THE INDUS SEALS FROM HARAPPA: STUDY ON THE ORIGIN OF RAW MATERIAL AND PRODUCTION TECHNOLOGY

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THE INDUS SEALS FROM HARAPPA: STUDY ON THE ORIGIN OF RAW MATERIAL AND PRODUCTION TECHNOLOGY

by

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
˚C	degree Celsius
3D	Three-dimensional
ASI	Archaeological Survey of India
BMAC	Archaeological complex Bactria Margian
BSE	Backscattered electrons
Ca	Calcite
CGAR	Centre for Global Archaeological Research
CISI	Corpus of Indus Seals and Inscriptions
Cl	Clinochlore
Cr	Cristobalite
CRL	Crystallinity index
Cu	Cummingtonite
DSM	Digital Stereo Microscope
E	Enstatite
EDS	Energy Dispersive Spectroscopy
EDX	Energy-Dispersive X-ray
EU	European Union
FATA	Federally Administered Tribal Areas
FATADC	Federally Administered Tribal Areas Development Corporation
GPS	Global Positioning System
GSI	Geological Society of India
GSP	Geological Survey of Pakistan
HARP	Harappa Archaeological Research Project
HSM	Harappa Site Museum
ICP-MS	Inductively coupled plasma-mass spectrometry
INAA	Instrumental neutron activation analysis

KPK	Khyber Pakhtunkhwa Province
MAG	Magnification
MgO	Magnesium oxide
MPBB	Earth Material Characterisation Laboratory
NWFP	Northwest Frontier Province
PCA	Principal Component Analysis
SEM	Scanning Electron Microscope
SiO2	Silicon dioxide
T	Talc
Tr	Tremolite
USM	Universiti Sains Malaysia
XRD	X-ray Powder Diffraction
XRF	X-Ray Fluorescence Technology

COP MOHOR TAMADUN INDUS DARI HARAPPA:

KAJIAN ASAL USUL BAHAN MENTAH DAN TEKNOLOGI PEMBUATAN

ABSTRAK

Kajian terhadap sumber bahan mentah yang digunakan untuk membuat cop mohor Indus, serta teknik pembuatannya dapat memberi maklumat penting mengenai aspek teknologi, ekonomi serta hubungan masyarakat Indus dengan dunia luar. Thesis ini mengkaji cop mohor Indus yang ditemui di tapak arkeologi Harappa, Pakistan. Kajian ini bertujuan untuk mengenalpasti sumber mineral steatite mentah yang digunakan untuk membuat cop mohor tersebut. Di samping itu, teknik yang digunakan oleh masyarakat Indus untuk mengukir dan mengeraskan mineral tersebut turut dikaji. Metod kajian yang digunapakai bagi penyelidikan ini melibatkan teknik analisis unsur surih dan teknik eksperimen arkeologi. Kajian ini telah menganalisis beberapa sampel steatite yang ditemui di Pakistan, Afghanistan serta sampel-sampel cop mohor Indus yang ditemui di Harappa. Teknik analisis unsur surih yang digunakan adalah kaedah XRD dan XRF, manakala teknik eksperimen arkeologi yang digunakan adalah eksperimen pemanasan, ujian kekerasan, serta ujian pengukiran. Hasil kajian ini telah menunjukkan bahawa masyarakat purba di Harappa telah mendapatkan sumber steatite dari luar kawasan tamadun Indus. Hal ini mencadangkan bahawa aktiviti perdagangan jarak jauh dengan masyarakat yang tinggal di kawasan Barat Laut dan Timur Afghanistan merupakan sebahagian daripada sosio-ekonomi masyarakat Harappa. Kajian eksperimen arkeologi menunjukkan bahawa alat gangsa telah digunakan untuk mengukir cop mohor tersebut, sebelum ia dipanaskan untuk dikeraskan. Kajian ini

menunjukkan kemahiran masyarakat Harappa dari segi aspek pembuatan cop mohor serta keberadaan rangkaian perdagangan dengan kawasan sekitarnya.

THE INDUS SEALS FROM HARAPPA:

STUDY ON THE ORIGIN OF RAW MATERIAL AND PRODUCTION TECHNOLOGY

ABSTRACT

The study of the raw materials used to make the Indus seals, as well as the production technique may give valuable information regarding the technology, economy, and the relation between the Indus societies with the outside world. This thesis examines the Indus seals found in Harappa in order to identify the sources of raw steatite used to make the Indus seals, the techniques employed to harden the soft steatites as well as the carving techniques. The research method ranged from elemental analysis to experimental studies. The elemental study involves analysing steatite samples from Pakistan and Afghanistan, as well as seal samples from Harappa using the XRF and XRD techniques, while the experimental methods included heating, hardness and scratching tests. The results of this study indicated that, in the process of obtaining the steatite sources, residents of Harappa interacted with peoples of north-western Pakistan and eastern Afghanistan. The result of this study also suggested that the steatite minerals were acquired by the Harappan people from sources outside of the Greater Indus region, which indicated that external trade was a continuous aspect of the socio-economic lives of the residents of Harappa. The experimental archaeology conducted revealed that the bronze tools were used to carve the steatite before these artefacts were being heated. This study revealed the ability of the Indus society living in Harappa, have an accurate and comprehensive knowledge of where steatite was available to the Harappans and establishing trade networks with the adjacent regions.

CHAPTER 1

INTRODUCTION

1.1 Background of Research

The Indus Valley civilisation (2600-1900 BC) is one of the oldest urban societies in the world (Kenoyer, 2008a; Mughal, 1990a; Parikh & Petrie, 2019; Petrie & Lynam, 2020). Contemporary with the Bronze Age societies in Egypt and Mesopotamia (Sameer et al., 2019), their material remains today are found scattered across vast regions of modern Pakistan, Afghanistan, and north-western India (Adams, 2018; Green & Petrie, 2018; Kenoyer, 2006; Mughal 1990a; Shaffer, 1982; Vats, 1940). The Indus people lived in the well-planned settlements (Sridharan, 2016). Although there are pieces of evidence for the presence of a writing system in Indus seals, those inscriptions have yet to be deciphered (Farmer et al., 2004; Kenoyer, 2016a). Due to this reason, our understanding regarding the Indus Valley civilisation is based exclusively on their cultural remains found during excavations (Fagan & Scarre 2016; Kenoyer & Meadow, 2010; Possehl, 1998).

The Indus Valley Civilisation remains were first discovered in Harappa, which are believed to have existed from 2600 to 1900 BCE (Green & Petrie, 2018; Kenoyer, 1998c; Mughal 1990a; Sameer & Zhang, 2018; Vats, 1940). To date, more than 1,500 sites have been reported in India, Pakistan and Afghanistan, consisting of several major urban centres as well as towns, villages, hamlets and camps (Figure 1.1) (Kenoyer, 2008a; Mughal, 1990a; Parikh & Petrie, 2019). Among the excavated sites, five major urban centres have been identified such as Mohenjo-Daro, Harappa, and Ganweriwala in Pakistan, as well as Rakhigarhi and Dholavira in India (Green, 2016a; Meadow & Patel 2002; Smith, 2006; Parikh & Petrie, 2019; Petrie et al., 2019).

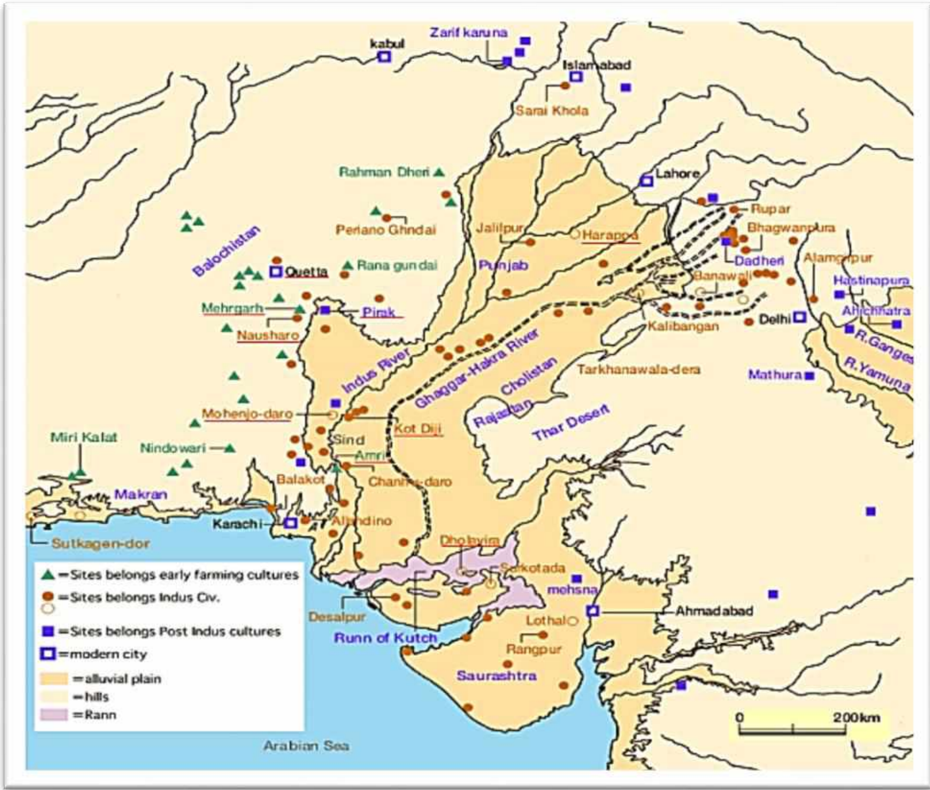

Figure 1.1: Major sites of the Indus Valley civilisation (Source: Javonillo, 2011).

The discovery of Indus Valley civilisation had led to the identification of several cultural features inherent in a complex society, which include social stratification and institutionalized authority (Wright, 2010). Important insights into this civilisation can be glimpsed through its various material remains, such as ceramics, beads, and seals (Kenoyer, 1997a, 1998a; Kenoyer & Meadow, 2010; Parikh & Petrie, 2019). Many aspects regarding the Indus society remains an enigma (Giosan et al., 2012; Kenoyer, 1987). The belief system of the Indus society is still unclear because decorative tombs of large temples associated with a secular or religious establishment have not yet been reported (Khan & Lemmen, 2013; Kenoyer, 1991, 2006; Miller, 2007; Parikh & Petrie, 2019; Umer, 2017). The lack of expressions/representations of political power, such as large monuments or murals cannot also be noticed from the excavated sites. Historical and archaeological evidence of organized warfare or any other form of coercive force has also not yet been reported (Danino, 2016; Khan & Lemmen, 2013; Kenoyer, 1991, 2006; Miller, 2007; Parikh & Petrie, 2019; Robinson, 2015b).

Indus sites produced many important forms of material culture, and the most prominent among them is the Indus seals, arguably the Indus civilisation's signature artefacts (Joshi & Parpola, 1987; Kenoyer & Meadow, 2010; Parpola, 2019; Parikh & Petrie, 2019). They have been recovered in all the major sites throughout the Indus civilisation, and found within different archaeological contexts, at sites throughout Pakistan and Northwest India and Afghanistan. Indus seals can also be found in several places outside the Indo-Pakistan Subcontinent, such as Mesopotamia, the Persian Gulf and at the highlands of Iran and Turkmenistan (Gibson, 1977; Kenoyer & Meadow, 2010; Miller, 2017; Parpola, 2019). The study on the Indus Seals had so far give important insights into the cultural and economic history of the region (Frenez et al., 2016).

Most Indus seals are square and made of steatite (rarely copper, terracotta) with a typically have raised perforated handles or "bosses" on the side reverse so that they can be hung from neck or belts (Figure 1.2) (Green, 2016, 2018; Konasukawa, 2013). The Indus seals are mostly engraved with the undeciphered script and various animal motives and mythological figures such as unicorns, horned elephants and horned tigers (Kenoyer, 2013; Parpola 1994, 2019; Possehl, 1996). Each seal has an average length of five Indus characters on the upper part (Franke-Vogt, 1991; Joshi & Parpola, 1987; Mahadevan, 1977; Parpola 1994, 2019; Possehl, 1996) (see, Figures 1.3). Some motifs consisted of geometric patterns such as concentric circles, crosses and swastikas (Figure 1.4).

Most Indus seals were found in Harappa and Mohenjo-Daro, which are believed to have been the two capital cities of Indus civilisation (Green, 2016a; Konasukawa, 2013). The research undertaken in the Indus archaeology has adopted

Figure 1.2: Perforated handles or “bosses” on the reverse side of the Indus seal (Source: Green, 2016a).

Figure 1.3: Large unicorn seal (H99-4064/8796-01) found on the floor of Room 591 in Trench 43, dating to late Period 3C. This is one of the largest seals found from any Indus site (Source: Green, 2016a).

Figure 1.4: A faience button seal with geometric motif (H2000-4491/9999-34) was found on the surface of Mound AB at Harappa by one of the workers (Source: Green 2016a).

Numerous viewpoints and methodologies to study the Indus seals (Green, 2016a; Kenoyer, 2009a; Lahiri, 1990; Parpola et al., 2010).

These studies included a comparative analysis of shapes, motifs and size of the seals, and they attempted to decipher the Indus script (Fairservis, 1986; Franke-Vogt, 1992; Gadd, 1931; Kenoyer, 2009a; Mackay, 1931; Parpola, 1986, 2011a, 2011b; Parpola & Janhunen, 2011; Parpola, 2019a; Rissman, 1989). To date, there are three published volumes (i.e., the corpus Indus seal and inscriptions) which compiled relevant data by including the photographs of the seals found at different sites (Joshi & Parpola, 1987; Parpola et al., 2010; Shah & Parpola, 1991).

The use and function of the scripts engraved on seals are believed to have served different purposes. Among the possible functions, including marking financial transactions, administrative activities, significant ceremonies, and private identification and possession of goods (Green, 2016a; Kenoyer, 2006a; Meadow & Kenyor, 2000; Nasim, 2010; Robinson, 2015b). However, there is no general agreement on the specific purposes of the seals found in certain sites because the scripts are still unreadable. However, it can be concluded that they had multiple functions due to the presence of different forms of engraved signs (Green, 2016a). Until the script can be deciphered appropriately, the best source of knowledge about the Indus script has to glance from the interpretation of the signs as well as the study on the associated archaeological remains (Kenoyer, 2006; Lahiri, 2017; Parpola, 1986, 1991, 2005, 2019b).

The present study focuses on the analysis of the origins of raw steatites used to make the Indus Seals found in Harappa, as well as the manufacturing method of the seals, where scientific approach such as XRD, XRF, SEM, techniques as well as experimental methods are adopted. This research also involves geological surveys and samplings in several areas of Pakistan and Afghanistan to retrieve steatite samples. The samples studied in this research include steatites extracted from the surveyed areas as well as samples of two actual seals taken from the Harappa Museum.

1.2 Statement of Problem

It is widely acknowledged that there is no natural formation of steatite in Harappa (Green, 2016a; Green & Petrie, 2018; Geological Survey of Pakistan, 2018; Jarrige, 1991; Kenoyer, 1991a; Law, 2006a, 2006b, 2011). As such, artifacts made of steatite found in Harappa, such as the Indus seals, cubical weights, and figurines raises the question on the sources of steatite used to make these artifacts. There are currently some speculations on how steatite made its way in the region to Harappa but unfortunately, there are few existing literature on how steatite was imported into the Harappa region

(Green, 2016a; Green & Petrie, 2018; Jarrige, 1991; Kenoyer, 1991a; Law, 2006a, 2006b, 2011).

Although, there are several possible speculations with regard to steatite acquisition. Dr Mark Kenoyer has argued that "one important factor in the development and expansion of Indus trade networks is that many essential raw materials needed by the Indus cities were available in more than one locality" (Kenoyer, 1998c). As far as steatite is concerned, it is a raw material which is needed and the trade-in was evidently "continuous and massive" (Vidale, 2000). Craftspeople and consumers at Indus cities i.e. Harappa and Mohenjo-Daro would have quite possibly depended on having access to stone from multiple sources. Beginning with Sir Edwin Pascoe, who wrote the chapter entitled "Minerals and Metals" (Pascoe, 1931) for the first Mohenjo-Daro site report (Marshall, 1931b), there has been a great deal of speculation by researchers about exactly where those sources might have been located (Kenoyer, 1998c; Lahiri, 1992; Law, 2002; Ratnagar, 2006; Vidale, 2000). Some recent speculations are well-informed while some are merely a repeat of what Pascoe wrote 75 years ago. For this study, it was crucial to have an accurate and comprehensive knowledge of where steatite was available to the Harappans in the Greater Indus region and to obtain samples for provenance analyses from as many sources as possible.

The above speculations are not the only ones that could explain how Harappan or Indus craftsmen sourced raw steatite from north-western sources. Differences from all this above may have occurred at the same time or at different times. An unknown third party may be involved. However, finding an answer to this question is important as it may also reveal geographical trade map and Harappans' socio-economic activities with its neighboring regions (Adams, 2018; Desrochers & Szurmak, 2017; Earle, 1982;

Shar & Kubar, 2018). To find out the possible sources of steatite in the region, this study involves uses samples from the north-western part of Pakistan and Afghanistan. These areas are considered the possible routes that the Harappans might have used to import steatite and other economic goods (Dales & Kenoyer, 1992; Meadow & Kenoyer, 2005; Kenoyer, 1995a; Law, 2011). Therefore, in this research, the samples are chosen from the north-western part of Pakistan and Afghanistan.

In addition to the origin of steatite in the Harappa, the discovery of the Indus seals crafted with hard steatite had also intrigued researchers (Green, 2016a; Green & Petrie, 2018; Kenoyer, 1995a; Law, 2006a, 2006b, 2011). Unlike steatite which is naturally found in the soft form, the Indus seals found in the Harappa are exceptionally hard, durable, consistent, static and unchanged from the last 7000 years. There is a scarcity of research on what techniques and skills the Harappans might have employed to turn the soft steatite into the hard steatite. The production of seals was an extremely complex process. Seals production was highly sophisticated in the Indus Valley, and recent studies indicate that Indus seals were stronger and technologically superior to that of ancient Egypt and Mesopotamia (Kenoyer, 2003, 2005b).

To make Indus seals and tablets artisans first sawed pieces of steatite into tiny blocks and then engraved characters of the Indus script into them (Kenoyer 2003, 2005b). These pieces served as moulds, which were then fired in coarse-tempered ceramic canisters that could withstand high temperatures (Kenoyer 2003, 2005b). Before this discovery, our understanding of the tools used in engraving seals was uncertain. Additionally, this study focused on a specific aspect of seal manufacturing and attempted to identify the carving methods of different tools and techniques by examining and comparing the two original Indus seal fragments from Harappa with the other steatite sample from other parts of Pakistan and Afghanistan. It was possible to identify similarities and contrasts in the signatures with SEM, Digital Stereo Microscope and EDX. The results and interpretations have revealed clear pictures of different tools and carving techniques of seal. Therefore, this study to uncover the possible skills and techniques the Harappans might have used to turn soft steatite into the hard steatite to carve the Indus seals.

To date, there is a lack of detailed study in seals production. Most of them have focused primarily on steatite beads and are therefore only tangentially related to this study (De Saizieu & Bouquillon, 1994, 1997; Kenoyer, 1995a; Miller 1994a, 2008; Vidale, 1986, 1987, 1989, 2000; Vidale & Miller, 2000), though they have highlighted technological processes involved in steatite craft production, especially pyro-technological components. The Indus craft specialization have focused on shells (Kenoyer, 1983), pottery production (Dales & Kenoyer, 1989, Roux, 1989, 1998, Wright, 1989), and stone bead production, based on ethnoarchaeological studies of modern industries in India (Guo, 2019; Kenoyer et al., 1991, 1994). Seals are among the most important artefacts of the Indus civilisation, and this study would likely to contribute significantly to our understanding of how and what tools were used to carve the seals. A detailed study of the Indus seals would therefore provide knowledge about on the Indus seals' production, heating, colouring and carving tools and techniques used to make them.

1.3 Research Questions

As discussed in the earlier section, there is currently no known source of steatite in Harappa, Pakistan that can be found to make the Indus seals at Harappa. Therefore, the obvious research question that arise would be

1. Where are the sources of raw steatite for making the Indus seals?

The existing steatite Indus seals in Harappa are all found in the hard form. As steatite is naturally found in soft form, the Harappans must have treated the natural soft steatite in order to make it hard and durable. Since most rock materials are treated with fire in ancient times, the research question that need to be answered is

2. What are the techniques employed by the Indus people in heating and hardening the Indus seal?

In addition, the Indus steatite seals found in Harappa are found with various types of inscriptions. These inscriptions must have been made when the steatite are soft but the techniques and tools used are still unknown. However, the methods of carvings and shaping the steatites as well as the type of metals used for the carving tools are not yet known. Therefore, the third research question this study hopes to answer is

3. What are the tools and techniques the Harappans used for making the inscriptions on the soft steatite Indus seals?

1.4 Research Objectives

a. To determine the sources of steatites used to make the Indus seals found in Harappa.

b. To trace the routes used to import the raw steatite in the Harappa region.

c. To study the durability of the Indus Seals.

d. To replicate the firing technology of the Indus Seals.

e. To examine the carving techniques of the Indus Seals.

1.5 Methodology

1.5.1 Research Flow

In this research, several methods were used taken to achieve the research objectives. They include library research, fieldwork, elemental analysis as well as experimental archaeology. These research methods were taken to get insights into the cultural and economic history as well as the technology of the people in the Indus Valley Civilisation. The systematic representation of the methodology is illustrated in Figure 1.5, where the fieldwork and samples collection of various steatite and Indus Seal samples is followed by elemental analysis and experimental archaeology. Both methods are tested directly on the archaeological and geological samples retrieved from the fieldwork.

1.5.2 Library research

Many studies have been conducted on the trade network of the Indus civilisation. Among the questions, researchers are trying to answer include the origin of the raw materials used to make Indus seals, and their connection between the production techniques of the seals with the Bronze Age culture in the region. (Kohl, 1975; Kristiansen et al., 2018; Kenoyer, 1997b, 2008b, 2016b; Lahiri, 1990, 1992; Parikh & Petrie, 2019; Valentine, 2016). The library research is important to track and locate the origin and sources of steatite as discussed and highlighted in previous studies (DiPietro et al., 1999; Geological Survey of Pakistan (GSP), 2018; Huang 2018; Kazmi & M.Q, 1997; Kenoyer, 2011, 2012, 2016; Law, 2002, 2006).

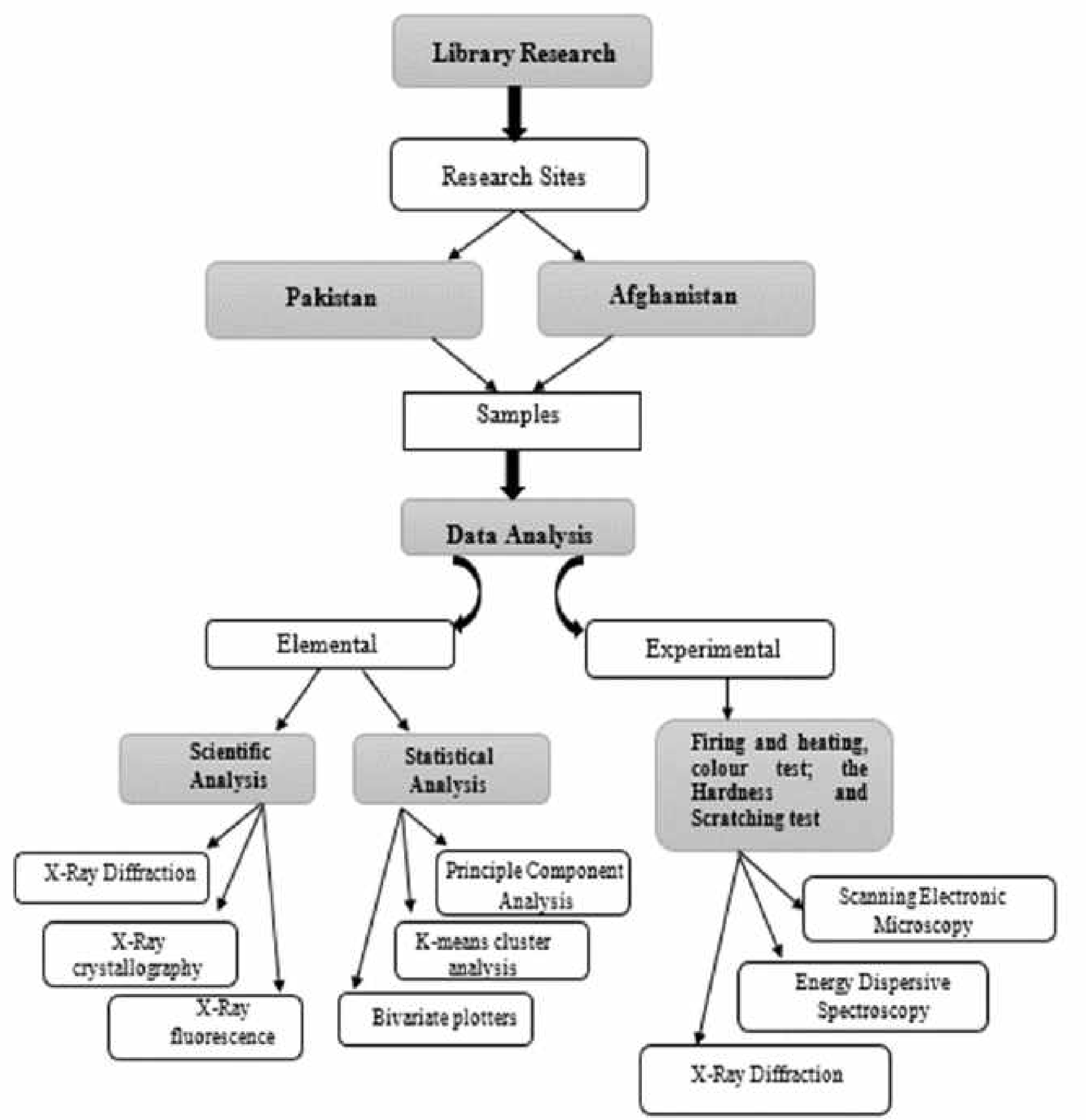

Figure 1.5: The systematic representation of the methodology

The location selection in Pakistan and Afghanistan is selected based on the surveys done by previous scholars (DiPietro et al., 1999; Doebrich et al., 2006; Geological Survey of Pakistan (GSP), 2018; Huang 2018; Kristiansen et al., 2018; Kenoyer, 1997b, 2008b, 2016c; Lahiri, 1990, 1992; Kazmi & M.Q, 1997; Kenoyer, 2011a, 2012, 2016; Law, 2002, 2006a; Orris & Bliss, 2002). Information accumulated from the published works helps in the planning of the fieldworks.

1.5.3 Fieldwork

Archaeological fieldwork involving documentation of seals in the Harappa Museum and a geological survey has been conducted to collect the relevant archaeological and mineral samples. The steps taken in the fieldworks were adopted from a research model of Reeves and Brooks (1978) for determining the geologic provenance of steatite artefacts. The steps taken are outlined in Table 1.1.

Table 1.1: The steps taken are outlined

STEP	ACTIVITIES
Step A	Locating the natural occurrences of the steatite or soapstone type being investigated.
Step B	Collection of a representative range of samples from each potential source area.
Step C	Demonstrating that the chemical/ mineralogical variability between Different geologic sources is greater than the variability within individual sources.
Step D	Establishing a set of analytical parameters that will allow geologic sources to be distinguished from one another with a high degree of confidence.

Before the fieldwork and archaeological documentation, the researcher has requested permissions from relevant authorities in Pakistan and Afghanistan. After receiving the approval from these agencies, explorations were conducted in several areas in Pakistan.

The fieldwork consisted of two main parts; first, the study and documentation of Indus seals, and second, the collection of steatite samples. Visit the Harappa site, as well as the Harappa Archaeological Museum, was done to understand the cultural environment of the site, as well as to document and study the Indus seals. To retrieve the steatite samples, site visits were done to the areas believed to have had connections with the Indus Civilisations. They include Kurram, Mohmand, Besham, Sherwan and

Tar, Chitral (Amjad et al., 2019; Kenoyer & Meadow, 1997; Kazmi & Jan, 1997; Law 2006; Middlemiss, 1912, 1921; Renfrew, 1975). Apart from Pakistan, vast deposits of steatites are also known in Afghanistan (Doebrich et al., 2006; Orris & Bliss, 2002), and believed to have had connections with the Indus civilisation. Thus, steatite samples from Khogyani and Achin in Afghanistan, which was retrieved by Dr Asif they are, also incorporated in the study.

1.5.4 Sampling of raw steatite and Indus seals

This study involved raw steatite samples from the Harappan site, the north-western regions of Pakistan, and Afghanistan. The samples included were based on the proposed research questions of the study. In the beginning, in this study, six sites were included from Pakistan: Harappa, Punjab; Parachinar, Kurram; Sakhohat, Qila Mohmand; Besham, Swat Valley; Sherwan, Abbottabad; and Tar, Chitral. Furthermore, two sites were included from Afghanistan: Khogyani and Achin situated in Nangarhar province were identified and visited individually. The sampling strategies varied according to the type of steatite and the geographical occurrence of a "source" in most cases. At least 10 samples were taken from each source, which is generally considered sufficient to make statistically significant assessments and comparisons. Although formal survey method was used (e.g., tracking transect or framework over a deposit and sampling at fixed or random intervals), concerted efforts were made to help geoscientific colleagues (see. Details in chapter 4) obtain samples that are deposited, both in the field space and in all macroscopic varieties present at each location.

As far as possible (and always depending on the type of material), the samples were taken with a geological hammer from recent exposures, rather than in unstructured contexts such as surface or tailings. An on-site visit is also indispensable for reasons beyond simply compiling a collection of comparative geological materials. Errors in the identification or misrepresentation of a steatite deposit sometimes occur in geological literature. Visual inspection and visit to a reported event to confirm or deny its existence and/or to clarify the nature of the material found there. This field visit of steatite sources shows the benefits of this strategy.

During a field visit, the researcher had also identified unpublished sources and attempted to locate several unreported steatite mines in the district of Lasbela, south of Balochistan in Pakistan. As these occurrences are not known locally, therefore, researcher can look into this in future study. Besides, in the Khyber Agency, talc in dolomite occurs on the western side of the Peshawar Valley, 6 km north of the Khyber Pass entrance at Jamrud (Ahmad, 1969). Although Ahmad (1969) reported that steatite occurs in dolomite around the Landi Kotal area of the Khyber Agency, he did not mention the name of the deposit or give an exact location. Moreover, the local people had informed of the presence of a handful of abandoned mines in the area. However, we could not visit these mines due to some security concerns.

As for the Indus seal, our samples are very limited for this study because only two original Indus can be obtained for analysis, which was provided by the Harappa museum. All the other museums at the rest of the sites, unfortunately, did not give us access to the Indus seals and we did not obtain any Indus seal samples. These museums were unwilling to handover samples of the Indus seals due to some legal restrictions. However, we managed to document some of the Indus seals using still photography and drawing.

After collecting the relevant steatite and Indus seal samples to address the research questions of the study, they were all packed with due care. The Centre for Global Archaeological Research (CGAR), USM had sought permission from the Malaysian custom department to bring in the raw steatite and Indus seal samples from Pakistan. Additionally, the custom's department of Pakistan was contacted to allow us to carry the samples to USM, Penang in Malaysia for research purposes.

1.5.5 Analysis

There are three main analysis used in this study 1. Elemental Analysis 2. Statistical Analysis, and 3. Experimental Archaeology.

Elemental analysis is a scientific approach to investigate and determine the concentrations of certain elements in a material (Glascock, 2016; Wilson, 1978). This analysis can be used to detect the constituent elements in archaeological samples. The sourcing of steatite artefacts using an analytical technique has long been an interest in archaeometry (Skowronek et al., 2020), considering its ability to provide extensive information about trade and exchange and origin. Archaeologists around the world have employed a wide variety of techniques and instrumentation in efforts to identify the geologic sources of an even wider variety of stone and metal artefacts (Henderson, 2000; Lambert, 1997; Pollard & Heron, 1996; Rapp, 2002). Simple, non-destructive mineralogical tests were conducted on several archaeological samples in this study.

The most common tests used were XRF, XRD and XRC. Multivariate Statistical analyses (namely Principal Component Analysis, PCA, and Hierarchical Clustering, (HC) and Bivariate plots) were performed considering areas for each XRF and EDX peak and band. Moreover, XRF and EDX signals were normalized to measuring time and Rayleigh scattering peak to take into account differences in the geometry of the samples. This procedure was chosen so to weigh signals corresponding to trace elements/minerals as much as prevailing ones.

Statistical analyses were performed to try to get a provenance classification considering simultaneously both XRF and EDX results. This should make the classification method more effective than XRF and/or EDX technique considered alone, and easier to handle than export comparison. In such instances, both methods will be presented for comparison. In this complex dataset, we looked for the possibility of applying a portable, low cost and non-destructive method that could fit also to precious objects, based on the join use of XRF and EDX. We developed than a statistical treatment of spectra obtained, so to get a synergic response of the three applied techniques. For this reason, we focused on a limited number of samples, comparing results obtained by different data elaboration.

In this study, the elemental method encompassed three main scientific techniques, which are X-Ray Diffraction (XRD), X-ray Crystallography (XRC) and X-ray Fluorescence (XRF). The result of this (XRF and EDX) elemental analysis is analysed by using three main statistical methods. The first statistical method was Principal Component Analysis (PCA) to identify similarities and dissimilarities in the components of different samples. For PCA, a correlation matrix was used; correspondingly, standardization of data was applied for HC analysis (ward linkage, Euclidean distance). Secondly, Herichal Cluster Analysis (also known as Data Segmentation) was used to break data into distinctive subsets or clusters, to observe the comparisons between analysis results of different sets of samples. The third statistical method included was the Bivariate Plots, which are used to represent two-dimensional images of the elemental abundances of two specific elements.

Other methods X-ray diffraction (XRD) and X-ray Crystallography (XRC) analysis enable one to unambiguously determine the identity of crystalline substances (Henderson, 2000). The patterns that the diffraction effects create were recorded and provide precise information about the atomic structure(s) of the mineral(s) within the sample. It is the only technique used here that can accurately distinguish between mineral polymorphs (minerals sharing the same chemical composition but having different crystal structures). For example, quantitative data on the abundance of silicon dioxide in a sample can be obtained using electron microprobe analysis, but only with XRD is it possible to determine which polymorph (i.e. quartz, tridymite or cristobalite).

Experimental research is another of archaeology's truly unique theoretical perspectives. Like ethnoarchaeology, it relies on the principles of analogy, used to develop models and test hypotheses about past human behaviour that cannot be directly observed (Coles, 1979; Marsh & Ferguson, 2008). In this sense, it is one of the best tools we have to try to link the material record with the human behaviour responsible for its creation, use and discard. The strengths of this approach have attracted many experts, and consequently, there is no unified concept of what experimental archaeology is how it works, or what it is meant to do. Broadly speaking, it refers to the process of replicating selected aspects of the production, use, or disposal of material culture (Skibo, 1992), but the mechanisms for doing so are as varied as the materials that are often studied. As such, it allows archaeologists to adhere to principles of the scientific method with great strength.

Experimental archaeology has been to examine archaeological materials and replicate them to try to determine methods of manufacture and function (Asher, 1961; Coles, 1979; Nami, 2010). The last general trend in experimental archaeology that is worth mentioning here has been the incorporation of quantitative and archaeometric methods into experimental research designs (Bronitsky, 1989; Jones, 2002; Kingery, 1987; Mathieu & Meyer, 1997). This has been influenced by a growing emphasis on these techniques in archaeological research in general (Shimada, 2005). New methods to evaluate various forms of material-culture either experimentally produced or from the archaeological record are important to maintaining objective and comparative analysis. Despite these advances, there are still many criticisms of experimental archaeology and no unifying theoretical background. Recent discussions have highlighted the need for long-term, multi-scalar experimental studies that emphasize the relationship between human behaviour and material culture, and more stringent application of controls in research design and comparative analyses (Shimada, 2005).

In this study, Experimental Archaeological method consisted of three basic techniques, which are 1. Firing and Heating Test, 2. Colour Test 3. Hardness and Scratching Test. Some of the Experimental Archaeology samples are analysed by using Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS), especially to study the surface morphology of steatite. Also, the X-ray Diffraction (XRD) was used to perform the structural analysis. Finally, the Mohs Scale Hardness test was used to test the durability and hardness of steatite before and after firing. For the firing test, the steatite samples are fired at different temperatures (Dynamic Firing Experiment). X-Ray Diffraction analysis is carried out on each sample fired at different temperatures to determine the mineralogical changes, which occurred throughout various stages of the firing.

1.6 The Significance of Research

There are four main significances of this research, which revolves around the descriptions and insights into the economic and cultural history of the Indus society, as well as their technology and material culture.

First, this study would also shed light on the question regarding the origin of the raw materials used to make the Indus seals. Additionally, this study also explores the trade routes through which steatite was transported from the mining ground to Harappa. This knowledge is essential to discover the connection between the societies living outside the Indus cultural sphere of influence with the Harappa society. The strength of this study also lies in the fact that the analysis of the actual seals was done.

Secondly, this study unravels the techniques and procedures followed by the Indus society to turn the soft steatite into a hard and durable material. The present study determines the firing method used to transform soft steatite into hard steatite. The mineralogical changes, which happened at different stages of firing, could give some insights into the technology and knowledge of the Indus people.

Thirdly, this study can give answers regarding the type of tools used by the Indus people to carve and shape the steatites. Besides, the materials used to make the tools, such as bronze, bone or stone tools can be determined from the experimental archaeology. This can give valuable information regarding the material culture of the Indus people.

Fourthly, this study may establish cultural and trade link between the societies in the Indus Civilisation with those living in other areas in the Indo-Pak Subcontinents, especially in the upper reaches of the Indus river of Pakistan and Afghanistan during the same period.

1.7 Scope and Limitation of Research

This section established the scope of research and the limitations of this study. Since the discovery of the Indus Valley civilisation more than 100 year ago, there had been many researches done and numerous new sites were discovered with Indus seals. This study, however, is limited to Pakistan and Afghanistan, mainly due to the geopolitical problems particularly with India as well as our limited fund, resources, and time for research.

Specifically, this study could not include samples from Balochistan and India due several reasons as for Balochistan, steatite occurs at a few places in the Las Bela District of south-eastern Balochistan. We have yet to find any reference on steatite occurrences from the geological or the historical literature. Moreover, it seems that there were no geological formations in the region, which could have hosted steatite deposits. In the case of India, although there is enriched Indus civilisation site in Rajasthan, India and the disputed territory of Jammu and Kashmir, the idea of studying sites in India and Jammu and Kashmir was dropped due to escalation of political issues and conflicts between Pakistan and India and it had been very difficult to obtain an Indian visa.

In this study, six sites were included from Pakistan: Harappa, Punjab; Parachinar, Kurram; Sakhohat, Qila Mohmand; Besham, Swat Valley; Sherwan, Abbottabad; and Tar, Chitral. The reason to include these sites is that they have been identified to share similar trade routes for steatite. Furthermore, two sites were included from Afghanistan: Khogyani and Achin situated in Nangarhar province. Steatite was collected from all the sites included in this study. However, two original broken seals were also given by the administration of the Harappa. Unfortunately, the administration of the rest of the museums did not allow access to the Indus seals for experimental purposes. Therefore, the Indus seals on those sites were only photographed. Due to these limitations, the results of this study cannot be exhaustive and conclusive. However, doing experiments on the original seals, which is also a rare opportunity and privilege, can generate help more data and results than solely relying on photographs.

Scientific, statistical and experimental methods were used to determine the analysis and results of this thesis. Therefore, it is necessary to use more advanced and recent analytical methods using a variety of high-precision scientific techniques including Spectrography, seals-application of FTIR and seals production-application of isotope study. Additionally, due to the limited resources and samples, the results cannot be generalised to include sites located in other counties like in India and Balochistan.

1.8 Organization of the Thesis

Chapter I: Introduction

This chapter presents the introduction of the study, research questions and objectives, significance of the research, the research area, the scope of research, and summary of the chapter.

Chapter II: Literature Review

The chapter includes an examination of the literature relevant to this study and an assessment of previous research studies.

Chapter III: Research Method

This chapter presents the research methods for the study and describes the purpose and procedures for each of the phases of the research.

Chapter IV: Fieldwork

This chapter presents the fieldwork, including the collection of the samples from Museum and briefly discusses each site of a collection of raw steatite and overall classification and documentation of the samples, as well as the samples strategy of this thesis.

Chapter V: Geochemical Study

This chapter illustrates the results of geochemical part of this study. The results are given according to the objectives of the study. Additionally, the results are also thoroughly discussed.

Chapter VI: Experimental Archaeology

This chapter presents experimental archaeology, the results of the work, including the firing test, hardness test and SEM scratching experiment test. The content analysis and classification of the problem statements, as well as the tests of the resulting classification structure and discussion of the results.

Chapter VII: Conclusion

The final chapter reviewed and finalized the key findings and discussed how the study contributed to the existing knowledge, provided some recommendations and implications for future practice. Finally, limitations and new areas of future research have been identified.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter gives a concise yet detailed background of the cultural history of the Indus Civilisation, previous research performed on Indus valley and Indus seals and finally the summary of the chapter. It also covers topics including geography, chronology, site and settlement patterns, social and economic society, and, of course, the Indus seals.

2.2 Cultural profile of Indus Valley Civilisation

The Indus Valley civilisation is located in one of the most fertile flood plains of the world (Kenoyer, 1997b, 2000; Wright, 2010). The sites associated with the Indus civilisation covered a vast region centred around the Indus River Valley and with smaller rivers joining the course (Kidwai et al., 2019; Petrie et al., 2017). In its largest expanse (about 2600-1900 BC), the area of the civilisation covers 2,000 square kilometres (Fagan & Scarre, 2016), considerably larger than the area of civilisations of Mesopotamia and Egypt combined (Guo, 2019; Kenoyer, 1997b, 2000; Petrie et al., 2017; Wright, 2010; Wengrow, 2011). At various periods, the societies of the Indus Civilisation interacted with the societies living in neighbouring regions of Balochistan and Afghanistan to the West and Northwest (Figure 2.1), the Makran coast and Oman to the south-West; the far edges of Gujarat and the Aravallis of Rajasthan to the south-East and east India and the Himalayas mountain regions to the north-East of Pakistan (Guo, 2019; Kenoyer, 1997a, 2000; Wright, 2010).