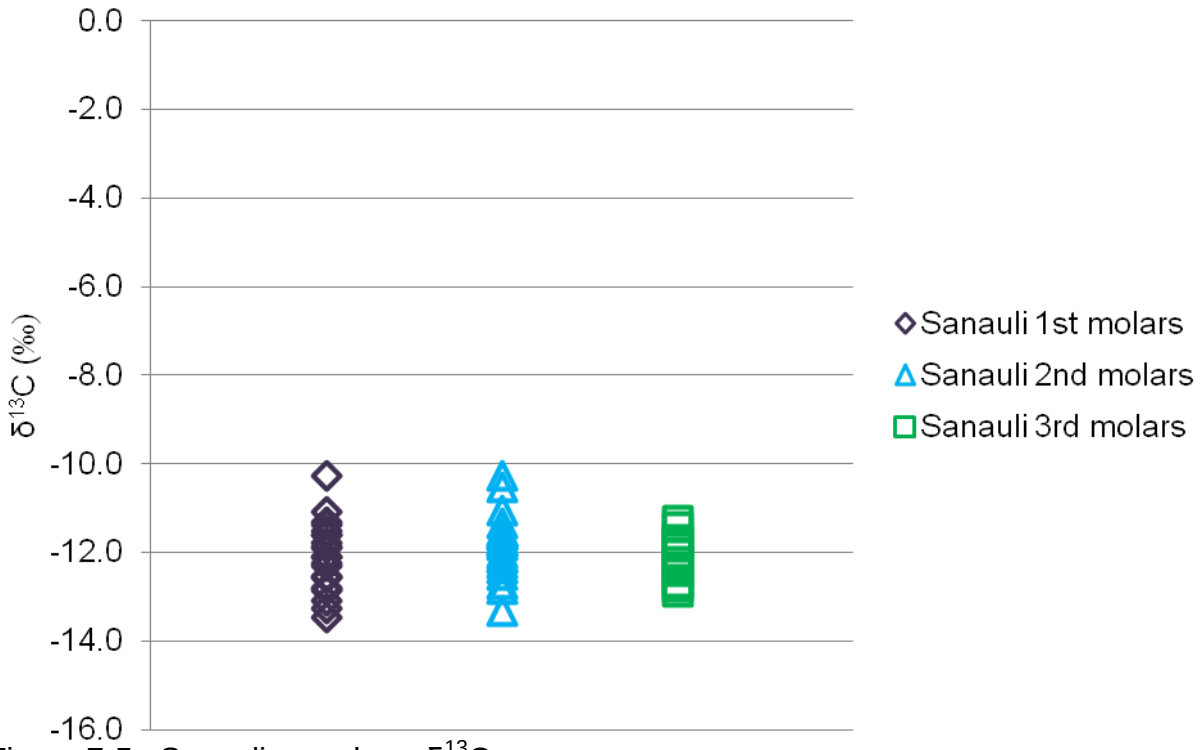

Figure 7-5. Sanauli samples—$\delta^{13}C$

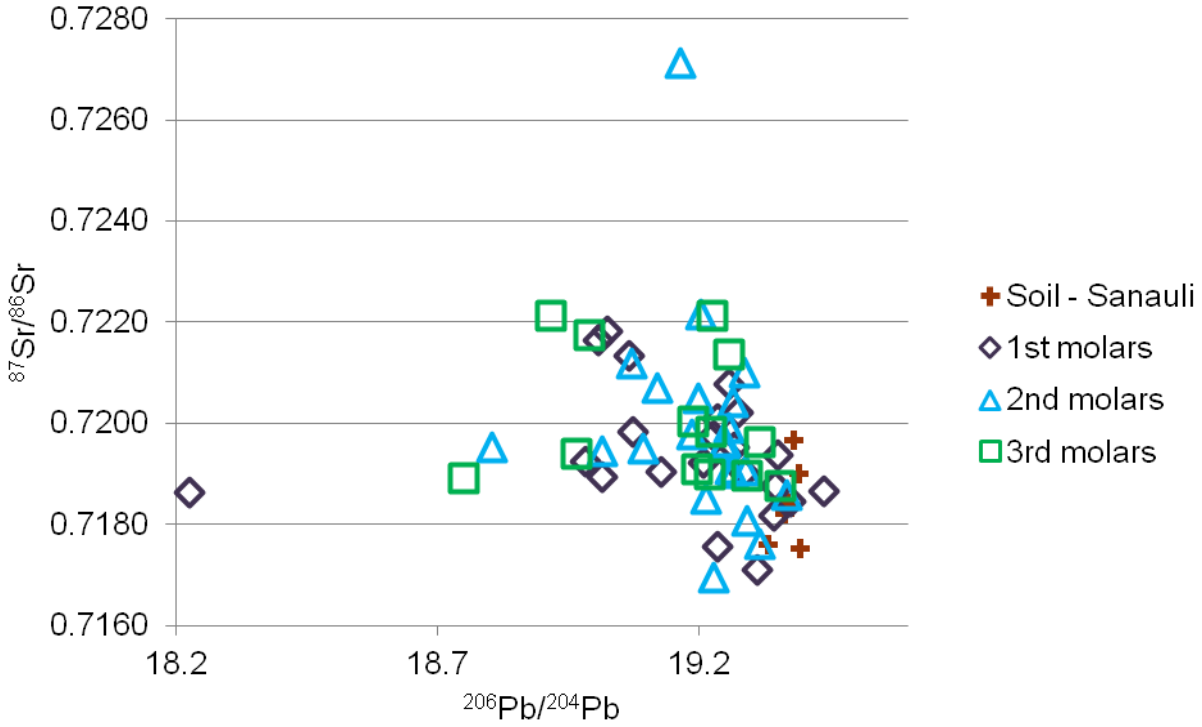

Figure 7-6. Sanauli in Pb-Sr space—$^{87}Sr/^{86}Sr$

CHAPTER 8
DISCUSSION

The isotope data presented in chapters 5, 6, and 7 are structured and several patterns emerge that require further discussion. In particular, isotope data from Farmana and Harappa are structured by tooth cohort and sex. At Farmana, the first molar cohort is completely segregated from all other human, faunal, and sediment samples by Pb isotope ratios (Figures 5-2 & 5-3), whereas there is little variation in $^{87}Sr/^{86}Sr$ (Figure 5-1). The first molar cohort at Harappa overlaps with both the second and third molar cohort with the exception that no first molar data plot in the local range inferred from the intersection of faunal and human heavy isotope data (Figure 6-6). Further, Pb, Sr, and O isotope datasets from Harappa are structured by sex. In general, females exhibit a wider range of variation in Pb-Sr space (Figure 6-6), and appear to show an increase in $\delta^{18}O$ between first and second molars (Figure 6-4), contrary to the expected decrease in $\delta^{18}O$ associated with weaning (Wright and Schwarcz 1998).

One possible interpretation is that inhumation at the Integration Era cemeteries of Harappa and Farmana was reserved for immigrants who left their natal groups at a young age, presumably without the company of their genetic kin. Further, provenience data are consistent with origins in the highlands, piedmont, or other hinterland regions outside of the foreland alluvium. As such, immigrants may have originated from non-Indus sites, although the present evidence is insufficient to unequivocally determine their cultural affiliations. If confirmed by future research, however, immigration from non-Indus sites might help explain their distinct cultural trajectories within a broader interregional system of economic exchange. Multiple lines of isotopic evidence are presented in support of the following claims:

- Nearly all individuals inhumed in Integration Era cemeteries were immigrants.
- The immigrants came from hinterland sites.
- Initial residence change occurred early in childhood.

By contrast, the isotope data from Sanauli suggest the mortuary population was less mobile and that migration largely occurred within the alluvial lowlands. Certain elements of the urban era institution of migration may have persisted into the post-urban era, but if so, the relationship between institutionalized immigration and cultural identity had fundamentally transformed.

As mentioned above, additional analyses are needed to resolve issues of equifinality in the geographic provenience and cultural affiliation of urban era individuals, however, a model of highland-lowland interaction is proposed predicated on the possibility that immigrants originated with non-Indus groups that were trading with lowland elites. The model provides an investigative framework for future hypothesis testing, and more broadly, demonstrates the need to account for diverse social dimensions when interpreting migration and exchange. The mere delineation of trade routes and migration paths does little to advance our understanding of past societies unless such provenience data are embedded within the social landscape.

Integration Era Mobility

Before moving forward with behavioral explanations for the isotope data, the validity of the data must be addressed. If the isotopic values had been altered at any stage in the post-mortem environment, it would compromise the utility of the data for modeling past human mobility. Fortunately, the structure of the data set provides evidence that the reported isotope values are representative of biogenic exposure rather than post-mortem diagenesis. First and foremost, the isotopic data would not be

patterned by tooth type if diagenesis were a major concern; instead, all teeth would display similar isotope values. The urban cemeteries show a trend towards non-local isotope values among the first molar cohort, whereas values of the second and third molar cohorts tend to plot near local sediments and fauna. Even at Sanauli, where there is no single pattern of convergence, intertooth variation appears to be structured along a series of mixing lines that cannot be readily explained by isotopic variation in local sediments. Therefore, the isotope data from Farmana, Harappa, and Sanauli appear to preserve the *in vivo* signal that reflects ingested environmental sources. It is conceivable that some partial post-mortem alteration occurred, thus shifting values towards those of the burial environment but not enough to eradicate the intra-individual patterns. It is difficult to disprove this possibility for any given sample, but as discussed in Chapter 3, the preponderance of data from analyses in a wide range of archaeological contexts suggests that enamel provides a high-fidelity record of isotopic exposure. Therefore, it is assumed that the isotopic values for Indus inhumations accurately represent weighted averages of environmental input at the time of enamel mineralization for each individual.

Immigrant Frequency

Multiple lines of isotopic evidence suggest that only first-generation immigrants received inhumation in the urban era cemeteries at Farmana and Harappa. When plotted by tooth cohort, isotope ratios of Pb and Sr show that all or part of early-life enamel mineralization occurred during a time when the individuals were exposed to non-local environmental inputs. The distinction between local and non-local is complicated by the inherent imprecision in any proxy measure of the human dietary catchment (Chapter 3). In this case, however, the internal structure of multi-isotope

datasets allows for a relatively precise estimate of local ratios. In scatter plots of Pb and Sr isotope ratios, the convergent distributions of fauna, sediment leachates, and late-developing human tooth enamel suggest that a relatively small range of ratios characterized the local environments at Farmana (Figure 8-1) and Harappa (Figure 8-2). Further, it is unnecessarily conservative to adopt the full isotopic range exhibited by fauna as the local estimate. Determination of the local range using a multi-proxy multi-isotope approach remains a visually subjective process in that no precise quantitative measure distinguishes between local and non-local within continuous distributions of baseline data; however, the increased interpretive power justifies the loss of quantitative rigor.

Several possible explanations apart from migration can explain non-local values in first molar cohorts. For example, exposure in childhood to anthropogenic sources of Pb could account for intertooth isotopic differences. This possibility will be discussed below with regard to the Farmana mortuary population. At Harappa, however, it is highly unlikely that anthropogenic exposure could explain sex-based differences in the isotope data. First molars of males and females are distinguished by Pb and Sr isotope ratios (Figures 6-1, 6-2, 6-3, & 6-4), whereas males and females may exhibit opposite shifts in $\delta^{18}O$ between first and second molars. Each isotope system is governed by different environmental factors, such that only the systematic sex-based application of dramatically different water management practices, differential exposure to industrial activity or metal-bearing goods, and differential consumption of imported foods could account for the patterning in the data set. Thus, anthropogenic sources of non-local isotope values can be ruled out.

Another possible source of non-local environmental input in early life is the maternal contribution imparted by immigrant mothers during gestation and breast feeding. In modern contexts, for example, Gulson et al. (2003) have documented the mobilization of the maternal skeletal Pb burden into breast milk and its subsequent uptake in the deciduous dentition of children. A similar process could happen with Pb and Sr in archaeological populations, potentially altering their respective isotope ratios which would otherwise reflect local maternal residence. Again, however, the sex-based structure of the Harappa data set suggests that it was the individuals themselves who moved rather than their mothers. It is highly unlikely that Cemetery R-37 contains only the sons of mothers from one region and the daughters of mothers from another region. Further, $\delta^{18}O$ of enamel formed *in utero* or during nursing reflects only the isotopic composition of maternal body water, a reservoir that is independent of skeletal $\delta^{18}O$. Yet mean male and female first molar $\delta^{18}O$ differs by 0.5‰, and nearly opposite shifts (~ ±1‰) are observed between the first and second molars of males and females. This difference is only possible if males and females inhumed at Harappa were actually raised in hydrologically distinct regions.

Unfortunately, the lack of reliable sex estimates means that similar interpretive logic cannot be applied at Farmana. Further, the $^{87}Sr/^{86}Sr$ (Figure 5-1) and $\delta^{18}O$ (Figure 5-4) data are equivocal, placing the burden of proof solely on the Pb isotope ratios. For many individuals, homogenous $^{87}Sr/^{86}Sr$ across tooth types is consistent either with local origins or with origins from elsewhere in a region of homogenous $^{87}Sr/^{86}Sr$. The latter possibility is consistent with the published data for the Thar Desert fringe (Chapter 4), although additional analyses of sediment leachates and archaeological fauna are

needed to confirm this trend. The $\delta^{18}O$ data are similarly inconclusive in that the relative homogeneity anticipated for much of the Ghaggar-Yamuna interfluve precludes the conclusive identification of immigrants. Despite the shift in $\delta^{18}O$ between tooth types, it is impossible to disentangle the effect of weaning on enamel $\delta^{18}O$ from the effects of interannual climatic variation, spatial climatic variation, and behavioral variation in water management or water metabolism.

Without corroborating evidence from Sr and O isotope systems, it is difficult to rule out the possibility that young individuals were systematically exposed in a local setting to anthropogenic Pb of non-local origin. In particular, surma could have been applied to the eyes of children as it is today in many parts of the world. If Law's (2008) identifications of Pb-bearing makeup at Harappa and Mohenjo Daro are correct, then it cannot be ruled out that individuals at Farmana may have been exposed to similar makeup at a young age. As discussed in Chapter 3, the use of surma and kohl is in some cases associated with increased blood lead concentration and can therefore alter the Pb isotope ratios recorded in tooth enamel. Another possibility is that the first molar cohort recorded the skeletal Pb burden mobilized in the breast milk of immigrant mothers, although the expectation is that their breast milk should eventually equilibrate with local Pb sources as a consequence of bone turnover. A third hypothesis is that anthropogenic Pb exposure indicates non-local residence at sites polluted by heavy smelting activity. This possibility is discussed in more detail below.

Immigrant Origins

The first molars at Farmana have less radiogenic heavy isotope ratios than other tooth types, and their distribution in Pb-Pb space suggests a mixing line between local values and an endmember that is unique among the environmental samples analyzed

for this study (Figure 8-3). No direct association can be made with the natural isotopic background of a given region, but there is some correlation in Pb isotope ratios between Farmana first molars and samples taken from large archaeological slag heaps at Singhana and Ganeshwar, two sites of the Ganeshwara-Jodhpura Cultural Complex associated with intensive copper production. The region has long been considered a primary source of copper for Indus people, and the non-Indus inhabitants very likely traded extensively with their closest Indus neighbors at sites like Farmana less than 150km to the north. If immigrants at Farmana came from this region, particulate from intensive smelting could potentially explain the isotopic similarity between human teeth and copper slags. Alternatively, the low Pb isotope ratios may simply reflect an uncharacterized background source derived from the Aravallis.

The Sr and O isotope data do not directly support an immigrant hypothesis, but neither do they contradict it. The inferred homogeneity in biologically available $^{87}Sr/^{86}Sr$ for the Thar Desert fringe and nearby areas is consistent with the small range of variation in the Farmana data set. Further, limited analyses of groundwater on a transect between Delhi and the Aravalli foothills (Bhattacharya et al. 1985) suggest minimal regional variation in $\delta^{18}O$. Additional environmental analyses are needed to confirm the plausibility of relatively large-scale homogeneity in Sr and O, but migration between copper smelting highland sites and agricultural lowland sites remains a viable explanation for the intertooth differences at Farmana.

Some individuals at Farmana are more clearly of non-local origin. Rather than low Pb isotope ratios and relatively stable $^{87}Sr/^{86}Sr$, three individuals represented only by second and third molars have more radiogenic Pb or Sr (Figure 8-1). Their

distribution with respect to Sanauli sediment leachates and some of the more peripheral Rakhigarhi fauna suggests a residence influenced more by radiogenic Himalayan alluvium to the north or northeast than the aeolian sands of the Thar Desert to the southwest. Lastly, no distinction can be made between individuals exposed to more or less radiogenic environments on the basis of mortuary material culture. The small number of more radiogenic individuals (burials 26, 66, and 67) precludes statistical analysis, but there is no clear relationship between isotope ratios and variation in ceramics, ornaments, burial type, or burial orientation. The radiogenic burials have modest quantities of pottery, appear with and without beads, have multiple burial types, and multiple burial orientations.

The isotope data from Harappa more clearly constrain the possible origins of migrants. When compared with the environmental samples in Pb-Sr space (Figure 8-4), the Harappa data suggest four primary non-local regions. Three data points exhibit intermediate values between those of Harappan fauna and the sediment leachates from Farmana and Sanauli which may indicate origins somewhere along the Ghaggar-Hakra basin. This is supported by a close identification with some of the more peripheral Rakhigarhi fauna. Two more data points extend in the opposite direction, towards much less radiogenic $^{206}Pb/^{204}Pb$, and $^{87}Sr/^{86}Sr$ of approximately 0.715. No faunal data characterize this region, although the Harappan data points exhibit isotope ratios very similar to those of first molars at Farmana. Incidentally, this suggests that the anthropogenic Pb exposure posited for Farmana individuals may be confined to a relatively homogenous Sr province and does not result from a widespread cultural practice. A third source region at Harappa is characterized by highly radiogenic $^{87}Sr/^{86}Sr$

and likely has geochemical origins to the north and northeast in the Himalayan foothills. The radiogenic area likely begins at the outer fringes of the Harappan provisioning catchment as indicated by three peripheral faunal data points.

The fourth source region and by far the most significant is characterized by $^{87}Sr/^{86}Sr$ between 0.712 and 0.716 with Pb isotope ratios very similar to those of fauna at southern sites such as Mehrgarh, Nausharo, and Allahdino (Figure 8-4). This strongly suggests an origin along the main Indus catchment upstream of the Western Fold Belt carbonate influx. It is difficult to establish precise geographic parameters based on the current data set, but a conservative estimate spans the middle reaches of the Indus River, beginning upstream of the confluence with foreland tributaries and extending well into the Himalayas. Importantly, this region includes many of the source areas from which the Harappan mineral assemblage was derived (Law 2008) along with sites of the Northern Neolithic and late occurring Kot Diji cultures.

Figure 8-5 adds further support to a western and northwestern provenience for the fourth isotopic region. Two mixing lines are suggested between a single less radiogenic end member with high Sr concentration and two low concentration end members with relatively high $^{87}Sr/^{86}Sr$. Farmana, Sanauli, and most Harappa data points above 0.716 plot along a single mixing line that is potentially defined at one end by radiogenic contributions to the Indus foreland from the HHC and Lesser Himalaya. The other end is characterized by low $^{87}Sr/^{86}Sr$ aeolian carbonates derived ultimately from the Western Fold Belt. The less radiogenic ratios from Harappa (<0.716) plot along a separate mixing line, presumably between the Western Fold Belt carbonates and a different radiogenic source including the Karakoram drainages. Faunal data from

Harappa and Rakhigarhi do not appear entirely comparable to human values, but their distribution is broadly consistent with the easternmost aeolian mixing system.

Thus, Harappan immigrants came primarily from regions in or adjacent to the northwestern highlands. A smaller influx of migrants originated from various places in a broad swath of territory stretching east and south from the northern foothills into the Ghaggar-Hakra basin and Thar Desert fringe. Interestingly, males came almost exclusively from the western and northwestern area, whereas females originated in each of the proposed source regions. Additionally, isotopic distinction between the sexes is consistent with morphometric studies of population affinity at Harappa that suggest genetic distance between males and females (Hemphill et al. 1991; Kennedy 2000). The available archaeological context is insufficient to assess whether or not there is a correlation between isotopic origin and sex, although Kenoyer (2011a) has suggested that males typically had less elaborate graves. This could potentially be related to their origins outside of the Indus heartland, but no conclusive statement can be made using the available evidence.

Mode of Migration

The timing of migration events in the Farmana and Harappa mortuary populations is less clearly constrained than the geographic provenience. If the low Pb isotope ratios exhibited by first molars from Farmana are attributed to non-local exposure then the data set strongly indicates that migration events began in early childhood. The sequential distribution from first to second and then tightly clustered third molars is best explained by a change in Pb exposure early in the mineralization phase of second molars around three or four years of age (Figure 8-6A). Note that most individuals had converged on the local range at some point prior to the mineralization of

their third molars which suggests local residence and normalized adult Pb exposure by the age of seven or eight (Figure 8-6B).

Intertooth sequences in Pb-Sr space (Figure 8-6A) show that four individuals originate in more radiogenic terrain, and at least two of them had not yet reached Farmana at the point of third molar mineralization. However, intertooth sequences also suggest that at least two of the more radiogenic individuals had changed residence one or more times during childhood. The other two radiogenic individuals are each represented by only a single data point. Nine individuals, eight of whom have multiple data points, were exposed to less radiogenic Pb exclusively in early childhood (Figure 8-6B). Again assuming that shifts in Pb isotope ratios reflect residence change, the preponderance of data suggests that all individuals first changed residence at an early age. Most significantly, no individual displays low Pb isotope ratios into adulthood, suggesting that only children migrated from less radiogenic environments. Such young migrants would presumably need to be cared for by a local family or kingroup, as there is no evidence in the isotopic sample for older individuals having made the same journey.

The opportunistic nature of the Harappa sample precludes a thorough analysis of developmental sequences. Only two such sequences can be confidently determined based on the available context, and both are consistent with an early childhood migration event (Figure 8-7). The sequences indicated on Figure 8-7 are of a first and third molar and an incisor and canine, and in both cases, the later mineralizing tooth plots closer to the local range at Harappa. The intertooth isotopic shift occurs for ratios of Sr and Pb, confirming that the sequence depicts actual residence change rather than

anthropogenic Pb exposure. Additional sampling is required to determine whether or not the entire mortuary population was mobile in early life. However, the oxygen isotope composition of female first and second molars provides one additional clue. The shift towards higher $\delta^{18}O$ in second molars (discussed above) runs counter to the typical weaning related reduction in $\delta^{18}O$, and is therefore consistent with an early life migration event. Small sample sizes and a lack of developmental sequences limit the interpretive power of individual isotopic measures at Farmana and Harappa, but taken collectively, they are highly suggestive of a pattern of early life migration from adjacent highlands associated in many instances with non-Indus cultures.

Localization Era Mobility

The structure of the Sanauli data set suggests significant changes in the Indus mortuary program during the post-urban era. Unlike the all immigrant mortuary profile proposed for Farmana and Harappa, Sanauli includes individuals born locally. Sediment leachates plot next to a large cluster of data points in Pb-Sr space, suggesting that many individuals lived near the mortuary site (Figure 8-8). The local range cannot be defined with precision without additional environmental samples, but the central hub of the radial distribution of Sanauli data points likely coincides with local isotope ratios. Depending on how conservatively one estimates the local range, between 11 and 23 individuals in the isotopic sample of 33 individuals spent all or part of their early lives outside the immediate vicinity of the site. The potential source regions can be categorized into three broad groups. Two individuals come from a region with low $^{87}Sr/^{86}Sr$ (<0.718) and high $^{206}Pb/^{204}Pb$ (>19.2) that plots near the most radiogenic Farmana data points. This distribution might represent parts of the Ghaggar-Yamuna interfluve to the north and east of the Thar Desert fringe. Eight individuals have high

$^{87}Sr/^{86}Sr$ (>0.72) and a relatively wide range of $^{206}Pb/^{204}Pb$ (>18.9), which suggests increased proximity to the relatively radiogenic terrain of the Himalayan foothills to the north or perhaps the Gangetic River to the east and northeast. Another eight individuals have intermediate $^{87}Sr/^{86}Sr$ (0.718-0.720) and low $^{206}Pb/^{204}Pb$ (<19.1). Those individuals with the least radiogenic Pb isotope ratios plot close to some of the peripheral Harappan fauna, suggesting possible origins to the west and northwest in the upper reaches of the foreland basin.

Overall, Sanauli individuals show considerable intertooth variability suggesting that migration in childhood was not uncommon (Figure 8-9). There is, however, no specific trend in the timing of migration. Some individuals show the most change between first and second molars, some between second and third molars, and some show relatively little change across all three tooth types. Further, first, second, and third molars often do not plot along a linear trajectory. It is unclear whether this indicates multiple changes of residence or simply the range of isotopic variation for a given region.

The relatively wide scatter of Sanauli data and lack of structure in the data set is most consistent with a typical breeding population. The presence of non-local individuals might be attributable to exogamy, although any specific explanations must remain speculative. No further clues are found in the mortuary material culture, as no obvious correlations with the isotope data can be detected. Sex identifications are too few to ascertain any patterning, and each potential source region includes individuals of all ages, ceramics of every quantity, and grave goods of all kinds. Even burials with more than one individual exhibit a range of isotopic values suggesting the deceased

were not united by common geographic origin. Unfortunately, the most unusual burial type, symbolic burials, lacked appropriate skeletal material for isotopic analysis. In summary, the Sanauli mortuary program was insensitive to or only indirectly concerned with geographic origin. The frequency of migration is still relatively high, and therefore the kind of person who received inhumation may have tended to be more mobile, but the proposed urban era correlation between migration and inhumation had changed. Further, the migration patterns at Sanauli suggest that residence change served as an internally integrative mechanism, connecting Sanauli to other Indus sites rather than settlements in the highlands.

Dietary Variability

The carbon isotope data do not show significant shifts between tooth types or any sex-based differences at the sampled sites (Figures 5-5, 6-5, & 7-5)). Likewise, they do not appear to be structured by mobility. Instead, they are suggestive of agricultural adaptations to regional climatic conditions. Harappa and Sanauli both have mean $\delta^{13}C$ of -11.9‰, whereas the mean value at Farmana is -10.0‰. These data contradict a simplified narrative of increasing millet consumption over time, and instead confirm that agricultural practices varied at the regional scale. Very few millets or other C_4 crops were consumed by individuals in the mortuary populations of Sanauli and Harappa, but millets contributed significantly to diet at Farmana. Their hardy nature and relatively low labor requirements means they could have been used to minimize the agricultural risks associated with semi-arid conditions in the Thar Desert fringe. Intertooth $\delta^{13}C$ variation provides additional insight into the mode of millet consumption at Farmana. Whereas intertooth variation at Sanauli rarely exceeds 1‰ for a given developmental sequence, $\delta^{13}C$ at Farmana varies by as much as 3‰ for the same individual (Tables 5-3 & 7-2).

At Farmana then, the decision to eat millets varied from year to year, probably as a function of interannual climatic fluctuations. Overall, the data support the notion put forward by Weber and colleagues (2010) that Indus agriculture is best understood in terms of ecological adaptations at the regional and sub-regional scales.

Towards an Integrated Model

Though additional research is needed to fully support the interpretations of migration made in the preceding sections, it is worth exploring the potential implications for broader Indus society. A model is needed to explain the presence of immigrant cemeteries in order to go beyond a simple presentation of data and provide a framework for future investigation. This section builds on the proposition that all individuals sampled at Harappa and Farmana were immigrants separated from their natal groups in the non-Indus highlands early in childhood. It is further proposed that during the urban era, the uncommon and relatively standardized practice of cemetery inhumation was part of a social institution revolving around particular types of immigrants. To reiterate the point made above, non-Indus origins cannot be unequivocally determined at this point. Nevertheless, the model outlined here illustrates the untapped potential for Indus provenience studies and serves as an important example of the analytical and inferential process. Further, it may be validated by future research as it fits well with the non-isotopic evidence.

For example, published studies focused on the physical anthropology at Harappa and Lothal (Possehl and Kennedy 1979; Kennedy et al. 1984; Hemphill et al.1991; Kennedy 2000) suggest genetic discontinuities that can be explained by systematic migration. The long-term maintenance of genetic distance between the sexes at Cemetery R-37 and Cemetery H may be better explained by an influx of immigrants

rather than ongoing marital exchanges between local and non-local groups. Further, skeletal similarities between the Lothal assemblage and contemporaneous hunter-gatherers in the southern Aravallis have been interpreted as the result of gene flow. It may be, however, that the Lothal skeletons belonged to immigrants from hunter-gatherer populations rather than their locally born offspring.

The all immigrant hypothesis also fits well with conventional archaeological evidence. Given the scarcity of Indus inhumations, it is difficult to model the mortuary populations as cross sections of interconnected breeding populations. There simply are too few inhumations in too few cemeteries for the collective urban era mortuary population to represent an ethnic group. Yet close similarities between inhumations from different cemeteries suggest strong ideological controls and common membership in an Indus group or institution. Additionally, the exclusive mortuary treatment carried out despite years of local residence implies a profound social distinction lasting even into death. This distinct social identity could be interpreted as membership within a peripheral class of first-generation immigrants attached to or otherwise affiliated with local groups.

The affiliate approach to Indus immigration is poorly explained by conventional relations of marriage and consanguinity. For a given kinship system to fit the isotope data, it must result exclusively in a mortuary population of individuals that spent their early childhood in at least one non-local location. Further, it must account for gender-based differences in the isotopic data set. Both of these results can be achieved given several assumptions. First, the mother of the deceased would have had to marry into the local community from non-local locations. On becoming pregnant, she would have

had to return to her paternal group for childbirth and nursing, not leaving for several years. Eventually, a mothers and her offspring would resume living with the husband's group, but the mother would return one last time to her non-local paternal group for burial. Locally born female offspring must follow a similar pattern by marrying outside of the local group but returning home to the father's community for childrearing and eventual burial. Male offspring must also marry outside of the local population, but not to the same group as their sisters. Further, they would be buried at their adult residence. If this residence pattern was maintained between three or more communities, any given mortuary population would contain only males and females with different non-local isotopic signatures in their early mineralizing dentition.

The hypothetical marital residence patterns (represented diagrammatically in Figure 8-10) result in distinct patterns of residence change that can be tested against the isotopic data. Following the three population system in Figure 8-10A for local mortuary population B, male dentition will reflect the isotope values at location C in infancy, location A in childhood, and finally location B (the adult residence) if they moved to their affinal residence before their third molars had finished mineralizing. Female dentition would reflect the sequence A, B, and potentially C depending on when they moved to their affinal residence. This scenario suggests that male second molars should coincide with female first molars, a pattern not supported by the heavy isotope data at Harappa (Figure 8-11). A residence system composed of four or more populations, as in Figure 8-10B, would result in the same migration sequence for females (A, B, and possibly C) but a different pattern for males. Note that males and females in Figure 8-10B never live in the same locations in early life, resulting in a male

isotopic sequence of D, E, and potentially B. Again, this pattern is not apparent in the Harappa data set (Figure 8-11) as males appear only to move between one non-local region and the local Harappan catchment.

Further analyses will permit a more refined test of these scenarios, but two additional complications suggest they are not applicable to the present data set. First, males who died young would have to be buried at the settlements of their aunts' affines—all without having reached the stage in life where they would have moved there in their own right. Further, decades of excavation in South Asia have yet to reveal cemeteries that could plausibly represent the complementary kin groups indicated in these mate exchange systems. Isotope data aside, too many special arguments are required to make a system of marital residence fit the mortuary profile at Harappa.

An institution of fictive or created kinship, however, is consistent with the isotopic data set. It can explain a mortuary population composed entirely of individuals who moved as children into lowland settlements from their natal groups in the Indus hinterland. It provides an ethnographically realistic context by which genetically unrelated children from non-Indus cultures can be fostered and raised under safe and healthy conditions within the Indus social system. And lastly, it explains how, despite years of participation within Indus society, those individuals could be perceived as socially distinct persons even in death as evinced by their inclusion within an extraordinarily uncommon mortuary program.

An Ethnographic Example

Fosterage, often literally or figuratively tied to the act of wet nursing, has been widely used as a strategic means of building alliances in many parts of the world including the Middle East and Eurasia (Altorki 1980; Goody 1982; Khatib-Chahidi 1992).

The practice was used among the historic kingdoms of the Hindu Kush—an area that was once the source for many of the raw materials imported to Harappa in Indus times. The rights and obligations generated through fosterage helped create the social foundation necessary for hierarchical political alliances between fractious peripheral polities (Gwynn 1913; Parkes 2001). Parkes (2001) extensively reviewed the late 19th century practice of fosterage in the Hindu Kush region in which fosterage most often involved the transfer of elite children to junior households. Foster families owed allegiance to the elite lineage and, having become 'milk kin,' were forbidden to intermarry. Should the elite child rise to power, foster families were compensated with land and positions of authority. There was variability in the practice, however, and Parkes (2001: 20-21) suggested that successive iterations of milk kinship could create relations of dependency between previously intermarrying descent groups. Eventually, the prohibitions against intermarriage would completely separate the groups such that the initially junior descent group could become a dependent status grade. People of the subordinate grade might then be bonded and transferable, potentially reversing the physical flow of bodies observed in prior relations of milk kinship.

It is unreasonable to suppose that the many means of creating kinship recorded historically in South Asia and elsewhere ever existed in identical form within the Indus Civilization. Projecting ethnography unchanged into the past has long been rejected as a valid approach for understanding archaeological peoples. However, a historical understanding of the frequency and diversity of ethnographic practices highlights common themes that could readily have applied to protohistoric South Asia. The ethnographic cases defy a simplistic understanding of the archaeological past, and the

often implicit assumptions that people in the past were immobile or that archaeological cemeteries always contain breeding populations must be abandoned (Cobb 2005; Jackes 2011). Adding to the complexity is the established premise that archaeological people, just like modern ones, are capable of appropriating and using non-local material culture. For this reason, no one-to-one correlation can be assumed between pottery types and ethnic groups (Jones 1997:122-124). In short, the notion that past individuals who participated in a vast, technologically sophisticated, and incredibly complex urban society were any less capable of transferring children between ethnic groups as a means of constructing kinship is wholly invalid. Shedding such implicit assumptions about the relationships between past mobility, mortuary practices, and material artifacts opens the door to a far richer understanding of Indus inhumations.

The Indus Model

In the pre-market economy of protohistoric South Asia, highland and lowland groups may have turned to the rights and obligations of kinship as a way of mediating economic exchange. Elite Indus groups likely sought economic advantages over each other, and they had strong incentives to secure preferential access to exotic raw materials. Likewise, highland groups must have desired access to the trade routes and sophisticated crafts of Indus merchants. This kind of economic interdependence came to define the way of life among Ganeshwar-Jodhpura peoples in the northern Aravallis, such that settlements were structured around the production of copper for trade with lowland communities (Agrawala 1984b; Rizvi 2007}}{{47 Agrawala,R.C. 1984 a; Rizvi 2007). A relationship structured by fosterage could have established the framework within which goods were exchanged, although it need not have been a relationship of equality.

Just as kin groups in the historic Hindu Kush kingdoms established asymmetric alliances through fosterage, elite Indus groups may have desired a form of kinship that prohibited marriage and consequently prevented inheritance claims to their accumulated wealth. Marriage creates a shared identity and presupposes relative equality between groups that once were socially distinct, but a fostered individual generates a different kind of bond. The fostered individual is a constant reminder of the obligations between two groups precisely because the individual is a living reference to those qualities, those things, and those ways of living that make two groups distinct. Through fosterage, an 'other' is transformed into a social hybrid that embodies qualities of both groups but can never fully become a member of either. In a way, they become a living contract, but the contract lasts only as long as the individual. On death, the tension of hybridity is resolved, dissolving obligations and requiring a new act of fosterage. Offspring of the fostered individual cannot restore the tension of mutual obligation because they are not truly of both cultural worlds. They are one or the other, but they are not both; and when dead, they are treated as such and granted the corresponding mortuary treatment. In the Indus region, only those who were fostered, the social hybrids, received inhumation in a cemetery. With their usefulness gone and having never acquired the full social identity of their Indus hosts, they were disposed of in a unique way that reflected their liminal status. Yet the need for a social hybrid remained, and for hundreds of years, new individuals were fostered to re-establish the groups' rights and obligations and in the process, reaffirm their separate cultural identities.

The asymmetric relationships of fosterage may have influenced broader cultural perceptions, much like modern cultural stereotypes of immigrants, and encouraged members of both groups to perceive the other as socially distinct. This could have reinforced social boundaries, resulting in relatively independent cultural trajectories for the highland groups linked in this way. In fact, this scenario is consistent with the limited archaeological evidence. Cultures in the highland regions connected by fosterage (e.g., late occurring Kot Diji, Northern Neolithic, Ganeshwar-Jodhpura) seemingly adopted fewer Indus traits over time than other highland cultures such as the Kulli (Chapter 2). Trade and migration in archaeology are often assumed to be integrative, but a close consideration of the structures of these phenomena suggests ways to explain alternate outcomes that move closer to the nuanced anthropological understandings of modern migration.

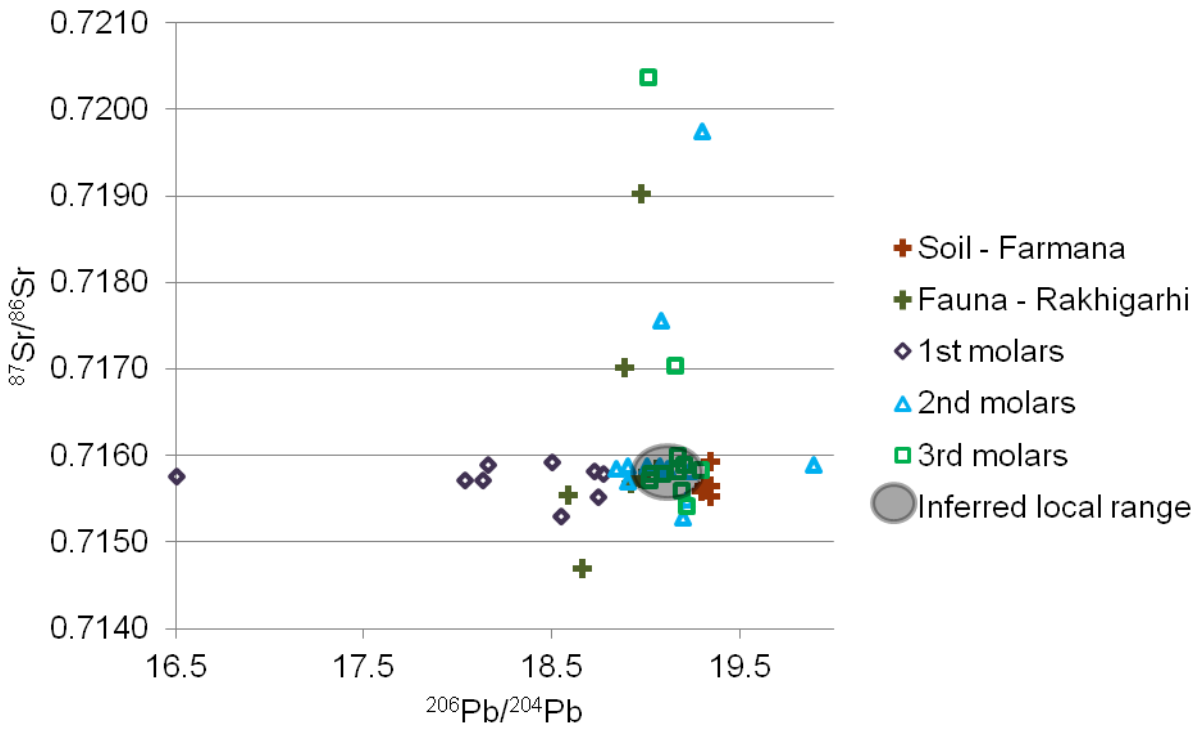

Figure 8-1. Local isotopic range at Farmana—Pb-Sr space

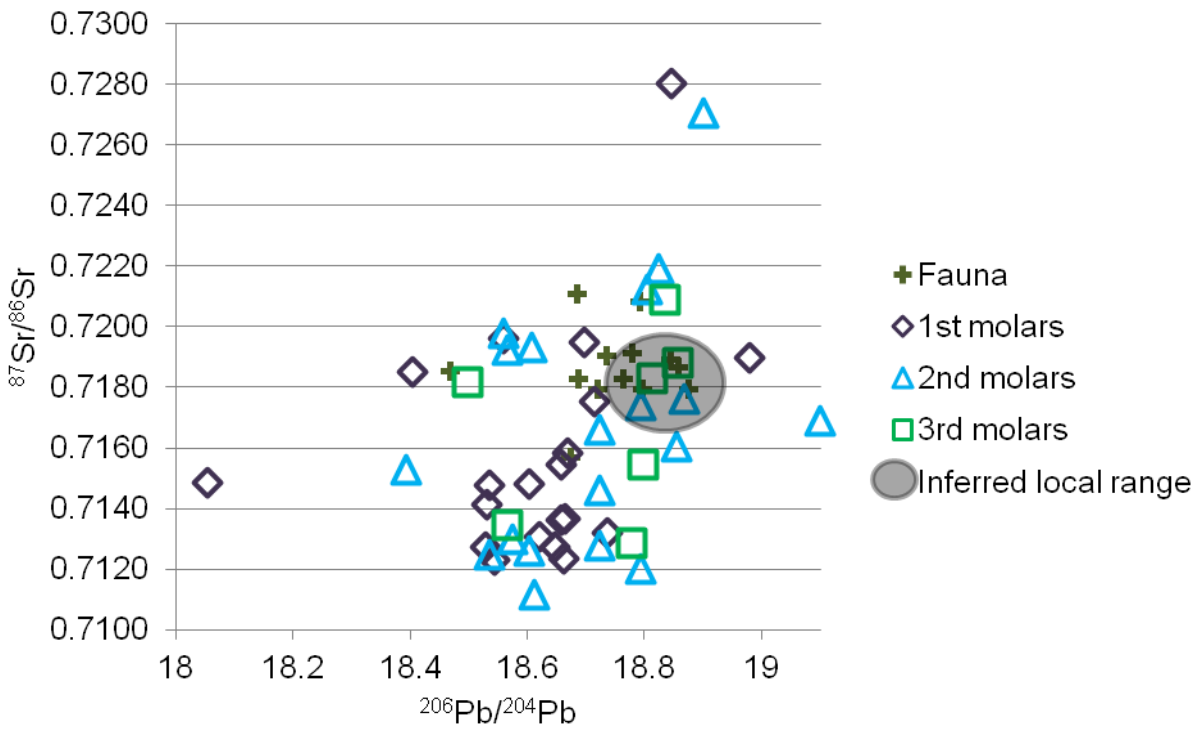

Figure 8-2. Local isotopic range at Harappa—Pb-Sr space

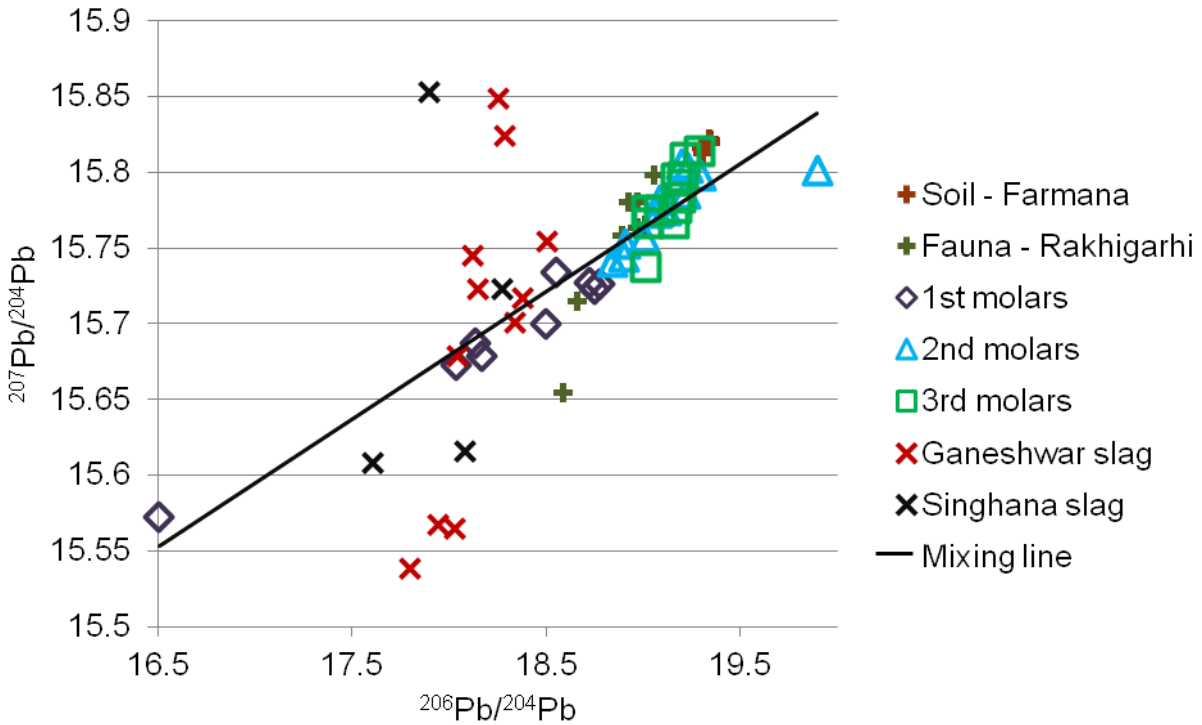

Figure 8-3. Mixing line at Farmana with non-local anthropogenic Pb [slag data from Law, R. W. 2008. Inter-Regional Interaction and Urbanism in the Ancient Indus Valley: A Geologic Provenience Study of Harappa's Rock and Mineral Assemblage. PhD dissertation (Page 744, Appendix 12.8). University of Wisconsin-Madison]

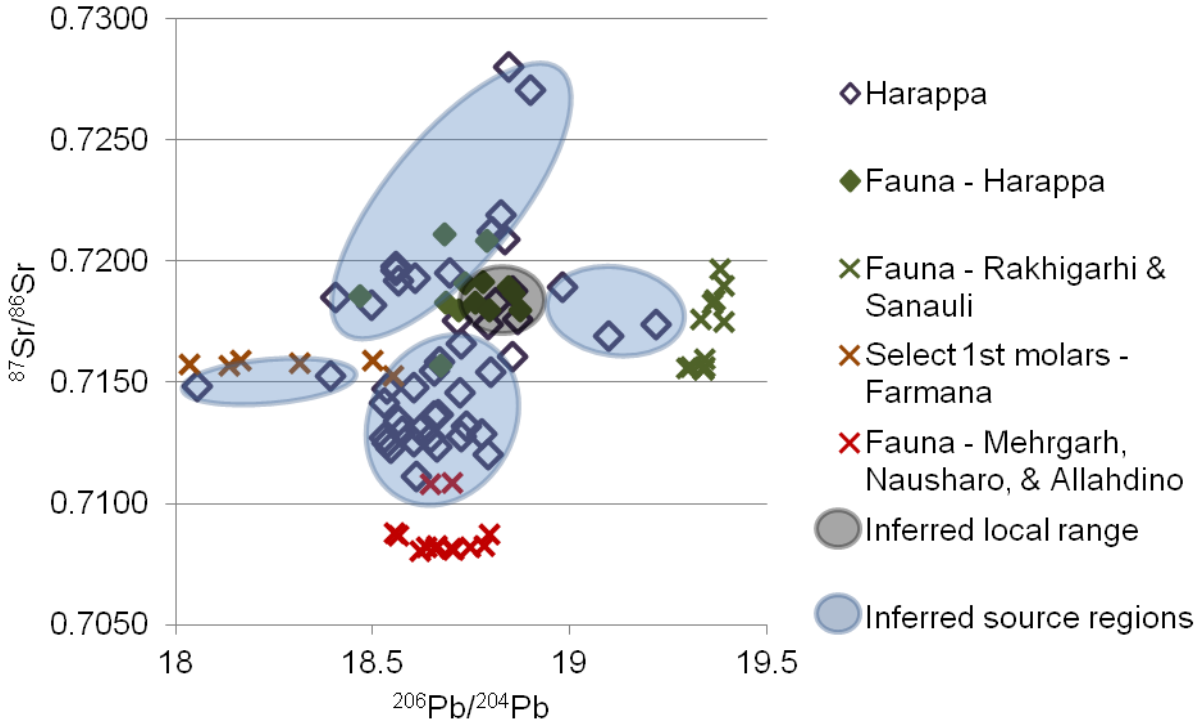

Figure 8-4. Four source regions at Harappa

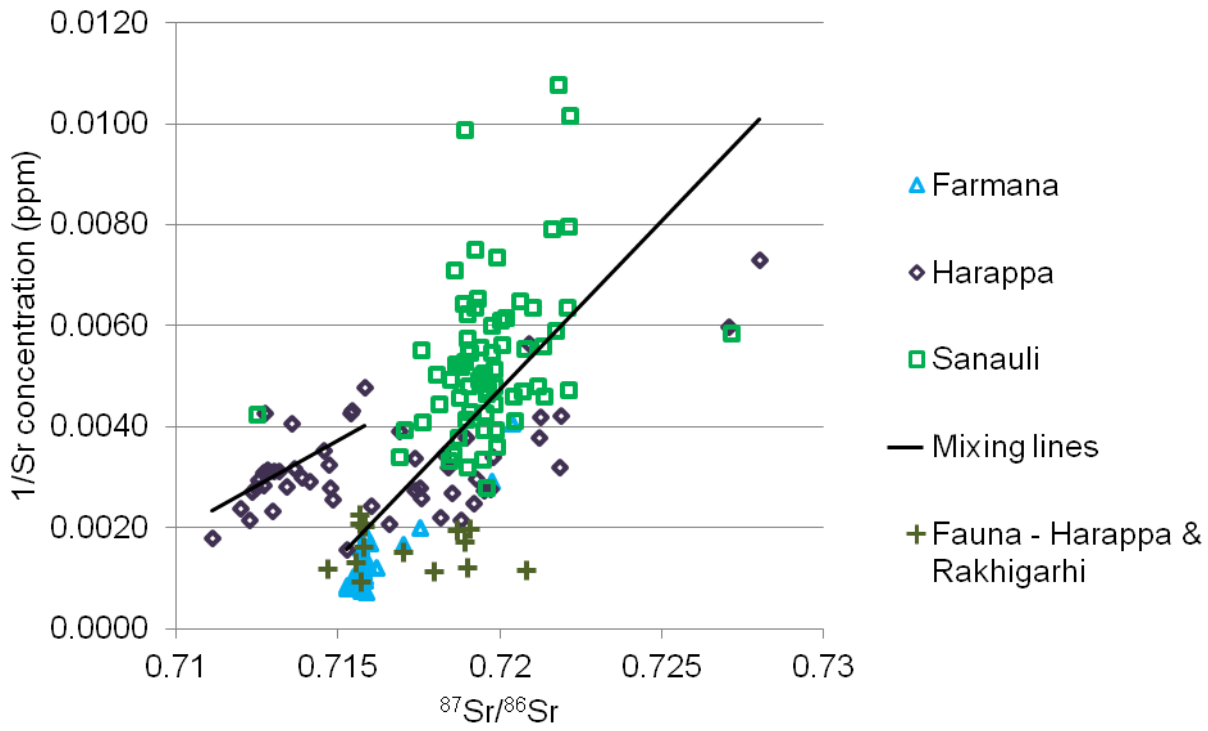

Figure 8-5. Two mixing lines in the Greater Indus region suggesting distinct geological inputs—Sr-Sr space

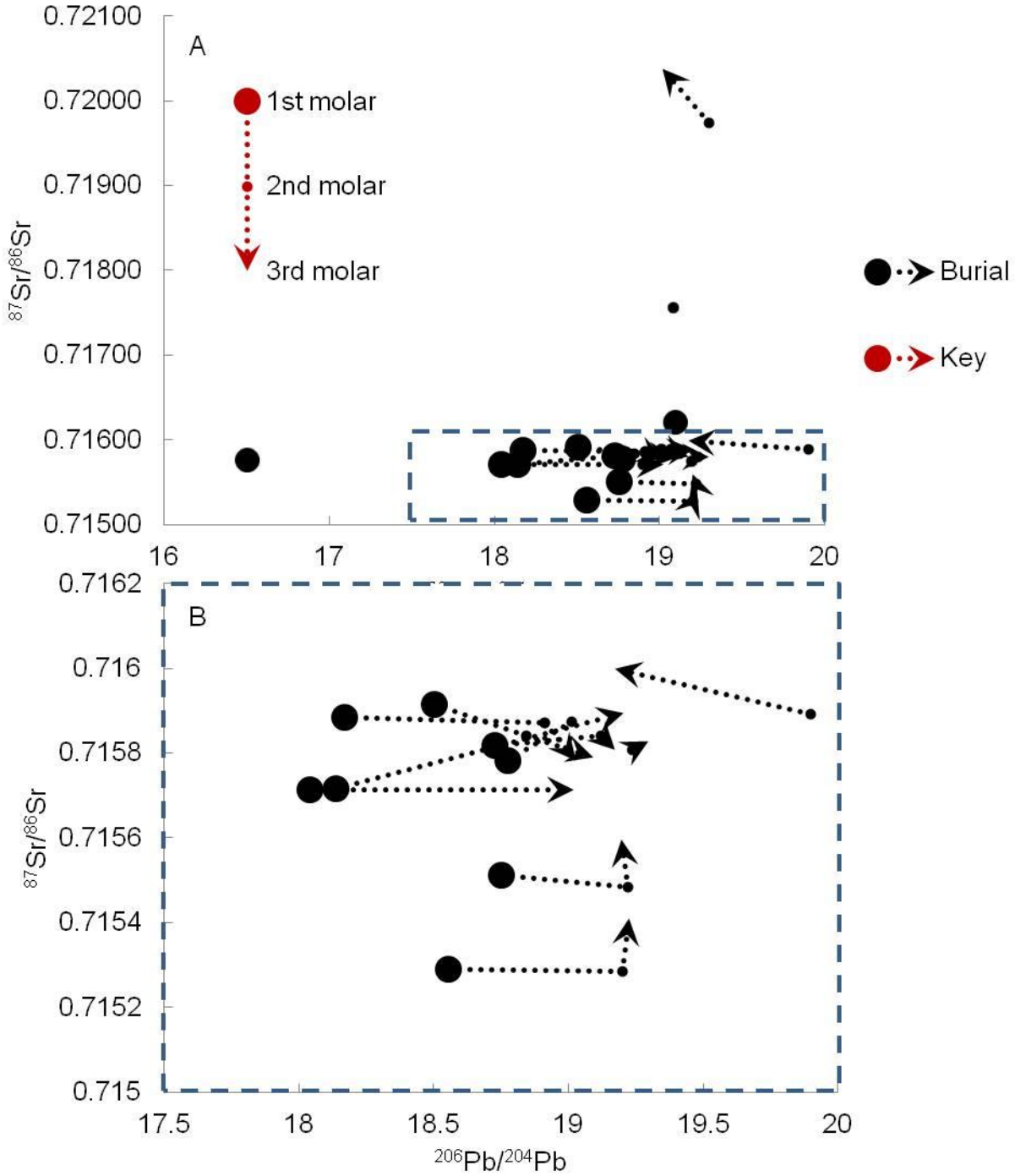

Figure 8-6. Intertooth developmental sequences at Farmana in Pb-Sr space showing childhood migration to the local area. A) Entire Farmana dataset with inset of Figure 8-6B. B) Closeup of Farmana intertooth variation.

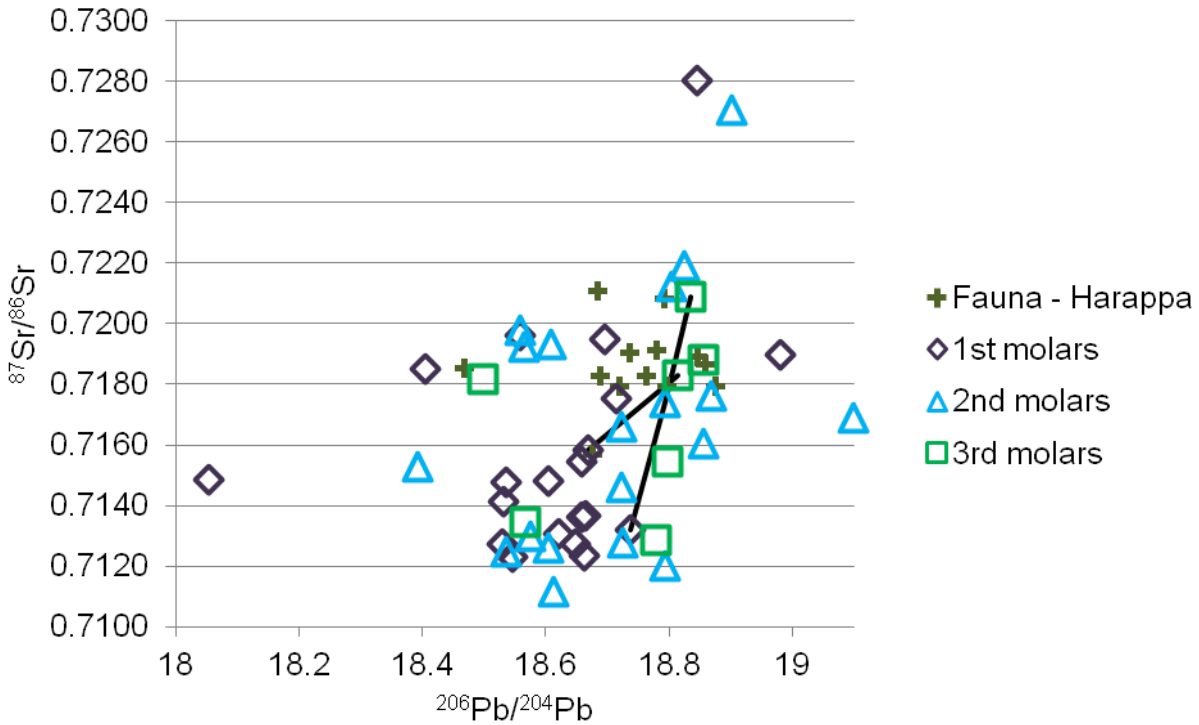

Figure 8-7. Intertooth developmental sequences at Harappa in Pb-Sr space showing childhood migration to local or near-local regions

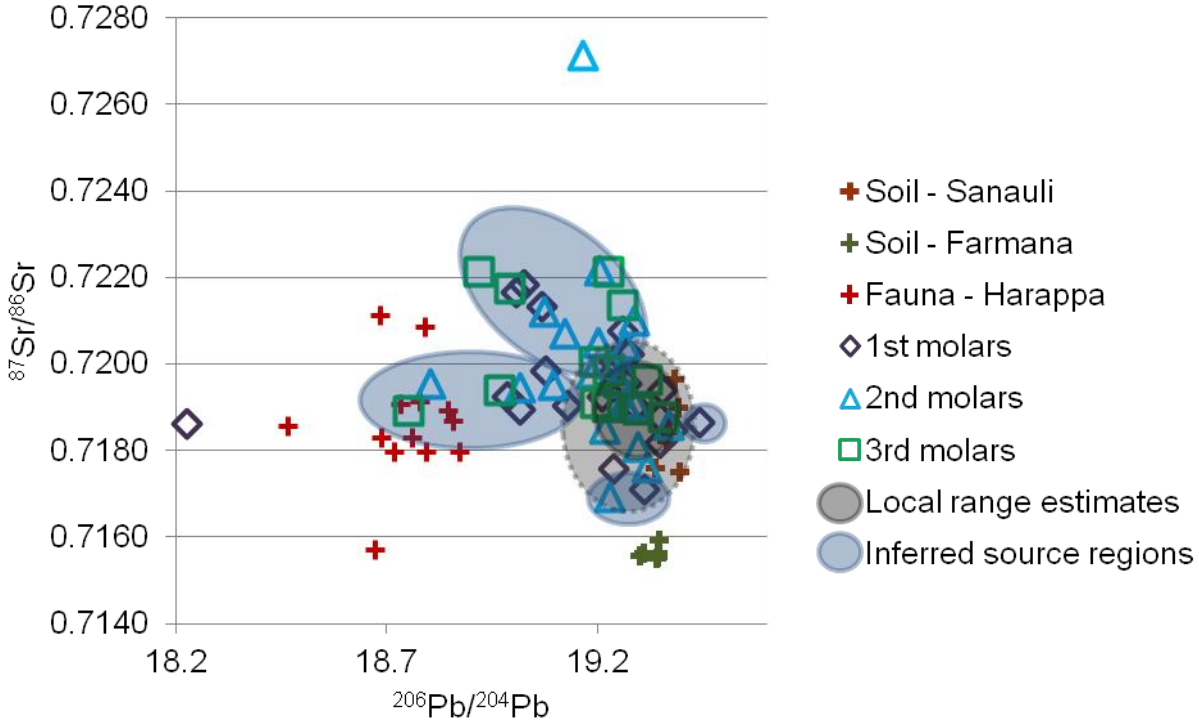

Figure 8-8. Two local range estimates and source regions at Sanauli—Pb-Sr space

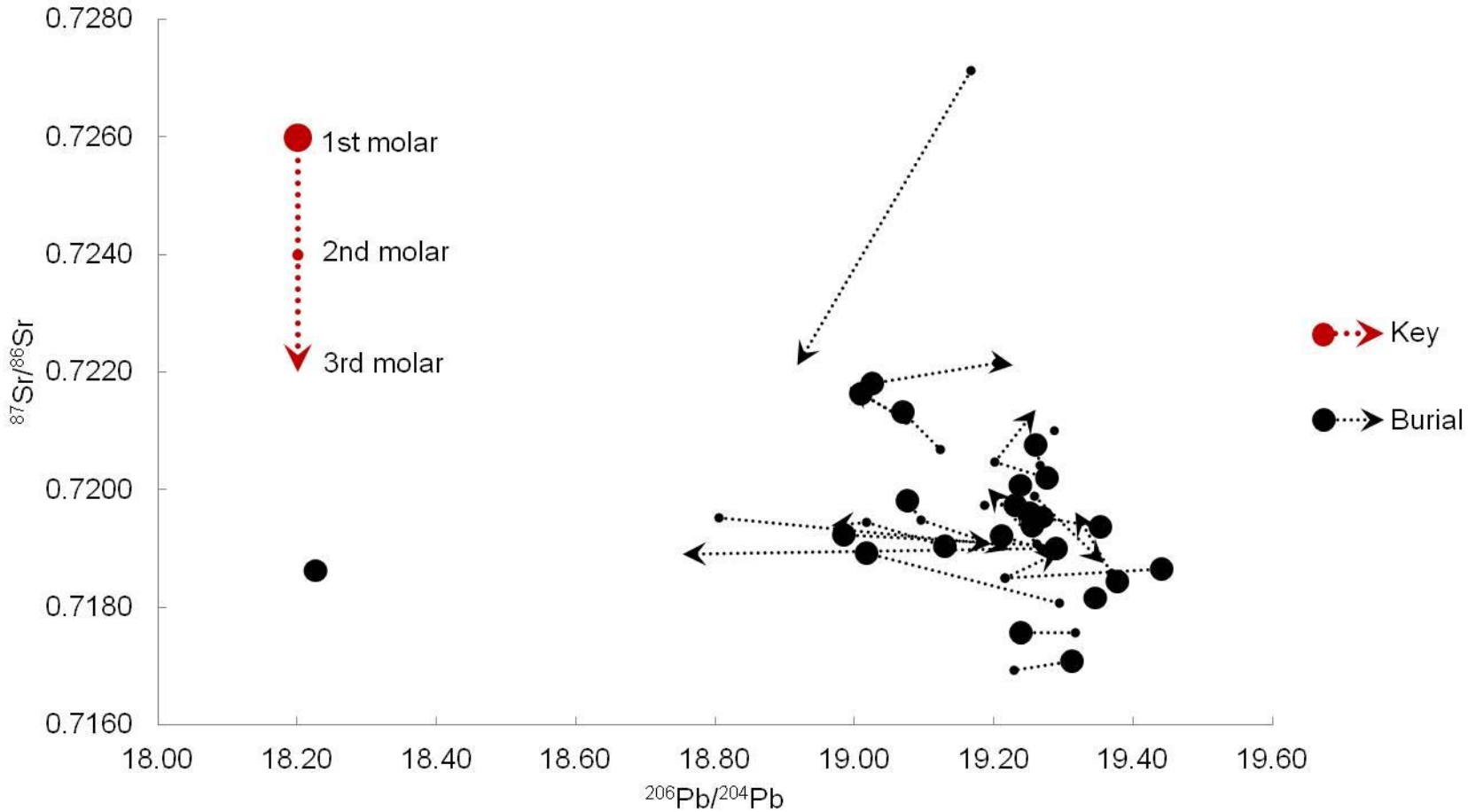

Figure 8-9. Intertooth developmental sequences at Sanauli in Pb-Sr space showing variation in the timing and direction of migration

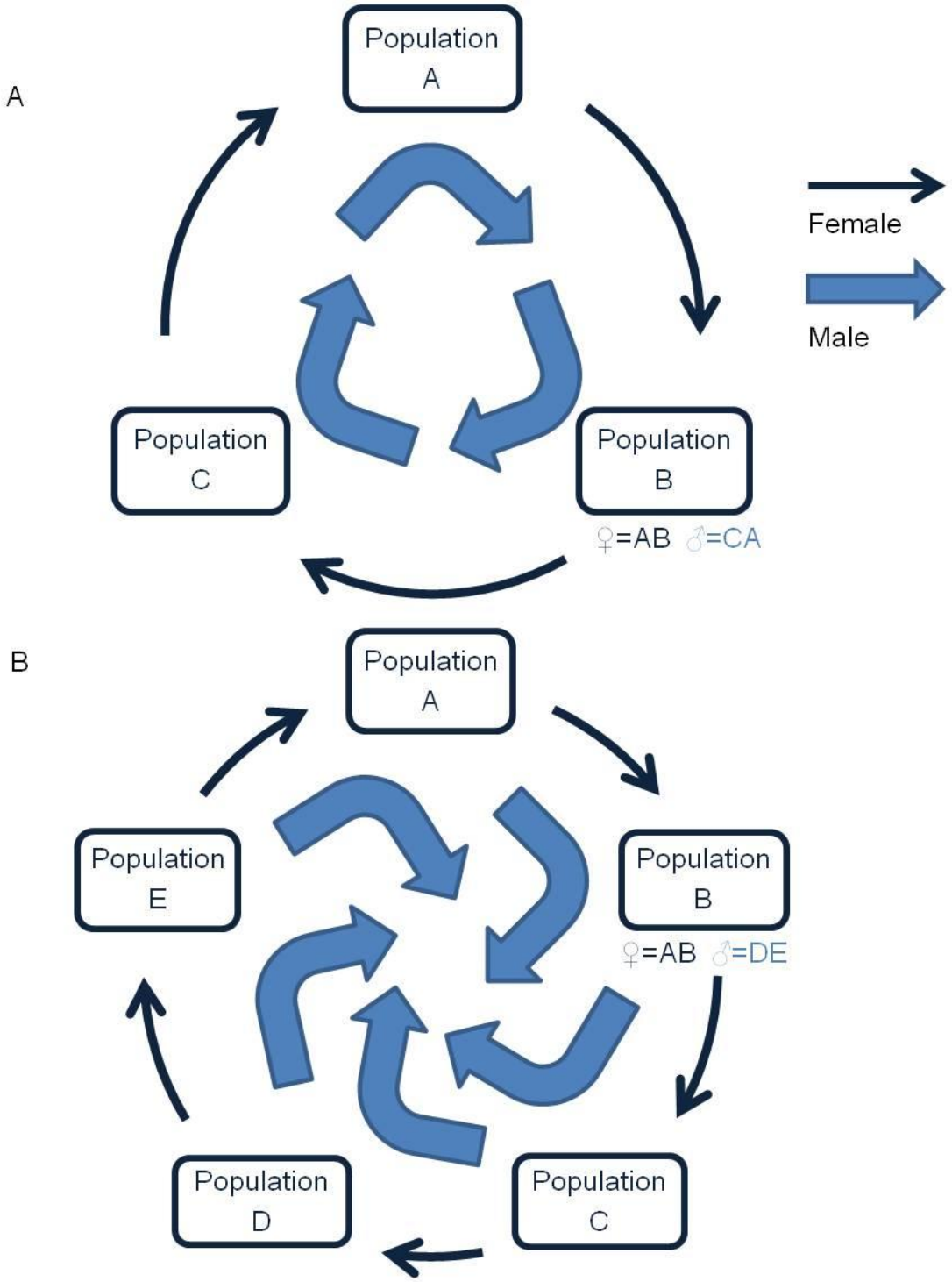

Figure 8-10. Theoretical marital residence patterns that might produce entirely immigrant mortuary populations. A) Marital exchange system with three groups. B) Marital exchange system with four or more groups.

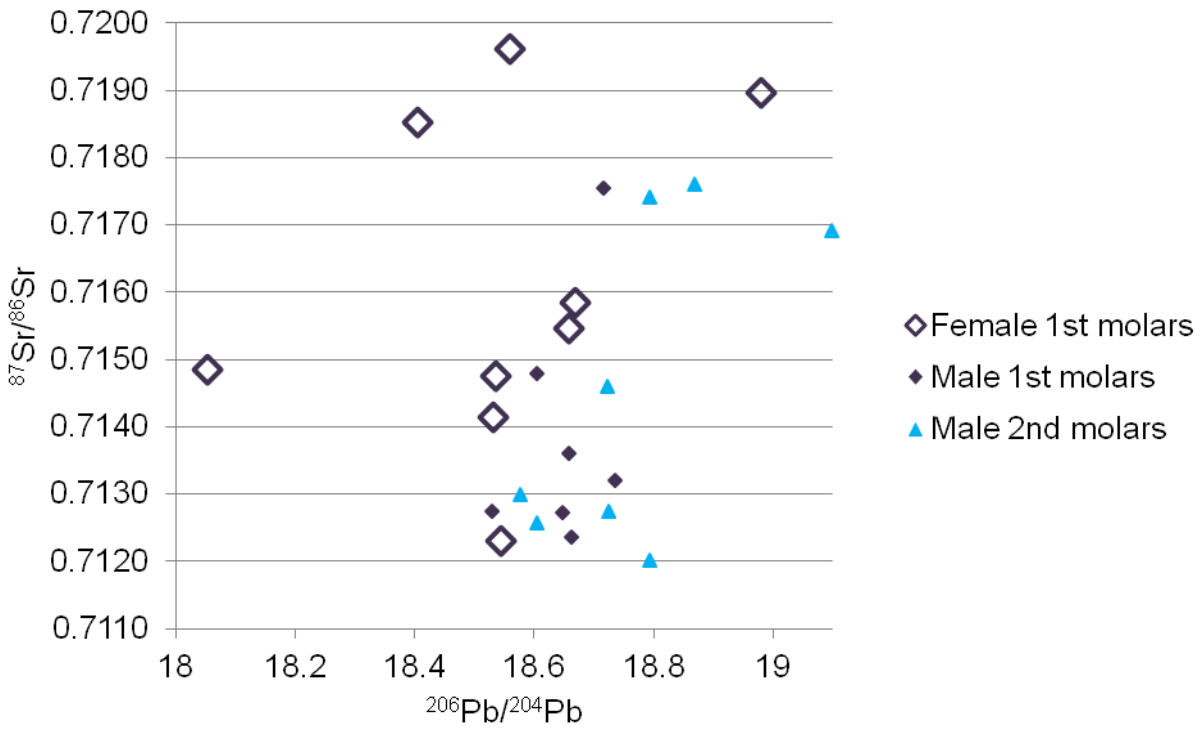

Figure 8-11. Early childhood residence and migration by sex at Harappa in Pb-Sr space characterized by non-overlapping male and female distributions and male residence at a single non-local locality

CHAPTER 9
CONCLUSION

If confirmed by future work, the model presented above has significant consequences for the study of the Indus Civilization and, more broadly, the study of mortuary populations and migration. This research challenges the implicit assumption in many bioarchaeological studies that cemetery remains are representative of local populations. Instead, the social identities of the deceased must be assessed before inferences can be made about a particular group. This further requires that bioarchaeological studies go beyond the application of analytical methods and are instead explicitly informed by models of social organization. In particular, the possibility must be considered that a given mortuary population has little genetic affinity with or only indirect association with local archaeological cultures. Though such biological and social distance may be uncommon, it must nevertheless be ruled out before claims can be made about the health, lifestyle, or demography of local cultural groups.

Further, this research emphasizes a more versatile understanding of the social consequences of migration than is typically employed in archaeological studies. Migration is often implicitly understood to connect groups and individuals in a way that leads to cultural homogenization. After all, an intuitive interpretation of contexts like those at Harappa and Farmana in which immigrants are associated with local material culture is that non-locals were culturally assimilated. By extension, it might be assumed that the sending and receiving societies were blending together or otherwise hybridizing. The model presented above, however, highlights the importance of the social structure of migration and the specific kinds of relationships that were indicated by immigrant bodies, both living and dead. Although different groups may be united in

certain ways by the flow of bodies between sending and receiving societies, the context of that movement could have reinforced perceptions of alterity. Migration can potentially lead to more diverse outcomes than suggested by the implicit diffusionism still present in the archaeology of migration, and students of migration must adopt theoretical frameworks that accommodate a wider range of cultural outcomes.

Additionally, the specific model presented above for Integration Era mortuary populations must be tested against future research. Further work is needed to better understand the nature of isotopic variation in the Greater Indus region and beyond so that immigrants can be more accurately identified and provenienced. Ultimately, many more baseline samples including sediment leachates and tooth enamel from archaeological fauna must be analyzed from a wide range of sites and taxa. The creation of a regional isotopic database will benefit not only Indus Civilization research, but any isotopic inquiry into past human behavior and ecology within the region. Most immediately, the faunal baseline samples from this project must be analyzed for Sr concentration to test the above inference that immigrants to Harappa came from one of two broad isotopic regions: either the middle and upper reaches of the Indus River Valley or the remainder of the western foreland basin. Future sampling must also emphasize comparability, such that full regional datasets are developed for each sample type (e.g., sediment leachates, *Sus* tooth enamel). Hypothesized source regions such as the northern Aravallis and northwestern Himalayas are especially vital if the ‘all immigrant’ model is to be tested.

In addition to isotopic baseline analyses, the Harappa mortuary population must be systematically analyzed for intertooth variation within individuals. If it is determined

that all individuals migrated early in life as suggested by the Farmana dataset and limited developmental sequences at Harappa, then it lends strong support to the premise that mortuary populations were composed of dependent individuals rather than independent groups. Similar analyses need to be conducted for other Integration Era mortuary populations. The Kalibangan cemetery is particularly promising given recent osteological work on the mortuary population by Robbins Schug (personal communication).

More details on mortuary variation are required to validate the primary interpretations of mortuary material culture discussed above—that urban cemetery mortuary populations are not strongly internally differentiated and are representative of a specific sub-population. Forthcoming comprehensive reports on excavations of cemetery R-37 (Kenoyer personal communication) will provide the information needed for a more nuanced assessment of Harappan mortuary variability. Another possibility that must be considered is that the means by which the living invested in mortuary ritual are poorly preserved. Feasting or some other form of communal commemoration might have been observed, although there is little corroborative evidence in the relatively modest mortuary assemblages. Residue analysis of mortuary ceramics, perhaps, could assess the nature of consumption associated with mortuary events. Further, additional mortuary details might help reconstruct the post-depositional treatment of remains in secondary contexts. More deliberate ritually-oriented treatment of human remains might suggest a lasting social role for the deceased—potentially leading to new inferences about the social role of the inhumed in life.

Though the conclusions reached by this research require further validation, they have yielded a model that will guide future hypothesis testing. If new evidence contradicts the specific interpretations presented above, the degree of isotopic variability in the datasets nevertheless demands novel social approaches to interregional interaction that emphasize the role of diverse individuals, groups, and institutions in structuring the Indus phenomenon. Though valuable in their own right, studies limited to the provenience of trade goods and human remains fall short of understanding the ways in which interregional interaction helped shape the Indus Civilization. ‘Interaction,’ when treated as a generic social process, cannot be the object of study. Instead, future work on the Indus Civilization must strive with renewed vigor towards a theory of communities and generate new testable models of the relationships between groups in the highly diverse and complex social landscape of the Indus Tradition.

LIST OF REFERENCES

Adams, William Y., Dennis P. Van Gerven, and Richard S. Levy
1978 The Retreat from Migrationism. Annual Review of Anthropology 7:483-532.

Agrawala, R. C.
1984 Aravalli, the Major Source of Copper for the Indus Civilization and Indus Related Cultures. *In* Frontiers of the Indus Civilization. B. B. Lal and S. P. Gupta, eds. Pp. 157-162. New Delhi: Indian Archaeological Society.

1984 Ganeshwar Culture—A Review. Journal of the Oriental Institute, Baroda 34(1-2):89-95.

Agrawala, R. C., and V. Kumar
1982 Ganeshwar-Jodhpura Culture: New Traits in Indian Archaeology. *In* Harappan Civilization. G. L. Possehl, ed. Pp. 125-134. New Delhi: Oxford & IBH Publishing Company.

Ahmad, Z.
1969 Directory of Mineral Deposits of Pakistan. Records of the Geological Survey Pakistan 15(3):1-220.

Ajithprasad, P.
2002 The Pre-Harappan Cultures of Gujarat. *In* Indian Archaeology in Retrospect, Volume 2 (Protohistory: Archaeology of the Harappan Civilization). S. Settar and R. Korisettar, eds. Pp. 129-158. New Delhi: Indian Council of Historical Research.

Akkermans, Peter M. M. G., and Glenn M. Schwartz
2003 The Archaeology of Syria: From Complex Hunter-Gatherers to Early Urban Societies (Ca. 16,000-300 BC). Cambridge: Cambridge University Press.

Alizai, Anwar, Andrew Carter, Peter D. Clift, Sam VanLaningham, Jeremy C. Williams, and Ravindra Kumar
2011 Sediment Provenance, Reworking and Transport Processes in the Indus River by U–Pb Dating of Detrital Zircon Grains. Global and Planetary Change 76(1–2):33-55.

Allchin, F. R.
1984 The Northern Limits of the Harappan Culture Zone. *In* Frontiers of the Indus Civilization. B. B. Lal and S. P. Gupta, eds. Pp. 51-54. New Delhi: Books and Books.

Allchin, R., and B. Allchin
1982 The Rise of Civilization in India and Pakistan. 3rd ed. Cambridge: Cambridge University Press.

Altorki, Soraya
1980 Milk-Kinship in Arab Society: An Unexplored Problem in the Ethnography of Marriage. Ethnology 19(2):233-244.

Ambrose, Stanley H., Jane Buikstra, and Harold W. Krueger
2003 Status and Gender Differences in Diet at Mound 72, Cahokia, Revealed by Isotopic Analysis of Bone. Journal of Anthropological Archaeology 22(3):217-226.

Ambrose, Stanley H., and John Krigbaum
2003 Bone Chemistry and Bioarchaeology. Journal of Anthropological Archaeology 22(3):193-199.

Ambrose, Stanley H., and L. Norr
1993 Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to those of Bone Collagen and Carbonate. *In* Prehistoric Human Bone:Archaeology at the Molecular Level. J. B. Lambert and G. Grupe, eds. Pp. 1-37. New York: Springer-Verlag.

Ammerman, A. J., and L. L. Cavalli-Sforza
1971 Measuring the Rate of Spread of Early Farming in Europe. Man 6(4):674-688.

Anthony, David W.
1990 Migration in Archeology: The Baby and the Bathwater. American Anthropologist 92(4):895-914.

1992 The Bath Refilled: Migration in Archeology Again. American Anthropologist 94(1):174-176.

1997 Prehistoric Migration as Social Process. *In* Migration and Invasion in Archaeological Explanation. John Chapman and H. Hamerow, eds. Pp. 21-32. Oxford: Archaeopress.

Arnold, Bettina
2002 A Landscape of Ancestors: The Space and Place of Death in Iron Age West-Central Europe. Archeological Papers of the American Anthropological Association 11(1):129-143.

Asthana, Shashi
1993 Harappan Trade in Metals and Minerals: A Regional Approach. *In* Harappan Civilization. G. L. Possehl, ed. Pp. 271-285. Delhi: American Institute of Indian Studies.

Balasse, Marie
2002 Reconstructing Dietary and Environmental History from Enamel Isotopic Analysis: Time Resolution of Intra-Tooth Sequential Sampling. International Journal of Osteoarchaeology 12(3):155-165.

Barth, Fredrik
1969 Introduction. *In* Ethnic Groups and Boundaries. Fredrik Barth, ed. Pp. 9-38. Boston: Little Brown.

Bataille, Clément P., and Gabriel J. Bowen
2012 Mapping $^{87}Sr/^{86}Sr$ Variations in Bedrock and Water for Large Scale Provenance Studies. Chemical Geology 304–305:39-52.

Bazin, D., and H. Hubner
1969 Copper Deposits in Iran. Geological Survey of Iran 13:1-195.

Beard, B. L., and C. M. Johnson
2000 Strontium Isotope Composition of Skeletal Material can Determine the Birth Place and Geographic Mobility of Humans and Animals. Journal of Forensic Sciences 45(5):1049-1061.

Beekman, Christopher S., and Alexander F. Christensen
2003 Controlling for Doubt and Uncertainty through Multiple Lines of Evidence: A New Look at the Mesoamerican Nahua Migrations. Journal of Archaeological Method and Theory 10(2):111-164.

Belcher, William R.
1991 Fish Resources in an Early Urban Context at Harappa. *In* Harappa Excavations 1986-1990. Richard H. Meadow, ed. Pp. 107-120. Madison: Prehistory Press.

2003 Fish Exploitation of the Indus Valley Tradition. *In* Indus Ethnobiology: New Perspectives from the Field. Steven A. Weber and William R. Belcher, eds. Pp. 95-174. Lanham: Lexington Books.

Bellwood, Peter
2004 The Origins and Dispersals of Agricultural Communities in Southeast Asia. *In* Southeast Asia: From Prehistory to History. Ian Glover and Peter Bellwood, eds. Pp. 21-40. London: Routledge Curzon.

Bentley, R. Alexander
2006 Strontium Isotopes from the Earth to the Archaeological Skeleton: A Review. Journal of Archaeological Method and Theory 13(3):135-187.

Bentley, R. Alexander., and C. Knipper
2005 Geographical Patterns in Biologically Available Strontium, Carbon and Oxygen Isotope Signatures in Prehistoric SW Germany*. Archaeometry 47(3):629-644.

Bentley, R. Alexander, Hallie R. Buckley, Matthew Spriggs, Stuart Bedford, Chris J. Ottley, Geoff M. Nowell, Colin G. Macpherson, and D. Graham Pearson
2007 Lapita Migrants in the Pacific's Oldest Cemetery: Isotopic Analysis at Teouma, Vanuatu. American Antiquity 72(4):645-656.

Bhan, K. K., and Jonathan Mark Kenoyer
1983 Nageswar, an Industrial Centre of Chalcolithic Period. Puratattva 12:115-119.

Bhan, Kuldeep K.
1986 Recent Explorations in the Jamnagar District of Saurashtra. Man and Environment 10:1-21.

Bhattacharya, S. K., S. K. Gupta, and R. V. Krishnamurthy
1985 Oxygen and Hydrogen Isotopic Ratios in Groundwaters and River Waters from India. Proceedings of the Indian Academy of Sciences—Earth and Planetary Sciences 94(3):283-295.

Bindler, Richard
2011 Contaminated Lead Environments of Man: Reviewing the Lead Isotopic Evidence in Sediments, Peat, and Soils for the Temporal and Spatial Patterns of Atmospheric Lead Pollution in Sweden. Environmental Geochemistry and Health 33(4):311-329.

Binford, Lewis R.
1971 Mortuary Practices: Their Study and their Potential. Memoirs of the Society for American Archaeology 25:6-29.

Bisht, R. S.
1989 A New Model of the Harappan Town Planning as Revealed at Dholavira in Kutch: A Surface Study of its Plan and Architecture. *In* History and Archaeology. B. Chatterjee, ed. Pp. 397-408. Delhi: Ramanand Vidhya Bhawan.

1991 Dholavira: A New Horizon of the Indus Civilization. Puratattva 20:71-82.

1997 Dholavira Excavations: 1990-94. *In* Facets of Indian Civilization: Recent Perspectives (Essays in Honour of Prof. B. B. Lal). Jagat Pati Joshi, ed. Pp. 107-120. New Delhi: Aryan Books International.

Blackman, M. James, and Massimo Vidale
1992 The Production and Distribution of Stoneware Bangles at Mohenjo-Daro and Harappa as Monitored by Chemical Characterization Studies. *In* South Asian Archaeology 1989. C. Jarrige, ed. Pp. 37-44. Madison: Prehistory Press.

Blakely, Robert L.
1989 Bone Strontium in Pregnant and Lactating Females from Archaeological Samples. American Journal of Physical Anthropology 80(2):173-185.

Bowen, Gabriel J., and Bruce Wilkinson
2002 Spatial Distribution of $\delta^{18}O$ in Meteoric Precipitation. Geology 30(4):315-318.

Brookman, Tom H., and Stanley H. Ambrose
2013 Kangaroo Tooth Enamel Oxygen and Carbon Isotope Variation on a Latitudinal Transect in Southern Australia: Implications for Palaeoenvironmental Reconstruction. Oecologia 171(2):403-416.

Brown, James A., ed.
1971 Approaches to the Social Dimensions of Mortuary Practices. Vol. 25. Washington: Society for American Archaeology.

Budd, P., J. Montgomery, A. Cox, P. Krause, B. Barreiro, and R. G. Thomas
1998 The Distribution of Lead within Ancient and Modern Human Teeth: Implications for Long-Term and Historical Exposure Monitoring. Science of the Total Environment 220(2–3):121-136.

Budd, P., J. Montgomery, J. Evans, and B. Barreiro
2000 Human Tooth Enamel as a Record of the Comparative Lead Exposure of Prehistoric and Modern People. Science of the Total Environment 263(1–3):1-10.

Budd, P., J. Montgomery, B. Barreiro, and R. G. Thomas
2000 Differential Diagenesis of Strontium in Archaeological Human Dental Tissues. Applied Geochemistry 15(5):687-694.

Buikstra, Jane E., and Douglas H. Ubelaker, eds.
1994 Standards for Data Collection from Human Skeletal Remains: Proceedings of a Seminar at the Field Museum of Natural History. Fayetteville: Arkansas Archaeological Survey.

Bunton, C. A., D. R. Llewellyn, C. A. Vernon, and V. A. Welch
1961 The Reactions of Organic Phosphates. Part IV. Oxygen Exchange between Water and Orthophosphoric Acid. Journal of the Chemical Society (Resumed):1636-1640.

Burmeister, Stefan
2000 Archaeology and Migration: Approaches to an Archaeological Proof of Migration. Current Anthropology 41(4):539-567.

Burton, James H., T. Douglas Price, and William D. Middleton
1999 Correlation of Bone Ba/Ca and Sr/Ca due to Biological Purification of Calcium. Journal of Archaeological Science 26(6):609-616.

Burton, James H., and Lori E. Wright
1995 Nonlinearity in the Relationship between Bone Sr/Ca and Diet: Paleodietary Implications. American Journal of Physical Anthropology 96(3):273-282.

Cannon, Aubrey
1989 The Historical Dimension in Mortuary Expressions of Status and Sentiment. Current Anthropology 30(4):437-458.

Capo, Rosemary C., Brian W. Stewart, and Oliver A. Chadwick
1998 Strontium Isotopes as Tracers of Ecosystem Processes: Theory and Methods. Geoderma 82(1–3):197-225.

Cerling, Thure E., and John M. Harris
1999 Carbon Isotope Fractionation between Diet and Bioapatite in Ungulate Mammals and Implications for Ecological and Paleoecological Studies. Oecologia 120(3):347-363.

Chakrabarti, Dilip K.
1990 The External Trade of the Indus Civilization. New Delhi: Munshiram Manoharlal Publishers.

Chakrabarti, Dilip K., and Nayanjot Lahir
1996 Copper and its Alloys in Ancient India. New Delhi: Munshiram Manoharlal.

Chakrapani, G. J.
2005 Major and Trace Element Geochemistry in Upper Ganga River in the Himalayas, India. Environmental Geology 48(2):189-201.

Chamyal, L. S., D. M. Maurya, and Rachna Raj
2003 Fluvial Systems of the Drylands of Western India: A Synthesis of Late Quaternary Environmental and Tectonic Changes. Quaternary International 104(1):69-86.

Chapman, Robert
1981 The Emergence of Formal Disposal Areas and the “Problem” of Megalithic Tombs in Prehistoric Europe. *In* The Archaeology of Death. Robert Chapman, Ian Kinnes and Klavs Randsborg, eds. Pp. 71-81. Cambridge: Cambridge University Press.

Chapman, John, and Pavel M. Dolukhanov
1992 The Baby and the Bathwater: Pulling the Plug on Migrations. American Anthropologist 94(1):169-174.

Charles, Douglas K., and Jane E. Buikstra
2002 Siting, Sighting, and Citing the Dead. Archeological Papers of the American Anthropological Association 11(1):13-25.

Chenery, Carolyn A., Vanessa Pashley, Angela L. Lamb, Hilary J. Sloane, and Jane A. Evans
2012 The Oxygen Isotope Relationship between the Phosphate and Structural Carbonate Fractions of Human Bioapatite. Rapid Communications in Mass Spectrometry 26(3):309-319.

Chenery, Carolyn, Gundula Müldner, Jane Evans, Hella Eckardt, and Mary Lewis
2010 Strontium and Stable Isotope Evidence for Diet and Mobility in Roman Gloucester, UK. Journal of Archaeological Science 37(1):150-163.

Chiaradia, M., A. Gallay, and W. Todt
2003 Different Contamination Styles of Prehistoric Human Teeth at a Swiss Necropolis (Sion, Valais) Inferred from Lead and Strontium Isotopes. Applied Geochemistry 18(3):353-370.

Christaller, W.
1966 Central Places in Southern Germany. Englewood Cliffs: Prentice-Hall.

Clift, Peter D., Jae Il Lee, Peter Hildebrand, Nobumichi Shimizu, Graham D. Layne, Jerzy Blusztajn, Joel D. Blum, Eduardo Garzanti, and Athar Ali Khan
2002 Nd and Pb Isotope Variability in the Indus River System: Implications for Sediment Provenance and Crustal Heterogeneity in the Western Himalaya. Earth and Planetary Science Letters 200(1–2):91-106.

Cobb, Charles R.
2005 Archaeology and the "Savage Slot": Displacement and Emplacement in the Premodern World. American Anthropologist 107(4):563-574.

Cohen, Abner
1974 Introduction: The Lesson of Ethnicity. *In* Urban Ethnicity. Abner Cohen, ed. Pp. ix-xxiv. London: Tavistock Publications.

Coplen, T. B.
1994 Reporting of Stable Hydrogen, Carbon, and Oxygen Isotopic Abundances. Pure and Applied Chemistry 66:273-276.

Critelli, Salvatore, and Eduardo Garzanti
1994 Provenance of the Lower Tertiary Murree Redbeds (Hazara-Kashmir Syntaxis, Pakistan) and Initial Rising of the Himalayas. Sedimentary Geology 89(3–4):265-284.

Dalai, Tarun K., S. K. Bhattacharya, and S. Krishnaswami
2002 Stable Isotopes in the Source Waters of the Yamuna and its Tributaries: Seasonal and Altitudinal Variations and Relation to Major Cations. Hydrological Processes 16(17):3345-3364.

Dalai, Tarun K., S. Krishnaswami, and Anil Kumar
2003 Sr and $^{87}Sr/^{86}Sr$ in the Yamuna River System in the Himalaya: Sources, Fluxes, and Controls on Sr Isotope Composition. Geochimica et Cosmochimica Acta 67(16):2931-2948.

Dales, George F.
1976 Shifting Trade Patterns between the Iranian Plateau and the Indus Valley in the Third Millennium B.C. *In* Le Plateau Iranien et l'Asie Central Des Origines a la Conquete Islamique. Pp. 67-78. Paris: Colloques Internationaux du Centre National de la Recherche Scientifique.

1991 Some Specialized Ceramic Studies at Harappa. *In* Harappa Excavations 1986-1990. Richard Meadow H., ed. Pp. 61-70. Madison: Prehistory Press.

Dales, George F., and Jonathan Mark Kenoyer
1986 Excavations at Mohenjo Daro, Pakistan: The Pottery. Philadelphia: University Museum Press.

1986 Preliminary Report on the First Season of Research at Harappa, Pakistan. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1987 Preliminary Report on the Second Season of Research at Harappa, Pakistan: January to April 1987. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1988 Preliminary Report on the Third Season (January - March) of Research at Harappa, Pakistan. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1989 Excavation at Harappa-1988. Pakistan Archaeology 24:68-176.

1989 Preliminary Report on the Fourth Season at Harappa, Pakistan, January 15 - March 31, 1989. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1990 Excavation at Harappa-1989. Pakistan Archaeology 25:241-280.

1990 Preliminary Report on the Fifth Season at Harappa, Pakistan, January 1 - March 31, 1990. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1991 Summaries of Five Seasons of Research at Harappa (District Sahiwal, Punjab, Pakistan) 1986-1990. *In* Harappa Excavations 1986-1990: A Multi-Disciplinary Approach to 3rd Millennium Urbanism. Richard H. Meadow, ed. Pp. 185-262. Madison: Prehistory Press.

Dales, George F., and Carl P. Lipo
1992 Explorations on the Makran Coast, Pakistan: A Search for Paradise. Berkeley: Archaeological Research Facility, University of California, Berkeley.

Dangi, Vivek
2009 Archaeology of the Ghaggar Basin: Settlement Archaeology of Meham Block, Rohtak, Haryana, India. *In* Occasional Paper 8: Linguistics, Archaeology, and the Human Past. Toshiki Osada and Akinori Uesugi, eds. Pp. 1-111. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Dansgaard, W.
1964 Stable Isotopes in Precipitation. Tellus 16(4):436-468.

Daux, Valerie, Christophe LeCuyer, Frederic Adam, Francois Martineau, and Francoise Vimeux
2005 Oxygen Isotope Composition of Human Teeth and the Record of Climate Changes in France (Lorraine) during the Last 1700 Years. Climatic Change 70(3):445-464.

Daux, Valérie, Christophe Lécuyer, Marie-Anne Héran, Romain Amiot, Laurent Simon, François Fourel, François Martineau, Niels Lynnerup, Hervé Reychler, and Gilles Escarguel
2008 Oxygen Isotope Fractionation between Human Phosphate and Water Revisited. Journal of Human Evolution 55(6):1138-1147.

de Certeau, Michel
1984 The Practice of Everyday Life. Berkeley: University of California Press.

DeNiro, Michael J., and Samuel Epstein
1978 Influence of Diet on the Distribution of Carbon Isotopes in Animals. Geochimica et Cosmochimica Acta 42(5):495-506.

Dhavalikar, M. K.
1992 Kuntasi: A Harappan Port in Western India. *In* South Asian Archaeology 1989. C. Jarrige, ed. Pp. 73-82. Madison: Prehistory Press.

1997 Meluhha, the Land of Copper. South Asian Studies 13:275-278.

Dikshit, K. N.
1979 The Late Harappan Culture in India. *In* Essays in Indian Protohistory. D. P. Agrawal and Dilip K. Chakrabarti, eds. Pp. 123-133. Delhi: B. R. Publishing.

Dillehay, Tom D.
1995 Mounds of Social Death: Araucanian Funerary Rites and Political Succession. *In* Tombs for the Living: Andean Mortuary Practices. Tom D. Dillehay, ed. Pp. 281-314. Washington: Dumbarton Oaks.

Driessens, F. C. M., and R. M. H. Verbeeck
1990 Biominerals. Boca Raton: CRC Press.

Dupras, Tosha L., and Henry P. Schwarcz
2001 Strangers in a Strange Land: Stable Isotope Evidence for Human Migration in the Dakhleh Oasis, Egypt. Journal of Archaeological Science 28(11):1199-1208.

Durrani, F. A.
1988 Excavations in the Gomal Valley: Rehman Dheri Excavation Report no. 1. Ancient Pakistan 6:1-232.

Durrani, F. A., I. Ali, and G. Erdosy
1995 New Perspectives on Indus Urbanism from Rehman Dheri. East and West 45(1-4):18-96.

Elias, Robert W., Yoshimitsu Hirao, and Clair C. Patterson
1982 The Circumvention of the Natural Biopurification of Calcium Along Nutrient Pathways by Atmospheric Inputs of Industrial Lead. Geochimica et Cosmochimica Acta 46(12):2561-2580.

ESCAP (Economic and Social Commission for Asia and the Pacific)
1995 Geology and Mineral Resources of Afghanistan. *In* Atlas of Mineral Resources of the ESCAP Region, Volume 2. New York: United Nations.

Evans, J. A., J. Montgomery, G. Wildman, and N. Boulton
2010 Spatial Variations in Biosphere $^{87}Sr/^{86}Sr$ in Britain. Journal of the Geological Society 167(1):1-4.

Evans, J. A., and S. Tatham
2004 Defining 'Local Signature' in Terms of Sr Isotope Composition using a Tenth- to Twelfth-Century Anglo-Saxon Population Living on a Jurassic Clay-Carbonate Terrain, Rutland, UK. Geological Society, London, Special Publications 232(1):237-248.

Fairservis, W. A.
1975 The Roots of Ancient India. Chicago: University of Chicago Press.

Farquhar, G. D., J. R. Ehleringer, and K. T. Hubick
1989 Carbon Isotope Discrimination and Photosynthesis. Annual Review of Plant Physiology and Plant Molecular Biology 40(1):503-537.

Farquhar, G. D., Marion H. O'Leary, and J. A. Berry
1982 On the Relationship between Carbon Isotope Discrimination and the Intercellular Carbon Dioxide Concentration in Leaves. Functional Plant Biology 9(2):121-137.

Faure, Gunter, and Teresa M. Mensing
2005 Isotopes: Principles and Applications. 3rd ed. Hoboken: John Wiley and Sons.

Fentress, M. A.
1976 Resource Access, Exchange Systems and Regional Interaction in the Indus Valley: An Investigation of Archaeological Variability at Harappa and Mohenjodaro. Ph.D. dissertation, Department of Oriental Studies, University of Pennsylvania.

1984 The Indus "Granaries": Illusion, Imagination and Archaeological Reconstruction. *In* Studies in the Archaeology and Palaeoanthropology of South Asia. Kenneth A. R. Kennedy and Gregory L. Possehl, eds. Pp. 89-97. New Delhi: Oxford & IBH.

Flam, Louis
1993 Excavations at Ghazi Shah, Sindh, Pakistan. *In* Harappan Civilization: A Recent Perspective. Gregory L. Possehl, ed. Pp. 457-467. Oxford: Oxford & IBH & American Institute of Indian Studies.

Frachetti, Michael D.
2011 Migration Concepts in Central Eurasian Archaeology*. Annual Review of Anthropology 40(1):195-212.

Francey, R. J., and G. D. Farquhar
1982 An Explanation of $^{13}C/^{12}C$ Variations in Tree Rings. Nature 297(5861):28-31.

Francfort, H. -P, C. Boisset, L. Butchet, J. Desse, J. Echallier, A. Kermorvant, and G. Willcox
1989 Fouilles de Shortughai: Recherches sur l'Asie Centrale Protohistorique. Paris: Diffusion de Boccard.

Franke-Vogt, U.
2000 The Archaeology of Southeastern Balochistan. Electronic document, http://www.harappa.com/baluch, accessed 5/24, 2012.

2005 Excavations at Sohr Damb/Nal: Results of the 2002 and 2004 Seasons. *In* South Asian Archaeology 2003. U. Franke-Vogt and H. -J Weisshaar, eds. Pp. 63-76. Aachen: Linden Soft.

Frenez, D., and M. Tosi
2005 Lothal Sealings: Records from an Indus Civilization Town at the Eastern End of the Maritime Trade Circuits Across the Arabian Sea. *In* Studi in Onore di Enrica Fiandra, Contributi di Archeologia Egea e Vicinorientale. Massimo Pernaa, ed. Pp. 65-103. Paris: Diffusion de Boccard.

Fricke, Henry C., and James R. O'Neil
1996 Inter- and Intra-Tooth Variation in the Oxygen Isotope Composition of Mammalian Tooth Enamel Phosphate: Implications for Palaeoclimatological and Palaeobiological Research. Palaeogeography, Palaeoclimatology, Palaeoecology 126(1–2):91-99.

Fricke, Henry C., James R. O'Neil, and Niels Lynnerup
1995 SPECIAL REPORT: Oxygen Isotope Composition of Human Tooth Enamel from Medieval Greenland: Linking Climate and Society. Geology 23(10):869-872.

Friedli, H., H. Lotscher, H. Oeschger, U. Siegenthaler, and B. Stauffer
1986 Ice Core Record of the $^{13}C/^{12}C$ Ratio of Atmospheric CO_2 in the Past Two Centuries. Nature 324(6094):237-238.

Fullagar, Paul D., Robert E. Lemmon, and Paul C. Ragland
1971 Petrochemical and Geochronological Studies of Plutonic Rocks in the Southern Appalachians: I. the Salisbury Pluton. Geological Society of America Bulletin 82(2):409-416.

Fuller, Dorian Q., and Marco Madella
2001 Issues in Harappan Archaeobotany: Retrospect and Prospect. *In* Indian Archaeology in Retrospect, Volume 2 (Protohistory: Archaeology of the Harappan Civilization). S. Settar and R. Korisettar, eds. Pp. 317-390. New Delhi: Manohar.

Gangal, K., M. Vahia, and R. Adhikari
2010 Spatio-Temporal Analysis of the Indus Urbanization. Current Science 98:846-852.

Garvie-Lok, Sandra J., Tamara L. Varney, and M. Anne Katzenberg
2004 Preparation of Bone Carbonate for Stable Isotope Analysis: The Effects of Treatment Time and Acid Concentration. Journal of Archaeological Science 31(6):763-776.

Gat, J. R.
1996 Oxygen and Hydrogen Isotopes in the Hydrologic Cycle. Annual Review of Earth and Planetary Sciences 24(1):225-262.

Gell, Alfred
1998 Art and Agency: An Anthropological Theory. Oxford: Clarendon Press.

Geological Survey of India
1994 Detailed Information on Copper-Lead-Zinc Ores in Rajasthan-Gujarat (India). Calcutta: Geological Survey of India.

Giblin, Julia I., Kelly J. Knudson, Zsolt Bereczki, György Pálfi, and Ildikó Pap
2013 Strontium Isotope Analysis and Human Mobility during the Neolithic and Copper Age: A Case Study from the Great Hungarian Plain. Journal of Archaeological Science 40(1):227-239.

Gillespie, Susan D.
2001 Personhood, Agency, and Mortuary Ritual: A Case Study from the Ancient Maya. Journal of Anthropological Archaeology 20(1):73-112.

Giosan, Liviu, Peter D. Clift, Mark G. Macklin, Dorian Q. Fuller, Stefan Constantinescu, Julie A. Durcan, Thomas Stevens, Geoff A. T. Duller, Ali R. Tabrez, Kavita Gangal, Ronojoy Adhikari, Anwar Alizai, Florin Filip, Sam VanLaningham, and James P. M. Syvitski
2012 Fluvial Landscapes of the Harappan Civilization. Proceedings of the National Academy of Sciences 109(26):E1688-E1694.

Gogte, S. T., Nandita Basu, Seeta Sinclair, O. P. Ghai, and N. K. Bhide
1991 Blood Lead Levels of Children with Pica and Surma Use. The Indian Journal of Pediatrics 58(4):513-519.

Goldstein, Lynne
1980 Mississippian Mortuary Practices: A Case Study of Two Cemeteries in the Lower Illinois Valley. Scientific Papers 4.

1981 One-Dimensional Archaeology and Multi-Dimensional People: Spatial Organization and Mortuary Analysis. *In* The Archaeology of Death. Robert Chapman, Ian Kinnes and Klavs Randsborg, eds. Pp. 53-69. Cambridge: Cambridge University Press.

Goody, E.
1982 Parenthood and Social Reproduction. Cambridge: Cambridge University Press.

Gorospe, Emmanuel C., and Shawn L. Gerstenberger
2008 Atypical Sources of Childhood Lead Poisoning in the United States: A Systematic Review from 1966–2006. Clinical Toxicology 46(8):728-737.

Gulson, Brian L., Karen J. Mizon, Jacqueline M. Palmer, Michael J. Korsch, Alan J. Taylor, and Kathryn R. Mahaffey
2004 Blood Lead Changes during Pregnancy and Postpartum with Calcium Supplementation. Environmental Health Perspectives 112(15):1499-1507.

Gulson, Brian L., C. William Jameson, Kathryn R. Mahaffey, Karen J. Mizon, Nicole Patison, Alistair J. Law, Michael J. Korsch, and Mary A. Salter
1998 Relationships of Lead in Breast Milk to Lead in Blood, Urine, and Diet of the Infant and Mother. Environmental Health Perspectives 106(10):pp. 667-674.

Gulson, Brian L., Karen J. Mizon, Michael J. Korsch, Jacqueline M. Palmer, and John B. Donnelly
2003 Mobilization of Lead from Human Bone Tissue during Pregnancy and Lactation—a Summary of Long-Term Research. Science of the Total Environment 303(1–2):79-104.

Gupta, S. K., and R. D. Deshpande
2005 Groundwater Isotopic Investigations in India: What has been Learned? Current Science 89(5):825-835.

Gupta, S. P.
1984 Internal Trade of the Harappans. *In* Frontiers of the Indus Civilization. B. B. Lal and S. P. Gupta, eds. Pp. 417-424. New Delhi: Books and Books.

1989 Copper Hoard. *In* An Encyclopaedia of Indian Archaeology. A. Ghosh, ed. Pp. 92. Delhi: Munshiram Manoharlal.

Gupta, S. K., R. D. Deshpande, S. K. Bhattacharya, and R. A. Jani
2005 Groundwater $\delta^{18}O$ and δD from Central Indian Peninsula: Influence of the Arabian Sea and the Bay of Bengal Branches of the Summer Monsoon. Journal of Hydrology 303(1–4):38-55.

Gwynn, E. J.
1913 Fosterage. *In* Encyclopaedia of Religion and Ethics. J. Hastings, ed. Pp. 104-109. Edinburgh: T. and T. Clark.

Hakenbeck, Susanne
2008 Migration in Archaeology: Are We Nearly There Yet? Archaeological Review from Cambridge 23(2):9-26.

Halim, Mohammad A., and Massimo Vidale
1984 Kilns, Bangles, and Coated Vessels: Ceramic Production in Closed Containers at Mohenjodaro. *In* Interim Reports, Volume 1: Reports on Field Work Carried Out at Mohenjo-Daro, Pakistan 1982-83. Michael Jansen and Gunter Urban, eds. Pp. 63-97. Aachen: RWTH-IsMEO.

Harke, Heinrich
2007 Ethnicity, 'Race' and Migration in Mortuary Archaeology: An Attempt at a Short Answer. *In* Early Medieval Mortuary Practices. S. Semple and H. WIlliams, eds. Pp. 12-18. Oxford: Oxbow.

Harrison, Roman G., and M. Anne Katzenberg
2003 Paleodiet Studies using Stable Carbon Isotopes from Bone Apatite and Collagen: Examples from Southern Ontario and San Nicolas Island, California. Journal of Anthropological Archaeology 22(3):227-244.

Hedges, R. E. M.
2003 On Bone Collagen—Apatite-Carbonate Isotopic Relationships. International Journal of Osteoarchaeology 13(1-2):66-79.

Helms, Mary W.
1988 Ulysses' Sail: An Ethnographic Odyssey of Power, Knowledge, and Geographical Distance. Princeton: Princeton University Press.

1993 Craft and the Kingly Ideal: Art, Trade, and Power. Austin: University of Texas Press.

Hemphill, Brian E., John R. Lukacs, and Kenneth A. R. Kennedy
1991 Biological Adaptations and Affinities of Bronze Age Harappans. *In* Harappa Excavations 1986-1990: A Multidisciplinary Approach to Third Millennium Urbanism. Richard H. Meadow, ed. Pp. 137-182. Madison: Prehistory Press.

Hide, Robin
2003 Pig Husbandry in New Guinea: A Literature Review and Bibliography. Canberra: Australian Centre for International Agricultural Research.

Hillson, Simon
1996 Dental Anthropology. Cambridge: Cambridge University Press.

Hodder, Ian
1982 The Identification and Interpretation of Ranking in Prehistory: A Contextual Perspective. *In* Ranking, Resource, and Exchange: Aspects of the Archaeology of Early European Society. A. C. Renfrew and S. J. Shennen, eds. Pp. 150-154. Cambridge: Cambridge University Press.

2012 Entangled: An Archaeology of the Relationships between Humans and Things. Chichester: John Wiley and Sons.

Hodell, David A., Rhonda L. Quinn, Mark Brenner, and George Kamenov
2004 Spatial Variation of Strontium Isotopes ($^{87}Sr/^{86}Sr$) in the Maya Region: A Tool for Tracking Ancient Human Migration. Journal of Archaeological Science 31(5):585-601.

Hoffman, Brett C., and Heather M. -L Miller
2009 Production and Consumption of Copper-Base Metals in the Indus Civilization. Journal of World Prehistory 22:237-264.

Hooja, R.
1994 Ganeshwar and the "Frontier Theory": A Possible Framework for Understanding Ganeshwar-Harappan Interaction. Shodhak 23(69):127-136.

Hoppe, K. A., P. L. Koch, and T. T. Furutani
2003 Assessing the Preservation of Biogenic Strontium in Fossil Bones and Tooth Enamel. International Journal of Osteoarchaeology 13(1-2):20-28.

Howland, M. R., L. T. Corr, S. M. M. Young, V. Jones, S. Jim, N. J. Van Der Merwe, A. D. Mitchell, and R. P. Evershed
2003 Expression of the Dietary Isotope Signal in the Compound-Specific $\delta^{13}C$ Values of Pig Bone Lipids and Amino Acids. International Journal of Osteoarchaeology 13(1-2):54-65.

Hu, Yaowu, Hong Shang, Haowen Tong, Olaf Nehlich, Wu Liu, Chaohong Zhao, Jincheng Yu, Changsui Wang, Erik Trinkaus, and Michael P. Richards
2009 Stable Isotope Dietary Analysis of the Tianyuan 1 Early Modern Human. Proceedings of the National Academy of Sciences 106(27):10971-10974.

Ingold, Tim
2011 Being Alive: Essays on Movement, Knowledge, and Description. Abingdon: Routledge.

Jackes, Mary
2011 Representativeness and Bias in Archaeological Skeletal Samples. *In* Social Bioarchaeology. Sabrina C. Agarwal and Bonnie A. Glencross, eds. Pp. 107-146. Chichester: Wiley-Blackwell.

Jansen, Michael
1984 Preliminary Results on the "Forma Urbis" Research at Mohenjo-Daro. *In* Interim Reports, Volume 2: Reports on Field Work Carried Out at Mohenjo-Daro, Pakistan 1983-84 by the IsMEO-Aachen-University Mission. Michael Jansen and Gunter Urban, eds. Pp. 9-22. Aachen: Forschungsprojekt "Mohenjo-Daro".

1993 Mohenjo-Daro: City of Wells and Drains, Water Splendour 4500 Years Ago. Bonn: Bergisch Gladbach Frontinus-Gesellschaft.

2002 Settlement Networks of the Indus Civilization. *In* Indian Archaeology in Retrospect, Volume 2 (Protohistory: Archaeology of the Harappan Civilization). S. Settar and R. Korisettar, eds. Pp. 105-128. New Delhi: Manohar.

Jarrige, C., J. -F Jarrige, Richard H. Meadow, and G. Quivron
1995 Mehrgarh: Field Reports 1974-1985, from Neolithic Times to the Indus Civilization. Karachi: The Department of Culture and Tourism, Government of Sindh.

Jarrige, J. -F
1995 Introduction. *In* Mehrgarh: Field Reports 1974-1985. C. Jarrige, J. -F Jarrige, Richard H. Meadow and G. Quivron, eds. Pp. 51-103. Karachi: The Department of Culture and Tourism, Government of Sindh.

Jenkins, P. C.
1994 Continuity and Change in the Ceramic Sequence at Harappa. *In* South Asian Archaeology 1993. Asko Parpola and P. Koskikallio, eds. Pp. 315-328. Helsinki: Suomalainen Tiedeakatemia.

Jim, Susan, Stanley H. Ambrose, and Richard P. Evershed
2003 Natural Abundance Stable Carbon Isotope Evidence for the Routing and De Novo Synthesis of Bone FA and Cholesterol. Lipids 38(2):179-186.

2004 Stable Carbon Isotopic Evidence for Differences in the Dietary Origin of Bone Cholesterol, Collagen and Apatite: Implications for Their Use in Palaeodietary Reconstruction. Geochimica et Cosmochimica Acta 68(1):61-72.

Jones, Sian
1997 The Archaeology of Ethnicity: Constructing Identities in the Past and Present. London: Routledge.

Joshi, Jagat Pati
1984 Harappa Culture: Emergence of a New Picture. Puratattva 13-14:51-54.

2003 Structures. *In* Excavations at Kalibangan: The Early Harappans (1960-1969). B. B. Lal, B. K. Thapar, Jagat Pati Joshi and Madhu Bala, eds. Pp. 51-94. New Delhi: Archaeological Survey of India.

Joyce, Rosemary A.
2001 Burying the Dead at Tlatilco: Social Memory and Social Identities. Archeological Papers of the American Anthropological Association 10(1):12-26.

Kadir, Muhammad Masood, Naveed Zafar Janjua, Sibylle Kristensen, Zafar Fatmi, and Nalini Sathiakumar
2008 Status of Children's Blood Lead Levels in Pakistan: Implications for Research and Policy. Public Health 122(7):708-715.

Kamenov, George D., P. A. Mueller, A. Gilli, S. Coyner, and S. H. H. Nielsen
2006 A Simple Method for Rapid, High-Precision Isotope Analyses of Small Samples by MC-ICP-MS. Eos Transactions AGU 87 Fall Meeting Supplement:V21A-0542.

Kamenov, George D., Paul A. Mueller, and Michael R. Perfit
2004 Optimization of Mixed Pb-Tl Solutions for High Precision Isotopic Analyses by MC-ICP-MS. Journal of Analytical Atomic Spectrometry 19(9):1262-1267.

Karim, Ajaz
1999 Hydrochemistry and Isotope Systematics of the Indus River Basin. Ph.D. dissertation, Department of Earth Science, University of Ottawa.

Karim, Ajaz, and Jan Veizer
2000 Weathering Processes in the Indus River Basin: Implications from Riverine Carbon, Sulfur, Oxygen, and Strontium Isotopes. Chemical Geology 170(1–4):153-177.

2002 Water Balance of the Indus River Basin and Moisture Source in the Karakoram and Western Himalayas: Implications from Hydrogen and Oxygen Isotopes in River Water. Journal of Geophysical Research: Atmospheres 107(D18):4362, doi:10.1029/2000JD000253.

Kazmi, A. H., and M. Q. Jan
1997 Geology and Tectonics of Pakistan. Karachi: Graphic Publishers.

Kellner, Corina M., and Margaret J. Schoeninger
2007 A Simple Carbon Isotope Model for Reconstructing Prehistoric Human Diet. American Journal of Physical Anthropology 133(4):1112-1127.

Kendall, Carol, and Tyler B. Coplen
2001 Distribution of Oxygen-18 and Deuterium in River Waters Across the United States. Hydrological Processes 15(7):1363-1393.

Kennedy, Kenneth A. R.
2000 God-Apes and Fossil Men : Paleoanthropology of South Asia. Ann Arbor: University of Michigan Press.

Kennedy, Kenneth A. R., John Chiment, Todd Disotell, and David Meyers
1984 Principal-Components Analysis of Prehistoric South Asian Crania. American Journal of Physical Anthropology 64(2):105-118.

Kenoyer, Jonathan Mark
1989 Socio-Economic Structures of the Indus Civilization as Reflected in Specialized Crafts and the Question of Ritual Segregation. *In* Old Problems and New Perspectives in the Archaeology of South Asia. Jonathan Mark Kenoyer, ed. Pp. 183-192. Madison: Department of Anthropology, University of Wisconsin, Madison.

1991 The Indus Valley Tradition of Pakistan and Western India. Journal of World Prehistory 5(4):331-385.

1991 Urban Process in the Indus Tradition: A Preliminary Model from Harappa. *In* Harappa Excavations 1986-1990. Richard H. Meadow, ed. Pp. 29-60. Madison: Prehistory Press.

1992 Harappan Craft Specialization and the Question of Urban Segregation and Stratification. Eastern Anthropologist 45(1-2):39-54.

1993 Excavations on Mound E, Harappa: A Systematic Approach to the Study of Indus Urbanism. *In* South Asian Archaeology 1991. A. J. Gail and G. J. R. Mevissen, eds. Pp. 165-194. Stuttgart: F. S. Verlag.

1995 Ideology and Legitimation in the Indus State as Revealed through Symbolic Objects. The Archaeological Review 4(1/2):87-131.

1995 Interaction Systems, Specialized Crafts, and Culture Change: The Indus Valley Tradition and the Indo-Gangetic Tradition in South Asia. *In* The Indo-Aryans of Ancient South Asia: Language, Material Culture, and Ethnicity. G. Erdosy, ed. Pp. 213-257. Berlin: deGruyter.

1997 Early City-States in South Asia: Comparing the Harappan Phase and Early Historic Period. *In* The Archaeology of City-States: Cross Cultural Approaches. D. L. Nichols and T. H. Charlton, eds. Pp. 51-70. Washington, D.C.: Smithsonian Institution Press.

1998 Ancient Cities of the Indus Valley Civilization. Oxford: Oxford University Press.

2000 Wealth and Socioeconomic Hierarchies of the Indus Valley Civilization. *In* Order, Legitimacy, and Wealth in Early States. J. Richards and M. Van Buren, eds. Pp. 88-109. Cambridge: Cambridge University Press.

2005 Bead Technologies at Harappa, 3300-1900 BC: A Comparative Summary. *In* South Asian Archaeology 2001. C. Jarrige and V. Lefevre, eds. Pp. 157-170. Paris: Editions Recerche sur les Civilisations.

2005 Culture Change during the Late Harappan Period at Harappa: New Insights on Vedic Aryan Issues. *In* The Indo-Aryan Controversy: Evidence and Inference in Indian History. Edwin F. Bryant and Laurie L. Patton, eds. Pp. 21-49. Oxon: Routledge.

2006 Cultures and Societies of the Indus Tradition. *In* Historical Roots in the Making of 'the Aryan'. Romila Thapar, ed. Pp. 41-97. New Delhi: National Book Trust.

2011 Changing Perspectives of the Indus Civilization: New Discoveries and Challenges. Puratattva 41:1-18.

2011 Regional Cultures of the Greater Indus Valley: The Ravi and Kot Diji Phase Assemblages of Harappa, Pakistan. *In* Cultural Relations between the Indus and the Iranian Plateau during the Third Millennium BCE. Toshiki Osada and Michael Witzel, eds. Pp. 165-217. Cambridge: Department of South Asian Studies, Harvard University.

Kenoyer, Jonathan Mark, and Richard H. Meadow
1996 New Inscribed Objects from Harappa. Lahore Museum Bulletin 9(1):1-29.

1999 Harappa: New Discoveries on its Origins and Growth. Lahore Museum Bulletin 12(1):1-12.

2000 The Ravi Phase: A New Cultural Manifestation at Harappa. *In* South Asian Archaeology 1997. M. Taddei, ed. Pp. 55-76. Rome: IsIAO.

2008 The Early Indus Script at Harappa: Origins and Development. *In* Intercultural Relations between South and Southwest Asia: Studies in Commemoration of E. C. L. during-Caspers (1934-1996). E. Olijdam and R. H. Spoor, eds. Pp. 124-131. Oxford: Archaeopress.

Kenoyer, Jonathan Mark, and Heather M. -L Miller
1999 Metal Technologies of the Indus Valley Tradition in Pakistan and Western India. *In* The Archaeometallurgy of the Asian Old World. V. C. Pigott, ed. Pp. 107-151. Philadelphia: University Museum, University of Pennsylvania.

Kenoyer, Jonathan Mark, and Massimo Vidale
1992 A New Look at Stone Drills of the Indus Valley Tradition. *In* Materials Issues in Art and Archaeology, III. P. Vandiver, J. R. Druzik, G. S. Wheeler and I. Freestone, eds. Pp. 495-518. Pittsburgh: Materials Research Society.

Kenoyer, Jonathan Mark, T. Douglas Price, and James H. Burton
2013 A New Approach to Tracking Connections between the Indus Valley and Mesopotamia: Initial Results of Strontium Isotope Analyses from Harappa and Ur. Journal of Archaeological Science 40(5):2286-2297.

Khan, F., J. R. Knox, and K. D. Thomas
1990 Sheri Khan Tarakai: A Neolithic Village in Bannu District, NWFP. *In* South Asian Archaeology 1987. M. Taddei and P. Callieri, eds. Pp. 111-127. Rome: IsMEO.

Khatib-Chahidi, J.
1992 Milk Kinship in Shi'Ite Islamic Iran. *In* The Anthropology of Breast Feeding. V. Maher, ed. Pp. 109-132. Oxford: Berg.

Khatri, J. S., and M. Acharya
1995 Kunal: A New Indus-Saraswati Site. Puratattva 25:84-86.

2005 Kunal Excavations: New Light on the Origin of the Harappan Civilization. *In* In Search of Vedic Harappan Relationship. A. Agrawal, ed. Pp. 104-117. New Delhi: Aryan Books International.

Kinaston, Rebecca, Hallie Buckley, Andrew Gray, Ben Shaw, and Herman Mandui
2013 Exploring Subsistence and Cultural Complexes on the South Coast of Papua New Guinea using Palaeodietary Analyses. Journal of Archaeological Science 40(2):904-913.

Klaminder, Jonatan, Richard Bindler, Ove Emteryd, and Ingemar Renberg
2005 Uptake and Recycling of Lead by Boreal Forest Plants: Quantitative Estimates from a Site in Northern Sweden. Geochimica et Cosmochimica Acta 69(10):2485-2496.

Klaminder, Jonatan, Richard Bindler, Hjalmar Laudon, Kevin Bishop, Ove Emteryd, and Ingemar Renberg
2006 Flux Rates of Atmospheric Lead Pollution within Soils of a Small Catchment in Northern Sweden and their Implications for Future Stream Water Quality. Environmental Science & Technology 40(15):4639-4645.

Klaminder, Jonatan, Richard Bindler, and Ingemar Renberg
2008 The Biogeochemistry of Atmospherically Derived Pb in the Boreal Forest of Sweden. Applied Geochemistry 23(10):2922-2931.

Klaminder, Jonatan, John G. Farmer, and Angus B. MacKenzie
2011 The Origin of Lead in the Organic Horizon of Tundra Soils: Atmospheric Deposition, Plant Translocation from the Mineral Soil Or Soil Mineral Mixing? Science of the Total Environment 409(20):4344-4350.

Knudson, K. J.
2009 Oxygen Isotope Analysis in a Land of Environmental Extremes: The Complexities of Isotopic Work in the Andes. International Journal of Osteoarchaeology 19(2):171-191.

Knudson, K. J., T. D. Price, J. E. Buikstra, and D. E. Blom
2004 The use of Strontium Isotope Analysis to Investigate Tiwanaku Migration and Mortuary Ritual in Bolivia and Peru. Archaeometry 46(1):5-18.

Koch, Paul L., Noreen Tuross, and Marilyn L. Fogel
1997 The Effects of Sample Treatment and Diagenesis on the Isotopic Integrity of Carbonate in Biogenic Hydroxylapatite. Journal of Archaeological Science 24(5):417-429.

Kohl, P. L.
1978 Archaeological Reconnaissances in Eastern Afghanistan, 1975-1976. Estratto Da ANNALI Dell'Istituto Orientale di Napoli 38:64-74.

Kohn, Matthew J.
2010 Carbon Isotope Compositions of Terrestrial C3 Plants as Indicators of (Paleo)Ecology and (Paleo)Climate. Proceedings of the National Academy of Sciences 107(46):19691-19695.

Kohn, Matthew J., Jennifer Morris, and Paul Olin
2013 Trace Element Concentrations in Teeth – a Modern Idaho Baseline with Implications for Archeometry, Forensics, and Palaeontology. Journal of Archaeological Science 40(4):1689-1699.

Kohn, Matthew J., Margaret J. Schoeninger, and John W. Valley
1996 Herbivore Tooth Oxygen Isotope Compositions: Effects of Diet and Physiology. Geochimica et Cosmochimica Acta 60(20):3889-3896.

Komárek, Michael, Vojtěch Ettler, Vladislav Chrastný, and Martin Mihaljevič
2008 Lead Isotopes in Environmental Sciences: A Review. Environment International 34(4):562-577.

Konasukawa, Ayumu, Hitoshi Endo, and Akinori Uesugi
2011 Minor Objects from the Settlement Area. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 369-529. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Krigbaum, John
2003 Neolithic Subsistence Patterns in Northern Borneo Reconstructed with Stable Carbon Isotopes of Enamel. Journal of Anthropological Archaeology 22(3):292-304.

Krishnaswami, S., J. R. Trivedi, M. M. Sarin, R. Ramesh, and K. K. Sharma
1992 Strontium Isotopes and Rubidium in the Ganga-Brahmaputra River System: Weathering in the Himalaya, Fluxes to the Bay of Bengal and Contributions to the Evolution of Oceanic $^{87}Sr/^{86}Sr$. Earth and Planetary Science Letters 109(1–2):243-253.

Kroeber, A. L.
1927 Disposal of the Dead. American Anthropologist 29(3):308-315.

Krueger, Harold W., and Charles Sullivan H.
1984 Models for Carbon Isotope Fractionation between Diet and Bone. *In* Stable Isotopes in Nutrition. Judith R. Turnlund and Phyllis E. Johnson, eds. Pp. 205-220. Washington: American Chemical Society.

Kumar, Manmohan
2009 *In* Occasional Paper 7: Linguistics, Archaeology, and the Human Past. Toshiki Osada and Akinori Uesugi, eds. Pp. 1-75. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Lahiri, Nayanjot
1992 The Archaeology of Indian Trade Routes Up to C. 200 BC: Resource use, Resource Access and Lines of Communication. Delhi: Oxford University Press.

Lal, B. B.
1951 Further Copper Hoards from the Gangetic Basin and a Review of the Problem. Ancient India 7:20-39.
1972 A Note on the Excavation at Sapai. Puratattva 5:46-49.

Lamberg-Karlovsky, C. C.
1972 Trade Mechanisms in Indus-Mesopotamian Interrelations. Journal of the American Oriental Society 92(2):222-229.

Lambs, L., K. Balakrishna, F. Brunet, and J. L. Probst
2005 Oxygen and Hydrogen Isotopic Composition of Major Indian Rivers: A First Global Assessment. Hydrological Processes 19(17):3345-3355.

Law, Randall William
2006 Moving Mountains: The Trade and Transport of Rocks and Minerals within the Greater Indus Valley Region. *In* Space and Spatial Analysis in Archaeology. E. C. Robertson, J. D. Seibert, D. C. Fernandez and M. U. Zender, eds. Pp. 301-313. Calgary: University of Calgary Press.

2008 Inter-Regional Interaction and Urbanism in the Ancient Indus Valley: A Geologic Provenience Study of Harappa's Rock and Mineral Assemblage. Ph.D. dissertation, Department of Anthropology, University of Wisconsin-Madison.

Lecuyer, Christophe, Patricia Grandjean, and Simon M. F. Sheppard
1999 Oxygen Isotope Exchange between Dissolved Phosphate and Water at Temperatures ≤135°C: Inorganic Versus Biological Fractionations. Geochimica et Cosmochimica Acta 63(6):855-862.

Lefebvre, Henri
1991 The Production of Space. Oxford: Blackwell.

Levin, Naomi E., Thure E. Cerling, Benjamin H. Passey, John M. Harris, and James R. Ehleringer
2006 A Stable Isotope Aridity Index for Terrestrial Environments. Proceedings of the National Academy of Sciences 103(30):11201-11205.

Levinson, A. A., Boaz Luz, and Yehoshua Kolodny
1987 Variations in Oxygen Isotopic Compositions of Human Teeth and Urinary Stones. Applied Geochemistry 2(4):367-371.

Lightfoot, Kent G., Antoinette Martinez, and Ann M. Schiff
1998 Daily Practice and Material Culture in Pluralistic Social Settings: An Archaeological Study of Culture Change and Persistence from Fort Ross, California. American Antiquity 63(2):199-222.

Longinelli, Antonio
1984 Oxygen Isotopes in Mammal Bone Phosphate: A New Tool for Paleohydrological and Paleoclimatological Research? Geochimica et Cosmochimica Acta 48(2):385-390.

Lorenzen, Gunnar, Christoph Sprenger, Paul Baudron, Dinesh Gupta, and Asaf Pekdeger
2012 Origin and Dynamics of Groundwater Salinity in the Alluvial Plains of Western Delhi and Adjacent Territories of Haryana State, India. Hydrological Processes 26(15):2333-2345.

Lukacs, John R., and J. N. Pal
1993 Mesolithic Subsistence in North India: Inferences from Dental Attributes. Current Anthropology 34(5):745-765.

Luz, Boaz, and Yehoshua Kolodny
1985 Oxygen Isotope Variations in Phosphate of Biogenic Apatites, IV. Mammal Teeth and Bones. Earth and Planetary Science Letters 75(1):29-36.

Luz, Boaz, Yehoshua Kolodny, and Michal Horowitz
1984 Fractionation of Oxygen Isotopes between Mammalian Bone-Phosphate and Environmental Drinking Water. Geochimica et Cosmochimica Acta 48(8):1689-1693.

Lyman, R. L., and MichaelJ O'Brien
2001 The Direct Historical Approach, Analogical Reasoning, and Theory in Americanist Archaeology. Journal of Archaeological Method and Theory 8(4):303-342.

Mackay, E. J. H.
1938 Further Excavations at Mohenjo-Daro. Delhi: Government of India.

Madella, Marco
2003 Investigating Agriculture and Environment in South Asia: Present and Future Contributions of Opal Phytoliths. *In* Indus Ethnobiology: New Perspectives from the Field. Steven A. Weber and William R. Belcher, eds. Pp. 199-250. Lanham: Lexington Books.

Madella, Marco, and Dorian Q. Fuller
2006 Palaeoecology and the Harappan Civilisation of South Asia: A Reconsideration. Quaternary Science Reviews 25(11–12):1283-1301.

Mahadevan, I.
1977 The Indus Script: Texts, Concordance and Tables. New Delhi: Archaeological Survey of India.

Mallah, Q.
2008 Research Report on Surface and Subsurface Analysis of Archaeological Sites Around the Lakes of the Bui Mirway Desert in Sindh, Pakistan. *In* Linguistics, Archaeology, and the Human Past: Occastional Paper 4. Toshiki Osada and Akinori Uesugi, eds. Pp. 1-81. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Manton, W. I., C. R. Angle, K. L. Stanek, D. Kuntzelman, Y. R. Reese, and T. J. Kuehnemann
2003 Release of Lead from Bone in Pregnancy and Lactation. Environmental Research 92(2):139-151.

Manton, W. I., C. R. Angle, K. L. Stanek, Y. R. Reese, and T. J. Kuehnemann
2000 Acquisition and Retention of Lead by Young Children. Environmental Research 82(1):60-80.

Marshall, J. H.
1931 Mohenjo-Daro and the Indus Civilization. London: Arthur Probsthain.

Masson, Charles
1844 Narrative of various Journeys in Balochistan, Afghanistan, the Panjab, & Kalât, during a Residence in those Countries: To which is Added an Account of the Insurrection at Kalat, and a Memoir on Eastern Balochistan. Vol. 4. London: Richard Bentley.

McArthur, J. M., R. J. Howarth, and G. A. Shields
2012 Strontium Isotope Stratigraphy. *In* The Geologic Time Scale 2012. Felix M. Gradstein, James G. Ogg, Mark D. Schmitz and Gabi M. Ogg, eds. Pp. 127-144. Oxford: Elsevier.

McBride, Murray B.
1994 Environmental Chemistry of Soils. Oxford: Oxford UniversityPress.

McIntosh, Jane R.
2002 A Peaceful Realm: The Rise and Fall of the Indus Civilization. Boulder: Westview Press.

2008 The Ancient Indus Valley: New Perspectives. Santa Barbara: ABC-CLIO.

Meacham, William
1977 Continuity and Local Evolution in the Neolithic of South China: A Non-Nuclear Approach. Current Anthropology 18(3):419-440.

Meadow, Richard H.
1989 Continuity and Change in the Agriculture of the Greater Indus Valley. *In* Old Problems and New Perspectives in the Archaeology of South Asia. Jonathan Mark Kenoyer, ed. Pp. 61-74. Madison: University of Wisconsin.

1989 Prehistoric Wild Sheep and Sheep Domestication on the Eastern Margin of the Middle East. *In* Animal Domestication and its Cultural Context. P. J. Crabtree, D. V. Campana and K. Ryan, eds. Pp. 24-36. Philadelphia: University Museum, University of Pennsylvania.

1996 The Origins and Spread of Agriculture and Pastoralism in the Northwestern South Asia. *In* The Origins and Spread of Agriculture and Pastoralism in Eurasia. D. Harris, ed. Pp. 390-412. London: UCL Press.

Meadow, Richard H., and Jonathan Mark Kenoyer
1992 Harappa Archaeological Project 1992: End of Season Report. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1993 Harappa Archaeological Project: 1993 Excavations. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1994 Excavations at Harappa 1993: The City Walls and Inscribed Materials. *In* South Asian Archaeology, 1993. Asko Parpola and P. Koskikallio, eds. Pp. 451-470. Helsinki: Suomalainen Tiedeakatemia.

1997 Excavations at Harappa 1994-1995: New Perspectives on the Indus Script, Craft Activities and City Organization. *In* South Asian Archaeology 1995. B. Allchin and F. R. Allchin, eds. Pp. 139-172. New Delhi: Oxford & IBH.

2001 Recent Discoveries and Highlights from Excavations at Harappa: 1998-2000. Indo-Koko-Kenkyu [Indian Archaeological Studies] 22:19-36.

2005 Excavations at Harappa 2000-2001: New Insights on Chronology and City Organization. *In* South Asian Archaeology 2001. C. Jarrige and V. Lefevre, eds. Pp. 207-226. Paris: Editions Recherche sur les Civilisations.

2008 Harappa Excavations 1998-1999: New Evidence for the Development and Manifestation of the Harappan Phenomenon. *In* South Asian Archaeology 1999. E. M. Raven, ed. Pp. 85-109. Groningen: Egbert Forsten.

Meadow, Richard H., Jonathan Mark Kenoyer, and Rita P. Wright
1994 Harappa Archaeological Research Project: Harappa Excavations 1994. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1995 Harappa Archaeological Research Project: Harappa Excavations 1995. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1996 Harappa Archaeological Research Project: Harappa Excavations 1996. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1997 Harappa Archaeological Research Project: Harappa Excavations 1997. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1998 Harappa Archaeological Research Project: Harappa Excavations 1998. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

1999 Harappa Archaeological Research Project: Harappa Excavations 1999. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

2001 Harappa Archaeological Research Project: Harappa Excavations 2000 and 2001. Report submitted to the Director General of Archaeology and Museums, Government of Pakistan, Karachi.

Metcalf, Peter, and Richard Huntington
1991 Celebrations of Death: The Anthropology of Mortuary Ritual.Cambridge University Press.

Miller, Heather M. -L
1991 Urban Palaeoethnobotany at Harappa. *In* Harappa Excavations 1986-1990: A Multi-Disciplinary Approach to 3rd Millennium Urbanism. Richard H. Meadow, ed. Pp. 121-126. Madison: Prehistory Press.

2006 Comparing Landscapes of Transportation: Riverine-Oriented and Land-Oriented Systems in the Indus Civilization and the Mughal Empire. *In* Space and Spatial Analysis in Archaeology. E. C. Robertson, J. D. Seibert, D. C. Fernandez and M. U. Zender, eds. Pp. 281-292. Calgary: University of Calgary Press and University of New Mexico Press.

2006 Water Supply, Labor Requirements, and Land Ownership in Indus Floodplain Agricultural Systems. *In* Agriculture and Irrigation in Archaeology. Charles Stanish and Joyce Marcus, eds. Pp. 92-128. Los Angeles: Cotsen Institute of Archaeology Press.

2008 Issues in the Determination of Ancient Value Systems: The Role of Talc (Steatite) and Faience in the Indus Civilization. *In* Intercultural Relations between South and Southwest Asia: Studies in Commemoration of E. C. L. during Caspers (1934-1996). E. Olijdam and R. H. Spoor, eds. Pp. 145-157. Oxford: Archaeopress.

Miller, Heidi
2005 A New Interpretation of the Stratigraphy at Chanhudaro. *In* South Asian Archaeology 2001. C. Jarrige and V. Lefevre, eds. Pp. 253-256. Paris: Editions Recherche sur les Civilizations.

Miller, Laura J.
2003 Secondary Products and Urbanism in South Asia: The Evidence for Traction at Harappa. *In* Indus Ethnobiology: New Perspectives from the Field. Steven A. Weber and William R. Belcher, eds. Pp. 251-326. Lanham: Lexington Books.

2004 Urban Economies in Early States: The Secondary Products Revolution in the Indus Civilization. Ph.D. dissertation, Department of Anthropology, New York University.

Miller, Daniel
1985 Ideology and the Harappan Civilization. Journal of Anthropological Archaeology 4(1):34-71.

Montgomery, Janet
2002 Lead and Strontium Isotope Compositions of Human Dental Tissues as an Indicator of Ancient Exposure and Population Dynamics. Ph.D. dissertation, Department of Archaeological Sciences, University of Bradford.

Montgomery, Janet, Jane A. Evans, and Rachel E. Cooper
2007 Resolving Archaeological Populations with Sr-Isotope Mixing Models. Applied Geochemistry 22(7):1502-1514.

Montgomery, Janet, Jane A. Evans, Dominic Powlesland, and Charlotte A. Roberts
2005 Continuity Or Colonization in Anglo-Saxon England? Isotope Evidence for Mobility, Subsistence Practice, and Status at West Heslerton. American Journal of Physical Anthropology 126(2):123-138.

Morris, Ian
1991 The Archaeology of Ancestors: The Saxe/Goldstein Hypothesis Revisited. Cambridge Archaeological Journal 1(2):147-169.

Morrison, Kathleen D.
1994 The Intensification of Production: Archaeological Approaches. Journal of Archaeological Method and Theory 1(2):111-159.

Moseley, Michael E.
1975 The Maritime Foundations of Andean Civilization. Menlo Park: Cummings.

Mughal, M. Rafique
1968 Harappa-1966 (Cemetery R 37). Pakistan Archaeology 5:63-68.

1982 Recent Archaeological Research in the Cholistan Desert. *In* Harappan Civilization: A Contemporary Perspective. Gregory L. Possehl, ed. Pp. 85-95. Delhi: Oxford & IBH & the American Institute of Indian Studies.

1990 Further Evidence of the Early Harappan Culture in the Greater Indus Valley: 1971–90. South Asian Studies 6(1):175-199.

1992 Jhukar and the Late Harappan Cultural Mosaic of the Greater Indus Valley. *In* South Asian Archaeology 1989. C. Jarrige, ed. Pp. 213-222. Madison: Prehistory Press.

1994 Ancient Cities of the Indus. Lahore Museum Bulletin 7(1-2):53-59.

1994 The Harappan Nomads of Cholistan. *In* Living Traditions: Studies in the Ethnoarchaeology of South Asia. B. Allchin, ed. Pp. 53-68. New Delhi: Oxford and IBH.

1997 Ancient Cholistan: Archaeology and Architecture. Lahore: Ferozsons.

Najman, Y., M. Bickle, and H. Chapman
2000 Early Himalayan Exhumation: Isotopic Constraints from the Indian Foreland Basin. Terra Nova 12:28-34.

Nandan, K. R. R., B. K. D. Rao, and M. L. Singhal
1981 Exploration for Copper, Lead and Zinc in India. Bulletins of the Geological Survey of India, Series A: Economic Geology 47:1-197.

Nath, Amarendra
1998 Rakhigarhi: A Harappan Metropolis in the Saraswati-Drishadvati Divide. Puratattva 28:39-45.

1999 Further Excavations at Rakhigarhi. Puratattva 29:46-49.
2001 Rakhigarhi: 1999-2000. Puratattva 31:43-45.

Naum, M.
2010 Re-Emerging Frontiers: Postcolonial Theory and Historical Archaeology of the Borderlands. Journal of Archaeological Method and Theory 17(2):101-131.

O'Leary, Marion H.
1988 Carbon Isotopes in Photosynthesis. Bioscience 38(5):328-336.

O'Shea, John M.
1984 Mortuary Variability: An Archaeological Investigation. Orlando: Academic Press, Inc.

Paleo-Labo AMS Dating Group
2011 AMS Radiocarbon Dating. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 831-838. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Palmer, M. R., and J. M. Edmond
1992 Controls Over the Strontium Isotope Composition of River Water. Geochimica et Cosmochimica Acta 56(5):2099-2111.

Pande, Kanchan, M. M. Sarin, J. R. Trivedi, S. Krishnaswami, and K. K. Sharma
1994 The Indus River System (India-Pakistan): Major-Ion Chemistry, Uranium and Strontium Isotopes. Chemical Geology 116(3–4):245-259.

Parkes, Peter
2001 Alternative Social Structures and Foster Relations in the Hindu Kush: Milk Kinship Allegiance in Former Mountain Kingdoms of Northern Pakistan. Comparative Studies in Society and History 43(1):pp. 4-36.

Parry, Carol, and Joseph Eaton
1991 Kohl: A Lead-Hazardous Eye Makeup from the Third World to the First World. Environmental Health Perspectives 94:121-123.

Passey, Benjamin H., Todd F. Robinson, Linda K. Ayliffe, Thure E. Cerling, Matt Sponheimer, M. Denise Dearing, Beverly L. Roeder, and James R. Ehleringer
2005 Carbon Isotope Fractionation between Diet, Breath CO_2, and Bioapatite in Different Mammals. Journal of Archaeological Science 32(10):1459-1470.

Pearson, Parker
1982 Mortuary Practices, Society, and Archaeology: An Ethnoarchaeological Study. *In* Symbolic and Structural Archaeology. Ian Hodder, ed. Pp. 99-113. Cambridge: Cambridge University Press.

Peebles, Christopher S., and Susan M. Kus
1977 Some Archaeological Correlates of Ranked Societies. American Antiquity 42(3, Essays on Archaeological Problems):421-448.

Pendall, Elise, and Ronald Amundson
1990 Soil/Landform Relationships Surrounding the Harappa Archaeological Site, Pakistan. Geoarchaeology 5(4):301-322.

Peters, S. G., S. D. Ludington, G. J. Orris, D. M. Sutphin, J. D. Bliss, and J. J. Rytuba
2007 Preliminary Non-Fuel Mineral Resource Assessment of Afghanistan. United States Geological Survey Open File Report 2007-1214.

Pin, Christian, and Chantal Bassin
1992 Evaluation of a Strontium-Specific Extraction Chromatographic Method for Isotopic Analysis in Geological Materials. Analytica Chimica Acta 269(2):249-255.

Pollard, A. M., M. Pellegrini, and J. A. Lee-Thorp
2011 Technical Note: Some Observations on the Conversion of Dental Enamel $\delta^{18}O_p$ Values to $\delta^{18}O_w$ to Determine Human Mobility. American Journal of Physical Anthropology 145(3):499-504.

Pollock, Amanda A.
2008 Change and Continuity in the Indus Valley Cultural Tradition as Manifested by Mortuary Practices. M.A. thesis, Department of Anthropology, University of Toronto.

Pollock, Susan
1991 Of Priestesses, Princes and Poor Relations: The Dead in the Royal Cemetery of Ur. Cambridge Archaeological Journal 1(2):171-189.

Possehl, Gregory L.
1977 The End of a State and the Continuity of a Tradition. *In* Realm and Region in Traditional India. R. Fox, ed. Pp. 234-254. Durham: Carolina Academic Press.

1979 Pastoral Nomadism in the Indus Civilization: An Hypothesis. *In* South Asian Archaeology 1977. M. Taddei, ed. Pp. 537-551. Naples: Instituto Universitario Orientale.

1980 Indus Civilization in Saurashtra. Delhi: B. R. Publishing Corporation.

1992 The Harappan Civilization in Gujarat: The Sorath and Sindhi Harappans. Eastern Anthropologist 45(1-2):117-154.

1992 The Harappan Cultural Mosaic: Ecology Revisited. *In* South Asian Archaeology 1989. C. Jarrige, ed. Pp. 237-244. Madison: Prehistory Press.

1993 Harappan Civilization: A Contemporary Perspective. *In* Harappan Civilization: A Recent Perspective. Gregory L. Possehl, ed. Pp. 15-28. New Delhi: Oxford and IBH.

1997 The Transformation of the Indus Civilization. Journal of World Prehistory 11(4):425-472.

1999 Indus Age: The Beginnings. Philadelphia: University of Pennsylvania Press.

2002 Harappans and Hunters: Economic Interaction and Specialization in Prehistoric India. *In* Forager-Traders in South and Southeast Asia. Kathleen D. Morrison and L. L. Junker, eds. Pp. 62-76. Cambridge: Cambridge University Press.

2002 The Indus Civilization: A Contemporary Perspective. Walnut Creek: Altamira Press.

Possehl, Gregory L., and C. F. Herman
1990 The Sorath Harappan: A New Regional Manifestation of the Indus Urban Phase. *In* South Asian Archaeology 1987. M. Taddei, ed. Pp. 295-320. Roma: Instituto Italiano per il Medio ed Estremo Oriente.

Possehl, Gregory L., and Kenneth A. R. Kennedy
1979 Hunter Gatherer/Agriculturalist Exchange in Prehistory: An Indian Example. Current Anthropology 20(3):592-593.

Prabhakar, V. N.
2012 Burial Practices of the Harappans: Sanauli Excavations, A Case Study. Ph.D. dissertation, Department of Ancient Indian History, Culture, and Archaeology, Kurukshetra University.

Price, T. Douglas., James H. Burton, and R. Alexander Bentley
2002 The Characterization of Biologically Available Strontium Isotope Ratios for the Study of Prehistoric Migration. Archaeometry 44(1):117-135.

Price, T. Douglas, James H. Burton, Robert J. Sharer, Jane E. Buikstra, Lori E. Wright, Loa P. Traxler, and Katherine A. Miller
2010 Kings and Commoners at Copan: Isotopic Evidence for Origins and Movement in the Classic Maya Period. Journal of Anthropological Archaeology 29(1):15-32.

Prowse, Tracy L., Henry P. Schwarcz, Peter Garnsey, Martin Knyf, Roberto Macchiarelli, and Luca Bondioli
2007 Isotopic Evidence for Age-Related Immigration to Imperial Rome. American Journal of Physical Anthropology 132(4):510-519.

Qu, Chang-Sheng, Zong-Wei Ma, Jin Yang, Yang Liu, Jun Bi, and Lei Huang
2012 Human Exposure Pathways of Heavy Metals in a Lead-Zinc Mining Area, Jiangsu Province, China. PLoS ONE 7(11):e46793.

Ramakrishnan, M., and R. Vaidhyanadhan
2008 Geology of India. Bangalore: Geological Society of India.

Ramesh, R., and M. M. Sarin
1992 Stable Isotope Study of the Ganga (Ganges) River System. Journal of Hydrology 139(1–4):49-62.

Rao, L. S., N. B. Sahu, Samir Diwan, and U. A. Shastry
2004 New Light on the Excavations of the Harappan Settlement at Bhirrana. Puratattva 35:60-68.

Rao, Shikaripur Ranganatha
1973 Lothal and the Indus Valley Civilization. Bombay: Asia Publishing House.

1979 Lothal: A Harappan Port Town (1955-62). Vol. 1. New Delhi: Archaeological Survey of India.

1985 Lothal: A Harappan Port Town (1955-62). Vol. 2. New Delhi: Archaeological Survey of India.

Ratnagar, Shereen
2001 Understanding Harappa: Civilization in the Greater Indus Valley. New Delhi: Tulika.

Reid, D. J., and M. C. Dean
2006 Variation in Modern Human Enamel Formation Times. Journal of Human Evolution 50(3):329-346.

Renfrew, Colin
1972 The Emergence of Civilisation: The Cyclades and the Aegean in the Third Millennium B.C. London: Methuen.

1973 The Explanation of Culture Change: Models in Prehistory. London: Duckworth.

2000 Archaeogenetics: Towards a Population Prehistory of Europe. *In* Archaeogenetics: DNA and the Population Prehistory of Europe. K. Boyle, ed. Pp. 3-11. Cambridge: McDonald Institute Monographs.

Reynolds, Amanda C., Jay Quade, and Julio L. Betancourt
2012 Strontium Isotopes and Nutrient Sourcing in a Semi-Arid Woodland. Geoderma 189–190:574-584.

Richards, Michael P., Paul B. Pettitt, Erik Trinkaus, Fred H. Smith, Maja Paunovic, and Ivor Karavanic
2000 Neanderthal Diet at Vindija and Neanderthal Predation: The Evidence from Stable Isotopes. Proceedings of the National Academy of Sciences 97(13):7663-7666.

Rizvi, Uzma Z.
2007 Configuring the Space in between: Redefining the Ganeshwar Jodhpura Cultural Complex in Northeastern Rajasthan, India. Ph.D. dissertation, Department of Anthropology, University of Pennsylvania.

Robbins Schug, Gwen, Kelsey Gray, V. Mushrif-Tripathy, and A. R. Sankhyan
2012 A Peaceful Realm? Trauma and Social Differentiation at Harappa. International Journal of Paleopathology 2(2–3):136-147.

Roscoe, Robert J., Janie L. Gittleman, James A. Deddens, Martin R. Petersen, and William E. Halperin
1999 Blood Lead Levels among Children of Lead-Exposed Workers: A Meta-Analysis. American Journal of Industrial Medicine 36(4):475-481.

Rozanski, K., L. Araguás-Araguás, and R. Gonfiantini
1993 Isotopic Patterns in Modern Global Precipitation. *In* Climate Change in Continental Isotopic Records. P. K. Swart, K. L. Lohmann, J. McKenzie and S. Savin, eds. Pp. 1-36. Washington: American Geophysical Union.

Sahni, Rai Bahadur Daya Ram
1921 Excavations at Harappa. *In* Annual Progress Report of the Superintendent, Hindu and Buddhist Monuments, Northern Circle, for the Year Ending 31st March 1921. Pp. 8-26. Lahore: Archaeological Survey of India.

1926 Exploration and Research, Northern Circle, Punjab, Harappa. *In* Annual Report of the Archaeological Survey of India, 1923-24. J. H. Marshall, ed. Pp. 52-54. Calcutta: Government of India Press.

1927 Exploration and Research, Northern Circle, Harappa. *In* Annual Report of the Archaeological Survey of India, 1924-25. J. F. Blakiston, ed. Pp. 73-80. Calcutta: Government of India Press.

Saini, H. S., and S. A. I. Mujtaba
2012 Depositional History and Palaeoclimatic Variations at the Northeastern Fringe of Thar Desert, Haryana Plains, India. Quaternary International 250:37-48.

Sana Ullah, K. B. M.
1940 The Sources, Composition, and Technique of Copper and its Alloys. *In* Excavations at Harappa. M. S. Vats, ed. Pp. 378-382. New Delhi: Government of India.

Sastri, K. N.
1965 New Light on the Indus Civilization. Vol. 2. Delhi: Atma Ram and Sons.

Saxe, Arthur A.
1970 Social Dimensions of Mortuary Practices in a Mesolithic Population from Wadi Halfa, Sudan. Ph.D. dissertation, Department of Anthropology, University of Michigan.

1971 Social Dimensions of Mortuary Practices in a Mesolithic Population from Wadi Halfa, Sudan. *In* Approaches to the Social Dimensions of Mortuary Practices. James A. Brown, ed. Pp. 39-57. Washington: Society for American Archaeology.

Scarborough, Vernon L.
2003 The Flow of Power: Ancient Water Systems and Landscapes. Santa Fe: School of American Research Press.

Schoeninger, M. J., M. J. Kohn, W. John, and J. W. Valley
2000 Tooth Oxygen Isotope Ratios as Paleoclimate Monitors in Arid Ecosystems. *In* Biogeochemical Approaches to Paleodietary Analysis in Archaeology. Stanley H. Ambrose and M. A. Katzenberg, eds. Pp. 117-140. New York, NY: Plenum Publishers.

Scholl, Martha A., James B. Shanley, Jan Paul Zegarra, and Tyler B. Coplen
2009 The Stable Isotope Amount Effect: New Insights from NEXRAD Echo Tops, Luquillo Mountains, Puerto Rico. Water Resources Research 45(12):- W12407.

Schroeder, Hannes, Tamsin C. O'Connell, Jane A. Evans, Kristrina A. Shuler, and Robert E. M. Hedges
2009 Trans-Atlantic Slavery: Isotopic Evidence for Forced Migration to Barbados. American Journal of Physical Anthropology 139(4):547-557.

Schuyler, Robert L.
1968 The Use of Historic Analogs in Archaeology. American Antiquity 33(3):390-392.

Schwarcz, Henry P.
2002 Some Biochemical Aspects of Carbon Isotopic Paleodiet Studies. *In* Biogeochemical Approaches to Paleodietary Analysis. Stanley H. Ambrose and M. Anne Katzenberg, eds. Pp. 189-209. New York: Kluwer Academic.

Schwarcz, Henry P., L. Gibbs, and M. Knyf
1993 Oxygen Isotope Analysis of Bones from Snake Hill as Indicator of Place of Origin. *In* Snake Hill Burial, an Investigation of a Military Cemetery from the War of 1812. S. Pfeiffer and R. Williamson, eds. Pp. 263-268. Toronto: Dundurn Press.

Sengupta, Saikat, and A. Sarkar
2006 Stable Isotope Evidence of Dual (Arabian Sea and Bay of Bengal) Vapour Sources in Monsoonal Precipitation Over North India. Earth and Planetary Science Letters 250(3–4):511-521.

Shaffer, J. G.
1992 The Indus Valley, Baluchistan and Helmand Traditions: Neolithic through Bronze Age. *In* Chronologies in Old World Archaeology, Volume 1. R. Ehrich, ed. Pp. 441-464. Chicago: University of Chicago Press.

Shaffer, Jim G., and Diane A. Lichtenstein
1989 Ethnicity and Change in the Indus Valley Cultural Tradition. *In* Old Problems and New Perspectives in the Archaeology of South Asia. Jonathan Mark Kenoyer, ed. Pp. 117-126. Madison: Wisconsin Archaeological Reports.

1999 Migration, Philology and South Asian Archaeology. *In* Aryan and Non-Aryan in South Asia. J. Bronkhorst and M. Deshpande, eds. Pp. 239-260. Cambridge: Harvard Oriental Series.

Sharma, A. K.
1999 The Departed Harappans of Kalibangan. Delhi: Sundeep Prakashan.

Sharma, D. V., K. C. Nauriyal, and V. N. Prabhakar
2005 Sanauli: A Late Harappan Burial Site in the Yamuna-Hindon Doab. Puratattva 34:35-44.

2007 Excavations at Sanauli 2005-06: A Harappan Necropolis in the Upper Ganga-Yamuna Doab. Puratattva 36:166-183.

Shinde, Vasant
2011 Harappan Cemetery at Farmana. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 550-673. Kyoto: Indus Project, Research Institute for Humanity and Nature.

2011 Site and its Environs. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 5-19. Kyoto: Indus Project, Research Institute for Humanity and Nature.

2011 Structural Remains in the Settlement Area. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 41-167. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Shinde, Vasant, Toshiki Osada, and Manmohan Kumar, eds.
2011 Excavations at Farmana: District Rohtak, Haryana, India 2006-2008. Kyoto: Indus Project, Research Institute for Humanity and Nature.

2011 Excavations at Girawad: District Rohtak, Haryana, India, 2006. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Shinde, Vasant, Toshiki Osada, M. M. Sharma, Akinori Uesugi, T. Uno, H. Maemoku, P. Shirvalkar, S. S. Deshpande, A. Kulkarni, A. Sarkar, A. Reddy, V. Rao, Vivek Dangi, and Manmohan Kumar
2008 Exploration in the Ghaggar Basin and Excavations at Girawad, Farmana (Rohtak District) and Mitathal (Bhiwani District), Haryana, India. *In* Occasional Paper 3: Linguistics, Archaeology and the Human Past. Toshiki Osada and Akinori Uesugi, eds. Pp. 77-158. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Shinde, Vasant, Toshiki Osada, Akinori Uesugi, and Manmohan Kumar
2008 A Report on Excavations at Farmana 2007-08. *In* Occasional Paper 6: Linguistics, Archaeology and the Human Past. Toshiki Osada and Akinori Uesugi, eds. Pp. 1-116. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Sillen, Andrew
1986 Biogenic and Diagenetic Sr/Ca in Plio-Pleistocene Fossils of the Omo Shungura Formation. Paleobiology 12(3):311-323.

1989 Diagenesis of the Inorganic Phase of Cortical Bone. *In* The Chemistry of Prehistoric Human Bone. T. Douglas Price, ed. Pp. 211-229. Cambridge: Cambridge University Press.

Sillen, Andrew, Grant Hall, Stephen Richardson, and Richard Armstrong
1998 $^{87}Sr/^{86}Sr$ Ratios in Modern and Fossil Food-Webs of the Sterkfontein Valley: Implications for Early Hominid Habitat Preference. Geochimica et Cosmochimica Acta 62(14):2463-2473.

Silverman, Helaine
2002 Introduction: The Space and Place of Death. Archeological Papers of the American Anthropological Association 11(1):1-11.

Singh, Upinder
2008 A History of Ancient and Early Medieval India: From the Stone Age to the 12th Century. Upper Saddle River: Pearson Education.

Smith, G.
1997 Political Units of the Mature Period Harappan Civilization. M.A. thesis, Department of Anthropology, University of Pittsburgh.

Sonawane, V. H.
1992 Fresh Light on the Specialized Crafts of the Harappans in Gujarat. The Eastern Anthropologist 45(1-2):155-172.

Sponheimer, Matt, and Julia A. Lee-Thorp
1999 Oxygen Isotopes in Enamel Carbonate and their Ecological Significance. Journal of Archaeological Science 26(6):723-728.

2001 The Oxygen Isotope Composition of Mammalian Enamel Carbonate from Morea Estate, South Africa. Oecologia 126(2):153-157.

Stacul, Giorgio
1992 Further Evidence for" the Inner Asia Complex" from Swat. *In* South Asian Archaeology Studies. Gregory L. Possehl, ed. Pp. 111-122. New Delhi: Oxford & IBH Publishing Co.

1994 Neolithic Inner Asian Traditions in Northern Indo-Pakistani Valleys. *In* South Asian Archaeology 1993. Asko Parpola and P. Koskikallio, eds. Pp. 707-714. Helsinki: Suomalainen Tiedeakatemia.

Stein, Aurel
1931 An Archaeological Tour in Gedrosia. New Delhi: Archaeological Survey of India.

1937 Archaeological Reconnaissances in Northwestern India and Southeastern Iran. London: Macmillan.

Stein, Gil J.
2002 From Passive Periphery to Active Agents: Emerging Perspectives in the Archaeology of Interregional Interaction. American Anthropologist 104(3):903-916.

Strathern, Marilyn
1996 Cutting the Network. The Journal of the Royal Anthropological Institute 2(3):517-535.

Sugiyama, Shinji
2011 Phytolith Analysis at the Farmana Site of the Indus Civilization. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 826-830. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Thomas, K. D., and J. R. Knox
1994 Routes of Passage: Later Prehistoric Settlement and Exploitation of a Frontier Region in Northwestern Pakistan. Bulletin of the Institute of Archaeology, University College London 31:89-104.

Thussu, J. L.
1995 Quaternary Stratigraphy and Sedimentation of the Indo-Gangetic Plains, Haryana. Journal of the Geological Society of India 46:533-544.

Tieszen, L. L., and T. Fagre
1993 Effect of Diet Quality and Composition on the Isotopic Composition of Respiratory CO_2, Bone Collagen, Bioapatite, and Soft Tissues. *In* Prehistoric Human Bone: Archaeology at the Molecular Level. J. B. Lambert and G. Grupe, eds. Pp. 121-155. New York: Springer-Verlag.

Tieszen, Larry L.
1991 Natural Variations in the Carbon Isotope Values of Plants: Implications for Archaeology, Ecology, and Paleoecology. Journal of Archaeological Science 18(3):227-248.

Tosi, Maurizio
1993 The Harappan Civilization Beyond the Indian Subcontinent. *In* Harappan Civilization: A Recent Perspective. Gregory L. Possehl, ed. Pp. 365-378. New Delhi: Oxford and IBH.

Touzeau, Alexandra, Janne Blichert-Toft, Romain Amiot, François Fourel, François Martineau, Jenefer Cockitt, Keith Hall, Jean-Pierre Flandrois, and Christophe Lécuyer
in press Egyptian Mummies Record Increasing Aridity in the Nile Valley from 5500 to 1500 yr before Present. Earth and Planetary Science Letters.

Trickett, Mark A., Paul Budd, Janet Montgomery, and Jane Evans
2003 An Assessment of Solubility Profiling as a Decontamination Procedure for the $^{87}Sr/^{86}Sr$ Analysis of Archaeological Human Skeletal Tissue. Applied Geochemistry 18(5):653-658.

Trigger, Bruce G.
2006 A History of Archaeological Thought. 2nd ed. Cambridge: Cambridge University Press.

Tripathi, Jayant K., Barbara Bock, V. Rajamani, and A. Eisenhauer
2004 Ca and Sr Dynamics in the Indo-Gangetic Plains: Different Sources and Mobilization Processes in Northwestern India. Current Science 87(10):1453-1458.

Tripathi, Jayant K., Barbara Bock, and V. Rajamani
2013 Nd and Sr Isotope Characteristics of Quaternary Indo-Gangetic Plain Sediments: Source Distinctiveness in Different Geographic Regions and its Geological Significance. Chemical Geology 344:12-22.

Tripathi, Jayant K., P. Ghazanfari, V. Rajamani, and S. K. Tandon
2007 Geochemistry of Sediments of the Ganges Alluvial Plains: Evidence of Large-Scale Sediment Recycling. Quaternary International 159(1):119-130.

Tripathi, Jayant K., and V. Rajamani
1999 Geochemistry of the Loessic Sediments on Delhi Ridge, Eastern Thar Desert, Rajasthan: Implications for Exogenic Processes. Chemical Geology 155(3–4):265-278.

Trivedi, Pramod Kumar
2009 Excavations at Tarkhanewala-Dera and Chak 86, 2003-2004. Delhi: Archaeological Survey of India.

Ucko, Peter J.
1969 Ethnography and Archaeological Interpretation of Funerary Remains. World Archaeology 1(2):262-280.

Uesugi, Akinori
2011 Pottery from the Cemetery. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 674-800. Kyoto: Indus Project, Research Institute for Humanity and Nature.

2011 Pottery from the Settlement Area. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 168-368. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Valentine, Benjamin, George D. Kamenov, and John Krigbaum
2008 Reconstructing Neolithic Groups in Sarawak, Malaysia through Lead and Strontium Isotope Analysis. Journal of Archaeological Science 35(6):1463-1473.

van der Merwe, Nikolaas J., and Ernesto Medina
1989 Photosynthesis and $^{13}C/^{12}C$ Ratios in Amazonian Rain Forests. Geochimica et Cosmochimica Acta 53(5):1091-1094.

1991 The Canopy Effect, Carbon Isotope Ratios and Foodwebs in Amazonia. Journal of Archaeological Science 18(3):249-259.

Vats, M. S.
1933 Excavations at Harappa. *In* Annual Report of the Archaeological Survey of India, 1928-29. H. Hargreaves, ed. Pp. 76-83. Delhi: Manager of Publications.
1935 Excavations at Harappa. *In* Annual Report of the Archaeological Survey of India, 1929-30. Sahni, Rai Bahadur Daya Ram, ed. Pp. 21-31. Delhi: Manager of Publications.

1936 Excavations at Harappa. *In* Annual Report of the Archaeological Survey of India, for the Years1930-31, 1931-32, 1932-33, and 1933-34. C. L. Fabri, ed. Pp. 72-90. Delhi: Manager of Publications.

1940 Excavations at Harappa. Delhi: Government of India Press.

Vidale, Massimo
1989 Specialized Producers and Urban Elites: On the Role of Craft Industries in Mature Harappan Urban Contexts. *In* Old Problems and New Perspectives in the Archaeology of South Asia. Jonathan Mark Kenoyer, ed. Pp. 171-182. Madison: Department of Anthropology, University of Wisconsin, Madison.

2000 The Archaeology of Indus Crafts: Indus Craftspeople and Why We Study Them. Rome: IsIAO.

Vidale, Massimo
1992 Produzione Artigianale Protostorica: Ethnoarchacologia e Archeologia. Padua: Universita degli Studi di Padova.

Vidale, Massimo, and Heather M. -L Miller
2000 On the Development of Indus Technical Virtuosity and its Relation to Social Structure. *In* South Asian Archaeology 1997. M. Taddei, ed. Pp. 115-132. Rome: IsIAO.

Wanzke, H.
1984 Axis Systems and Orientation at Mohenjo-Daro. *In* Interim Reports, Volume 2: Reports on Field Work Carried Out at Mohenjo-Daro, Pakistan 1983-84 by the IsMEO-Aachen-University Mission. Michael Jansen and Gunter Urban, eds. Pp. 23-32. Aachen: Forschungsprojekt "Mohenjo-Daro".

Wasserman, R. H., F. W. Lengemann, and C. L. Comar
1958 Comparative Metabolism of Calcium and Strontium in Lactation. Journal of Dairy Science 41(6):812-821.

Weber, Steven A.
1999 Seeds of Urbanism: Palaeoethnobotany and the Indus Civilization. Antiquity 73:813-826.

2003 Archaeobotany at Harappa: Indications for Change. *In* Indus Ethnobiology.New Perspectives from the Field. Steven A. Weber and William R. Belcher, eds. Pp. 175-198. Lanham: Lexington Books.

Weber, Steven A., Tim Barela, and Heather Lehman
2010 Ecological Continuity: An Explanation for Agricultural Diversity in the Indus Civilization and Beyond. Man and Environment 35(1):62-75.

Weber, Steven A., and William R. Belcher, eds.
2003 Indus Ethnobiology: New Perspectives from the Field. Lanham: Lexington Books.

Weber, Steven A., Arunima Kashyap, and Laura Mounce
2011 Archaeobotany at Farmana: New Insights into Harappan Plant use Strategies. *In* Excavations at Farmana: District Rohtak, Haryana, India, 2006-2008. Vasant Shinde, Toshiki Osada and Manmohan Kumar, eds. Pp. 808-825. Kyoto: Indus Project, Research Institute for Humanity and Nature.

Weeks, Lloyd R.
2004 Early Metallurgy of the Persian Gulf: Technology, Trade, and the Bronze Age World. Boston: Brill Academic Publishers.

Weiss-Krejci, Estella
2011 The Formation of Mortuary Deposits: Implications for Understanding Mortuary Behavior of Past Populations. *In* Social Bioarchaeology. Sabrina C. Agarwal and Bonnie A. Glencross, eds. Pp. 68-106. Chichester: Wiley-Blackwell.

Wenke, Robert J.
2009 The Ancient Egyptian State: The Origins of Egyptian Culture (C. 8000-2000 B.C.). Cambridge: Cambridge University Press.

Weyhenmeyer, Constanze E., Stephen J. Burns, H. Niklaus Waber, Werner Aeschbach-Hertig, Rolf Kipfer, H. Hugo Loosli, and Albert Matter
2000 Cool Glacial Temperatures and Changes in Moisture Source Recorded in Oman Groundwaters. Science 287(5454):842-845.

Weyhenmeyer, Constanze E., Stephen J. Burns, H. Niklaus Waber, Phil G. Macumber, and Albert Matter
2002 Isotope Study of Moisture Sources, Recharge Areas, and Groundwater Flow Paths within the Eastern Batinah Coastal Plain, Sultanate of Oman. Water Resources Research 38(10):1184.

Wheeler, R. E. Mortimer
1947 Harappa 1946: The Defences and Cemetery R-37. Ancient India 3:58-130.

1968 The Indus Civilization. 3rd ed. Cambridge: Cambridge University Press.

Whipkey, C. E., R. C. Capo, O. A. Chadwick, and B. W. Stewart
2000 The Importance of Sea Spray to the Cation Budget of a Coastal Hawaiian Soil: A Strontium Isotope Approach. Chemical Geology 168(1–2):37-48.

White, Christine D., Rebecca Storey, Fred J. Longstaffe, and Michael W. Spence
2004 Immigration, Assimilation, and Status in the Ancient City of Teotihuacan: Stable Isotopic Evidence from Tlajinga 33. Latin American Antiquity 15(2):176-198.

White, Christine, Fred J. Longstaffe, and Kimberley R. Law
2004 Exploring the Effects of Environment, Physiology and Diet on Oxygen Isotope Ratios in Ancient Nubian Bones and Teeth. Journal of Archaeological Science 31(2):233-250.

Willey, Gordon R., and Philip Phillips
1958 Method and Theory in American Archaeology. Chicago: University of Chicago Press.

Wright, Rita
1991 Patterns of Technology and the Organization of Production at Harappa. *In* Harappa Excavations 1986-1990: A Multidisciplinary Approach to Third Millennium Urbanism. Richard H. Meadow, ed. Pp. 71-88. Madison: Prehistory Press.

2010 The Ancient Indus: Urbanism, Economy, and Society. Cambridge: Cambridge University Press.

2013 Commodoties and Things: The Kulli in Context. *In* Connections and Complexity: New Approaches to the Archaeology of South Asia. Shinu Abraham, Praveena Gullapalli, Teresa P. Raczek and Uzma Z. Rizvi, eds. Pp. 47-62. Walnut Creek: Left Coast Press.

Wright, Rita P., R. Bryson, and J. Schuldenrein
2008 Water Supply and History: Harappa and the Beas Regional Survey. Antiquity 82:37-48.

Wright, Lori E.
2005 Identifying Immigrants to Tikal, Guatemala: Defining Local Variability in Strontium Isotope Ratios of Human Tooth Enamel. Journal of Archaeological Science 32(4):555-566.

2012 Immigration to Tikal, Guatemala: Evidence from Stable Strontium and Oxygen Isotopes. Journal of Anthropological Archaeology 31(3):334-352.

Wright, Lori E., and Henry P. Schwarcz
1998 Stable Carbon and Oxygen Isotopes in Human Tooth Enamel: Identifying Breastfeeding and Weaning in Prehistory. American Journal of Physical Anthropology 106(1):1-18.

Zahran, Sammy, Mark A. S. Laidlaw, Shawn P. McElmurry, Gabriel M. Filippelli, and Mark Taylor
2013 Linking Source and Effect: Resuspended Soil Lead, Air Lead, and Children's Blood Lead Levels in Detroit, Michigan. Environmental Science & Technology 47(6):2839-2845.

BIOGRAPHICAL SKETCH

Benjamin Valentine was born in Denton, Texas to a military family. At a young age, he began learning about the diverse peoples of the world through his father's travels, sparking an interest in human cultural variation that has underscored Benjamin's academic career. Though he initially pursued more 'practical' vocations (Benjamin earned his B.S. in telecommunication from the University of Florida in 2003), Benjamin eventually returned to his intellectual passions, matriculating to the University of Florida Department of Anthropology in 2005. He earned his M.A. in 2007 and his Ph.D. in 2013. He looks forward to continuing his international research and raising his two children as his family raised him—ever curious to know more about a world bigger than ourselves and the many ways we might fit into it.