CONSERVATION AND ELEMENTAL ANALYSIS OF LATE KUSHAN COPPER COINS AT ISLAMABAD MUSEUM, ISLAMABAD

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A Dissertation Submitted to The Department of Archaeology, Hazara University Mansehra, In Partial Fulfilment of The Requirement for
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This Dissertation is dedicated

to

My Parents

DECLARATION

The work presented in this PhD Dissertation was carried out by me under the supervision of Dr. Naveed Usman, Lecturer, Department of Archaeology, Hazara University Mansehra and Co-supervision of Prof. Dr. Gul Rahim Khan, Adjunct Faculty, Department of Archaeology, Hazara University Mansehra. It is based upon my own original research.

Attiya Malik
PhD Scholar

We certify that, to the best of our knowledge, the above statement is correct.

Dr. Naveed Usman
Supervisor/Lecturer

Prof. Dr. Gul Rahim Khan
Co-Supervisor/ Adjunct Faculty

Abbreviations

BCE	Before Common Era
BTA	Benzotriazole
CE	Common Era
INCO	International Cooperation
KFCH	Korean Foundation for Cultural Heritage
LIBS	Laser-Induced Breakdown Spectroscopy
NCP	National Centre for Physics
RBS	Rutherford Backscattering Spectrometry
SEM-EDX	Scanning Electron Microscope-Energy-Dispersive X-ray analyzer
XRD	X-ray Diffraction
XRF	X-ray Fluorescence Spectroscopy

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Abstract

Archaeometallurgy is the study of metalworking structures, tools, waste products and finished metal artefacts, from the Bronze Age to the recent past. There are various scientific techniques used in elemental analysis regarding archaeological artefacts. Some of the techniques are destructive, while others are non-destructive and safe for valuable objects like coins. These techniques not only help us to understand the elemental composition of the objects reported from the archaeological context but they are also useful to conserve these objects for a longer period. The present dissertation absolutely deals with metals and hence focuses on "Conservation and Elemental Analysis of Late Kushan Copper Coins at Islamabad Museum, Islamabad".

The Islamabad Museum Islamabad possesses thousands of coins in its reserve collection. Of these, a parcel/ hoard of 390 pieces of the Late Kushan copper were selected for the research purpose. In view of design, style of figures, weight analysis and physical condition, they obviously belonged to the Late Kushan rulers came after succession of Vasudeva I. The coins of this period generally look like same but they were issued by different rulers. Accordingly, this lot of coins was selected for conservation and elemental analysis. By utilizing advanced techniques in a well-equipped conservation laboratory, the study seeks to identify efficient, non-destructive methods to clean and conserve the coins, which have suffered from corrosion over time. The findings are expected to contribute significantly to the understanding of the manufacturing techniques and material composition of Kushan coinage, while also offering a recommended conservation approach for similar artefacts found in the Gandhara region. The morphometric features on this group of coins, through RBS (Rutherford Backscattering Spectrometry) were investigated to understand how and what type of corrosion has taken place. The research highlights the presence of corrosion compounds such as malachite, azurite, and attacamite, alongside copper oxides like cuprite and tenorite, indicating the environmental impact on these coins. Further to know how these coins can be prevented from further decay. The conservation process includes pre-treatment investigations, stabilization treatments, and meticulous documentation, ensuring the long-term preservation of these historical artefacts for future generations.

This study investigates the concentration of present elements, the identification various mints and process of the fabrication of Late Kushans coins through elemental analysis such as X-ray Fluorescence Spectroscopy (XRF). The analyses were based on the archaeometallurgical observations. This study offers a comprehensive analysis of 22 Late Kushan copper coins, revealing key insights into the technological, economic, and metallurgical practices of the

Kushan Empire. The findings suggest that the coins were primarily struck rather than cast, reflecting sophisticated minting techniques. A detailed content analysis using X-ray fluorescence (XRF) shows the inclusion of alloys such as tin, lead, and nickel, pointing to advanced alloying practices aimed at enhancing coin durability. The study also identifies the use of sulphide ores in smelting, though with significant impurities like silica, iron, and sulphur, suggesting less refined smelting processes in the incomplete removal of impurities like sulphur, iron, and silica due to low firing temperatures and improper poling. The study also identifies striations and micro-cracks within the coin interiors, likely caused by the mechanical stress of punching or hammering during minting. The coins are found to be single-phase copper with impurities of Si, Ni, P, and Ag, and black spots of copper sulphide present in the inner core.

The decision to use pure copper instead of common alloys like bronze or brass underscores economic considerations and resource management strategies within the Kushan Empire. The research concludes that the distinctive characteristics of these coins, including their composition and fabrication, reflect the regional diversity in ancient coinage practices and the Kushan Empire's adaptive responses to economic challenges.

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CHAPTER-1

INTRODUCTION

1.1 Beginning of Coins

Metal is one of the major materials continuously being used by human since the chalcolithic era. After its introduction, metal has been used in different forms and for various purposes. The precious metals such as gold, silver, copper and platinum have been used as jewellery and medium of exchange i.e. coins (Gupta, 1969).

From the three quarters of a century ago much of communications were occurred through coins. In the history people had different ways to measure their wealth and property like herds of cattle, hides, land, gold bars, bonds and stock certificates and some sort of bank statement. But all these were not used for small items or object. Small objects such as shark and shell disc, glass beads, feathers, walrus teeth and cartwheels were used as a medium of transaction. The extensive use of coins started when metal objects took a proper shape (Quantum Books, 1999).

1.1.1 Importance of Ancient Coins in Archaeology

The study of ancient metal and analysis of tools furnish much valuable information about the rulers, culture, economy, religion, social stratification, trade and commerce of certain eras.

'Ambition signed; she found it vain to trust
The faithless column and the crumbling bust;
Huge moles, whose shadow stretched from shore to shore,
Their ruins perished and their place no more!
Convinced she now contracts her vast design,
And all her triumphs shrink into a coin;
A narrow orb each narrow conquest keeps:
Beneath her palm here sad Judaea weeps;
Now scantier limits the proud Arch confine,
And scarce are seen the prostrate Nile and Rhine;
A small Euphrates through the piece is rolled,
And little eagles wave their wings in gold.'

(Charles 1864).

Coins hold significant historical importance, serving as invaluable artefacts that complement and authenticate information found in the literature. Crafted from various metals such as gold, silver, copper, or alloys, coins bear legends or simple marks that contribute to the rich tapestry of history. In the context of ancient Indian history, coins play a crucial role and are considered an integral part of archaeological sources (Gupta, 1969).

The diversity in metals and the presence of inscriptions on coins provide a unique window into the past. Coins with dates become particularly valuable as they contribute to establish a reliable framework for ancient Indian chronology. The inscriptions on these coins not only showcase the craftsmanship of the time but also convey vital information about the territories over which the rulers held sway (Ibid).

One of the most important foundation of information from which archaeologists can try to understand the past is called coins. Relationship between coins and humans exists since 2700 years ago when people were using the coins as a medium of transaction. Ancient Coins tell us the story of king who ruled over different lands. They give information about religious prospective of certain rulers and also the chronological sequence of dynasties (Ibid).

Coins are also related with history and knowledge about paleography and archaeological epigraphy. Therefore, coins have a much importance in a history especially, in the religious history because almost every ruler depicted his own religious perspective. Kushans, who ruled in north-western India dating back to the first century CE and second century CE; bear the Greek inscriptions and Buddhist god and goddesses. In their coins they showed their religion and faith in the form of iconographic perspective (Ibid).

Coins save historic records more accurately with the authenticity than the historic monuments and buildings because they give information about names and portraits of kings who ruled during that historic period. They provide complete help in identification and sequence about miniatures of dynastic rulers such as Greek, Bactrian, Parthian, Sasanian and Kushan kings (Sohail, 1998).

Government society, succession of reigns, chronological sequence of dynasty can be judged by coin inscriptions. These inscriptions also reflect the image of conquests, political wars, social life, internal work or religious reforms of that particular dynasty. Ancient Numismatic is a source from which we can analyze the economy of historic society (Collin Discovery Encyclopedia, 2005). Coins give enormous contribution to our knowledge and understanding of ancient society after scientific excavations of coins. From these excavations archaeologists can easily reconstruct ancient sites and date them easily. Keeping in view the importance of coins, it can be said that numismatic is directly related to archaeology. The combine efforts of archaeologists and numismatics experts can facilitate more discoveries and analysis that neither discipline could generate in isolation (Archaeological institute of America august 7, 2007).

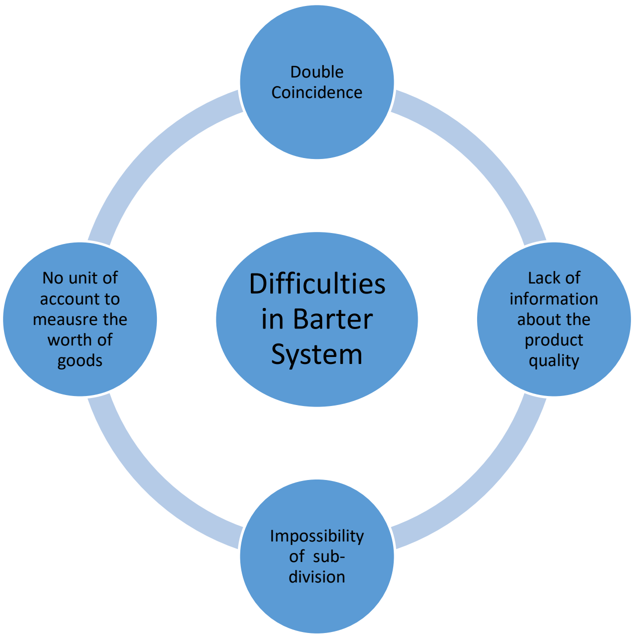
1.2 Notion of Coin

1.2.1 Barter System

The chronicle narrative of coin is interlinked with the evolution of man. When man settled with his family, they used shelter, food and covering by their own home land. Later they were gradually developed and interacted with the tribal communities of the other region and developed their life style more accurately. They could make objects themselves and necessity to both communities lead to exchange their products with each other. In this way the mutual exchanging system was started among the various tribes. Gradually, emergence of 'the notion of a unit of value' emerged as an important step for the transaction. This exchanging system within communities and localities were called barter system (Chakraborty, 1931).

Many objects were used as a medium of exchange. Firstly, hard stones and then the fur and skins were used by the Jews and the Estonians. The North America used furs as a medium of transaction with the Red Indians. After some time, Leather (the earliest currency) was used as a medium in Russia, Rome, Sparta and Carthage (Ibid).

1.2.2 Cow as a medium of transaction



Flow chart showing the difficulties in barter system

Although barter system laid the foundation of medium of transaction but they were not a standard medium so some difficulties had arisen. Due to development of civilization people felt that they need enduring and suitable medium as a transaction for trading the objects. They seem cow as a unit of wealth. Approximately 3000 BCE, the Vedic people (Indus Valley) used cows as a medium of transaction till fifth century BCE in the ruins of Panini (Ibid).

1.2.3 Nishka

After some time, some people thought about one standard value of transaction object because large things could not be exchanged with the small objects and vice versa (Gupta, 1969). Then Vedic people found a standard object for exchanging material known as Nishka which means some sort of necklace. Nishka was expensive amongst all the ornaments in the Vedic society (Ibid).

1.2.4 Metal

After the innovation of small object as a medium of exchange, metal has been naturally arrived. Metal was an earliest give in value in the monetary pattern or level (Burgess, 1913). All these small objects used as a medium without any measuring for long time. In this way measuring standard was still a problem for Vedic people so they used balance and weight system to make the medium standardized.

Seed have a standard weight so people used weighting system of metal against seeds. Seed was also known as *Krishnala*. Story of seed was mentioned in the historic literature as *Raktika* and today it is known as *Ratti*. Seeds were irregular in shape and size so they needed proper scale and value for standardization so they started modifying metal in round shape known as *Satamanas*. This word is also mentioned later in the literature of *Samhilas* and *Brahmanas*. One another metallic piece was introduced called *Pada* which means one-fourth. This name was mentioned in Brihadaranyaka Upanishad in the description of the Bahudakrhina sacrifice performed by king Janaka of Videha. After standard weight, sealing system was introduced many metallic pieces were designed with stamp. This was the time when coin was born (Gupta, 1969).

1.3 Origin of Coinage

The limitation of barter system and then use of various commodities as a medium of exchange led to the utilization of valuable metals. Earlier, certain commodities were used as standard of exchange without measuring for a long time. In course of time people introduced measures and balance to make their medium standardized to some extent. There was a time when the concept of currency was understood, and a measure of valuable metals was gradually adopted as a medium of exchange. Later on, pieces of valuable metals being circulated on standard weight given shape like round and square and then stamped with certain designs usually taken from daily life, myths, religions and traditions. In this way regular coins were introduced in Lydia (Turkey) in the mid of seventh century BCE. Soon after this, the art spread to the Greek world in the west and Persian Empire in the east. Along with this the ancient Indians and Chinese people started metallic currency of their own style which prevailed in respective regions for a long time (Gupta, 1969).

Firstly, coinage was started independently China, Lydia and India. The oldest coins were used by Lydian people in 700 BCE. They also had known as inventors of coins because they issue gold and silver coins first time in history (Chakraborty, 1931). According to the Vedic literature, coins evolution in the Sub-continent dating back to the 1500 and 800 BCE. From this achievement Vedic society become vaster and could easily exchange their material from one place to another. In this stage minting system was not still exist in the Sub-continent. During the time of Ashtadhyayi, dated in sixth and seventh century BCE, the earliest stamping metallic coins were introduced in the Sub-continent. This was an advanced stage of Indian coinage where first minting coins were introduced and they were used freely in India. Therefore, it can be claimed that the invention of coins in India was made at least one century before Lydia or China (Ibid).

Number of coins which were found in different part of the Sub-continent has not yet found an authentic date. A number of the theories presented by different scholars for the origin of coinage (Kumar & Srivestava, 1998). Number of the European scholars such as H. H. Wilson and James Prinsep told that Indian coins were not an indigenous creation. These were introduced by the Greeks of Bactria (Wilson, 1836). S. R. Goyal describes that origin of coin in the Sub-continent was due to the Greek kings. He gives the authentic point that when Greeks spread their hold in India, the Greek kings ordered for the first time to make coins according to artistic merit (Goyal, 1995).

According to the Ephesus, invention of coins in India dating back to sixth century BCE and Lydia in 656 BCE which shows that the Indian coins were earliest coins in the whole world (Kokatanur, 2015). Coins can be divided under the economic, legislative, metrological and artistic perspectives. Ancient Indian coins started as punch marked coins (Ibid).

1.3.1 Punch-Marked Coins

The origins of the "punch-marked coins" trace back to the Indus Valley Civilization sites of Harappa and Mohenjo Daro, although there is no definitive evidence linking these coins directly to that era. Widely believed to have been issued between the seventh or eighth century BCE and the first century CE, these coins are notable for their distinctive manufacturing technique, which involved embossing symbols onto silver pieces using punches, hence their name (Ibid).

Punch-marked coins have been firstly evolved in two regions of the Sub-continent. One in the north western part of the Indian Sub-continent and the second probably in the Mid-Gangetic Valley by Mahajanapadas (Mukherjee, 2007).

This primitive currency in the Indian Sub-Continent was struck in silver and copper. In ancient literature, the early native currency was popularly called as *karshapana* and sometimes also known with the names such as *nishka*, *suvarna*, *pana* etc. The present-day scholars usually identify these pieces with the term ‘Punch-marked Coins’. This name is given due to the manufacturing technique in which the coins were produced. These coins were stamped with different punches, not by a single die, applied separately at various points. These coins were widely circulated in Afghanistan, Pakistan, India and Bangladesh (Khan, 1998).

Earliest Indian coins had no any definite shape or structure without any particular weight or any type of proper shape inscribed on it. These coins had just irregular shapes which were influenced by nature such as animals, trees, human figures, hills, etc. these shape were struck by a proper stamping device known as punching machine. Mostly found coins are made up of silver metal and the characteristics associated to the Indian coins are related to the Greece (Kokatanur, 2015). Punch marked coins discovered all over in India from earlier strata till the second century CE. These coins were only un-inscribed Punch-marked coins.

During the reign of Satavahana dating back to second century BCE, Romans` portrait influence was found on coins. During this period, coins having different symbol like animal’s portrait, mountains etc. were introduced for the first time in the Sub-continent. Punch-marked coins became standard value which replaced the barter system (Reddy, 2011). Recent archaeological excavations have proved that coins were more developed during the Mauryan period. These Punch-marked coins proved that during Janapadas at the time of Buddha, number of silver and copper coins were issued with definite Punch-mark (Raj Pai, 1976).

1.3.2 Dynastic Coins

Dynastic coins mostly related to dynastic rulers such as Kushanas, Saka-Pahlavas and Indo-Greeks dating back from first century CE. These coins mostly contained the portraits of rulers, figures of gods and goddesses depicted on the surface of coins which showed the identity of ruler of the specific time and his or her religion (Kokatanur, 2015). These earliest Indian coins show culture, architecture, faith, language and worth of the particular period when different rulers ruled the region (Ibid).

1.3.3 Difference Between Early and Late Kushan Copper Coins

The Early and Late Kushans reflects the empire's transition from a period of expansion and prosperity to one of decline and fragmentation. During the Early Kushan period, particularly under rulers like Kanishka the Great, the empire reached its zenith, extending its territory across Central Asia and Northern India. This era was marked by strong political power, cultural synthesis, and economic prosperity, with the Kushans playing a key role in the spread of Buddhism and the flourishing of trade along the Silk Road (Sharma, 2005). In contrast, the Late Kushan period saw a gradual decline in imperial power, characterized by internal strife, succession disputes, and increasing pressure from external forces like the Sassanian and Gupta Empires. This decline was accompanied by a reduction in economic stability, as well as a shift towards more localized cultural and religious practices, signaling the empire's fragmentation and the end of its dominance in the region (Kennedy, 2011).

The difference between early and late Kushan coins reflects the broader changes within the empire over time. Early Kushan coins, particularly those from the reigns of emperors like Vima Kadphises and Kanishka the Great, are characterized by their high artistic quality, detailed imagery, and the use of precious metals such as gold and silver. These coins often featured portraits of the rulers in elaborate attire, showcasing their wealth and power, along with symbols representing a fusion of Greek, Indian, and Zoroastrian influences. The inscriptions on early coins were typically in Greek or a blend of Greek and Kharosthi scripts, reflecting the cosmopolitan nature of the empire.

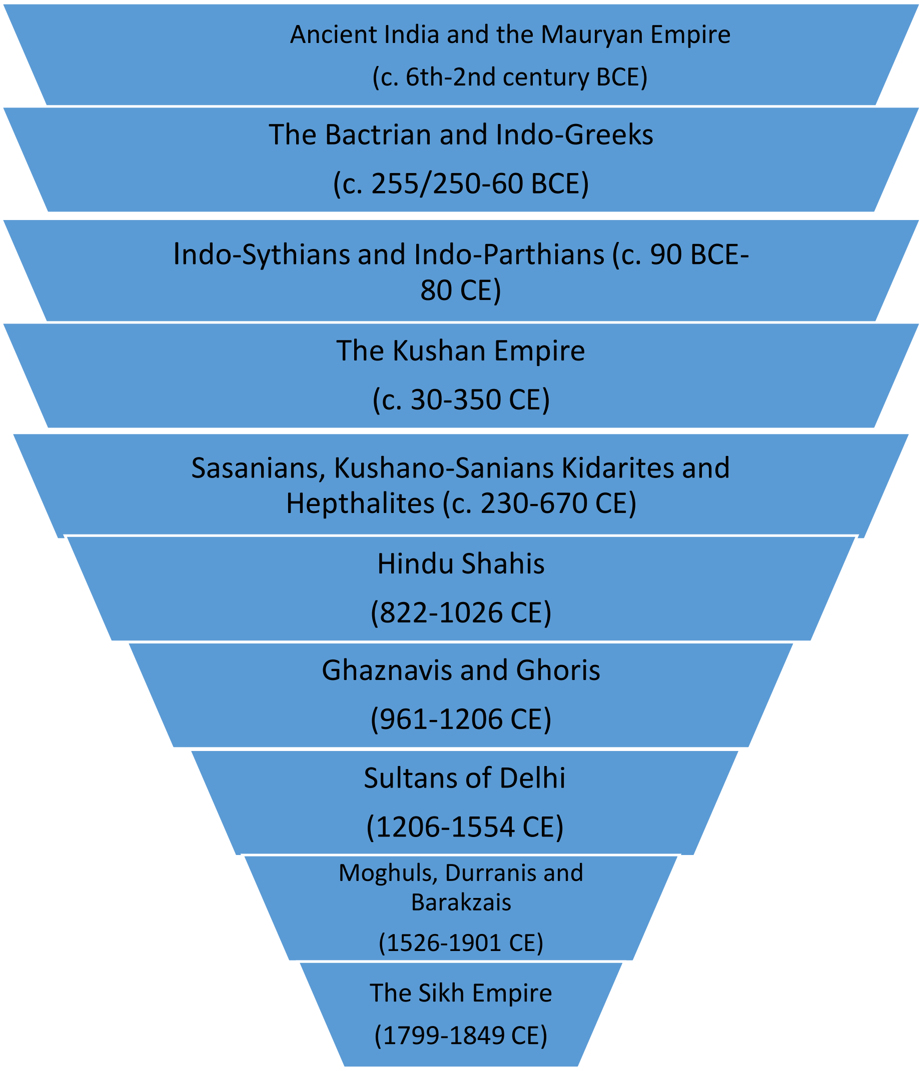
In contrast, late Kushan coins show a noticeable decline in quality and artistic detail. The use of precious metals decreased, with more coins being struck in copper, indicating economic challenges and a reduction in the empire's wealth. The imagery on late Kushan coins became less refined, with cruder depictions of rulers and symbols. Additionally, the inscriptions during this period shifted more towards local scripts, such as Brahmi, reflecting the increasing influence of regional cultures as the empire's central control weakened. This decline in the quality of coinage during the late Kushan period mirrors the broader political and economic decline of the empire (Ibid).

1.3.4 Late Kushan Copper Coins

The Kushans initiated their rule from Bactria in the mid of first century CE and then steadily controlled the adjacent areas such as Kabul Valley, Central Asia, Gandhara, the Punjab and Northern India. The rule of Kushan dynasty in certain area is known for three hundred years. This was the prosperous period of this region in which Buddhism was greatly flourished that brought Gandhara (present Pakistan) in the civilized world. It was the great centre of learning and hub of trade and commerce which always connected the east and the west. The Kushan coins are usually reported in gold and copper and rarely in silver. The basic formula of the Kushan coinage was the Hellenistic origin which they inherited from their predecessors like Bactrian Greeks, Indo-Scythians and Indo-Parthians. But soon, they introduced coins of new designs modelled on the divinities of Roman and Persian origin. This type of coins was struck in the combination of gold and copper (Khan, 1998).

The Kushan coinage shows its resemblance with contemporary coins not only in design of royal figures and religious images, but also in the form of languages, legends, symbols and inscriptions. In view of the historical importance and archaeological significance, number of scholars and numismatists have widely conducted research on the various aspects of the Kushan coins.

The gold coins were issued in dinar weight of 8.00 grams and copper coins in Greek tetradrachm unit 17.00 grams. Beside this, these coins were produced in several denominations. Somewhere in the mid of Huvishka rule, the fifth ruler of the dynasty, the weight of copper coins uniformly reduced by 25% and the new coins were unanimously struck below 13.00 grams. After this the weight of copper was progressively decreased in the subsequent reigns and reached at the age of decline as low as 1.00 gm. Along with this, the gold coins also began to debase after Kanishka II, the seventh ruler of the Kushans. The gold coins of the Later Kushans lost the gold contents by 50% which then contained the mixture of other metals like silver, copper, etc. (Khan, 2008).



Flow Chart showing the Chronological Sequence of Dynastic Coins

1.4 Late Kushan Copper Coins at Islamabad Museum

The late Kushan copper coins from the reserve collection of the Islamabad Museum present a fascinating yet complex subject for research. These coins, having no documented provenance, add an element of mystery to the historical narrative they represent. Typically, artifacts from well-excavated sites provide crucial context for understanding their historical significance, but in this case, the lack of clear origin complicates the task of historians and numismatists. The coin's untraceable journey from illegal digging sites or seizures at airports highlights the broader issue of antiquities trafficking and the challenges it poses to preserving cultural heritage.

Despite these challenges, the coins still hold substantial research value. They offer insights into the economic, religious, and political aspects of the late Kushan period. The imagery, inscriptions, and metallurgical composition of these coins can help piece together aspects of Kushan rule, trade routes, and cultural exchanges. However, the absence of precise archaeological context limits the ability to fully interpret these coins within their original environment, underscoring the importance of provenance in archaeological research. The study of these coins can therefore also serve as a call to action for more rigorous protections against the illicit trade of cultural artifacts, ensuring that future discoveries can be properly documented and preserved for posterity.

1.5 Conservation Issues of Late Kushan Copper Coins at Islamabad Museum

The conservation, chemical analysis and all aspects concerning the research of archaic metals is referred to the field of archaeometallurgy. Conservation of metallic objects is the practice to protect the physical and chemical decay of objects and different techniques used for the art of cleaning these metals artefacts (Elmor and Becker, 2013).

The cleaning and preservation of ancient metal artefacts from Europe and other parts of world is a very worthwhile undertaking. Often though, they are discarded because they are considered as too complicated and dangerous. As a result, not much development has been made in the use of these technique in conservations and preservation of metal objects. There have been periods where few or no conservators specialized in archaeological conservation have been working. As a result, the large amount of both un-conserved artefacts and artefacts in need of re-conservation are badly damaged. This applies to most material categories but this research will focus the problems concerning the Late Kushan copper coins.

Many copper coins in different museums of Pakistan are losing their originality due to constant decay as they have not been cleaned and treated in appropriate way. The Islamabad Museum also houses hundreds of copper coins including those of the Late Kushans which are yet to be cleaned and conserved. The political history, chronology and geographical area of the Late Kushan have been exposed by the direct help of coin. But no archaeometallurgical analysis has ever been done before. This study is the first lab activity on the coins of this particular period. As no study about the metallurgy of these coins has been undertaken, it can be a crucial step to do research on the unknown facts of this class of coins.

1.6 Reasons for the Selection of Material

The present study deals with the conservation and cleaning methods of copper coins of the Late Kushans housed in the cabinet of Islamabad Museum**.** This selected group of coins occurred in the period where they were progressively reduced in weight, have been taken for experimental analysis in conservation laboratory at Islamabad Museum. On some coins, designs are partly visible having standing figure of kings on one side and deities on the other but the remaining coins are rusted and in poor state of preservation. The main reasons of the selection of this group of copper coins for the present study are:

1. Accessibility to the conservation laboratory in Islamabad Museum to apply cleaning and conservation techniques on the copper coins of the Late Kushans (Kanishka II and successors).
2. As discussed above, these coins were struck in reduced weight obviously yield important information regarding workshop, metal contents, monetary devaluation, manufacturing technique, etc.
3. The selected group of coins have not yet been cleaned and therefore more suitable for applying cleaning and conservation techniques.
4. The elemental analysis of the selected group is not only essential to know about the elemental composition of these coins, but it will also help to apply the required cleaning and conservation techniques.

The present research aims to investigate the morphometric features on this group of coins and to understand the nature of corrosion how it was developed. Further, how coins of this material can be prevented from further decay. The present study will find out an efficient and least harmful method for the cleaning and conservation of copper coins of Vasudeva-I, Kanishka II and their successors. After successful application, this technique will be recommended for the researchers to apply it for a certain group of coins commonly reported from different sites in Gandhara region. The study aims to investigate the composition of Late Kushans coins through scientific (material) analysis. For the analytical and elemental study of these coins the conservation laboratory at Islamabad Museum is selected for experimental work. This laboratory is well-equipped with modern devices for cleaning and conservation of antiquities including conservation of consumable items that help to control the humidity. The stereomicroscope has been applied to analyse the physical condition and composition of such coins whereas the ultrasonic cleaner is used to clean rusted coins without damaging any physical feature of coins.

Research Question

This study looks into the causes of corrosion, previous methods used for conservation, problems concerning the cleaning process, techniques of cleaning and elemental analysis of the selected coins. The present research aims to seek the answer of the following questions:

1. What are the major causes of deterioration of the Late Kushan copper coins?
2. What are the least destructive and more efficient cleaning methods?
3. What methods are non-destructive for repairing and maintenance of copper coins?
4. What are the most suitable methods used for the analysis of elemental composition of ancient coins?
5. What were the political and economic conditions reflected by the fabrication of these coins?

1.7 Aims and Objectives

The present study aims to:

1. **Investigate the morphometric features to clear the nature of the patina on the coins**
2. **Study the major causes and the level of corrosion**
3. **Explore the non-destructive and more efficient and long term cleaning and conservation methods**
4. **Examine the major elements of ancient coins, whether they were made from the same material or passed through the process of depreciation**
5. **Study the content ratio of the more and less valuable metal applied**

1.8 Research Design and Methods

The most critical aspect of this study is the research methodology. It comprises the field work (collection of coins, sampling, documentation, observation, interpretation, survey and recording) followed by detailed scientific analysis.

There are very few scientific laboratories dealing with conservation of coins in Pakistan. Of these, only two laboratories are functional. One of these conservation labs is located at Lahore Fort, which was established in 2011 by the Department of Archaeology and Museums, Govt. of the Punjab. In this lab, the archaeological artefacts including coins are cleaned and treated only by the chemical method. But there is no preservation chamber to consolidate the artefacts after conservation. The second laboratory is located in Islamabad Museum, Islamabad. This laboratory is new, better and well equipped as compared to the former one. In Islamabad

Museum, there is a well-established digitalization section that enabled the scholar to document almost 390 coins of Late Kushans for the present research.

Elemental analysis of the Late Kushan copper coins at Islamabad Museum has been carried out through material science, numismatic literature and archaeometallurgical observations. Various methods will be applied in the investigation process, such as conservational techniques (physical and chemical), X-ray Fluorescence (XRF) Spectroscopy and Rutherford Backscattering Spectroscopy (RBS).

The elemental analysis of the metal artefacts is important mechanism with help of which we can understand the elemental composition of metal and technological advancement of the past. Elemental studies of coins result in valuable information about metal combination used in the manufacture of coins. The laboratory techniques such as XRF provides the additional information about the metal contents, ores and the way to identify the various mints, when more than one, from composition of metals. The relative proportion of the contents of the main elements provides valuable information about, the inflation of, money, economic growth or deprecation and political conditions of that period. The connection between microstructure and mechanical properties enables the materials scientist to surmise the use of processes such as hammering, heating and quenching used in ancient times.

1.8 Expected Outcomes

The study of ancient metals gives us valuable information about the economy, religion, social stratification, trade and commerce of certain era. Similarly, the elemental analysis of the metal artefacts is important mechanism which helps to understand the chemical composition of metal and technological advancement of the past. The major reason of the selection of this group of copper coins for the present study is the accessibility to the conservation laboratory in Islamabad Museum. This group of coins, as known from weight, was struck in reduced weight obviously yield important information about the economic devaluation, condition of metal, manufacturing technique and acquisition of material etc. Elemental analysis of the selected group may help to know about their minting process and composition of alloys. The selected group of coins has not yet been cleaned and therefore more suitable for applying cleaning and conservation techniques. Very limited research has been carried out on cleaning and conservation of copper coins of this period. Elemental analysis of the selected group is not only essential to know about the elemental composition of these coins but it will also help to apply the required

cleaning and conservation techniques. In this way the present research aims to investigate the morphometric features on this particular group of coins, understand how corrosion takes place and how it can be prevented from further decay. The present study will find out an efficient and least destructive method for the cleaning and conservation of copper coins of Vasudeva I, Kanishka II and their successors. The study aims to investigate the composition of Late Kushan coins through Rutherford Backscattering Spectrometry (RBS) and X-ray Fluorescence (XRF) spectroscopy techniques. This material is commonly found in historic period sites in Gandhara and other regions in Pakistan. But these coins always yield hard patina which is difficult to remove through conventional chemicals and thus always deteriorate the surface of coins in this process. If the causes of patina and its remedy are discovered it will be very helpful for the archaeologists, numismatic experts and the museum staff to treat these coins in appropriate way and to preserve them for a long time.

CHAPTER-2

LITERATURE REVIEW

The term "coin" is believed by some to have Greek origins, derived from "Koivsf," meaning common, while others propose a Latin origin from "cuneus," meaning a wedge, possibly reflecting the early currency's wedge or ingot-like form. Herodotus attributes the Lydians as the first to mint gold and silver into money, while the Parian Chronicle credits the Aeginetans, under Pheidon, king of Argos, around 895 BCE., for its origin. Lydian and early Persian coins, coined between 522 and 486 BCE during the reign of Darius I, are considered among the earliest. Coins are categorized into ancient and modern, with the former further divided into Greek, Roman, and Barbarian. The ancient coins span the period before the fall of the Western Empire, while modern coins encompass those minted since. The earliest known Greek copper coins, date back to Gelon, king of Syracuse, around 490 BCE., and gold coinage in Greece is traced to Philip of Macedon. Athens lacked gold currency at the start of the Peloponnesian War in 431 BCE (Manfred, 1858).

Coins hold a crucial role in historical understanding, serving as important corroborative evidence alongside inscriptions and literature. Crafted from various metals such as gold, silver, copper, or alloys, coins bear legends or simple marks that contribute to the reconstruction of ancient Indian history. As integral archaeological sources, dated coins are particularly valuable for establishing the framework of Indian chronology. In the context of Indo-Scythian and Indo-Bactrian rulers, coins, especially bilingual ones, function as Rosetta Stones for deciphering ancient Indian writings. The purity of metal in coins offers insights into the financial conditions of the Gupta Empire, while inscriptions on coins reveal the territories ruled by different leaders. Some coins provide detailed information on personal events of rulers, and the discovery of identical coins in various locations aids in determining the territorial extent of different kingdoms in ancient India (Kokatanur, 2015).

Coinage in the Indian subcontinent has a rich history dating back to the sixth century BCE. Various rulers and dynasties issued coins during different periods and eras, and these coins can be categorized based on their designs, inscriptions, and historical significance. The diverse coinage reflects the cultural, political, and economic changes that occurred over the centuries in the region. Studying these coins provides valuable insights into the history, art, and economic systems of ancient and medieval India (Khalid and Anwar, 2011).

The history of human civilization is intricately connected to the utilization of metals, playing a vital role in the extraction, purification, and application of these materials. Despite the 20th century being dubbed the "Plastic Age," the world currently relies on metals more extensively than ever before. From wooden ships to steel vessels, metal has replaced traditional materials in various aspects of modern life, including transportation, construction, and energy production. The transition from an agricultural to an industrial economy was facilitated by advancements in metallurgy, enabling the development of machinery and infrastructure crucial for progress. Metals also hold significant cultural heritage value, with archaeological artefacts such as grave goods and weaponry, as well as historical metalwork like sculptures and industrial machinery, representing important aspects of human history (Walker, 2003).

The conservation and analysis of metal objects from the Iron Age constitute an integrated discipline requiring a comprehensive understanding of contextual information and the chemical attributes of such objects. Accurate analysis of metal artefacts is crucial for understanding various aspects of Iron Age life, including social structures, economic activities, technological advancements, cultural practices, and religious rituals. Recent advancements in excavation and analytical techniques have demonstrated their potential to illuminate diverse facets of Iron Age societies, providing valuable insights into ancient human behaviors and lifestyles (Becker, 2013).

Within the realm of numismatics, the literature review highlights the critical role that coins play as rich sources of historical information, particularly regarding the rulers who issued them. Scholars and researchers have extensively explored the details embedded in coins, exploring into the iconography, inscriptions, and symbols to gather insights into the political, cultural, and religious contexts of different dynasties. The literature review thus serves as a guide for researchers, emphasizing the multidimensional nature of numismatic studies and encouraging a comprehensive understanding that goes beyond the superficial appearances of these historical artefacts.

The study of Kushan coinage has attracted significant attention from scholars and numismatists due to its historical importance and archaeological significance. Kushan coins exhibit resemblances with contemporary and, at times, previous coin practices in terms of the design of royal figures, religious images, as well as the form of languages, legends, symbols, and inscriptions. The study involves a multidisciplinary approach, incorporating historical, archaeological, linguistic, and numismatic perspectives. The findings contribute not only to our understanding of the Kushan Empire but also shed light on broader regional and cultural interactions during that period.

The study of conservation and analysis of ancient coins has indeed been a significant field of research for several decades. Scholars and researchers from diverse disciplines, including numismatics, archaeology, art history, and anthropology, have contributed to the understanding of ancient coins. Interdisciplinary collaboration has been a hallmark of the study of ancient coins. Natural scientists contribute their expertise in materials analysis, helping to identify the composition of the coins and the technology used in their production. Social scientists, on the other hand, probe into the sociocultural implications of coinage, exploring how coins reflect political changes, religious beliefs, and societal structures.

The secondary sources contribute significantly to the scholarly discourse on Kushan coinage and conservation of ancient coins enriching our understanding of this fascinating chapter in the history.

Coins serve as a crucial foundation of information for archaeologists seeking to unravel the mysteries of the past, with a history dating back approximately 2700 years. The use of coins as a medium of transaction provides a valuable lens through which to examine the economic systems and daily life of ancient civilizations. These artefacts not only depict the images of kings but also provide insights into the political, social, and cultural contexts of different regions and periods. The study of ancient coins facilitates the reconstruction of historical timelines and the establishment of chronological sequences for various dynasties.

Numismatics, the study of coins, helps archaeologists piece together the rise and fall of civilizations, the succession of rulers, and the interconnectedness of different regions through trade and political alliances. As archaeologists meticulously examine and interpret these artefacts, they uncover layers of information that contribute to a more comprehensive and nuanced understanding of the past (Lal Gupta, 1969).

2.1 Archaeometallurgy

Metallurgy is a meadow of materials, science and engineering that concerns with the physical and chemical behaviour of metallic fundamentals. Their intermetallic compounds and mixtures are called alloys (Gill et al., 2017).

Metallurgical analysis in itself is the study of metals, their waste elements, and other chemicals analysis methods. The topic of metallurgy can be considered as a combination of chemistry, physics and mechanics with special reference to metals. Metallurgy is an ancient subject which linked to the history of mankind. The development of civilizations from stone age, bronze age and iron age can be followed by the discovery of copper and iron (Seetharaman, 1996).

The conservation, analysis and all aspects concerning the research of archaic metals is referred to the field of archaeometallurgy. Conservation of metallic objects is the practice of observation, the physical and chemical decay of objects and different techniques used for the art of cleaning these metal artefacts (Elmor and Becker, 2013).

Archaeometallurgy is the study of historic and prehistoric metals. They can also be used in chemical, physical and anthropological fields. It is one of the oldest manifestations of archaeometric research and using science based approaches to address cultural-historical question of coin artefacts, isotopes-archaeometallurgy and archaeometry (Rehren, 1994).

The primary emphasis is on the analysis of publications within the archaeometry domain, with a particular focus on the theme of archaeometallurgy. The author directs attention towards the significance of coin and object analysis within archaeometry, often coupled with the development of innovative methods. This dual focus not only highlights the archaeological value of coins and objects but also underscores the importance of continually evolving methodologies in this specialized field of study.

The term "archaeometry" signifies the application of various scientific techniques and methodologies to archaeological investigations, enhancing our understanding of cultural and historical aspects. Within this context, archaeometallurgy emerges as a crucial avenue, employing scientific methods to glean insights into the metallurgical aspects of ancient societies. This retrospective analysis not only pays homage to the roots of the discipline but also illustrates the evolution of methodologies and the growing sophistication of scientific approaches over time (Rehren, 2008).

They argue in favour of the idea that metallurgy had a singular origin, and subsequent cultural transmission of this technology occurred as groups of metalworkers followed the diffusion of exotic metal objects. The authors propose that the spread of metallurgical technology was facilitated by the movement of groups of metalworkers who trailed the dissemination of metal objects. By advocating for a single invention theory and emphasizing the role of cultural transmission through metal objects, the authors contributed to the ongoing discourse on the development of metallurgy in Eurasia. This approach suggests a connected and interdependent network of early metalworking communities, challenging notions of independent and parallel developments (Benjamin et al., 2008).

Sultanate coins, as the most significant and frequently unearthed artefacts from the Sultanate period of Bengal, serve as valuable historical resources. The study of the archaeometallurgy of these coins provided a unique and unexplored avenue for understanding the political, social, and economic aspects of medieval Bengal. By analyzing the metal content of the coins, researchers aim to unravel crucial information about the economic systems that prevailed during the Sultanate period. The composition of the coins gave insights into the availability and utilization of metal resources in Bengal during that era. The study thrown light on the technological advancements in metallurgy and coin minting, providing a glimpse into the craftsmanship of that time. Different rulers and dynasties may have employed distinct metallurgical techniques or chosen specific metals for their coins, reflecting their policies, preferences, and economic strategies (Al Hasan, 2013).

Archaeometallurgical analysis of metal samples excavated from ed-Dur, situated on the west coast of the Oman Peninsula and occupied from the first century BCE to the first half of the second century CE. The study examined a diverse range of materials, including copper alloys, lead, silver, litharge, local SE-Arabian coinage, iron, and metal slag. Through optical metallography, SEM-EDX, and lead isotopic analysis via ICP-MS, the research aimed to characterize the metal assemblage and understand the site's role in international trading networks. Notable findings included European origin lead, potential Indian lead fragments contradicting historical records, and significant overlap between silver isotopic fingerprints and British ores, indicating extensive trade networks (Delrue, 2008).

The literature shows a number of scholars that have been working in the Kushan coins for example:

Joe Cribb made significant contributions to the understanding of historical practices in Central Asia and South Asia. Focusing on the intricate details of these coins, his work goes beyond a mere cataloging of artefacts, emphasizing the broader significance of numismatics. Through his research, he highlighted insights gathered from the coins, revealing a concept of unified tradition within the Indian subcontinent. The importance of numismatics, extends beyond the economic aspects of these ancient currencies. By carefully examining the designs, inscriptions, and materials of the Kushan coins, he distinguished patterns that hinted at a cohesive cultural heritage prevailing across the Indian subcontinent (Cribb, 1981).

The exploration, coupled with Cunningham's earlier efforts, collectively contributed to a comprehensive understanding of the historical, cultural, and economic aspects surrounding the use of coins in the region. The concept of a unified tradition, as revealed through these numismatic studies, adds a layer of complexity to our understanding of the interconnected societies that once thrived in Central Asia and South Asia. In essence, Kushan coinage became more than a medium of exchange; it became a tangible link to a shared cultural identity across the vast landscapes of the Indian subcontinent (Cribb, 1985).

Inflation in antiquity manifested through the debasement of coinage, where the intrinsic value of coins, primarily composed of precious metals like gold and silver, was reduced by mixing in base metals such as copper. This practice progressively diminished the metal purity over successive reigns, as evidenced by studies on Merovingian, Byzantine, and Beneventan coinage from the 6th to 9th centuries. Similarly, the Late Kushana gold coinage visibly reflects this gradual debasement. Analyzing the gold content of these coins can help establish the chronological order of their issuance, especially in cases where numismatic evidence is unclear, and further confirm the sequence where it appears certain. This method highlights how inflation impacted ancient economies differently than today, where modern token currencies are less directly tied to material value (Oddy and Cribb, 1995).

The study addressed the longstanding challenge of attributing the anonymous Soter Megas coins of the Kushan period, which have puzzled scholars since their discovery in the early nineteenth century. By examining over a thousand examples, the study suggests that these coins likely originated towards the end of the reign of the first Kushan king, Kujula Kadphises, and continued through the rule of his son and successor, Wima Takto. The research re-evaluated previous attributions and proposed a new classification system based on a thorough examination of the coins. These anonymous coins, characterized by the Greek titles "ΣΩΤΗΡ ΜΕΓΑΣ" (meaning the Great Saviour), are significant for Kushan studies as they lack the name of the issuing ruler. They have been found across a vast region spanning from Uzbekistan and Tajikistan to northern India, contributing to our understanding of Kushan numismatics and their historical context (Cribb, 2015).

An exemplary study of Kushan numismatics has been done by accurately identifying and classifying the extensive list of Kushan coinage, particularly those associated with the reign of Kanishka. With meticulous attention to detail, organized the diverse array of gold and copper coins attributed to Kanishka into seven fundamental groups, providing a systematic framework for scholars and researchers. By categorizing these coins into distinct groups, not only facilitated the study of individual coins but also laid the groundwork for a deeper understanding of the historical, cultural, and economic contexts in which they were minted and circulated. The work continued to serve as a cornerstone in the field of numismatics, offering valuable insights into the complexities of Kushan coinage and contributing significantly to our understanding of the ancient civilizations that once thrived in Central Asia and beyond (Cunningham, 1892).

A significant contribution to the understanding of Kushan coinage by meticulously arranging the series of these ancient coins housed in the Lahore Museum. Following a cataloging method established earlier for the coins in the British Museum, Whitehead's work provided a systematic organization of the Kushan coins, enhancing accessibility for scholars and researchers. By adopting a consistent classification system, Whitehead's efforts not only facilitated a detailed study of individual coins but also promoted a comparative analysis with collections in other institutions (Whitehead, 1914).

Another study of Kushan coinage has been carried out by Mitchiner, particularly those associated with Kanishka, by adopting a meticulous approach to categorization. This work has focused on dividing Kanishka coins into various groups based on stylistic features, allowing for a nuanced analysis of the coins' design elements and artistic characteristics. This detailed classification was instrumental in providing a more comprehensive understanding of the evolving styles and variations within the Kushan numismatic tradition. Stylistic analysis allocated these coins to different mints, enhancing the specificity and granularity of his numismatic categorization. Style and mint location provided a multi-dimensional perspective of the Kushan coinage under Kanishka, offering researchers and historians a more refined tool for studying the numismatic landscape of the time. Systematic classification has since become an essential reference in the field of Kushan numismatics, guiding scholars in their exploration of the cultural, economic, and political facets embedded in these ancient coins (Mitchiner, 1978).

A comprehensive overview of the archaeological discoveries made during the excavation done by John Marshall at Taxila. One notable aspect of research is his meticulous examination and documentation of twelve thousand coins recovered from various sites at Taxila. The author went beyond a mere listing of these coins, taking the initiative to present selected examples with accompanying photographs, offering readers a visual glimpse into the rich numismatic heritage of Taxila. Marshall's account left a notable gap in the discussion of the process of cleaning and the methods employed for the conservation of these ancient coins.

As these coins are invaluable historical and cultural artefacts, a more thorough exploration of the cleaning and conservation aspects would have contributed to a more holistic understanding of the archaeological practices employed at Taxila during the specified excavation period. Despite this omission, Marshall's work remained a significant contribution to this field, providing a valuable resource for those interested in the archaeological treasures of Taxila (Marshall, 1957).

The primary objective of the scholarly work is to establish a framework of best practices that museums can adopt for the preservation and administration of their ancient coin holdings. Author conducted an informal investigation into American museums with ancient coin collections, adding a practical dimension to the research. Through this dual approach, the author aimed to shed light on the current state of affairs in American museums regarding the management of ancient coins, identifying potential areas for improvement. By offering both a theoretical foundation through the literature review and real-world examples through the informal investigation, the study seeks to encourage museums to reassess their current methodologies and embrace best practices in the field (Hurzeler, 2018).

"Medieval Indian Coinages: A Historical and Economic Perspective" is a comprehensive exploration of the numismatic history of medieval India. By meticulously examining these three coinage groups, the author shed light on the multifaceted nature of medieval Indian coinage. The differentiation in their sources of origin and metallurgical processes signifies the diverse economic and historical contexts within which these coins were minted. This insightful perspective allows readers to grasp not only the monetary aspects but also the broader historical and economic narratives that these coins encapsulate (Amiteshwar, 2001).

The strong allure that cities hold for numismatists when it comes to associating the minting of coins with specific urban centers. Despite the absence of concrete evidence, the desire to establish such associations is pronounced among numismatists. The author indicates that the paper will delve into this topic by presenting examples of cities that can be connected, to varying extents, with specific issues of Kushan coins. The study suggested that the research will provide insights into the correlation between coin minting and particular cities, shedding light on the historical and geographical aspects of Kushan numismatics (Bracey, 2012).

The focus is on the Kushan Empire during the first centuries of the Christian era, portraying it as a vast inland empire in the Central Asia. The Kushans are likened to other contemporary superpowers such as the Chinese, Persians, and Romans. The formation of the Kushan dynasty remains a subject of debate, with elusive precise dates for the kings.

A study introduced the idea that Kushan coins were gaining increasing visibility in the ancient market. Described as exotic, obscure, beautiful, and under-appreciated, these coins were portrayed as valuable artefacts that are now garnering more attention. The mention of international trade in silk and spices contributing to a flow of gold through the kingdom suggests the economic prosperity and importance of the Kushan Empire in the ancient world (Markowitz, 2019).

During the first centuries CE, the Kushan Empire emerged as a challenging inland power, resembling the influence of China, Persia, and Rome. The exact origins and formation of the Kushan dynasty remain subjects of ongoing debate, with elusive precise dates, particularly for the later kings. Evidence for the reigns of certain Kushan kings is derived from cryptic references in Chinese and Kashmiri records, supplemented by contemporary inscriptions on stone and metal, along with the abundance of Kushan coinage. In some cases, the only knowledge of certain Kushan kings comes from their names appearing on coins. Chronological understanding of kings in Central Asia heavily relies on numismatics and epigraphy, with coin finds providing crucial evidence at many Kushan-era archaeological sites (Jongeward and Cribb, 2014).

Author has been actively involved in research related to Kushan coins, having authored numerous articles on both Kushan and post-Kushan coinage. His work likely contributes valuable insights to the field of numismatics, providing a deeper understanding of the historical, cultural, and economic aspects associated with these coinages. The articles written by Gul Rahim Khan are likely to cover various aspects of Kushan and Post-Kushan coins, including topics such as coin designs, inscriptions, historical contexts, and potentially their influence on subsequent coinages for example:

In recent publications by Khan, a notable focus has been on coin hoards and various coins housed in different museums. Specifically, in the paper titled "Post Kushana Gold Coins in the Cabinet of the National Museum of Pakistan, Karachi," the author investigated the identification and periodization of gold coins from the Post-Kushan era, which are currently part of the collection at the National Museum. An article centered around Kushan copper coins, titled "Kanishka Copper Coins in the National Museum of Pakistan, Karachi: Analysis & Classification," as published in 2009. This particular work addressed the analysis and classification of Kanishka copper coins found in the National Museum of Pakistan, Karachi (Khan, 2009).

The National Museum of Pakistan houses a significant collection of copper coins from the Kushan period, particularly those of Kanishka I. This collection includes ninety-one coins of Kanishka I, alongside three gold coins of the same ruler previously published by Khan in 2009. Copper coins of Kanishka are widespread in both public museums and private collections throughout Pakistan. They are recognizable for their uniform design, featuring a standing figure of the king on the obverse and a deity on the reverse. The legends on these coins, transition from Greek to Bactrian over time, with inscriptions on both sides indicating the king's name and title on the obverse and the deity's name on the reverse. These copper coins are known to come in three denominations: large (tetradrachm), medium (didrachm), and small (drachm) units (Khan, 2009).

Another particular work of the same author stands out for its systematic classification of coins associated with Vasudeva and his successors, offering a comprehensive catalogue that enhances our understanding of this specific numismatic domain. By employing a methodical approach, Khan has successfully categorized and organized the copper coins, providing scholars and enthusiasts with a valuable resource for studying the numismatic history associated with Vasudeva and his lineage in the region of Taxila. Through this meticulous cataloging, Khan's article not only aids in academic research but also serves as a significant reference for those interested in the coinage and historical context of Vasudeva and his successors in the rich tapestry of Taxila's numismatic heritage (Khan, 2010).

Similarly, another study of Khan has focused the significance of the rearrangements of bilingual coins attributed to Vima Kadphises. The author notes that the coins with a continuous Greek legend on the obverse are likely the early issues of Vima Kadphises, given their similarities to the coins of his predecessors. The study emphasized on the evolution of a new style of legend initiated by Vima Kadphises, which then became a characteristic feature for the obverse legend of subsequent rulers of the Kushans. This implies that the numismatic changes introduced by Vima Kadphises had a lasting impact on the coinage of the Kushan rulers who followed him (Khan, 2012).

A Late Kushan hoard, comprising gold and copper coins, was discovered by a landowner in Ray Dheri (low mound), Charsadda. Although unearthed a few years prior, it was first presented to the authors in the summer of 2017. The hoard consisted of 56 gold coins along with a larger quantity of copper coins. The authors had the opportunity to examine a portion of the hoard, including a quarter of the gold coins and some of the copper coins. The gold coins primarily imitate those of Vasudeva I and were issued by the Kushano-Sasanian kings from Bactria. In contrast, the copper coins belong to the reign of Kanishka II, the successor of Vasudeva I. Notably, both the gold and copper coins were from the same period. Based on the latest contents of the hoard, it is inferred that it was deposited around the mid of third century CE. (Khan and Durrani, 2018).

The discovery of copper hoards, especially those accompanied by a small quantity of coins from the Kushan period, is not commonly highlighted in publications. However, when such findings are contextualized properly, scholars highly value them. Such collections, despite their size, often reveal significant insights, such as provenance details and associations with Buddhist sites near Peshawar. Of particular interest are instances where the hoards contain coins depicting images of the Buddha, adding new dimensions to our understanding of the period's history and cultural significance (Khan & Qazi, 2014).

A hoard of coins, accompanied by a clearly documented find spot, is presented to scholars for examination. These hoards are invaluable in tracing the circulation of specific coins within a particular period and location. The said collection of coins held significance in shedding light on the coinage and historical context of the Late Kushans in the ancient Gandhara region, providing crucial evidence for researchers studying this era (Khan & Shakirullah, 2013).

Similarly, a small hoard of 24 copper coins was discovered in Chamkani village, near Peshawar, during construction work by labours has been studied. The hoard, found intact in an earthenware bowl, was accidentally unearthed and later donated to the SSAQ Museum of Archaeology at the University of Peshawar by the property owner. Due to poor preservation, only 18 coins have been included in the study, with many exhibiting damage along the edges (Khan et al., 2010).

research meticulously examines the metallurgical composition of gold coins to trace patterns of debasement and economic shifts across different reigns. His findings reveal a progressive decline in gold purity, reflecting economic pressures and monetary policies aimed at stretching precious metal reserves. By comparing variations in gold content, Maity contributes to the chronological classification of coinage and offers insights into the broader economic strategies of these ancient empires. His work remains significant in numismatic studies for its empirical approach to understanding ancient monetary systems and their responses to inflationary pressures (Maity, 1958).

The complexities surrounding the copper coinage of the later Kushana period, focusing on its production, distribution, and economic significance have been studied. This study investigates the abrupt decline in the quality and volume of copper coinage during the late Kushana era, contrasting it with the earlier period characterized by well-struck and standardized issues. He examines numismatic evidence, such as variations in weight, fabric, and iconography, to understand the reasons behind these changes. Author suggests that economic instability, administrative decentralization, and the shifting political landscape contributed to the deterioration of coin standards. His analysis also considers the role of local mints and the possible influence of external pressures, such as invasions and trade disruptions, in shaping the evolution of Kushana copper currency. The broader economic implications of this debasement, proposing that the declining quality of copper coinage reflects a weakening central authority and reduced state control over monetary production. He links this deterioration to the broader fragmentation of the Kushana Empire, highlighting how economic and political factors intertwined to impact currency systems. The study also raises questions about the circulation and acceptance of these debased coins among the populace, suggesting a gradual erosion of trust in the state's monetary policy. Significantly contributes to numismatic scholarship by offering a nuanced understanding of how economic pressures and political instability influenced the Kushana coinage system, providing valuable insights into the empire's eventual decline (MacDowall, 2005).

2.4 Mints

Study has been conducted on the strong inclination among numismatists to link coin minting with specific cities, even when evidence is lacking. Focusing on Kushan coins, the study examined the available evidence regarding minting locations. Through the exploration of various example cities, the study demonstrated the varying degrees of connection between these cities and specific coin issues (Bracey, 2012).

Scholars examined seven Indian copper coins from the Kushan Period (First–Third centuries C.E.) using various analytical techniques like WD-XRF, XRD, and FESEM-EDX. Results revealed a compositional gradient in elemental distribution from the external surface to the inner core, along with isolated patches of surface mineralization leading to the formation of copper oxides, magnesium silicate, and silica. The analysis suggested the use of sulfide ore of copper for smelting, indicating poor workmanship due to impurities like sulfur, iron, and silica remaining from inadequate smelting conditions. Internal striations and micro-cracks at grain boundaries suggested stress from punching or hammering during coin fabrication. Overall, the coins were found to be single-phase copper with associated impurities, including black spots of copper sulfide in the inner core (Mamaniaa & Singhb, 2019).

2.5 Corrosion Process

A comprehensive study has been carried on the long-term behaviour of ancient bronzes recovered from burial conditions, focusing on the region of Dobrudja, Romania. The scientific interest lies in understanding the influence of soil parameters on the degradation mechanisms of ancient bronze alloys. The research involved a two-part approach. In the first part, the study characterized bronze artefacts through both non-destructive (micro-FTIR, reflectance mode) and micro-destructive (sampling and stratigraphic section analysis using OM and SEM-EDX) methods. Burial soils are geologically classified and chemically analyzed (pH, conductivity, anions content). The majority of analyzed objects exhibit a coarse and inhomogeneous corroded structure, attributed to the silt nature of soils, which are accessible to water and air due to their low clay content. The second part of the study involved simulation experiments on commercial Cu-Sn alloys with compositions resembling those of ancient artefacts. Electrochemical measurements, particularly cyclic potentio-dynamic experiments, are conducted in natural electrolytes extracted from soil at archaeological sites and seawater. The soil extract's electrolyte is deemed non-aggressive, while an artificial solution with increased anion concentration induces pitting corrosion in the alloy (Quaranta, 2009).

A study conducted at the archaeological excavation of Palazzo Valentini in Rome, the researchers collected ancient coins along with soils from varying proximity. Through the application of diverse analytical techniques, they aimed to establish a correlation between the corrosion products on the coins and the chemical-physical characteristics of the soil. The analysis included measurements of soluble salts in the water-bearing stratum and surfacing at the site. The findings highlighted the significant influence of alkaline soils on the formation of patina, with cerussite identified as the main corrosion product, likely originating from water circulation in layers rich in marble and plaster fragments. Soil surrounding the coins exhibited traces of copper, lead, and vanadium. Cluster and multivariate analysis of the data revealed correlations between specific coins and the nearby soil samples, providing valuable insights into the factors influencing the corrosion of ancient metallic objects in this archaeological context. (Rita et. al, 2012).

A comprehensive study resulted in a book titled “Corrosion of Metallic Heritage Artefacts” is a crucial resource that delves into the essential aspects of understanding long-term corrosion processes, particularly in the realms of archaeology and conservation. The book comprehensively explored themes such as the fundamental processes driving corrosion over extended periods, methodologies for measuring corrosion rates, and strategies for material conservation. Beginning with an overview of the study and conservation of metal archaeological artefacts, subsequent chapters delve into the long-term corrosion of specific metals like steel, iron, and bronze. Environmental factors influencing corrosion rates have thoroughly been examined. It has also explored instrumental techniques such as electrochemistry and scanning electron microscopy for corrosion measurement (Dillmann et. al, 2007).

The climate risks to museum objects in Dutch museums based on temperature and humidity data. The study discussed the evolution of museum climate guidelines and proposed new methods for risk assessment. It has also provided background on museum climate guidelines and research methods, examined degradation processes influenced by indoor climate, introduced a general climate risk assessment method, proposed a more specific method, applied these methods to museums and compared their effectiveness, used computational models to analyze the impact of building modifications on indoor climate and object preservation. The study concluded that low-risk indoor climates can be achieved with various building configurations and control measures, highlighting the importance of proper management and monitoring (Martens, 2012).

The phenomenon of corrosion in metals, emphasizing its natural occurrence and the environmental factors contributing to it. The author described the corrosion as a spontaneous process wherein metals deteriorate into more stable, lower-energy forms when exposed to the environment, often leading to the formation of corrosion products like rust. Despite efforts to prevent corrosion, it remains an inherent challenge, impacting the utility properties of metals and potentially causing environmental contamination. The study also touched upon corrosion engineering principles, including setting acceptable corrosion rates and implementing corrosion protection measures (Novak, 2007).

Iinvestigation has been done on the corrosion of ancient coins from an archaeological excavation site in Palazzo Valentini, Rome. By analyzing both the coins and the surrounding soils using various analytical techniques, the study aimed to identify significant parameters influencing corrosion and the correlation between corrosion products on the coins and soil characteristics. Results indicated that alkaline soils had a notable influence on patina formation, with cerussite identified as the main corrosion product. Additionally, the presence of copper, lead, and vanadium in the surrounding soil was observed. Conductivity, pH, and soluble salts content analysis helped to distinguish coins from different stratigraphic units. Cluster and multivariate analysis revealed correlations between certain coins and nearby soil samples, providing insights into the environmental factors affecting corrosion (Reale, 2010).

Study has been conducted on the corrosion attack on the surface of silver-based alloys when exposed to soil conditions. The study involved preparing laboratory samples with compositions and features similar to ancient alloys and subjecting them to artificial pre-aging before soil corrosion simulation. Various analytical techniques, including Glancing Angle X-ray Diffractometry (GAXRD), Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), and optical microscopy, are employed to analyze the resulting patina layers. The examination revealed that the corrosion patterns consistent with those observed on authentic artefacts, indicating the effectiveness of the experimental setup in simulating real-world corrosion processes (Novakovic, 2008).

2.6 Conservation Procedure

The history of human civilization is intricately connected to the utilization of metals, playing a vital role in the extraction, purification, and application of these materials. Despite the 20th century being dubbed the "Plastic Age," the world currently relies on metals more extensively than ever before. From wooden ships to steel vessels, metal has replaced traditional materials in various aspects of modern life, including transportation, construction, and energy production. The transition from an agricultural to an industrial economy was facilitated by advancements in metallurgy, enabling the development of machinery and infrastructure crucial for progress. Metals also hold significant cultural heritage value, with archaeological artefacts such as grave goods and weaponry, as well as historical metalwork like sculptures and industrial machinery, representing important aspects of human history (Walker, 2003).

The conservation and analysis of metal objects from the Iron Age constitute an integrated discipline requiring a comprehensive understanding of contextual information and the chemical attributes of such objects. Accurate analysis of metal artefacts is crucial for understanding various aspects of Iron Age life, including social structures, economic activities, technological advancements, cultural practices, and religious rituals. Recent advancements in excavation and analytical techniques have demonstrated their potential to illuminate diverse facets of Iron Age societies, providing valuable insights into ancient human behaviors and lifestyles (Becker, 2013).

A study has been conducted on the potential advantages and drawbacks of implementing a mass-conservation system at the National Museum of Iceland. The study addressed the historical context wherein periods of limited or no specialized conservators in archaeological conservation existed at the museum. Such circumstances have resulted in a significant backlog of both un-conserved artefacts and those requiring re-conservation across various material categories. The research aimed to contribute to the discourse by discussing general facts about iron and corrosion products, reviewing

common iron conservation methods in Northern Europe, and proposing approaches applicable to mass-conservation (Einarsdottir, 2012).

The intricate challenges associated with the preservation of silver coins with diverse compositions and varying states of preservation from the early post-medieval period have been noted. The primary objective of the study was to identify the most suitable method for conserving these poorly preserved coins. The investigative approach involves a comprehensive analysis of both the metal composition and the corrosion products present on the ancient coins. Subsequently, experiments employing different cleaning methods were conducted to discern the least damaging yet most effective approach. Notably, the study went beyond mere cleaning, extending to a test that evaluates the necessity and effectiveness of stabilizing the surface of the coins post-cleaning. By systematically assessing these variables, the research aimed to contribute valuable insights into the preservation of ancient silver coins, striving to strike a delicate balance between efficacy and minimal harm to the historical artefacts under consideration (Viljus & Viljus, 2013).

Investigation has been done on the proper techniques for the conservation of ancient coins, incorporating Mechanical, Chemical, and Electrolysis techniques. The aim of the study was to take comprehensive insights into the nuanced art of cleaning the historical artefacts. However, a notable challenge arose from the fact that many of the chemicals mentioned in the study were not easily accessible in the market. This posed a practical hurdle for individuals seeking to implement the techniques discussed, as obtaining the required chemicals may prove to be a complex and potentially limiting factor. Despite the efficacy of the methods presented, the availability and practicality of the recommended chemical solutions underscore a crucial consideration for those engaging in coin conservation practices (Sandes, 2017).

The conservation treatment of brass washing dish bowl rests within the Faculty of Applied Art's Museum. The research objective was to present a comprehensive overview of conservation procedures applied to the washing dish bowl, employing traditional techniques such as mechanical and chemical cleaning, as well as addressing issues like straightening the twist decorative units and caring for loose parts. To gain insights into the composition and alterations brought about by the conservation process, solid and powdered samples from the washing dish bowl were meticulously examined before and after treatment. Utilizing Scanning Electron Microscopy (SEM) coupled with

Energy Dispersive X-ray Spectroscopy (EDS) and X-ray Diffraction (XRD), the researchers identified the alloy composition (62.5% copper, 36% zinc, 1.50% iron, and traces of lead) and various impurities present in the brass washing dish. EDS results indicated that the corrosion mechanism was influenced by the museum's daily activities and internal climate during exhibitions. XRD results unveiled that prominent copper corrosion compounds included malachite and attacamite. The effective removal of chloride ions from the brass washing dish, achieved through the use of sodium hydroxide, was highlighted (Saleh, 2017).

A conservation strategy tailored for the Mediterranean region. The process involves successive washing using deionized water within an ultrasonic waves bath. The objective was to crush and eliminate both soluble and insoluble corrosion products. For the soluble corrosion products, various chemical parameters such as anions, pH, conductivity, and redox potential were continuously monitored. These parameters provided valuable insights into the composition of the corrosion products and their behavior during the cleaning process. The collected data, including weight loss and chemical parameters, were then utilized to construct a matrix. This matrix was subjected to explorative data analysis, a statistical technique aimed at uncovering patterns and trends within the dataset. The analysis helped identify any discernible trends in the washing series and determined which variables were the most strongly correlated with the latent variable being investigated (Visco et al., 2010).

The efficacy of laser technology in both cleaning and performing Laser-Induced Breakdown Spectroscopy (LIBS) analysis on Islamic Marine Archaeological coins recovered from beneath the Red Sea waters. Q-switched Nd: YAG laser at 1064 nm was employed in laser tests conducted on two distinct types of corroded coins. To evaluate the proposed laser setup protocol, the coins underwent examination before and after the laser cleaning process, utilizing a Scanning Electron Microscope with an attached Energy-Dispersive X-ray Analyser (SEM-EDX). The results of this investigation revealed the significance of the number of laser-induced breakdown spectroscopy (LIBS) shots in acquiring meaningful data (Abdel-Kareem et al., 2016).

Study has been conducted on the use of electrochemical techniques in the conservation of metal artefacts. Traditionally, these techniques were often set aside in favour of mechanical and chemical methods. In recent years, there has been a growing acknowledgment among conservation experts regarding the significance of

electrochemical techniques. These methods are now recognized for their role in comprehending corrosion processes, monitoring them, and addressing specific conservation challenges. A noteworthy development is the integration of instruments, once exclusive to corrosion scientists, into the domain of conservation. The contemporary approach involved combining electrochemical and analytical techniques in parallel. This convergence was aimed at gaining a comprehensive understanding of the behaviour of metal artefacts during conservation processes (Degrigny, 2009).

Various approaches have been explored on conserving and interpreting ancient coins, discussing case studies from terrestrial and underwater contexts, including coins made of different metals and even forged currency. The study revealed that the conservation of coins is a crucial task for conservators dealing with archaeological finds, as coins serve as primary dating evidence and are vital for site interpretation. Numismatics plays a key role in museum and research collections, providing insights into metallurgy, economy, politics, art, and technology. Conserving coins can be challenging due to factors like rarity, absence of contextual evidence, prior inappropriate treatment, or severe deterioration. Achieving legibility is a primary concern, and stabilizing the metal is crucial. The process often involves micro-excavation to uncover burial stratigraphy. Collaborating with archaeologists, numismatists, and scientific researchers, conservators aim to reveal the historical significance of coins (Chemello & Mardikian, 2013).

Study conducted on the development of conservation processes for archaeological silver coins excavated from burial soil at al-Ukhdoud castle in Najran, Saudi Arabia. The coins were covered with soil deposits, encrustations, and corrosion layers, hindering the analysis of their decorations and inscriptions. Various cleaning processes were tested, including mechanical cleaning, alkaline Rochelle salt technique, alkaline dithionite reduction technique, and electrolytic reduction techniques. Through XRD analysis, SEM with EDAX, and other methods, it was determined that the most effective method involved mechanical removal of loosely bound corrosion layers followed by treatment with alkaline Rochelle salt. The study successfully revealed the decorations and inscriptions on the coins, identifying them as belonging to the kingdoms of Qataban and Ḥimyar, dating from the first century BCE to the second century CE. These findings provided valuable insights into the economic and technical developments of ancient Najran and served as a guide for conservators and archaeologists working with similar artefacts (Al-Zahrani & Ghoniem, 2012).

2.7 Bronze Disease

The universal phenomenon of corrosion affecting metal objects due to interactions with their surroundings such as ground, water, or air. Corrosion is a continuous process influenced by factors like the type of metal and the severity of reacting agents. It is emphasized that corrosion is particularly accelerated in humid climates due to the presence of moisture facilitating chemical reactions. The text highlights the extensive study of corrosion by scientists, not only concerning cultural property but also in industrial and other applications. The conservation field follows specific steps, including the analysis of metals, examination of corrosion products, conservation treatment, application of protective coatings, and ensuring safe storage and display of objects (Agrawal, 1987).

The literature on the conservation of metals highlights a prevalent focus on 'Bronze Disease,' a phenomenon of accelerated corrosion affecting copper-based metal objects, including pure copper, brasses (alloys with zinc and other elements), and bronzes (alloys with tin and other elements). While many papers discuss 'Bronze Disease,' there is often a limited understanding among conservators about the underlying chemistry of this corrosion problem. This paper aims to address this gap by exploring the physical and chemical nature of the processes involved in 'Bronze Disease.' The corrosion in many bronzes and brasses can lead to the formation of micropits under specific conditions, serving as a foundation for further active corrosion. The hope is that this discussion will guide researchers towards effective avenues for addressing and solving the challenges posed by 'Bronze Disease (Macleod, 1981).

The protection of cultural heritage, particularly copper alloy artworks, poses unique challenges in the selection of coatings. Despite numerous projects addressing new treatments for copper alloys in recent decades, no universally accepted solution has emerged, and traditional choices with known limitations persist. The absence of standardized testing methods for new coatings complicates comparisons across studies and hinders practical application in restoration. These issues include the presence of corrosion products, previous protective treatments, cleaning methods, and surface unevenness. The paper provides an overview of these surface properties, emphasizing their impact on coating performance. Methodological considerations for selecting mock-ups, testing techniques, and weathering procedures are discussed, with a particular focus on ensuring relevance to real artworks. The goal is to contribute to the

development of more effective coatings for the preservation of copper alloy cultural heritage objects (Letardi, 2021).

Bronze disease is a form of self-progressing corrosion affecting bronze, believed to be triggered by humidity and exacerbated by the formation of chlorine-containing compounds that react with the air. This corrosion poses a significant threat to bronze artefacts, potentially leading to their destruction. Preserving these priceless objects requires the identification of effective "cures" to halt or mitigate the corrosion process. The study emphasizes the importance of determining the efficacy of potential treatments to prevent valuable artefacts from deteriorating into a green powder. The proposed method involves using Scanning Electron Microscopy (SEM) to examine the impact of various treatments on bronze disease at a small scale. This approach enables a minimally destructive case study, offering insights into the effectiveness of common treatments for addressing bronze disease (Pauley, 2018).

Study conducted on the inhibitory mechanism of Benzotriazole (BTA) on pure copper and a copper–tin alloy (CNR 128) to protect against degradation processes like 'bronze disease.' Surface-sensitive techniques, including field emission SEM with Energy-Dispersive X-ray Spectrometer (EDS) and XPS, were employed to analyze corrosion products, such as cuprite (Cu_2O) and attacamite ($Cu_2Cl(OH)_3$) compounds, grown on pure copper and CNR 128 alloy. The BTA molecule was applied to the prepared samples, mimicking its common use in conserving cultural heritage artefacts. The XPS analysis on pure copper revealed that the BTA molecule promotes the formation of Cu (I) species when adsorbed on an attacamite-enriched surface, and Cu (II) species when adsorbed on a cuprite-enriched surface. In the case of degraded CNR 128 alloy with attacamite or cuprite as the main components of the patina, XPS results indicated the presence of Cu (II) oxidation state on the bronze surface. This detailed investigation provides insights into the interaction of BTA with different corrosion products, contributing to a better understanding of its inhibitory effects on bronze degradation (Mezzi et al., 2012).

2.8 Analysis

The ancient copper coins from various Greek cities and confederacies, as well as the Macedonian and Thessalian Koina. A non-destructive approach was employed. Proton Induced X-ray Emission (PIXE) was utilized following the removal of the patina from the coins. These particular copper coins were minted during the period of Roman Imperial rule, spanning from 31 BCE to 268 CE. The study focused on the quantitative determination of eleven elements present in the coins, and the correlation between the composition of these elements and the time of minting was explored. This analysis aimed to shed light on any potential patterns or variations in the elemental composition of the coins over the specified time frame (Kallithrakas-Kontos et al., 1996).

Researchers have analyzed the coins from the Hindu Shahis Dynasty of Kabul, dating back to the period of 990–1015 CE. Researchers utilized the Proton-Induced X-ray Emission (PIXE) technique. The study employed a 3 MeV proton beam sourced from the Pelletron Accelerator at the Institute of Physics, Bhubaneswar, India, to generate X-rays. Detection was carried out by a Si(Li) detector positioned at a 90° angle to the beam, characterized by a full width at half maximum (FWHM) of 180 eV at 5.9 keV. To ensure the accuracy of the analytical system, thin foils of Micromatter standards such as Fe, CuS, KCl, and RbNO3 were used for reliable calibration. The concentration of trace elements in the coins was determined using the GUPIX computer code. Analysis revealed the presence of elements including Ca, Ti, Cr, Fe, Ni, Zn, As, Sb, Pb, and Bi, alongside the major components Cu (copper) and Ag (silver) in these Hindu Shahi coins. In terms of the metal sources, the comparison of results with ores from various mines indicated that the copper in these coins likely originated from the Khetri mine in Rajasthan (Hajivaliei et al., 1999).

Scholars employed a portable X-ray fluorescence system (pXRF) to analyze gold, silver, and billon coins from the Museu Histórico Nacional do Rio de Janeiro collection, struck during the Brasil Colônia period under Dutch occupation and in Portuguese mints during the reigns of Fernando I and João I. The experimental setup included a mini Si-PIN detector and a 238Pu radioactive source for sample excitation. The study aimed to assess the capabilities and limitations of the portable system in determining coin base alloys and to verify if results align with historical facts. Preliminary results indicate Brasil Colônia period coins contain approximately 80.5% gold and 96.8% silver. Portuguese coins suggest a potential monetary debasement during João I's reign. No matrix corrections were applied to these initial findings (Paulo et al., 2009).

Scientific investigations have been carried out on archaeological coins discovered in Najran, Saudi Arabia. The study utilized Optical Microscopy (OM), Scanning Electron Microscopy (SEM) with Energy Dispersive Spectrometry (EDS), and X-ray Diffraction (XRD) to examine corrosion features, identify the patina's nature, and analyze elemental composition. Morphological analysis revealed various corrosion shapes, such as reniform, coral reef, and dendritic forms, along with a diverse multi-color patina on the coins' surfaces. The coins were determined to be made of a silver-copper alloy and were covered by three superficial corrosion layers. The predominant corrosion compounds identified included copper carbonate, copper chloride, copper silicates, silver chlorides, and silver sulphide. The study proposed a corrosion mechanism indicating heavy degradation caused by corrosive species and soil contaminants. The corrosion processes resulted in the depletion of copper and the enrichment of silver near the surface compared to the core composition (Al-Zahrani and Ghoniem, 2012).

A case study focusing on the conservation of highly deteriorated archaeological silver and copper objects adorned with colored enamel has been carried out. These artefacts, dating back to the Qajar dynasty in Persia (1794-1925), were showcased at the museum of the Faculty of Applied Arts, Helwan University in Egypt. The paper aims to investigate the chemical and mineralogical composition of the copper and silver corrosion products. Various analytical techniques, such as X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) coupled with Energy Dispersive X-ray Spectroscopy (EDS), were employed to analyze metal samples, corrosion products, and colored enamel. The restoration treatments involved mechanical and chemical cleaning, along with the replacement of missing parts of the enamels. This comprehensive approach not only contributes to understanding the composition of the corroded materials but also provides insights into effective conservation methods for preserving these valuable archaeological artefacts from the Qajar dynasty (Gharib & Madkour, 2014).

A metallurgical study focusing on a nineteenth-century Scudo coin from the Papal States has been carried out, which was historically repurposed into a pendant through the practice of brazing. The investigation explored the internal structure of the coin, emphasizing the brazing drop, to understand the solidification microstructure resulting from the non-equilibrium brazing process. The analysis reveals silver (Ag) content ranging from 92% in the bulk to 97% on the surface due to enrichment. The brazing material is identified as an Ag-Cu-Zn-Pb alloy, and its melting temperature is estimated. Minor element distribution shows zinc (Zn) segregating in secondary (Cu-rich) b-dendrites and the entire eutectic structure, while lead (Pb) is present in Ag-based phases, suggesting its role in reducing Zn solubility within primary (Ag-rich) a-dendrites. This research provides insights into the historical practice of transforming coins into decorative or devotional objects and contributes to understanding the solidification processes involved in brazing (Breda et al., 2013).

A study conducted on compositional, crystallographic, and microstructural properties of incuse silver didrachmae from the Achaean colonies of Metapontum and Caulonia. The focus included metal sources, fabrication processes, and degradation phenomena such as incrustation and embrittlement. Utilizing techniques such as Energy Dispersive X-ray spectroscopy, X-ray Diffractometry, and Scanning Electron and Optical Microscopies, the research revealed a patina primarily composed of chlorargirite. The coins were made of a silver-rich alloy containing approximately 1% each of gold (Au) and copper (Cu). Metallographic analyses expose a complex scenario of inclusions, including unalloyed copper grains, copper/bismuth globuli, and chalcocite. SiO_2 and iron oxide inclusions are prevalent. Distorted twin and strain lines indicated work-hardening of recrystallized flans, with occasional grain polygonalization suggesting secondary recrystallization. Irregularly shaped iron oxide particles acted as crack initiation sites, and inter-granular de-cohesion and inter-granular cracks containing AgCl were observed. The study proposed that information on inclusions and significant gold content may help address provenance and fabrication issues (Giovannelli and Natali, 2005).

Investigations made on ancient Macedonian specimens from seven tombs near the ancient city Lete, dating back to the fourth century BCE. The focus of the study was on metal containers found among grave goods, preserving their original content. The physico-chemical analysis employed non-invasive Energy Dispersive Micro-X-Ray Fluorescence (EDμXRF) spectroscopy for the containers, revealing that a case and a small Pyxis were made of a Cu-Sn alloy with slight impurities, while two miniature bowls were made of almost pure Cu. For content analysis, a combination of EDμXRF, X-Ray Diffraction (XRD), and Gas Chromatography-Mass Spectrometry (GC-MS) were used. This interdisciplinary analytical approach enhances our understanding of pharmaceutical practices in Macedonia during the fourth century BCE (Katsifas, 2018).

An archaeometallurgy based study including the study of metalworking artefacts, tools, waste products, and finished metal objects spanning from the Bronze Age to recent history has been carried out. The study focused on Romanian coins from the nineteenth to early twentieth century CE. The analysis aimed to interpret differences in their composition, considering the nuances of Romanian coinage manufacturing during that period. The unexpected variations in alloy composition from year to year were explored, offering insights into specific historical contexts influencing these changes. The study employed scientific techniques, enhancing the understanding of Romanian coin metallurgy and its evolution over the examined timeframe (Fierascu, 2008).

Another study carried out on the evolution and importance of archaeometry, a field concerned with analyzing archaeological artefacts using scientific methods. It highlighted the historical development of elemental analysis techniques, such as atomic and nuclear methods, for studying objects like coins and glasses. These methods have been crucial in addressing various historical questions related to artefacts composition, manufacturing technology, and provenance. The text emphasizes the significance of tailoring analytical approaches to specific archaeological materials and historical contexts, particularly in solving issues like fineness, debasement, recasting, and forgery in coins, as well as understanding manufacturing techniques and origins in glasses (Guerra, 1995).

A study has been carried out on nondestructive analysis techniques, including quadrupole Inductively Coupled Plasma–Mass Spectrometry (ICP-QMS) and Polarizing, Multi-target, Energy Dispersive X-ray Fluorescence (PEDXRF), to examine Judean coins from the first century BCE and first century CE. The aim was to assess the effectiveness and limitations of these methods for analyzing numismatic artefacts with a patina. By comparing the results with destructive analyses and existing literature databases, the study demonstrated the value of non-destructive techniques even in cases of corrosion. As a case study, the dating of Herod Agrippa I or II "canopy" coins, which holds significance for Biblical historians, was explored. Multiple lines of evidence pointed to attributing these coins to Agrippa I, with a date range of 41 to 45 CE, and suggested their production using ores from Faynan (Feinan), Jordan, and Cyprus (Bower, 2010).

A recent study has employed Rutherford Backscattering Spectrometry (RBS) to examine late Kushan copper coins, aiming to compare the results obtained and shed light on the characteristics of their patina, as well as the underlying causes of corrosion. RBS, a powerful analytical technique commonly used in archaeometry, allows researchers to probe the elemental composition of materials, making it particularly well-suited for investigating the intricate layers of patina and corrosion on ancient metallic artefacts. By leveraging RBS, this work seeks to deepen our understanding of the preservation challenges faced by late Kushan copper coins and provide insights into the environmental and chemical factors influencing their degradation over time (Mayer, 2003).

Compositional study, specifically elemental analysis, has been a fundamental aspect of archaeological chemistry for over a century. This method involves measuring the composition of materials to determine the presence and amount of various elements, allowing all types of archaeological objects to be studied. Over time, compositional analysis equipment has significantly advanced, enabling instruments to measure not only elemental abundances but also isotopic ratios, thereby providing new dimensions of inquiry in archaeological research. This progress has been instrumental in understanding the elemental composition of metal artefacts, which in turn reveals the technological advancements of past civilizations. In particular, the elemental study of coins provides valuable insights into the metal combinations used in their manufacture, shedding light on historical metallurgical practices and economic conditions. Through these analyses, researchers gain a deeper understanding of the technological capabilities and cultural developments of ancient societies (Price & Burton 2011).

Coins are objects of extraordinary historical value and are extensively studied in archaeometry because they provide crucial information about various aspects of the civilizations that used them. The development of ancient coins involved numerous changes in designs, shapes, patterns, and epigraphs, offering both visual and practical insights into different cultures. These changes help researchers understand the chronology and methodologies of ancient societies, revealing information about their economic practices, artistic expressions, political shifts, and technological advancements. The study of coins thus serves as a rich source of historical data, illustrating the evolution of civilizations through tangible, everyday objects (Vijayan, et. al, 2003).

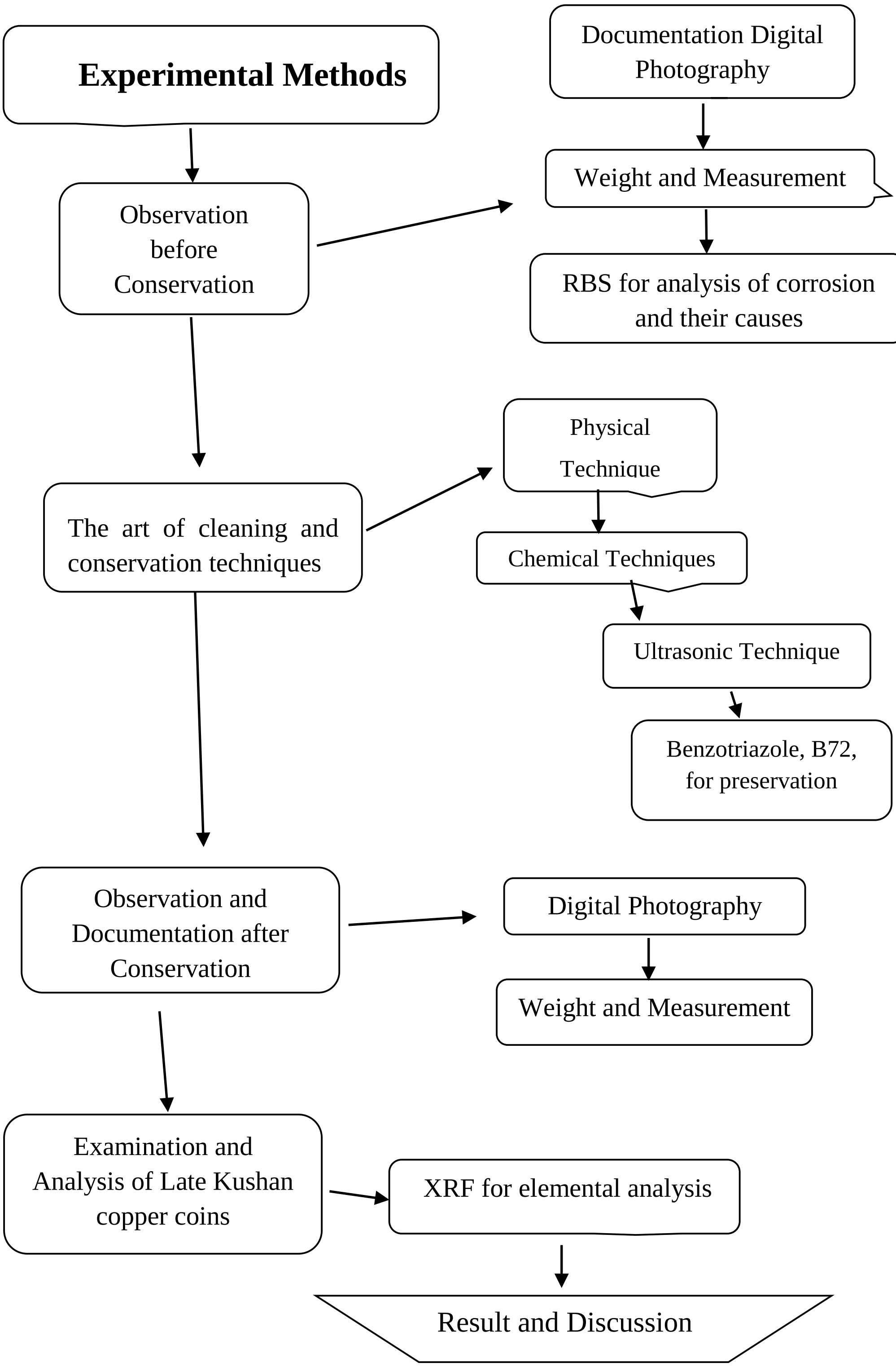
The compositional study of trace elements in ancient coins provides essential information about the technology, geography, politics, and historical contexts of the periods in which they were minted. Elemental analysis reveals the economic conditions and metallurgical practices of the time, offering insights into the resources and techniques used in coin production. This analysis also highlights the direct relationship between a civilization's economy and its metallurgical capabilities. Additionally, the precise minting of coins, often featuring accurate portraits of reigning monarchs, reflects the technological proficiency and political significance of coinage. By examining these elements, researchers can gain a comprehensive understanding of the historical and cultural landscape during the time of the coins' creation (Kallithralias-Kontos, et. al, 1996).

Energy Dispersive X-ray Fluorescence (EDXRF) has emerged as a powerful tool for obtaining both quantitative and semi-quantitative information on cultural heritage materials. This technique is highly valued for its non-destructive nature, rapid analysis, and ability to detect multiple elements simultaneously. By analyzing the surface of samples, EDXRF determines their elemental composition with precision, making it an ideal choice for studying artefacts without causing any damage. Its application in cultural heritage studies ensures the preservation of valuable historical objects while providing essential data that can inform conservation strategies, provenance studies, and the understanding of ancient manufacturing techniques (Guerra, 1998).

CHAPTER-3

RESEARCH METHODOLOGY

A flowchart showing the different steps involved in the conservation and elemental analysis in this present research.



The research methodology employed in this study is crucial to its success, with particular emphasis on the careful execution of the fieldwork and subsequent scientific analysis. The initial phase involved comprehensive fieldwork, including the collection of coins, thorough sampling procedures, detailed documentation, judicious observation, nuanced interpretation, thorough surveying, and precise recording of data. This phase was fundamental as it laid the groundwork for the subsequent scientific analysis. Following the fieldwork, a rigorous scientific analysis was conducted, employing various methodologies and techniques to probe deeper into the collected data. This analysis was characterized by its careful attention to detail, adherence to scientific protocols, and utilization of state-of-the-art tools and technologies. By integrating robust fieldwork with rigorous scientific analysis, the study ensured a comprehensive understanding of the subject matter, yielding insights that contribute significantly to the body of knowledge in the field. Thus, the research methodology served as the cornerstone of the study, underpinning its credibility, reliability, and scholarly precision.

In Pakistan, the landscape for scientific laboratories dedicated to the conservation of coins is relatively meager, with only two functional facilities known to exist. One of these labs operates within the historical confines of Lahore Fort and was established by the Department of Archaeology and Museums, Govt. of the Punjab, back in 2011. Despite its presence, this lab's capabilities are somewhat limited; it primarily relies on chemical treatments for the cleaning and treatment of archaeological artefacts, including coins. However, a notable absence is the lack of a preservation chamber, which is essential for consolidating artefacts post-conservation. In contrast, the second laboratory situated within the Sir Syed Memorial at Islamabad Museum presents a more promising picture. This newer facility boasts better equipment and resources compared to its Lahore counterpart. Notably, the Islamabad Museum lab houses a well-established Digitalization and Conservation Section, a feature that proved invaluable for the present research endeavor. The digitalization capabilities enabled the scholar to accurately document a substantial collection of coins, particularly focusing on the Late Kushans, thereby enriching the scholarly understanding of this historical period.

In the Conservation Section, a variety of digital machines are available to facilitate the cleaning and preservation of archaeological artefacts. These machines include an ultrasonic machine (Ultrasonic Cleaning Bath), which utilizes high-frequency sound waves to remove dirt and debris gently. Additionally, an incubator aiding in the precise measurement and control of various environmental factors such as temperature and humidity, crucial for optimal artifact preservation. Furthermore, a dehydrator plays a vital role in removing moisture from artefacts, preventing deterioration caused by fungal growth or corrosion. Various chemicals are also utilized for conservation purposes, each serving specific functions such as cleaning, stabilizing, or protecting artefacts from further decay.

In addition to digital equipment, physical tools are essential for the manual cleaning of artefacts. These tools may include brushes, scalpels, tweezers, and microscopes, among others, allowing conservators to delicately remove dirt and corrosion without damaging the artifact's surface.

The present study is focused on investigating several key aspects related to Late Kushan copper coins. Firstly, it aims to investigate the morphometric features of these coins, seeking to understand their physical characteristics and dimensions in detail. Additionally, the study aims to identify the major causes and levels of corrosion affecting these artefacts, shedding light on the environmental and historical factors contributing to their deterioration. Furthermore, the research endeavors to explore non-destructive and more efficient cleaning and conservation methods, recognizing the importance of preserving these cultural artefacts for future generations. Finally, the study seeks to analyze the major elements present in the Late Kushan copper coins, providing insights into the metallurgical composition and production techniques employed during this historical period. By addressing these multifaceted aspects, the study aims to contribute significantly to our understanding of Late Kushan coinage while also offering practical insights into their preservation and conservation.

The present study unfolds through a systematic approach comprising three fundamental steps:

1. Initially, the focus lied on accurately documenting the Late Kushan copper coins, meticulously recording their physical attributes and any observable deterioration. This step served as a crucial foundation, providing a comprehensive understanding of the artefacts before any conservation interventions.
2. Subsequently, the study transitioned into the implementation of conservation methods aimed at addressing the identified deterioration causes. Through careful selection and application of preservation techniques, the aim was to mitigate further degradation and ensure the long-term survival of these historical artefacts.
3. Finally, the study culminated in the analysis of the composition of Late Kushan copper coins. By delving into the metallurgical makeup of these coins, insights into their production methods, as well as the materials used, can be gleaned, enriching the understanding of Kushan numismatics and ancient metallurgy. Through these sequential steps, the study

endeavoured to not only preserve but also deepen our knowledge of the Late Kushan coinage, contributing to the broader field of archaeology and cultural heritage conservation.

3.1 Conservation Process of Late Kushan Copper Coins

The purpose of conservation treatment for metal cultural heritage is multifaceted, aiming not only to restore the original appearance of cultural properties damaged by corrosion but also to ensure their long-term preservation by mitigating further corrosion. While metal cultural heritage encompasses a wide range of materials such as iron, copper, gold, and silver, this research is specifically focused on conservation treatment methods for copper coins. Copper coins, like other metal artefacts, are subject to corrosion and deterioration over time due to environmental factors such as moisture, air, and pollutants.

The conservation treatment of copper coins followed a systematic process to ensure comprehensive care and preservation. It began with a pre-treatment investigation, which involved assessing the coins' condition through methods like photography and scientific analysis. Next, washing and removal of foreign substances revealed the true state of the coins by eliminating surface dirt and grime. Subsequently, stabilization treatment using compounds like benzotriazole (BTA) helped inhibit further corrosion, followed by thorough drying to remove excess moisture. where needed, reinforcement and restoration work has been undertaken to address structural weaknesses or damage and restore the coins' original appearance.

Once the treatment was completed, high-quality photographs were taken to document the coins' restored condition. Finally, a treatment record card was prepared, detailing the conservation process, observations, and treatments applied. The coins were then carefully packed using archival materials to ensure their protection during storage or display. This structured approach guarantees the effective preservation of copper coins, safeguarding their historical and cultural significance for future generations (KCHF, 2022).

3.1.1 Pre-treatment Investigation

Pre-treatment investigation is an essential initial step in the conservation process for copper coins, aimed at understanding their shape, structure, and degree of corrosion. This comprehensive process involved several key components such as photography, actual measurements, scientific non-destructive investigation techniques and preparation of conservation record cards. Together, these steps formed a comprehensive pre-treatment investigation that guided conservation efforts to preserve copper coins for future generations (Soyoung, 2021).

3.1.1.1 Photography

Photography, as an art and a profession, relies on a variety of tools to achieve its desired outcomes. In the present research, initially work started with the documentation by proper photography of Late Kushan copper coins before applying conservation techniques. A collection of 390 Late Kushan copper coins were selected within the cabinets of the Islamabad Museum, the origins and documentation of which remained unknown. This selected group of coins has not undergone cleaning processes, making them ideal objects for the application of cleaning and conservation techniques. The absence of prior cleaning provided an opportunity for researchers to apply specialized methods to reveal any hidden details or inscriptions that may offer clues about the coins' origin and historical significance.

Fig 1: Selected coins from reserve collection of Islamabad Museum

To begin the photography process, the camera and lights were first installed on the photo stand. With the setup ready, coins were methodically placed one by one, alternating between obverse and reverse sides, each accompanied by name tags for identification. The background paper, with its consistent color and texture, provided a neutral backdrop against which the coins stand out. Throughout this process, the camera was consistently set in a horizontal composition, maintaining a uniform framing for the photographs (KCHF, 2022).

Fig 2: the camera and lights are installed

Fig 3: Tag numbers for identification   Fig 4: background paper, with its consistent color and texture

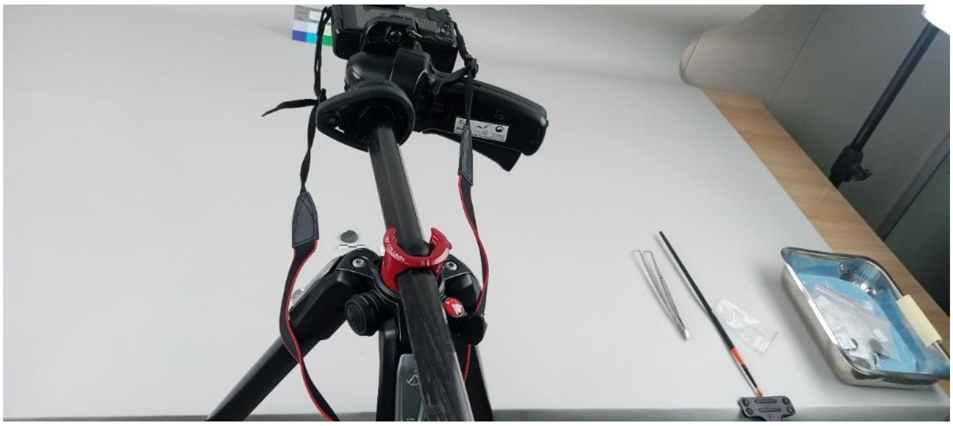


Fig 5: camera set in a horizontal composition

3.1.1.2 Actual Measurement

Scaling

After precisely documenting the Late Kushan copper coins, the researcher proceeded to measure them using a Vernier Caliper, a critical tool for ensuring accurate dimensions. Alongside the Vernier Caliper, the toolkit comprised conservation record cards, pencils, and scales, among other essential instruments. Each step of the measurement process was conducted with utmost care and precision to capture the intricate details of these Late Kushan copper coins.

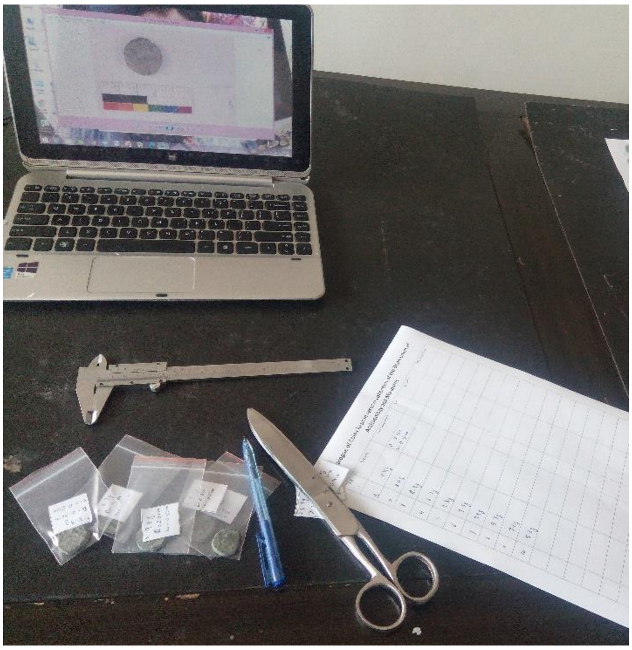
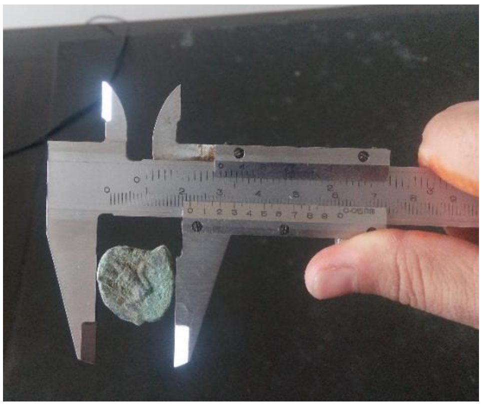


Fig 6: tools for Scaling

The researcher carefully positioned the coin between the calipers, ensuring alignment with its surface, and proceeded to note the width and diameter. Reading the scale of the calipers, measurements were recorded in millimeters with precision. During the measurement process, particular attention was paid to measure the front of the coin to account for potential variations in dimensions across its surface. In instances where different areas of the coin exhibited distinct dimensions, the researcher diligently noted both the minimum and maximum values observed. This meticulous approach ensured thorough documentation and provided a comprehensive understanding of the coin's physical attributes. Such detailed measurements are invaluable for scholarly research, aiding in classification, analysis, and preservation efforts within numismatics and historical studies (Ibid).



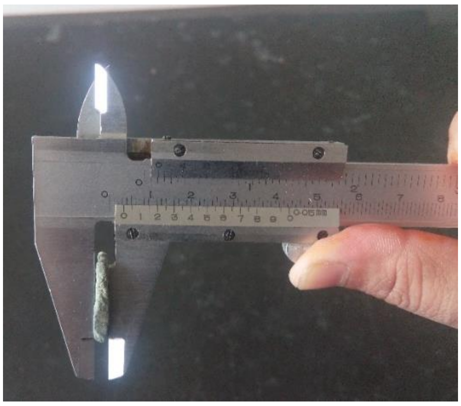


Fig 7: measurement of diameter **Fig 8: measurement of width**

Weight

To measure the weight of the coins, researcher employed an Electronic Scale Machine (Weighing Balance) known for its sensitivity and accuracy. Carefully placing the coin to be measured on the balance, waited patiently for the scale to stabilize, ensuring an accurate reading. Once the number on the electronic scale ceased fluctuating, researchers recorded the weight in grams before conservation. This particular process guarantees precise measurements, essential for cataloging and analyzing the coins within numismatics and historical research (Ibid).

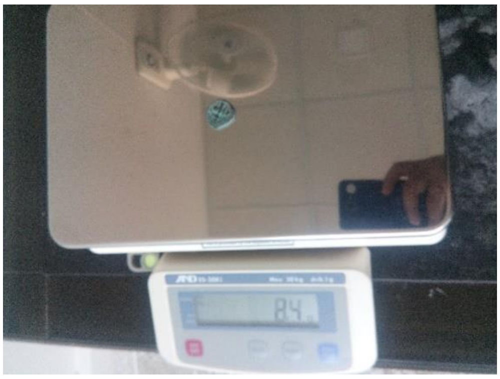


Fig 9: weight machine to stabilized **Fig 10: recorded weight in grams**

Following the scaling and weight measurement process, each Late Kushan copper coin was precisely placed into individual sample bags, one by one. Alongside each coin, a corresponding record card was carefully inserted to facilitate classification and identification of the specific copper coin. With every coin securely stored and accompanied by its record card, researcher efficiently cataloged, studied, and interpreted the historical significance of the Late Kushan copper coins within the broader context of numismatics and ancient civilizations.

Fig 11: coin in sample bag with record card before conservation

Fig 12: all coins documented with record card

Experimental research predominantly took place within laboratory settings to establish a foundational understanding. The primary advantage of employing experimental designs was the opportunity to identify unknown specimens and samples.

3.1.1.3 Examine Corrosion Causes through Rutherford Backscattering Spectrometry (RBS)

Rutherford Backscattering Spectrometry (RBS) is a powerful nuclear method utilized for analyzing the near-surface layers of solid materials. In this technique, a target material is bombarded with ions at energies typically ranging from 0.5 to 4 MeV (Mega electron Volts). The backscattered projectiles are then detected, and their energies are recorded using an energy-sensitive detector, commonly a solid-state detector.

One of the primary advantages of RBS is its ability to provide quantitative determination of material composition and depth profiling of individual elements. RBS is non-destructive, meaning it does not cause damage to the sample being analyzed. RBS offers excellent depth resolution, typically on the order of several nanometers, allowing precise characterization of thin surface layers. The technique also exhibits very good sensitivity for heavy elements, with detection limits reaching down to the parts-per-million (ppm) level. The depth of analysis achievable with RBS depends on the incident ion species, with He-ion bombardment typically probing depths of around 2 µm and proton bombardment reaching depths of approximately 20 µm (Mayer, 2013).

Rutherford Backscattering Spectrometry (RBS) traces its roots back to the seminal experiments conducted by Ernest Rutherford in 1911, where he utilized the backscattering of alpha particles from a gold film to unveil the fine structure of the atom, ultimately leading to the discovery of the atomic nucleus. However, it wasn't until 1957 that RBS emerged as a method for materials analysis, with its formal description provided by Rubin et al. This milestone laid the foundation for the modern applications of RBS, which have since become widespread in various fields.

Rutherford Backscattering Spectrometry (RBS) encompasses a range of elastic ion scattering techniques employing incident ion energies typically spanning from 500 keV to several MeV. Protons, alpha particles (4He), and occasionally lithium ions serve as common projectiles in RBS analyses. These ions are directed towards the target material at backscattering angles typically falling within the range of 150 to 170 degrees, although variations in angles or the use of different projectiles may occur in specialized applications. By selecting specific incident energies, angles, and projectile types, researchers can tailor RBS experiments to suit the requirements of their particular analysis, enabling precise characterization of material composition and structure with excellent depth resolution and sensitivity (Ibid).

This technique relies on the principle of elastic scattering of ions, typically helium or hydrogen, from the atoms in the sample material. However, it's important to note that RBS can only probe a surface layer of limited depth, typically ranging from a few micrometers to a few tens of micrometers. Consequently, while RBS provides valuable insights into surface chemistry and elemental composition, it may not capture information about subsurface layers or bulk material properties. Despite this limitation, RBS remains a powerful tool for characterizing ancient coins and other artefacts, offering valuable information for archaeological and historical studies (Ibid).

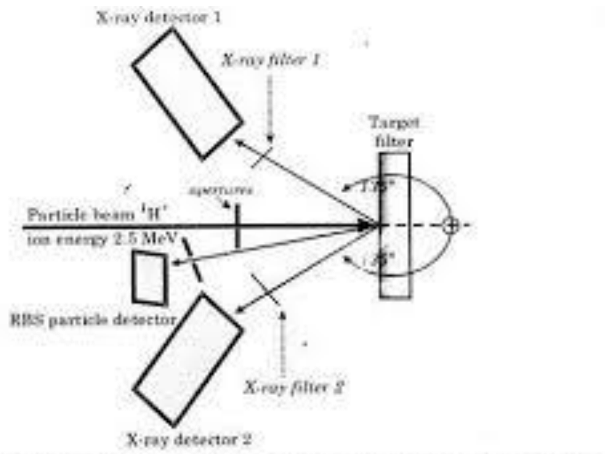


Fig 13: Schematic diagram of a Rutherford Backscattering Spectrometer (Mayer, 2003)

Material and Methods

5 copper coins of Late Kushans period were selected for RBS analysis which were collected from the reserve collection of Islamabad Museum. These coins displayed severe corrosion, often concealed beneath thick layers of patina. Late Kushan Copper Coins have been submitting to the National Centre for Physics **(NCP)** Laboratory known as Data Analysis Lab. All the coins

were analyzed for the elemental composition of surface layer. The coins were then subjected to Rutherford Backscattering Spectrometry (**RBS)** analysis.

Experimental Set-up

The experiments were performed at the Data Analysis Labs of the National Centre for Physics **(NCP) '**Islamabad**'.** The detection limit of RBS has been derived theoretically and representation of trace element analysis has been calculated. It has been shown that the best detection limit obtained with 4 MeV alpha ion beams which only depend on the sample matrix.

3.1.2 Cleaning and foreign substances removal

Cleaning is the essential activity of eliminating dirt or foreign substances attached to a surface and removing corroded compounds adhering to it. Whether it's scrubbing away grime from kitchen counters or polishing tarnished silverware, cleaning serves to restore surfaces to their pristine state. However, in the realm of artefacts and historical objects, cleaning takes on a more specialized meaning. Here, it encompasses not just the removal of dirt and grime but also the delicate process of uncovering an object's original form. This nuanced approach involves meticulous attention to detail, utilizing techniques and tools tailored to the specific material and historical context of the artifact. In this context, cleaning becomes an act of uncovering history, peeling away layers of debris to reveal the true essence of an object, allowing it to shine once again in its intended glory (KCHF, 2022).

Cleaning coins is an art not a science. This is because all the coins are not in equal size and present in the same condition. Some coins are clean with just only scrub of tooth brush, soap and water but many coins need proper techniques and methods to clean them properly. Coins need to be cleaned depending on the coin metal and according to the dirt, crustation, and/or oxidation present on the coin. Throughout the entire process, researcher will document their work to keep a record of the treatment methods applied and the changes observed (Sandes, 2017).

In the realm of cleaning and removing foreign substances, two primary methodologies prevail: physical and chemical methods. The physical approach involves tools such as toothpicks, scalpels, cotton swabs, and brushes. One notable advantage of the physical method is its minimal risk of secondary damage from the introduction of chemicals. However, it falls short in terms of ease of foreign substance removal when compared to chemical methods. On the other hand, chemical methods, exemplified by techniques like the silver oxide method, offer the advantage of swift and efficient removal. Nevertheless, they carry a heightened risk of causing secondary damage due to residual chemicals. Thus, while physical methods mitigate the risk of drug-induced harm, they may struggle with complete foreign substance removal, whereas chemical methods provide easy removal but entail a higher potential for secondary damage (KCHF, 2022).

In the present research, there were three different cleaning techniques used for Late Kushan copper coins which were collected from the reserved collection of Islamabad Museum. These techniques were:

- Physical Technique
- Chemical Technique
- Electrical or Electroplating Technique

A method of cleaning ancient coins began with two non-acidic oils. One was kerosene oil also known as paraffin, a combustible hydrocarbon liquid which is derived from petroleum recommended to clean the object following contact with oily materials. In the present research, Late Kushan copper coins were first placed in kerosene oil for a week. This practice is not recommended for the reason that the solvent may defeat the skin and rust could not be removed from the surface of the coins. It can be used to clean bicycle and motorcycle chains of old lubricant oil before re-lubrication (Shaltami, 2020).


Fig 14: Late Kushan cooper coins after kerosene oil

Using olive oil as a cleaning agent for ancient coins is a practice that has garnered mixed opinions among numismatists and conservationists. While olive oil is indeed low in acid and can effectively penetrate encrustations and loosen dirt and grime, its long-term effects on coin surfaces can be concerning. Late Kushan copper coins were soaked in olive oil and allowing them to rest for a week. However, the dark or burnt appearance have been observing may indicate that the oil has interacted with the coin's patina or surface layer in a way that altered their appearance. While olive oil may initially seem like a gentle cleaning agent, its impact on the long-term preservation and authenticity of ancient coins warrants careful consideration (Sandes, 2017).

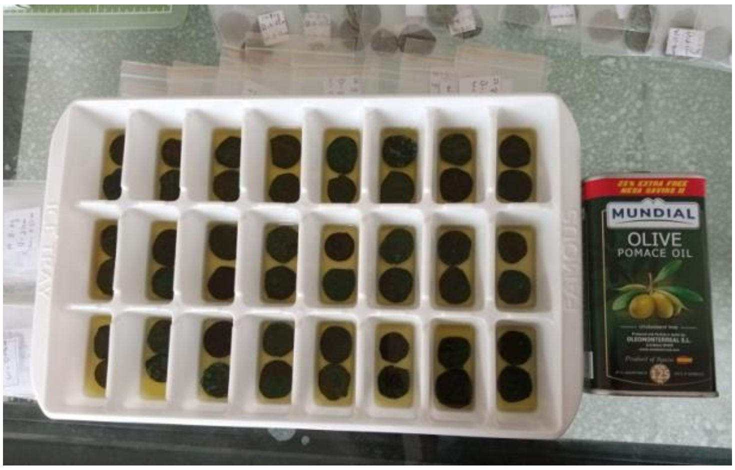


Fig 15: Late Kushan copper coins in olive oil

The process for cleaning the ancient coins after removing them from the olive oil involved using liquid soap and a toothbrush to scrub away remaining dirt and grime. Liquid soap worked by lowering the surface tension of water, which allowed it to penetrate dirt, blend grease, and lift dirt into foam. In the context of cleaning ancient coins, removing dirt is crucial as it can obscure details and affect their overall appearance and value. It is essential to approach cleaning with caution, as overzealous scrubbing or prolonged exposure to cleaning agents can potentially damage the coins' surfaces or remove valuable patina. Once the majority of visible dirt and grime have been removed, it's generally advisable to stop cleaning to avoid any potential damage. Ultimately, patience and careful observation are key when cleaning ancient coins to achieve the desired results while minimizing the risk of unintended harm (Ibid, 2017).

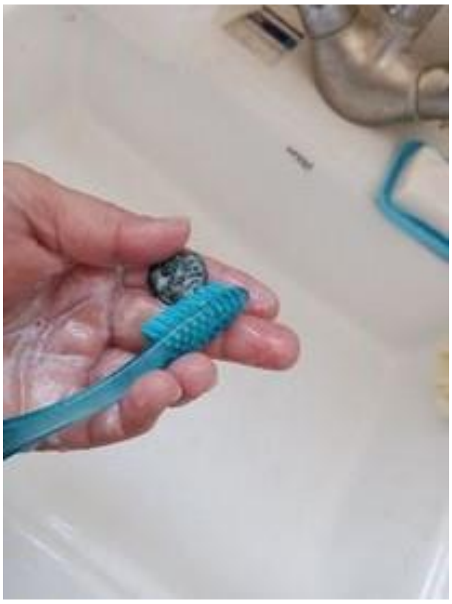


Fig 16: Wash Late Kushan copper coins with brush

After removing as much dirt and mud as possible from the ancient coins using a brush and soap under running water, it's crucial to ensure thorough rinsing to eliminate any residue left behind by the cleaning process. Residue can potentially interfere with the coin's appearance and long-term preservation. Proper drying techniques are then essential to prevent moisture from causing further damage, such as corrosion or the development of mold. In this case, employing an advanced dehydrator dish and placing the Late Kushan copper coins in a dehydrator chamber respectively is a prudent approach. A dehydrator is a device designed to remove moisture from artefacts, aiding in their preservation. By utilizing a combination of heat and airflow, the dehydrator facilitates the reduction of water content in the coins, expediting the drying process while minimizing the risk of damage. This method ensured that the Late Kushan copper coins were thoroughly dried, reducing the likelihood of moisture-related issues and contributing to their long-term stability and conservation (KCHF, 2022).

Fig 17: Late kushan copper coins in Advance Dehydrator Chamber

Late Kushan Copper Coin after olive oil

Fig 18: obverse side

Fig 19: reverse side

The variability in soil conditions can pose challenges in cleaning ancient coins, as some may not fit neatly into previously established cleaning categories regardless of the soaking duration. Following the dehydration process, the coins are carefully placed back into sample bags according to their assigned numbers. At this stage, meticulous examination under a stereo-microscope is essential to assess the coins' condition and identify areas requiring further attention. Subsequently, the mechanical cleaning of Late Kushan copper coins commences, utilizing diamond-dusted dental pick tools. These tools offer precision and control, allowing conservators to gently remove stubborn encrustations and debris without causing damage to the coin's surface. The use of diamond-dusted tools ensures that the cleaning process is both effective and delicate, minimizing the risk of unintentional harm to the coins. This methodological approach to cleaning ensured that each coin is treated with care and attention to detail, ultimately contributing to their preservation and continued study within the field of numismatics

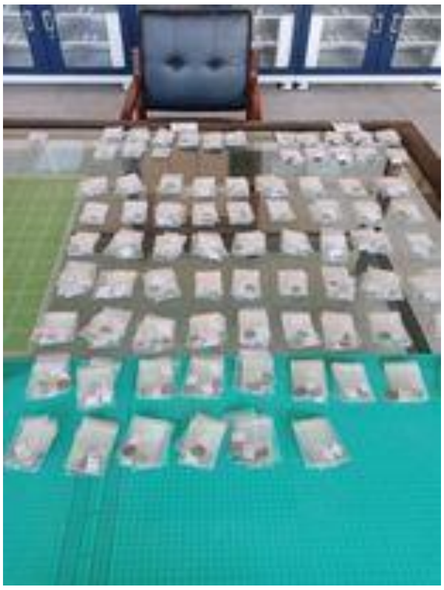


Fig 20: Classification of Late Kushan copper coins

Fig 21: observe Late Kushan copper coin under Stereo microscope

3.1.3 Physical Cleaning and Observing Morphometric Features of Late Kushan Copper Coins Using a Stereomicroscope

The process of cleaning and observing the morphometric features of Late Kushan copper coins using a stereomicroscope required careful handling and a methodical approach to ensure both the conservation of the coin and the accuracy of the observations.

The study of ancient coins, particularly those from the Late Kushan period, requires detailed analysis of their physical characteristics to better understand their typology, production techniques, and historical significance. One of the most effective tools for observing the morphometric features of these copper coins is the stereomicroscope, which allows for three-dimensional visualization at magnified levels.

The use of a stereomicroscope in the observation of Late Kushan copper coins is crucial for the detailed analysis of their morphometric features. It provides a clear and magnified view of the coin’s surface, enabling researchers to study intricate details that are not visible to the naked eye. By integrating these observations with other archaeological data, scholars can gain deeper insights into the economic, cultural, and historical contexts of the Late Kushan Empire (Korea Culture Heritage Foundation: 2022).

Sample Selection and Preparation

Before the observation, a representative sample of Late Kushan copper coins is selected based on the condition of the coin. Each coin is cleaned carefully to remove surface dirt and patina while observing its original features. The coins are then placed under the stereomicroscope for detailed observation, ensuring that each coin is stable to avoid movement during examination (Ibid).

Stereomicroscope Setup and Calibration

The stereomicroscope placed on a stable, flat surface to prevent any movement during the observation process. Once securely positioned, connect the power cord to illuminate the work area and provided the necessary light to view the coin’s fine details clearly.

The stereomicroscope is configured with appropriate magnification levels, usually between 10x and 40x, depending on the size and complexity of the features on the coin. Calibration is essential to ensure that the measurements taken during the observation are accurate. The stereomicroscope's lighting system is adjusted to avoid shadows and reflections that could distort the image. The use of angled light sources enhances the visibility of fine details, such as inscriptions, mint marks, and die errors (Ibid).

Observation of Morphometric Features

After setting up the stereomicroscope, placed the Late Kushan copper coin to be examined on the stage or base of the microscope. Adjusted the magnification using the coarse adjustment knob to bring the coin into general focus. The coarse adjustment knob allowed for significant changes in focus, making it easier to view the overall structure and surface details of the coin. Once the coin is visible, further refine the focused using the fine adjustment knob, which enables precise focusing for clearer and sharper images. Fine adjustments are critical for viewing intricate details such as inscriptions, symbols, and any mint marks.

The stereomicroscope allowed for a close examination of the morphometric features of Late Kushan copper coins, such as diameter, thickness, edge patterns, and surface wear. Detailed notes and photographs are taken for each coin, with particular attention to any unique or irregular features that may indicate variations in production or wear patterns over time (Ibid).

Observing the Coin Through the Oculars

With the stereomicroscope properly focused, observe the Late Kushan copper coin through the ocular lenses, which are the eyepieces of the microscope. The stereoscopic nature of the microscope provided a three-dimensional view, making it possible to study both the flat and raised areas of the coin in great detail. This is especially useful when examining reliefs, engravings, and other surface irregularities. By rotating the coin under the microscope, every angle can be observed, ensuring that no detail is overlooked (Ibid).

Cleaning and Removal of Outer Substances

Once the coin's surface has been examined, the next step is to clean the coin. The stereomicroscope's high magnification allows for the identification of any foreign substances, such as dirt, corrosion, or other materials that may have accumulated over time. Cleaning is done carefully to avoid damaging the coin's original features. Soft brushes, non-abrasive tools, or micro-tools are used to gently remove dirt and corrosion from the surface. Throughout the cleaning process, the stereomicroscope is used to monitor progress, ensuring that only unwanted material is removed, while preserving the coin's original patina and features.

Corrosive deposits or other tough materials adhering to the coin's surface are examined closely under magnification to determine the best method of removal. In some cases, mild solvents may be applied to soften the corrosion, which can then be delicately scraped off using fine tools. The stereomicroscope provides a clear, magnified view during this process, allowing for precise removal without compromising the coin's historical integrity (Ibid).

Final Examination and Documentation

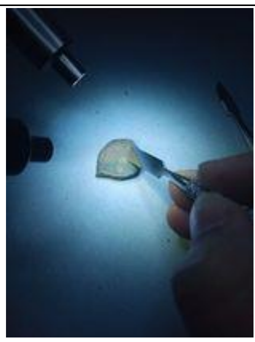
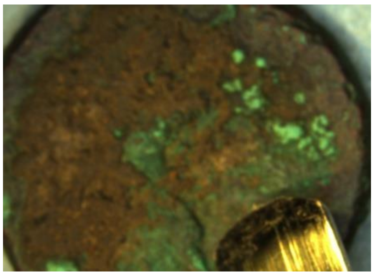
After cleaning, the coin is re-examined under the stereomicroscope to ensure that all foreign substances have been successfully removed and the coin's features are clearly visible. The fine adjustment knob may be used again to enhance the clarity of the newly cleaned surface. Detailed photographs or sketches are taken to document the coin's features post-cleaning, capturing inscriptions, design elements, and any changes resulting from the cleaning process. This documentation is crucial for further analysis and for maintaining records of the coin's condition and features before and after cleaning (Ibid).

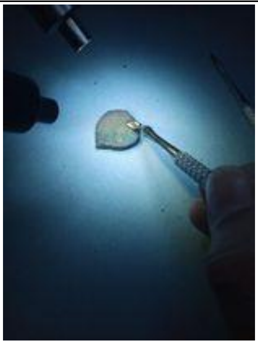
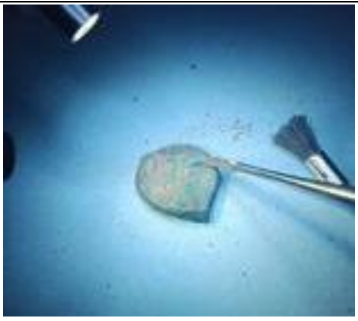
3.1.4 Physical Technique

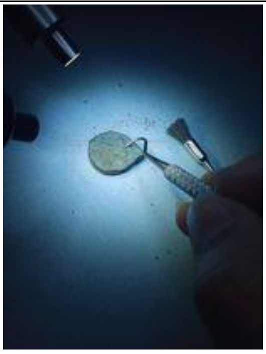
Physical Technique is a long and time consuming method for cleaning ancient coins. In this technique used various laboratory equipment for mechanical cleaning process. It is totally depending upon the scraping and brushing to clean coins (Sandes, 2017). Different steps which have been used during physical technique discussed below:

- The process of physically removing soil and foreign substances from ancient coins involves several meticulous methods tailored to preserve their integrity. Using a toothpick, conservators gently dislodge soil, carefully manoeuvring to avoid damaging the coin's surface. Blowing away loose debris with a blower aids in this process, while stubborn soil is delicately addressed with the toothpick. Special attention was paid to organic matter, aiming to maintain its attachment to copper coins wherever possible.
- Employing a scalpel for physical cleaning allowed for precise removal of soil and foreign substances, observed under a stereoscopic microscope to ensure accuracy. While corrosion and foreign substances are meticulously removed, rust formation on the coin's surface is ideally left untouched. Regular use of a blower during cleaning helps maintain visibility and cleanliness, with utmost care taken to avoid surface damage with the scalpel.
- Another method involves using a cotton swab and ethyl alcohol for physical cleaning, ensuring the swab is replaced if contaminated to prevent cross-contamination. Attention to the coin's surface and any changes during cleaning is paramount, with close observation for any signs of alteration or exfoliation.
- Similarly, cleaning with a brush and ethyl alcohol requires frequent cleaning of the brush to prevent contamination. As with other methods, the state of the coin's surface is carefully monitored, with any changes noted and addressed accordingly to preserve its integrity (KCHF, 2022).
- The diamond-dusted dental pick, with its sharp points and durable steel construction, serves as a valuable tool in the cleaning of copper coins. Its precision allows conservators to delicately explore the coin's surface, gently removing encrustations and debris without causing damage. These tools offer the advantage of enhanced visual access during treatment, enabling conservators to navigate the intricacies of each coin with care and precision. However, utilizing dental pick tools for coin cleaning demands ample time and patience. Given the delicate nature of the process and the need for meticulous attention to detail, conservators must exercise patience and diligence as they work to reveal the coin's features while preserving its historical integrity. Through the careful application of these tools, conservators can effectively clean copper coins, unveiling their hidden details and ensuring their long-term preservation for future study and appreciation (Sandes, 2017).

Fig 22: Diamond-dusted dental pick tools

<table>
<tr>
<td>
Equipment: X acto-knife
Function: X acto-knife is used to as a scalpel for cleaning technique. It is very simple craft knife also known as common house hold tool. It removed dirt over the plan surface area of the Late Kushan copper coins. Only used the curved blade seen right, rather that the flat blades and with all cleaning tools, this one is used for specific purposes only.</td>
<td>

Stereomicroscopic image
Equipment: Shovel tool
Function: Firstly overall surface of coins cleaned from shovel tool. It helped to clear rust which was present in the most upper layer of the coin.</td>
</tr>
</table>

<table>
<tr><td></td><td>Shovel clear smoothly the large surface rust at one time circulation.</td></tr>
<tr><td>
Equipment: Pointed Shovel dental tool
Function: After surface cleaning, removed rust from the little depth of the Late Kushan copper coins by pointed shovel dental tool. Pointed dental pick used in coins from sideways rather than point first. Little pressure applied and used the tool in a circular manner rather than left-right or up and down manner.</td><td>
Equipment: Spoon Excavator dental tool
Function: Another metal stick-type tool but designed with a tiny spoon shaped cutting edge. Variations of this tool have allowed removing different levels of softened decay or temporary fillings.</td></tr>
<tr><td>
Equipment: Discoid-Cleoid Carver
Function: Discoid cleoid is disk like shaped. It has pointed, sharp and carve end which remove rust</td><td>
Equipment: Pointed Dental Pick Tool
Function: Pointed tool removed the dirt from small depths and edge of the images. Pointed tool as flat as</td></tr>
</table>

from edge of the coins images by carving method.	possible against the coin’s surface and used only circular motion.
 Equipment: **Explorers** Function: The common dental pick, with its hard steel, sharp and thin pointed tips have been used to probe and scrape off the dirt and corrosions surface of the coins. Used the tool on the coin’s field, rather than the details. Little pressure has been applied\in a circular manner rather than left-right or up and down. It removed all the remaining rusted surface edges which other tools could not be clean.	 Equipment: **Scalpel Handle with Blades** Function: Scalpel Handles is a small and extremely sharp instrument used for surgery and anatomical dissection. Scalpel Handles have been intended to be used with surgical blades for separated or cuts the outer layer of coin’s rust and encrustation easily (Sandes, 2017).

Each of these methods exemplifies the meticulous care and attention required in the cleaning process, balancing the removal of soil and foreign substances with the preservation of the coin's historical integrity and physical condition. Through precise techniques and close observation, conservators ensure that ancient coins are cleaned effectively while minimizing the risk of damage or alteration (Ibid, 2017).

3.1.4.1 Physical cleaning with Dremel Mini-Mite Tools

The Dremel Mini-Mite, a battery-powered tool known for its lightweight design and responsiveness, is a versatile precision tool suitable for various tasks including drilling, sanding, shaping, detailing, and rust removal. Specifically, when it comes to the cleaning and polishing of Late Kushan copper coins, the Dremel Mini-Mite proves to be a valuable asset. Its precise control and range of accessories make it well-suited for delicately removing excess rust and other surface imperfections from coins without causing damage. By utilizing the tool at its lowest speed setting of 5000rpm, researcher can ensure gentle and controlled treatment of the coins, minimizing the risk of overworking or damaging the metal. The Dremel Mini-Mite's combination of portability, precision, and versatility makes it an effective tool for numismatists and conservators seeking to clean and restore Late Kushan copper coins while preserving their historical integrity and value.

Fig 23: diamond-dusted Dremel tools

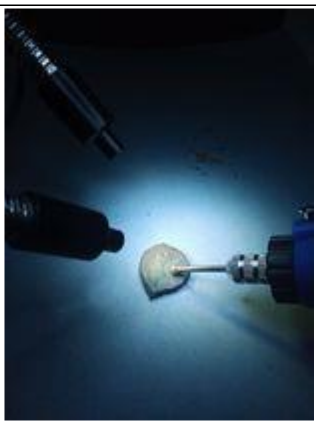
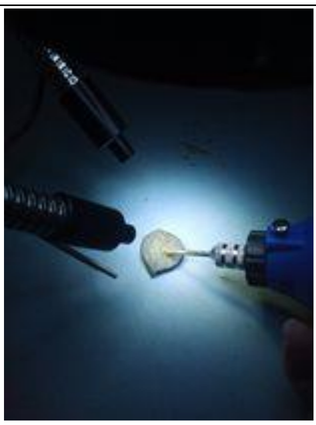
Utilizing ten tiny diamond-dusted Dremel tools, along with rubber Dremel tools for surface smoothing, has proven effective in cleaning fixed coins of encrustations. The precision and versatility of Dremel tools make them valuable assets in the restoration process of ancient coins. However, their usage demands not only practice but also patience, as the delicate nature of coin surfaces requires careful handling. Despite their effectiveness in removing encrustations, Dremel tools are chosen selectively, ensuring minimal harm to the patina of ancient coins. They are primarily reserved for coins that cannot be adequately cleaned using diamond-dusted dental pick tools, thus preserving the integrity and historical value of the coins. This selective approach ensures that Dremel tools are employed judiciously, contributing to the careful restoration and preservation of ancient coinage.

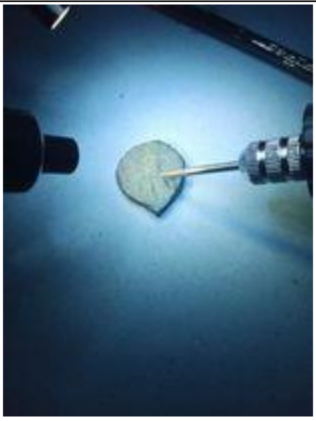
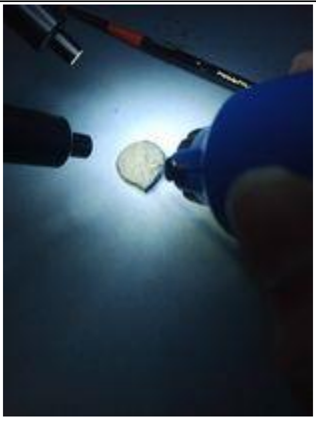
Fig 24: Ten tiny Diamond Dusted Dremel Tools

Fig 25: Cleaning ancient coins

In present study the safer approach was consistently employed by utilizing diamond-dusted Dremel tools in circular motions. This technique allowed for a more controlled and gentle cleaning process, minimizing the risk of unintended abrasions or scratches on the coin's surface. Circular motions distributed the pressure evenly, reducing the likelihood of causing harm to the coin's patina or details. By adhering to this method, researcher prioritize the preservation of the coin's historical integrity while effectively removing encrustations and debris. It's essential to employ techniques that prioritize caution and precision when cleaning ancient coins to ensure their long-term preservation and value (Ibid).

Fig 26: physical cleaning under stereomicroscope

	
Equipment: **Bullet tip Dremel tool** Function: Bullet tip Dremel tool have been removed encrustations or dirt and better see the legends, field and details at low pressure. Only touched the bullet tip to the surface of the coins and let them to do work.	Equipment: **The Flame Tip** Function: The Flame Tip is a broad tip and I have used it for the encrustations, fields and specially coin's details. It could be harsh so have only used under some massive encrustation conditions.

 Equipment: **The flame thin tip** Function: This Tip is thin and sharp than the previous flame tip. This tool is used for further cleaning and smoothing. Its sharp end was enough to cleaned legends and details of rusted coins.	 Equipment: **The point tip** Function: The point tip is best for cleaning between the details and legends. I have used point tip to remove the bulk of the remaining rust on the ancient coins. Point tip helped to clean dirt from the deep edges of the coins.
 Equipment: **Bullet Tip** Function: I have used Diamond dusted rubber tools for cleaning and smoothing	 Equipment: **Bullet Arrow** Function: Narrow arrow of bullet defined the images or surface of the coins. For more smoothing stripped

portrait and the fields of the ancient rusted coins.	and sharp details have been brightened and shined.
 Equipment: **Dremel Soft brass bristle cup brush** Function: The Dremel soft brass bristle cup brush is a remarkable tool that can be used for many purposes. I did not develop any pressure on coins and just touched the coin surface with the bristles. Never placed the bristles flat-wise against the coins surface. It is too abrasive and may cut thin patina layer.	 Equipment: **Dremel soft cotton brush** Function: Used soft tip of the brush on the surface of the coins. They did not use cleaning, they only used for polishing purpose. This tool makes ancient coins smooth and shining. It used at the end of this technique to polish the coin (Sandes, 2017).

3.1.5 Chemical Techniques

Using olive oil for cleaning coins is a common practice among numismatists due to its ability to penetrate and loosen corroded layers on the coin's surface. The traces of minerals in olive oil can aid in breaking down these layers, making it easier to clean and reveal the coin's original details. However, while olive oil serves well in the initial cleaning phase, it poses significant challenges for long-term conservation. This is primarily because any residual oil left on the coin can prevent subsequent conservation treatments from properly adhering to the surface, thus impeding their effectiveness.

The necessity of removing olive oil from coins after the initial cleaning is crucial for several reasons. Firstly, olive oil is organic and can degrade over time, potentially causing further damage to the coin. As it breaks down, it can leave behind residues that attract dirt and other contaminants, which can accelerate the coin's deterioration. Additionally, olive oil can create a barrier that prevents other cleaning solutions and conservation materials from directly contacting the coin's surface or its patina. This barrier effect can compromise the effectiveness of these treatments, leading to suboptimal conservation outcomes.

To remove olive oil from the surface of coins, the use of mouthwash has been suggested. Mouthwash, typically containing alcohol, can effectively dissolve and wash away the oily residues. The alcohol in the mouthwash acts as a solvent, breaking down the oil into smaller particles that can be easily rinsed off. Moreover, mouthwash often contains other ingredients that can help in cleaning and disinfecting, ensuring that the coin is free from any residual organic matter that could cause harm over time (Rezki and Halimah, 2020).

Fig 27: Sample late Kushan copper coins soak in mouthwash

The use of mouthwash to remove olive oil from coins is an interesting approach that takes advantage of the solution's alcohol content and mild acidity. Mouthwash can indeed be effective in dissolving and removing oily residues, which can help prepare the coin for further conservation treatments. However, this method requires careful consideration of several factors to ensure it does not inadvertently damage the coin.

Firstly, the mild acidity of most mouthwashes can be beneficial for cleaning old pennies, as the slight acidity can help in breaking down residual corrosion and debris. However, this acidity must be carefully monitored. Prolonged exposure to acidic solutions can potentially damage the coin’s surface, especially if the metal is already weakened or corroded. Therefore, while soaking the coins in mouthwash for 12 to 18 hours can be effective, it is important to ensure that the mouthwash used does not have a highly acidic pH that could cause harm over extended periods.

Once the coins are soaked in mouthwash and the debris has been loosened, the next step involves rinsing them with ethanol. Ethanol is an effective solvent that can remove any remaining residues from the mouthwash and ensure that the coin's surface is clean. Washing the coins with ethanol also helps to evaporate any water content quickly, reducing the risk of water-induced corrosion. However, it is important to thoroughly rinse the coins with ethanol and not just a quick dip. This ensures that all traces of mouthwash and loosened debris are completely removed.

Finally, after rinsing with ethanol, the coins should be patted dry with a clean, lint-free cloth. It is critical to ensure that the coins are completely dry to prevent any moisture from causing further corrosion. This step may require a gentle touch, especially with older or more delicate coins, to avoid scratching or damaging the surface (Alshehri, 2017).

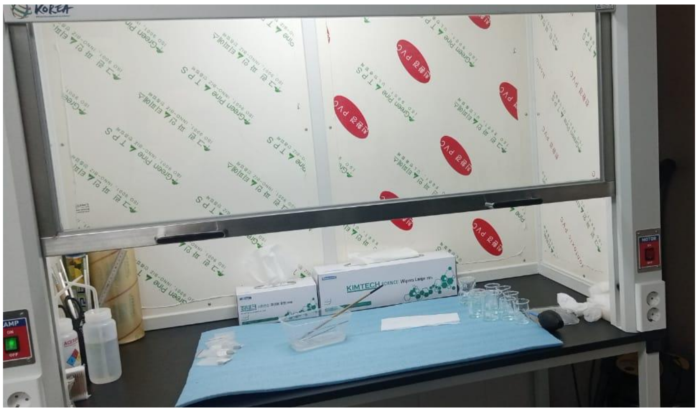


Fig 28: wash with ethanol and dry

Fig 29: obverse side before mouthwash cleaning **Fig 30: obverse side after mouthwash cleaning**

Fig 31: reverse side before mouthwash cleaning Fig 32: reverse side after mouthwash cleaning

3.1.5.1 Ultrasonic Treatment

An ultrasonic cleaner is a device that uses high-frequency sound waves (ultrasonic waves) to clean various objects and materials. It is commonly used in industrial, commercial, and even household settings to remove dirt, grease, grime, and contaminants from a variety of items.

3.1.5.1.1 Ultrasonic Cleaner Components: Typical components of an ultrasonic cleaner include a tank or chamber for holding the cleaning solution, ultrasonic transducers or generators to produce the high-frequency waves, and a control panel for setting parameters such as cleaning time, temperature, and ultrasonic frequency.

Fig 33: Ultrasonic Cleaner

Efficient and thorough cleaning, including hard-to-reach areas. Reduced manual labor and scrubbing. Preservation of delicate or intricate objects, as it is a gentle cleaning method. Fast cleaning cycles, which save time and increase productivity (Fuchs, 1992).

3.1.5.1.2 Cleaning Mechanism: Ultrasonic cleaners work on the principle of cavitation. The cleaner generates high-frequency sound waves, typically in the ultrasonic range (above 20,000 Hz), which create tiny, rapidly collapsing bubbles in a cleaning solution. The implosion of these bubbles produces intense energy and microscopic shockwaves that dislodge dirt and contaminants from the surfaces of objects being cleaned.

3.1.5.1.3 Cleaning Solutions: Ultrasonic cleaners use water-based solutions or specialized cleaning agents. These solutions can be tailored to the specific cleaning task, such as removing oil, grease, rust, dirt, or even biological contaminants like bacteria or blood (Wick & Veilleux, 1985).

Utilizing an ultrasonic cleaner with a mixture of distilled water and ethyl alcohol is a sophisticated and effective method for cleaning delicate artefacts, such as the 15 Late Kushan copper coins. The use of distilled water ensures that no additional minerals are introduced during the cleaning process, while ethyl alcohol helps in dissolving organic contaminants and accelerates drying by reducing surface tension. This method is particularly advantageous for preserving the intricate details and patina of the Kushan copper coins, as it minimizes the risk of physical damage and leaves the coins in a stable, clean state suitable for further conservation or display.

Fig 34: sample for ultrasonic treatment

Here are the steps in detail:

Materials Needed:

- Ultrasonic cleaner
- Distilled water
- Ethyl alcohol (isopropyl alcohol can also be used)
- Plastic container
- Scientific tissue
- Artefact to be cleaned
- Brush

- Timer

Procedure:

3.1.5.1.4 Preparation of the Ultrasonic Cleaner:

Made sure that the ultrasonic cleaner was clean and in good working condition. It's placement on a stable surface was ensured.

Filling the Ultrasonic Cleaner:

Clean the late Kushan copper coin using ultrasonic sound waves. Fill the Ultrasonic Cleaner with distilled water at the operating line (KCHF, 2022).

Fig 35: level of water

Placement the copper coin on the plastic container

To clean the copper coins effectively using an ultrasonic cleaner, ethanol was poured into a float plastic container positioned within the ultrasonic cleaner tank. This setup ensured that the copper coins will be partially submerged in the ethanol when placed in the container. The ethanol facilitated the cleaning process by acting as a solvent to dissolve organic contaminants and residues from the coins. When the ultrasonic cleaner was activated, high-frequency sound waves generated cavitation bubbles in the ethanol, enhancing its cleaning action by dislodging dirt and corrosion from the coin surfaces without causing mechanical damage. This method combines the solvent properties of ethanol with the gentle, thorough cleaning power of ultrasonic, ensuring the coins are cleaned effectively and safely (Ibid).

Fig 36: ethanol and plastic container

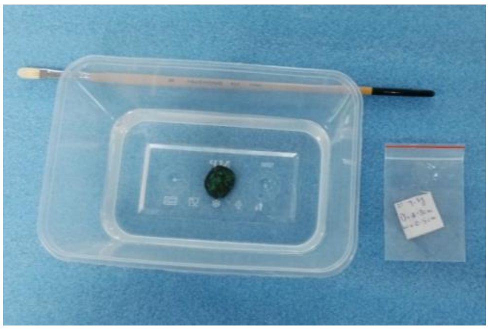


Fig 37: ethanol and late Kushan copper coin on container

Fig 38: Ethanol in plastic container

Gently the copper coin was placed inside the container and ensure that the copper coin was not touching the sides of the container.

Setting Timer and Turning On:

The timer on the ultrasonic cleaner was set on to the desired cleaning time. In this case, mentioned only 5 minutes. It was made sure the cleaner was set to operate at an appropriate ultrasonic frequency for the type of cleaning required.

Cleaning:

The ultrasonic cleaner was then turned on. The ultrasonic waves created and microscopic cavitation bubbles in the ethanol, which helped dislodge dirt and contaminants from the artifact's surface.

Monitoring the Cleaning Process:

While the ultrasonic cleaner was running, the cleaning process was monitored to ensure the copper coin was not being damaged or dislodged from the plastic container.

Drying After Ultrasonic Cleaning:

After the 5-minute cleaning cycle was completed, turned off the ultrasonic cleaner. Carefully removed the plastic container with the copper coin from the ultrasonic cleaner's tank. Gently blotted/ air-dried the copper coin.

Inspecting and Storage:

Inspected the late Kushan copper coin to ensure it's clean up to the satisfaction level. Where required, the ultrasonic cleaning process was repeated. Once satisfied with the cleanliness, the copper coin was stored appropriately, keeping it away from contaminants (Ibid).

3.1.5.2 Stabilization Treatment

The stabilizing treatment using the Benzotriazole (BTA) method is a specialized process aimed at inhibiting corrosion, particularly for copper artefacts such as Late Kushan copper coins. This treatment involves the application of Benzotriazole, a corrosion inhibitor, which reacts with copper to form a protective Cu-BTA complex, effectively suppressing further corrosion. This method is particularly beneficial for ancient coins, where preservation of the historical and cultural value is paramount (KCHF, 2022).

The process began with the preparation of the necessary materials: a stainless steel vat, ethyl alcohol, Benzotriazole (BTA), and wrap. The stainless steel vat served as a non-reactive container for the treatment solution. Ethyl alcohol acted as a solvent, ensuring the effective dissolution and even distribution of BTA around the coin. When the coins were immersed in this solution, BTA reacted with the copper to form a stable Cu-BTA membrane, which acted as a barrier to protect the metal from further oxidative damage and environmental corrosion (Ibid).

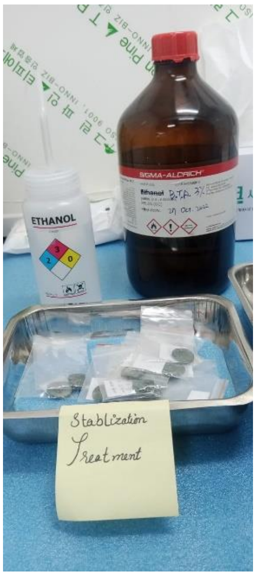


Fig 39: Material for stabilization treatment

This treatment is especially advantageous for copper coins that have developed corrosion layers and have micro-cracks where corrosion can propagate. The Cu-BTA membrane penetrates these minute cracks and interfaces between the corrosion layer and the metal core, stabilizing the structure and preventing further deterioration. This is crucial for preserving the detailed features and inscriptions on ancient coins, which are often subject to damage if corrosion is not properly managed.

However, it is important to acknowledge the health and safety risks associated with the use of Benzotriazole. BTA contains benzene, a known Group 1 carcinogen, which poses significant health risks if proper precautions are not taken. Therefore, stringent safety protocols must be followed during the conservation treatment. Protective equipment such as gloves, masks, and eye protection have been worn to prevent direct exposure to benzene. Additionally, the treatment has been carried out in a well-ventilated area or under a fume hood to minimize inhalation risks (Ibid).

Fig 40: well-ventilated area for chemical treatment

The careful execution of the BTA method ensures that Late Kushan copper coins can be preserved effectively. By forming a protective Cu-BTA membrane, the coins are safeguarded against further corrosion, thus maintaining their structural integrity and historical significance. This method, while requiring careful handling due to the toxic nature of benzene, offers a precise and reliable means of corrosion inhibition, essential for the conservation of valuable archaeological artefacts (Ibid).

Fig 41: samples prepared for the stabilization treatment

3.1.5.2.1 Vacuum Impregnator for stabilization treatment

A vacuum impregnator is a vital tool for the stabilization and reinforcement of metal artefacts, especially in the context of conservation and restoration. This process involves placing the artifact in a vacuum chamber to remove air from the material's micro-pores and internal voids. Once a sufficient vacuum is achieved, a liquid resin or sealant is introduced into the chamber.

The vacuum conditions allow the sealant to deeply penetrate and fill the porous structure of the metal. After impregnation, the artifact is subjected to pressure to ensure thorough infiltration of the sealant. Finally, the sealant is cured, typically through heating, to solidify it within the artifact's structure. This process not only stabilizes the artifact by filling and sealing the internal voids, preventing further deterioration, but also reinforces its structural integrity, making it more durable and resistant to environmental factors. Vacuum impregnation is essential in preserving the historical and functional value of metal artefacts, ensuring their longevity and stability (Ibid).

Fig 42: vacuum impregnation unit

A vacuum impregnation unit, a vat was prepared, including vat with a lid, gloves, dust mask, Paraloid 15% and other reagents, tools. The power was connected to the vacuum impregnation unit to prepare for operation. The switch was pressed in the panel to turn on the power and cold trap then waited till temperature of the impregnator reached 60 degree to facilitate the operation of vacuum pump on and vent close.

Fig 43: Impregnator under process for stabilization treatment

Then, rotated the latching device anti-clockwise in both sides of the cover for release. Opened the cover to put the vat where the Late Kushan copper coins was held, closed the cover and locked the latch (Ibid).

Fig 44: Late Kushan copper coins on impregnator unit

The decompression valve was turned anti-clockwise to reduce the pressure. When the pressure has reduced to 70cm/Hg, turned back the valve to discontinue the process. The vacuum state was maintained for one hour for vacuum impregnation. When the process was completed, the decompression state was released by turning the valve anti-clockwise. Then, the Late Kushan copper coins were soaked by leaving it in the normal pressure for 2 hours. The stabilizing treatment was conducted after immersing Late Kushan copper coins in a 3% solution of BTA. It is most important that the BTA solution binds to the metal surface, and if the rust layer of copper coin is thick, impregnation should be preceded until bubbles rise. When this process was over, the latch was released to open the cover, took out the vat and closed the cover to turn off the power (Ibid).

3.1.5.2.2 Dry Oven

After completing the stabilization treatment of Late Kushan copper coins, it is crucial to ensure thorough drying to remove all residual moisture from the coins. This step is essential to prevent any further corrosion or deterioration of the metal. The drying process was effectively carried out by allowing the coins to air dry for a minimum of three hours, although the exact duration may vary depending on environmental conditions and the specific circumstances of each coin (Ibid).

Fig 45: Late Kushan copper coins on Dry Oven at 80℃

3.1.5.2.3 Removing white BTA solution

During the drying process of Late Kushan copper coins treated with a large amount of Benzotriazole (BTA) solution, a white BTA powder was formed on the surface of the coins. This residue can detract from the visual and historical value of the coins if not properly addressed. To remove the BTA powder, ethyl alcohol was used. Applying ethyl alcohol with a brush and cotton swab allowed for precise and controlled cleaning, ensuring that the residue was gently lifted without causing damage to the coin's surface or patina. The alcohol acted as a solvent, dissolving the BTA powder and enabling its removal. This cleaning method not only restored the coin's appearance but also ensured that the protective treatment was not compromised (Ibid).

3.1.5.3 Reinforcement Process

The reinforcement process for Late Kushan copper coins, as described, involved a sophisticated method aimed at mitigating the effects of corrosion through the use of synthetic resins i.e. Paraloid B72. This process, particularly the vacuum impregnation method, offers a highly controlled environment to ensure the resin penetrates the microscopic voids in the metal, thereby strengthening the coin and providing a barrier against further deterioration. The detailed steps involving the vacuum impregnation system highlight the precision and care needed to avoid damaging the delicate artefacts during the process.

The process to give structural strength to Late Kushan copper coins that are likely to be damaged by corrosion is called reinforcement process. This has the effect of blocking corrosion factors by injecting synthetic resin into weakened metal coins to strengthen the surface. Method of reinforcement process included vacuum impregnator, natural impregnator and Paraloid B72 was used. A 3-20% solution was made using Paraloid B72 (10%) and solvent (Acetone, Xylene). Materials required for the reinforcement process include stainless steel vat, Acetone, Paraloid B72, wrap and vacuum impregnator machine (Ibid).

The reinforcement process was divided according to the vacuum impregnation system. After putting the Late Kushan copper coins into the vacuum impregnation system and creating a vacuum state, when the vacuum state was released, the synthetic resin penetrated into the inside of the microscopic voids of the Late Kushan copper coins where air was present. As the resin dried, the surface of Late Kushan copper coins was coated. Where there was no impregnation system, reinforcement work was done by natural impregnation method and application method.

The vacuum impregnation system consisted of a power button, a vacuum release valve, vacuum valve and a measuring plate. The Late Kushan copper coins were put into the impregnation system and locked. Turned on the vacuum release valve clockwise (close) and the vacuum valve counterclockwise (open). At this time as the air escaped and it became a vacuum state. When the measuring plate read cmHg 60, turned the vacuum valve clockwise (close) (Ibid).

Fig 46: The measuring plate reads cmHg 60, turn the vacuum valve clockwise (close).

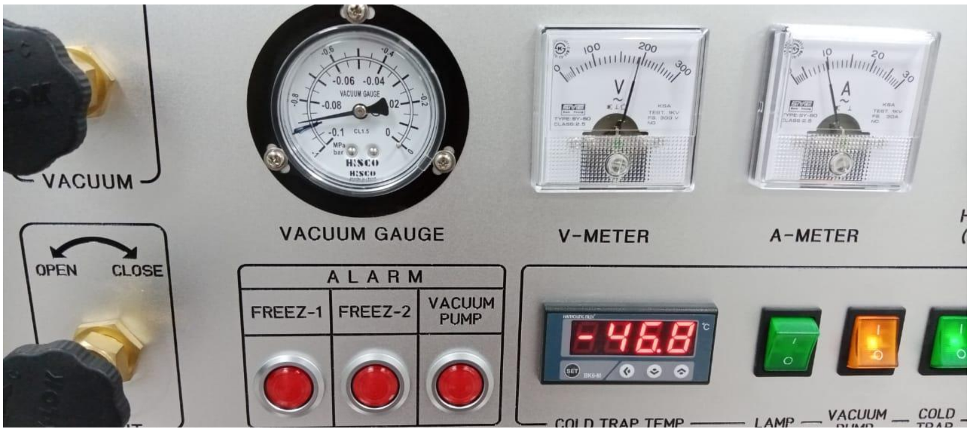


Fig 47: Release valve clockwise (close) and the vacuum valve counterclockwise (open).

Fig 48: The air escapes, it becomes a vacuum state.

The impregnation proceeded for about 1 hour. Turned the vacuum release counterclockwise (open). At this time, the vacuum release valve was released slowly. When cmHg reaches 0, the vacuum release valve was turned clockwise (close). The vacuum impregnation system was then turned off and taken out the Late Kushan copper coins inside the vacuum impregnation system.

The process can simply be summarized as:

Put 10% Paraloid B72 in Acetone in the vat and completely deposit the copper coins. Use the vacuum impregnation system until air bubbles are removed. After that, it is impregnated for the reinforcement for about 1 hour depending on the state of the Late Kushan copper coins and then dried (Ibid).

Fig 49: Deposit Late Kushan copper coins on impregnator for reinforcement process

Fig 50: Dried copper coins after reinforcement process

3.1.5.4 Treating Bronze Disease from Late Kushans copper coins

Bronze disease, also known as "bronze rot," is indeed a destructive and irreversible corrosion process that affects copper-based alloys such as bronze. It occurs when chlorides, often from the environment or surrounding materials, come into contact with the metal. This reaction leads to the formation of a greenish or whitish corrosion product on the surface of the alloy (Scott and David, 1990).

The primary mechanism behind bronze disease involves the interaction between the chlorides and the copper present in the alloy. Chlorides can originate from sources like polluted air, seawater, or other contaminated materials in the environment. When chlorides react with copper, they can form soluble copper chlorides, which can then migrate within the porous structure of the alloy. As these compounds move through the metal, they can cause further corrosion and degradation of the material.

The resulting corrosion products can appear as a dark green coating, often referred to as the "green disease," or as a lighter whitish fuzzy or furry green coating. These coatings are visually distinctive and can seriously compromise the structural integrity and aesthetic appeal of bronze artefacts or structures are called bronze disease (Macleod, 1981).

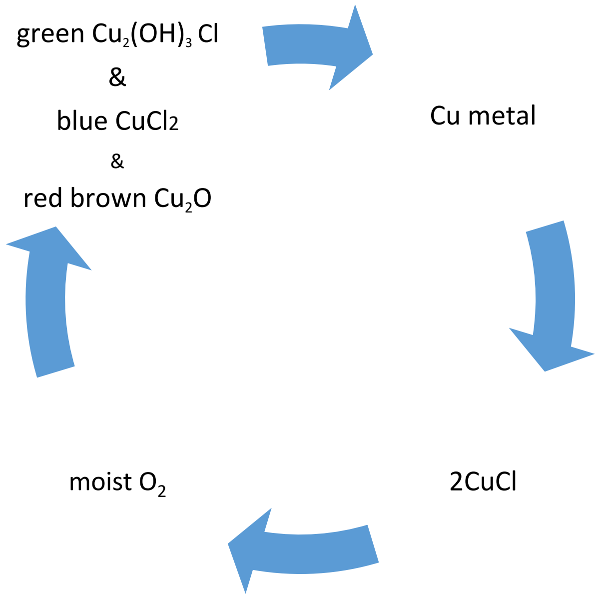


Fig 51: Diagrammatic depiction of the cyclic nature of bronze disease (Macleod, 1981).

Preventive measures are crucial to avoid bronze disease. Protecting bronze objects from exposure to chlorides and other corrosive agents, controlling humidity levels, and maintaining a clean environment are essential steps in preventing this type of corrosion. If bronze disease is suspected, professionals in conservation and restoration should be consulted to assess the extent of the damage and determine appropriate actions to mitigate further deterioration.

3.1.5.4.1 Removal of Bronze Disease from Late Kushans Copper Coins

Removing bronze disease from copper coins is a delicate process that was carried out by some steps:

Isolation: The coins with bronze disease were isolated it from other coins to prevent the spread of corrosion.

Stabilization: Before attempting to remove the corrosion, the first step was to stabilize the affected coin. This might involve treating the coin to halt the ongoing corrosion process. Methods for stabilization can vary depending on the severity of the corrosion and the coin's condition.

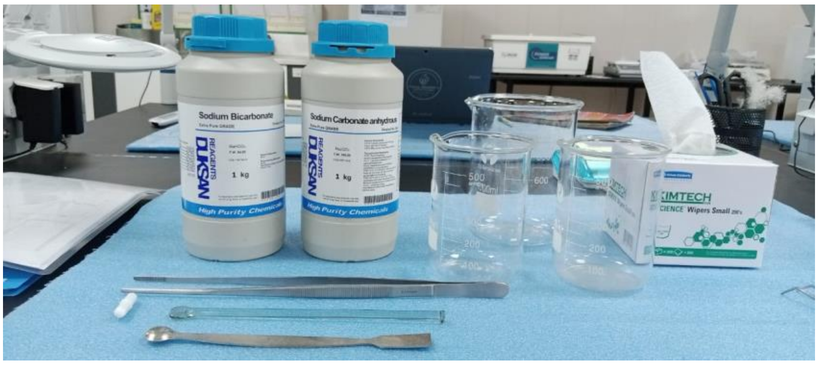


Fig 52: Apparatus for treatment of Bronze Disease

100g of sodium carbonate and 100g of sodium bicarbonate were taken.

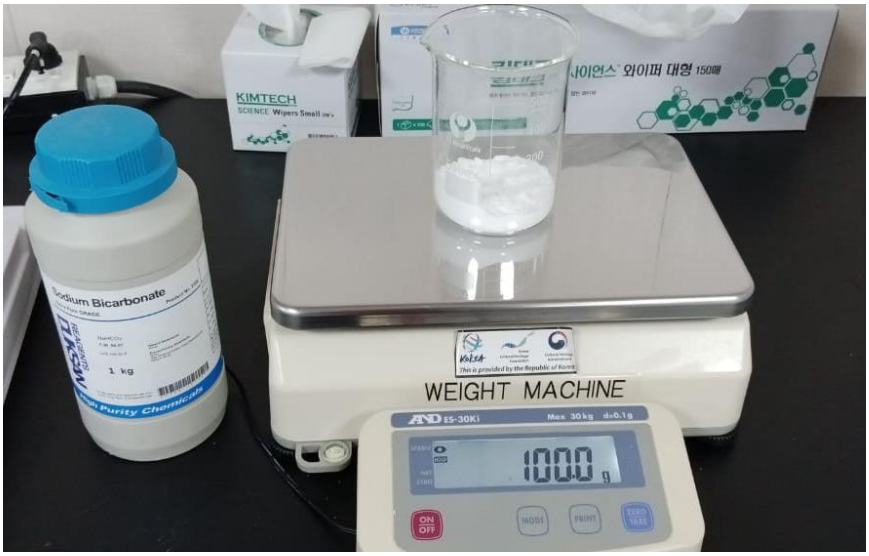


Fig 53: 100g of sodium bicarbonate.

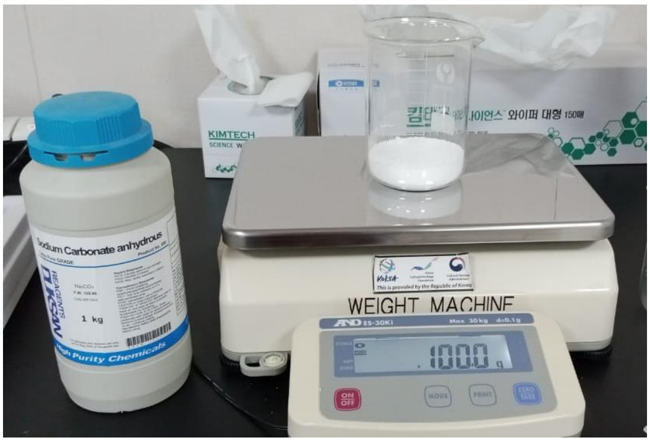


Fig 54: 100g of sodium carbonate

100 gram of sodium carbonate and 100 gram of sodium bicarbonate was dissolved in 1 litre of distilled water. The solution was boiled and then filtered to make precipitation called

sodium sesquicarbonate.10-gram sodium sesquicarbonate was then dissolved in 100 ml of water to make 10% solution for the removal of bronze disease (Methrotra, 1987).

The sodium sesquicarbonate treatment outlined above has been the standard treatment for fragile cupreous artefacts with chloride contamination, especially when the patina on these artefacts is desirable to preserve (Weisser, 1987).

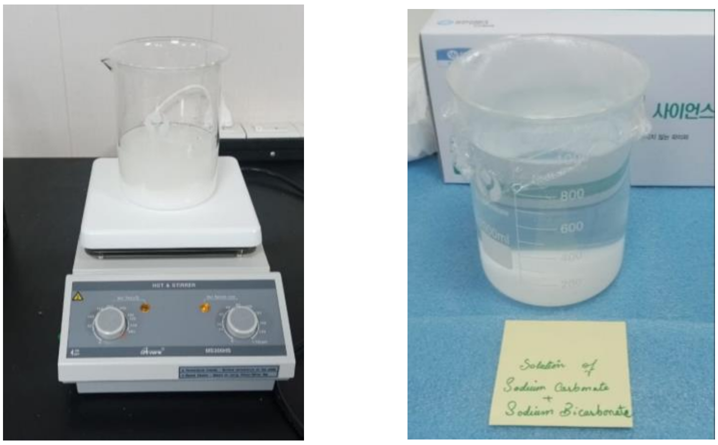


Fig 55: sodium carbonate and sodium bicarbonate dissolved

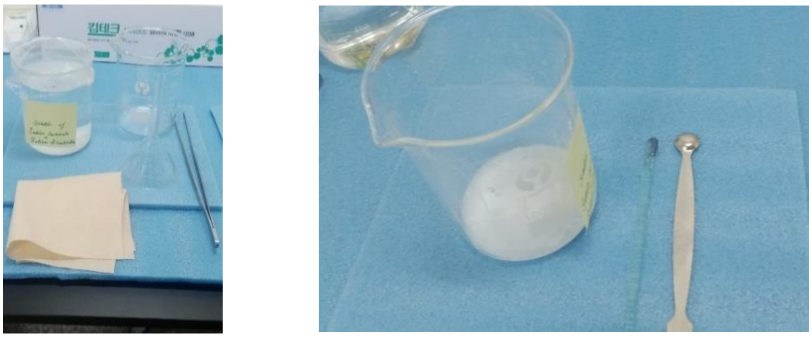


Fig 56: filtration process

Fig 57: sodium sesquicarbonate precipitation

Fig 58: sesquicarbonate solution

Coin were then put into the solution. The coins were subjected to a cleaning process involving a 10 % solution of sodium sesquicarbonate. Initially, the solution turned blue within a few hours, indicating the reaction between the solution and contaminants on the coins. The following morning, the coins were thoroughly washed with tap water to remove any residue. They were then placed back into the sodium sesquicarbonate solution.

Fig 59: Treatment of bronze disease

It is a slow process and with the passage of time solution became blue in colour. The cleaning solution was replaced every three to four days, accompanied by brushing and mechanical cleaning to further remove dirt and corrosion. This procedure continued for approximately six weeks, although the exact duration varied depending on the condition of each coin. The frequent replacement of the solution was crucial for the effective removal of chloride ions, which were progressively diminished over the treatment period.

Fig 60: blue colour of the solution

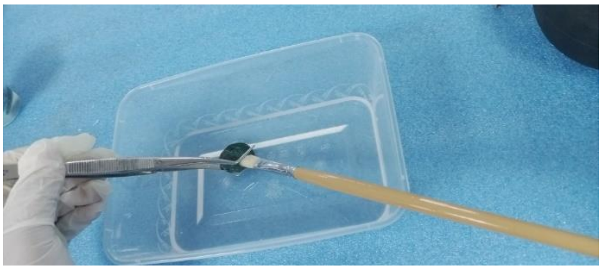


Fig 61: brushing coin in ethanol solution

Throughout the process, the concentration of chloride ions in the solution was monitored. It was observed that the amount of chloride decreased progressively, with only minimal traces detected in the final stages of cleaning. This indicated the thorough removal of contaminants, resulting in the effective preservation and restoration of the coins (Methrotra, 1987).

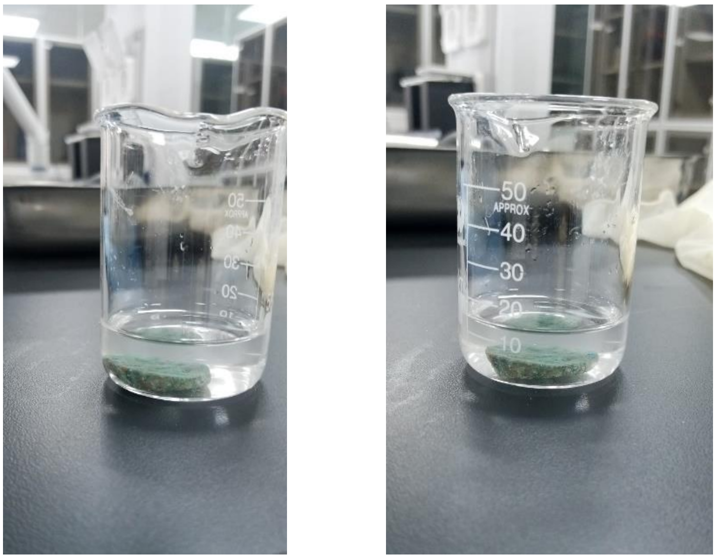


Fig 62: final stage of bronze treatment

Nitric test (nitrogen oxide) was used to check either bronze disease removed from the coin or not. In this process, one drop of nitrogen oxide was added to the blue colour solution. If colour is change into white, then disease was still present on coin surface otherwise vanished.

Fig 63: after bronze disease treatment

3.2 Elemental Composition of Late Kushan Copper Coins using X-ray Fluorescence (XRF) Spectroscopy

The research aims to explore and analyze the most suitable elemental composition techniques for the conservation of ancient copper coins from the Late Kushan period, housed at the Islamabad Museum. A key technique used in this investigation is X-ray Fluorescence (XRF), a radiation technique that provides surface composition analysis with limited depth, typically from a few micrometers to a few tens of micrometers. However, the study acknowledges that surface alterations, such as active corrosion or surface enrichment, can lead to inaccuracies in the data obtained through XRF, as the altered surface may not represent the bulk composition of the coins (Mamaniaa and Singhb, 2019).

X-ray fluorescence spectrometry (XRF) is a non-destructive analytical method used for the elemental analysis of both solids and liquids through the application of an x-ray beam. When a sample is irradiated, it emits fluorescent x-rays, which are then collected and displayed in a spectrum via either an energy dispersive or wavelength dispersive detector. The qualitative analysis of the sample is achieved by identifying the wavelengths of the emitted x-rays, while the quantitative aspect is determined by measuring the intensity of these x-rays. XRF is primarily a bulk analysis technique, with the depth of analysis ranging from less than 1mm to 1cm, depending on the energy of the emitted x-ray and the composition of the sample. This technique allows for the detection of elements from sodium to uranium, making it highly versatile and widely applicable in various fields, including cultural heritage studies, materials science, and environmental analysis (Ibid).

In this study, portable XRF system was utilized to analyze 22 Late Kushan copper coins from the Islamabad Museum's collection. The analysis was conducted at Experimental Archaeology Lab, Department of Archaeology, Hazara University Mansehra. This investigation highlights the system's practical application in non-invasive elemental analysis. The portability of the XRF device enabled on-site examination, preserving the integrity of the historical artefacts while providing valuable compositional data. This approach underscores the significance of portable XRF technology in archaeological research, facilitating the detailed study of cultural heritage objects without compromising their preservation (Ibid).

The literature lacks comprehensive documentation on the elemental composition used in the fabrication of Late Kushan copper coins, making this research particularly significant. The study employs XRF (X-ray Fluorescence) to perform detailed analyses on both the obverse and reverse sides of the Late Kushan copper coins. This technique aims to provide a highly sensitive and reliable assessment of the elemental composition and their distribution on the coin surfaces. This multi-analytical approach is crucial for understanding the metallurgical processes and the composition of the Late Kushan coins.

The laboratory techniques such as XRF provided additional information about the metal contents, ores and the way to identify the various mints, if more than one, from composition of metals. The relative proportion of the contents of the main elements provided valuable information about, the inflation of, money, economic growth or deprecation and political conditions of that period. The connection between microstructure and mechanical properties enabled the researcher to surmise the use of processes such as hammering, heating and quenching used in ancient times.

3.3 Wrap-up After Treatment

In the case of Late Kushan Copper Coins for which the concentration treatment process is finished, the treatment process and used chemicals have been recorded on a record card, and taken pictures before wrap-up. Late Kushan Copper Coins might be stored under suitable temperature and humidity conditions.

3.3.1 Packing

Material required for packaging include ESCAL film, humidity indicator, oxygen indicator, silica gel, RP Agent-A, and Sealing machine.

Dig out the toilon according to the size of the Late Kushan Copper Coin. Care have been taken to ensure that the dug-out space is not too tight or too large. The reason for creating finger-size sunken slot right next to the dugout space, is to make it easy to take the Late Kushan Copper Coins out of the tolin (before left). Put Late Kushan Copper Coins, silica gel, RP agent, oxygen indicator, and humidity indicator in the ESCAL film and seal it using a sealing machine.

Fig 64: Sealing Machine

ESCAL is a special vinyl that prevents outside air or gas from penetrating into the seal. Silica gel functions to remove moisture. If the silica gel is blue, it can be used. When it absorbs moisture, it turns red. RP Agent-A absorbs and removes oxygen, moisture and corrosive gases caused by chemical reactions, and preserves Late Kushan Copper Coins from corrosion and oxidation. The oxygen indicator detects the presence or absence of oxygen. It is blue when oxygen is more than 0.5% and becomes red when it is less than about 0.1%. the humidity indicator turns red when it absorbs moisture.

Late Kushan Copper Coins have been stored in suitable temperature and humidity conditions. The appropriate temperature is 21±3℃ and the appropriate relative humidity is 45±50%. High humidity is a cause of rapid corrosion of Late Kushan Copper Coins, humidity must be lowered. When packing bronze Late Kushan Copper Coins, it is desirable to complete seal it hermetically with special vinyl (ESCAL Film). The dehumidifying agent such as silica gel is not permanently usable and must be replaced periodically through continuous observation.

Fig 65: Sealed Late Kushan Copper Coin

CHAPTER-4

RESULTS AND DISCUSSION

4.1 Causes and Level of Corrosion in Late Kushan Copper Coins

4.1.1 Corrosion

The concept of corrosion is as ancient as the Earth itself, yet it has been referred to by various names throughout history. Commonly recognized as rust in modern times, corrosion is an undesirable phenomenon that undermines the luster and beauty of objects while also diminishing their longevity (Naixin et al., 2002).

Corrosion is the disintegration of metal through an unintentional chemical or electrochemical action, typically starting at its surface. This phenomenon is inherent to all metals, although some are more prone to oxidation than others. The corrosion process primarily involves electrochemical reactions, resembling the workings of a battery. When metal atoms come into contact with an environment containing water molecules, they may relinquish electrons, thus transforming into positively charged ions, provided there's a completed electrical circuit. This effect can manifest locally, leading to the formation of pits or cracks, or it can spread across a wider area, resulting in general deterioration. Corrosion stands as the primary mechanism through which metals degrade. When metals come into contact with water (or even moisture in the air), acids, bases, salts, oils, and specific chemicals, they typically undergo corrosion. Additionally, exposure to gaseous substances such as acidic vapors, formaldehyde gas, ammonia gas, and sulfur-containing gases can also induce corrosion in metals (Matthew, 2013).

4.1.1.1Corrosion Process in Copper

Bronze, composed of copper and tin, contrasts with brass, which consists of copper and zinc. Understanding the oxidation of copper alloys requires knowledge of copper's chemistry. Copper, the first member of the group 1B in the periodic table, exhibits minimal chemical reactivity and oxidizes slowly in air due to its noble position in the electrochemical series. Copper and its alloys develop a protective green patina, such as basic $CuSO_4.3Cu(OH)_2$, that acts as a barrier against further oxidation, isolating the metal from the atmosphere (Agrawal, 1987).

Despite its susceptibility to corrosion, copper possesses the remarkable ability to form stable corrosion crusts or passivation layers on the surfaces of objects. These protective layers serve as a barrier against further corrosion in many environments. When exposed to oxygen or hydrogen sulfide, copper undergoes oxidation processes, yet the formation of this protective layer helps mitigate further damage. Consequently, copper alloy objects dating back thousands of years can still be studied and displayed, despite exhibiting a crust or patina resulting from corrosion. This preservation of copper artefacts showcases the durability and resilience of copper alloys over extended periods, allowing for their continued examination and appreciation by researchers and the public alike (Huisman et al, 2022).

The corrosion of copper artefacts over time can be influenced by several factors. One significant factor is the interaction with environmental elements. Copper slowly oxidizes in the presence of oxygen to form cuprite (Cu_2O), which can further transform into tenorite (CuO). Additionally, the presence of chlorine ions can accelerate corrosion and lead to the formation of various copper compounds. For instance, copper can react with chlorine to produce nantokite ($CuCl$). Moreover, the combination of copper with hydroxide ions and chlorine can result in the formation of minerals like atacamite, paratacamite ($Cu_2(OH)_3Cl$), and malachite ($CuCO_3Cu(OH)_2$). These reactions illustrate how environmental factors such as oxygen and chlorine ions contribute to the corrosion process of copper artefacts, leading to the formation of different compounds over time (Elsayed, 2016).

In archaeometry, coins stand out as the most extensively studied metallic objects due to their ability to yield fruitful results. Typically, coins are composed of alloys with well-controlled compositions, often minted by known authorities and sometimes bearing inscriptions such as dates of issue. This inherent documentation makes coins valuable for researchers, as references can be found in ancient documents, and their typology, metrology, and chronology have been thoroughly investigated. However, challenges arise in cases where written documentation is lacking, leading to experimental difficulties for researchers in understanding the origins and contexts of these coins.

One of the most significant analytical challenges in archaeometry revolves around the examination of patina, the layer of corrosion and oxidation that forms on metallic objects over time. While gold, electrum, and pure silver coins typically lack significant corrosion and oxidation and can be analyzed using various sampling methods, but coins made of "billon" (a silver/copper alloy) and copper alloys present complexities due to surface phenomena that limit analysis. These surface phenomena, including enrichment and depletion effects, result in sample inhomogeneity, leading to potentially random analytical outcomes. Consequently, the concentrations of elements such as silver, zinc, tin, and lead measured on the surface of copper alloy coins may not accurately reflect their interior composition. This disparity poses a challenge for researchers striving to understand the metallurgical properties and historical contexts of these artefacts (Guerra, 1995).

4.1.2 Morphometric Features of the Late Kushan Copper Coins through Stereo Microscope

Surface corrosion emerges as a significant factor contributing to the pattern damages observed on Late Kushan copper coins sourced from the Islamabad Museum. This study focuses on analyzing the morphometric features of these coins to elucidate their corrosion mechanisms. The findings shed light on the relationship between corrosion thickness and etching rates, revealing a successive reduction in etching rates with decreasing corrosion thickness. This phenomenon may be attributed to the unique macro-features of the surface pattern of the coins.

The Late Kushan copper coins exhibit noticeable deterioration, evident from the visible cracks and broken edges present across their surfaces. Additionally, concretion has formed, likely contributing to the appearance of blue and green tones on the coins. Examination revealed a metallic core surrounded by a green-grey corrosion layer at the edges of the sample coins. These observations provided crucial insights for analyzing the condition of the coins before initiating any conservation techniques. Understanding the extent and nature of the deterioration is essential for devising appropriate strategies to preserve and protect these historical artefacts.

The investigation of Late Kushan copper coins utilizing a stereo microscope has provided valuable insights into the condition of these artefacts. The examination revealed that the surface of the coins was predominantly covered with Cuprite (Cu_2O), a copper oxide compound formed through the interaction of the coins with oxygen in their environment. Additionally, black areas of Tenorite (CuO) were observed on some parts of the coins, indicating a transformation from Cuprite due to increased oxygen levels in the surrounding medium.

Furthermore, the stereo microscope examination unveiled additional details about the physical state of the coins. Some coins were found to be adhered to each other, suggesting that corrosion processes may have caused them to fuse over time. Additionally, numerous cracks were evident on the surface of the coins, likely resulting from the expansion and contraction of the metal during corrosion or due to mechanical stress.

Overall, the stereo microscope analysis provided a comprehensive view of the condition of the Late Kushan copper coins, highlighting the presence of corrosion products, structural changes, and physical damage. These findings contribute to a deeper understanding of the degradation processes affecting these artifacts and can inform conservation strategies to preserve them for future study and appreciation.

4.1.3 Corrosion Mechanisms of Late Kushan Copper Coins

The corrosion mechanisms of Late Kushan copper coins were analyzed through the construction of growth models, providing insight into the formation and progression of corrosion products on their surfaces. Initially, the smooth surfaces of the coins underwent corrosion upon continuous exposure to oxygen in the air (Figure 11(a)). This process led to the formation of different corrosion products at varying rates in distinct areas, inducing surface stresses within the coins (Figure 11(b)).

The interior stresses subsequently resulted in the unexpected formation of surface micro-cracks (Figure 11(c)), through which micro and nanoparticles, along with oxygen, penetrated and reacted with the copper to form metallic corrosion. The continuous growth of corrosion products eventually enriched the surface cracks (Figure 11(d)), where different phases of corrosion products formed at varying rates in local areas (Figure 11(e)). Consequently, the corrosion products experienced additional stresses in numerous local domains, leading to the appearance of new cracks at the intersections of old ones (Figure 11(f)).

These newly formed cracks provided conducive conditions for the infiltration of oxygen and carbon into the surface cracks of corrosion particles (Figure 11(g)), further promoting the growth of corrosion products. Substantial growth of corrosion products gradually led to the formation of new microcracks (Figure 11(h)), which continued to corrode and expand outward, intersecting the old cracks to form striated corrosion products (Figure 11(i)).

Due to the uneven growth of striated corrosion features, new microcracks continuously developed alongside the striated microstructures, eventually forming dendritic microcracks (Figure 11(j)). As corrosion persisted, these microcracks expanded, intersecting older ones and causing the dendritic structures to evolve into sub-reticulate formations (Figure 11(k)). As the corrosion of Late Kushan copper coins intensified, the sub-reticulate microstructures gradually transformed into dense reticulate structures (Figure 11(l)), with new cracks emerging within the reticulate pattern (Figure 11(m)).

Continued penetration of corrosion particles led to the growth of corrosion products across the entire surface of the coin, forming a dense layer in localized areas (Figure 11(n)). Within these corrosion layers, notable differences in phase variation, growth rate, and bonding form of corroded surfaces resulted in significant stress variations. These uneven stress distributions gave rise to new microcracks within the dense corrosion layers (Figure 11(o)) (Yin, et. Al, 2022).

Fig 66: Examine coin under stereomicroscope

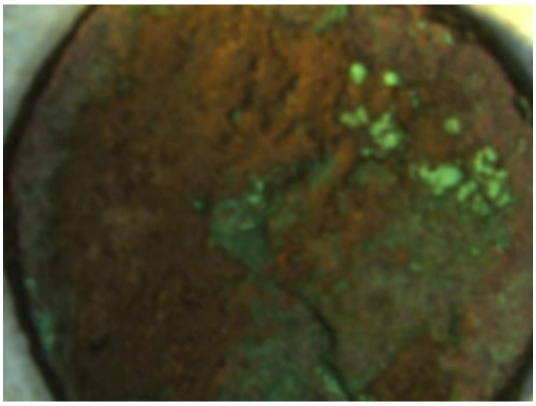


Fig 67: Stereomicroscopic image (before conservation)

Consequently, during the self-healing and self-degradation process of surface micro-cracks, competitive mechanisms operated, influencing the corrosion thickness. This detailed progression illustrates the complex interplay of corrosion processes and structural changes, providing insights into the mechanisms driving the evolution of corrosion features on Late Kushan copper coins. Understanding these processes is essential for devising effective strategies for the preservation and conservation of these historical artefacts.

Overall, this detailed analysis elucidates the complex and dynamic nature of corrosion processes affecting Late Kushan copper coins, providing valuable insights into the mechanisms driving their degradation over time. Understanding these mechanisms is crucial for developing effective preservation and conservation strategies for these historical artefacts (Appendix- II).

4.2 Results of Rutherford Backscattering Spectroscopy (RBS) Technique

In the present research, the backscattering spectrum from Late Kushan copper coins are discussed. Five Late Kushan copper coins were selected randomly for the analysis of corrosion level and their causes. This spectrum likely showed peaks corresponding to the backscattering of ions from the different elements present in the Late Kushan copper coin sample.

Typically, analysts rely on the characteristic energy levels or "front edges" of the elements to determine their presence and concentration in the sample. By analyzing the energy distribution of the backscattered ions, researchers inferred the composition of the material and the relative amounts of each element present.

4.2.1 Data Analysis

The ancient period of Late Kushan Dynasty approximately ends in fourth century CE. A research study on the deterioration of Late Kushan copper coins. The study utilized various analytical methods to investigate the corrosion nature and its effects on the coins.

4.2.1.1 Corrosion Process:

The corrosion of Late Kushan copper coins over time is influenced by various factors, each playing a significant role in the degradation process as different metals exhibit varying degrees of susceptibility to corrosion. Surface characteristics, such as roughness or smoothness, as well as the presence of imperfections or coatings, can also influence corrosion rates. The thickness of the coin is another crucial consideration; as thicker coin may corrode more slowly due to a higher volume of material to degrade.

Environmental factors play a pivotal role in corrosion processes. The burial environment, including factors such as soil composition, moisture levels, and temperature fluctuations, can accelerate or decelerate corrosion rates. The pH value of the surrounding environment is also critical; as acidic or alkaline conditions can promote corrosion.

The presence and concentration of specific ions in the environment, such as oxygen, chlorine, and carbon, can significantly affect corrosion rates. Oxygen ions, for example, are often implicated in the oxidation of these coins.

The research focused on the corrosion process of copper coins caused by factors like oxygen in the environment. This leads to the formation of copper oxides on the surface of the coins.

In the present sample Late Kushan copper coins, the reaction between metallic copper and carbon dioxide along with moisture in the air produces a greenish layer to causing a condition known as bronze disease. These Late Kushan copper coins unearthed from earth are often adorned with a green or blue crust called patina. This noble patina formation, reaching its maximum basicity within approximately 70 years, not only pleases the eye but also serves as a protective shield against further deterioration of the copper artefacts.

This outer greenish crust of the patina on the Late Kushan copper coins primarily consists of basic copper carbonate, while beneath it lies reddish-colored copper oxide, with the metal core at its base. This layered composition contributes to the unique appearance and protective properties of the patina, safeguarding the underlying metal from further corrosion (Agrawal, 1987).

4.2.2 Physical Examination:

These coins have endured inadequate storage practices, lacking any preventative treatments to halt the corrosion process. As a result, they have become entirely mineralized within their plastic enclosures, indicating significant degradation over time.

The absence of proper storage techniques has allowed environmental factors to accelerate the corrosion of the coins. Without intervention to mitigate corrosion, the copper surfaces have undergone extensive chemical reactions, leading to the formation of corrosion layers. These layers likely comprise various compounds, including copper oxides such as Cuprite (Cu_2O) and Tenorite (CuO), as well as other elements present in the surrounding environment.

The coins' complete mineralization within their plastic bags underscores the severity of the corrosion damage they have suffered. This mineralization process suggests that the corrosion has progressed to a point where the original copper material has undergone substantial transformation, impacting both the physical and chemical properties of the coins.

By analyzing the corrosion layers and understanding the environmental conditions that led to their formation, this research aims to provide valuable insights into the deterioration processes affecting Late Kushan copper coins. Additionally, it underscores the importance of proper storage and conservation practices to prevent further degradation of valuable cultural artefacts. The coins exhibited more cracks and various corrosion layers, indicating significant deterioration.

4.2.3 Chemical Composition:

To determine the RBS analytical results of the Late Kushan copper coins, all the coins which have been recovered from reserve collection of the Islamabad Museum having similar elemental composition. In the Late Kushan copper coins, the elements of Ca, O, Si, and Fe are the most important metallic impurities in relating the metal back to the original type of ore. The presence of iron (Fe) as impurity in the samples that can be related to the surface contaminations.

RBS analysis revealed the elemental composition of the coins. The primary element present was copper, along with traces of other elements like silicon, calcium, aluminum, oxygen, iron, lead, zinc, and nickel. The elements Ca, Fe, O, Si, Ni, Al, Pb and Zn were detected in the coin along with the major component Copper (Cu) by the present experimental set-up. According to the spectrum, the analyses results confirm the fact that copper was abundantly available during the time of Kushan dynasty. High concentration of Cu in coins indicates that, it has been added deliberately to show monetary policy or economic necessity (Appendix V).

4.2.3.1 Corrosion Compounds:

The patina may contain compounds such as malachite (Basic $CuCO_3(OH)_2$), azurite (Basic $2CuCO_3Cu(OH)_2$), and attacamite (Basic $Cu_3(OH)2Cl_2$), mixed with corellite (CuS) and other salts depending on the burial environment of the coin object. The main compounds identified on the surface of the coins were copper oxides, specifically Cuprite (Cu_2O) and Tenorite (CuO). Overall, the study provides insight into the corrosion process and its effects on Late Kushan copper coins, offering valuable information for preservation and conservation efforts (Elsayed, 2016).

4.3 Result of Physical Cleaning

(Before mechanical cleaning)

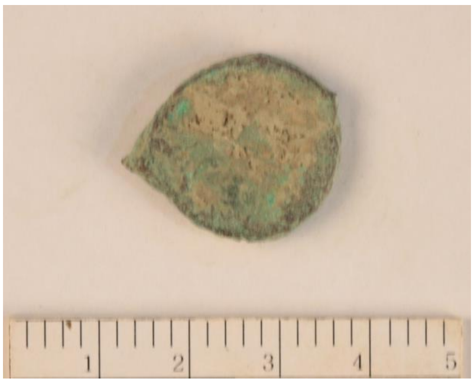


Fig 68: obverse

Fig 69: reverse

(After physical cleaning)

Fig 70: Obverse side of the coin (15)

Fig 71: Reverse side of the coin (15)

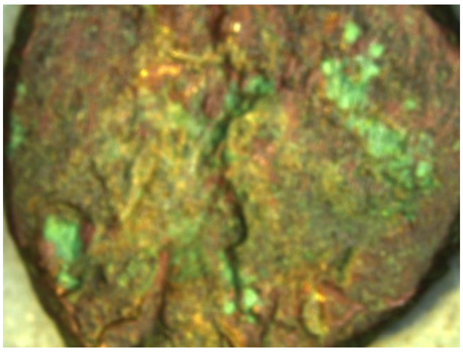


Fig 72: Stereomicroscopic image of the obverse side

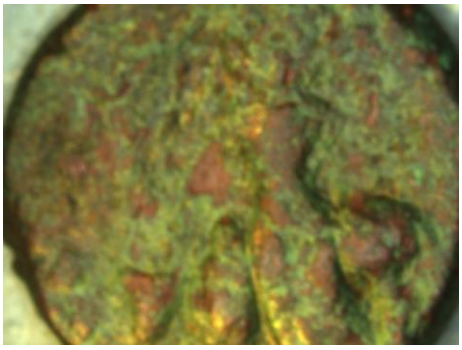


Fig 73: Stereomicroscopic image of the reverse side

4.3.1 Results of Physical Cleaning Technique

The use of common dental pick tools in the cleaning and conservation of Late Kushan copper coins is a meticulous process that underscores the importance of non-destructive methods in preserving historical artefacts. The primary advantage of using dental picks is their precision; these tools allow researcher to remove rust and dirt particles with minimal risk of damaging the Late Kushan copper coin's surface. This level of control is crucial when dealing with Late Kushan copper coins, as even slight abrasions can significantly reduce their historical and monetary value. The slow pace of this method, while often seen as a drawback, is actually beneficial in ensuring that each step of the cleaning process is carefully executed, thereby preserving the Late Kushan copper coin's integrity.

Despite its benefits, physical cleaning with dental pick tools is not without limitations. One major drawback is its inability to restore the original color of the Late Kushan copper coins.

Over time, Late Kushan coins often lose their original luster due to oxidation and other environmental factors. While dental picks can remove superficial grime, they cannot reverse these chemical changes. As a result, the Late Kushan copper coins may still appear dull or discolored after cleaning, which can be disappointing for collectors and historians seeking to appreciate the coins in their original state.

Furthermore, physical cleaning is ineffective against green encrustation, commonly known as bronze disease. This condition, caused by the formation of copper chlorides, can severely damage bronze coins if left untreated. Dental picks cannot remove this encrustation because it is a chemical issue that requires a chemical solution. So the researcher must therefore complement physical cleaning with chemical treatments to address bronze disease effectively. This necessity highlights the limitations of relying solely on physical methods and the importance of a comprehensive approach to Late Kushan copper coins' conservation.

In the broader context of conservation, physical cleaning with dental picks is an essential but insufficient step on its own. It must be integrated into a multi-faceted preservation strategy that includes both physical and chemical techniques. While dental picks are excellent for initial cleaning and detail work, they must be used in conjunction with chemical treatments to fully restore and protect Late Kushan copper coins. This combined approach ensures that all aspects of the coins' preservation are addressed, from surface cleaning to the treatment of underlying chemical issues.

In conclusion, while the use of dental pick tools plays a vital role in the non-destructive cleaning of ancient coins, it is clear that physical cleaning alone cannot achieve comprehensive conservation. The limitations of this method, particularly in restoring the original color and removing bronze disease, necessitate a multi-disciplinary approach. By integrating physical and chemical methods, researcher can ensure the thorough preservation of late Kushan copper coins, safeguarding their historical value for future generations (Appendix-I).

4.4 Results of Ultrasonic Cleaning

Ultrasonic cleaning is a highly effective method for removing a wide range of contaminants from various materials, leveraging high-frequency sound waves in an aqueous medium to achieve thorough cleaning. This technique is particularly useful in the metals industry, where it is employed to remove dirt, oil, grease, buffing/polishing compounds, and mold release agents.

Materials such as metals, glass, and ceramics can benefit from this cleaning process due to its ability to reach and clean intricate surfaces and tight spaces.

The process works by immersing the items to be cleaned in a liquid solution within a cleaning tank. High-frequency sound waves generate microscopic cavitation bubbles in the solution, which implode with great energy, dislodging contaminants from the surface of the materials. This cavitation effect is powerful enough to remove tough contaminants, yet gentle enough to avoid damaging the underlying substrate. As a result, ultrasonic cleaning provides excellent penetration and effectiveness, even in the smallest crevices and between tightly spaced parts.

In the context of the metals industry, ultrasonic cleaning is particularly valuable for removing rust and corrosion. However, the effectiveness of this process depends significantly on the condition of the metal. For instance, with ancient coins such as late Kushan copper coins, ultrasonic cleaning can remove corrosion but typically does so in a manner that is gentle enough to preserve the integrity of the coins. The process effectively removes soft and light rust and surface corrosion without stripping away significant material from the coins. This ensures that while the surface contaminants are eliminated, the underlying historical and numismatic value of the coins is maintained.

The ability of ultrasonic cleaning to remove rust and corrosion without significant material loss is crucial when dealing with valuable or delicate items. In cases where corrosion is deeply embedded or where the material has significant historical importance, a more aggressive cleaning method might risk damaging the substrate or losing critical details. Ultrasonic cleaning thus offers a balanced solution, providing enough power to clean effectively while maintaining the integrity of the items being cleaned (Appendix-III).

4.4.1 Analysis of Stabilization and Reinforcement process on Late Kushan copper coins

The BTA (Benzotriazole) treatment method for Late Kushan copper coins is a sophisticated and effective approach to corrosion inhibition, crucial for preserving the historical and cultural integrity of these artefacts. By forming a protective Cu-BTA membrane, the method stabilizes the coins, especially those with existing corrosion and microcracks, preventing further damage. However, the process presents significant health risks due to the presence of benzene, a known carcinogen, necessitating strict safety measures. While the technique is invaluable for conservation, its reliance on hazardous chemicals highlights the need for balancing preservation with safety, and possibly exploring safer alternatives.

The reinforcement process for Late Kushan copper coins using Paraloid B72, particularly through the vacuum impregnation method, represents a highly specialized and effective approach to preserving these ancient artefacts. By creating a 3-20% solution of Paraloid B72 with a solvent like acetone or xylene, and applying it via a vacuum impregnation system, the process ensures deep penetration of the resin into the microscopic voids and cracks within the metal. This method significantly enhances the structural integrity of the coins, offering a protective barrier against further corrosion. The use of a vacuum impregnator is particularly beneficial as it allows for precise control, minimizing the risk of damage during the reinforcement process and ensuring that the resin reaches even the most inaccessible areas of the coins.

However, the process is not without its challenges. The reliance on solvents like acetone or xylene, which are volatile and flammable, necessitates stringent safety measures to protect the conservators and the environment. Moreover, the application of synthetic resins like Paraloid B72, while effective in stabilizing the coins, raises concerns about the long-term reversibility and potential impact on the artifact's appearance. The reinforcement process must therefore be carefully managed to balance the need for preservation with the integrity of the coin's original material and appearance. Despite these challenges, the reinforcement process using Paraloid B72 is a vital tool in the conservation of historically significant artefacts, ensuring their preservation for future generations while maintaining their cultural and historical value (Appendix-IV).

4.5 Result after Bronze Treatment

Fig 74: obverse

Fig 75: obverse

Fig 76: reverse

Fig 77: reverse

Fig 78: obverse

Fig 79: obverse

Fig 80: reverse

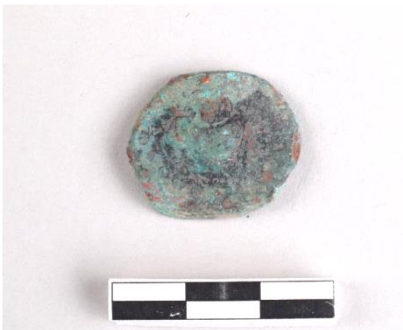


Fig 81: reverse

4.5.1 Result of Bronze Treatment

Bronze disease is a significant concern for the preservation of copper-based metal artefacts, including pure copper, brasses, and bronzes. This type of corrosion, characterized by the formation of micropits under specific conditions, is primarily driven by the chemical reactions involving the major alloying element, copper. The self-progressing nature of bronze disease is exacerbated by humidity, which facilitates the formation of chlorine-containing compounds. These compounds react with air, perpetuating the corrosion process. The result is a progressive degradation that can severely damage or even destroy priceless artefacts, reducing them to green powder. Given the cultural and historical importance of such artefacts, it is crucial to find effective treatments to halt and reverse this corrosion.

The evaluation of current treatments for bronze disease highlights the necessity for methods that are not only effective but also tailored to the specific characteristics of the artefacts being treated. While some treatments have proven to be highly effective in removing bronze disease and restoring the natural copper color, they are not universally successful. For instance, the treatment of Late Kushan copper coins revealed a significant limitation. Although the inscriptions on the coins became visible after treatment, the process was notably slow and less effective in reaching the deeper areas of the copper coins. This indicates that while the treatments can be beneficial, their effectiveness can vary significantly depending on the nature and condition of the artifact.

The inconsistency in treatment outcomes underscores the importance of a more nuanced approach to managing bronze disease. It suggests that a one-size-fits-all solution may not be feasible and that treatments need to be customized to address the specific corrosion patterns and structural nuances of each artifact.

Current treatments for bronze disease offer some hope in preserving copper-based artefacts, their variable effectiveness necessitates a deeper understanding and more targeted approach. Preservationists must continue to refine these treatments and develop new strategies to ensure the longevity and integrity of culturally and historically significant artefacts. Only through such dedicated efforts can we hope to protect and preserve our shared heritage from the ravages of bronze disease.

4.6 Experimental Results of X-ray Fluorescence (XRF) Spectroscopy

The Energy Dispersive X-ray Fluorescence (EDXRF) has been performed on 22 Late Kushan copper coins described above. Analysis by WD-XRF. The copper coin under study is the major elements identified in these coins are Cu and Si, whereas P, S, Co, Ni, Ag, and Pb are present in trace quantities in Late Kushan copper coins. The chemical composition of the coins derived from sensitive WD-XRF is shown in Table 3.11. As the coins are not much corroded, the WD-XRF was targeted on noncorroded surfaces on a larger surface area. The copper percentage on the obverse side varied between 77.339 to 98.629% (Table 3.11). On the reverse side, the percentage of copper varied between 75.916 to 91.769%, showing copper as the main constituents of the Late Kushan copper coins. Except for coin No. 313, none of the copper coins showed the presence of any Cobalt (Co) on the exterior surfaces. Coin No. 313 shows variations of sulfur from 0.169% on the obverse to 0.145% on the reverse side. None of the coins showed any traces of iron on the external surfaces wherein iron was noticed through RBS analysis before conservation of coin No. 340 from traces to as high as 2.64%. All the copper coins are free from the presence of any chloride, K, Na, and iron on the external surfaces. The elements Co (No. 313), Pb (No. 5), and Ag (No. 5) are present in traces on the surface. Ni is present in traces (0.12%) on the obverse and reverse side of majority coins which may be impurity/contamination during smelting. The obverse/ reverse composition of all the coins show the presence of silica in major quantities from 0.821 to 17.305%. Probably, silica could not be removed during the metallurgical process, which points towards poor workmanship for this hoard. Phosphorus in traces (0.021 to 0.025%) is present in all the studied coins (Appendix-VI b).

4.6.1 Discussion

The Late Kushan copper coins are a window into the technological capabilities and minting practices of the Kushan Empire. Archaeological evidence suggests that the primary method of coin production was striking rather than casting. This is indicated by the presence of consistent design elements and detailed imprints, which are more characteristic of struck coins. Analysis of minting tools and die remnants found at archaeological sites supports this conclusion, showing extensive wear patterns that point to high-volume production. The sophistication of the dies and the precision in the coin designs reflect a significant level of craftsmanship and technological proficiency in the Kushan mints.

The content analysis of Late Kushan copper coins reveals a complex alloying process. Using techniques such as X-ray fluorescence (XRF) it becomes evident that these coins were not made from pure copper but included varying amounts of other metals such as tin, lead, and nickel. These metals were likely added to enhance the coins’ durability and to economize on copper. The presence of these alloys suggests that the Late Kushan minting authorities were adept at manipulating metal properties to achieve desired characteristics in their coinage, balancing durability and cost-effectiveness.

The gradual weight loss observed in Late Kushan copper coins can be attributed to several factors. Firstly, the natural wear and tear from circulation would inevitably lead to a reduction in weight over time. Coins exchanged hands frequently, resulting in surface abrasion and loss of material. Secondly, copper is prone to corrosion, especially in the burial environments where many coins are found today. The corrosion products formed on the coin surface contribute to a measurable loss in weight. Additionally, there is evidence to suggest changes in minting practices over time. Faced with economic pressures, the Kushan authorities might have gradually reduced the metal content per coin to stretch their resources further. This practice would result in newer coins being lighter than their predecessors.

The presence of impurities and alloying elements in the Late Kushan copper coins is significant. These impurities could stem from the raw materials used, reflecting the quality of copper ore available to the Kushan mints. Alternatively, they could be the result of intentional alloying practices. Metals such as tin and lead were often added to copper to improve hardness and durability, making the coins more resistant to wear. The technological constraints of the time also played a role, as refining techniques were not as advanced as they are today, leading to a higher presence of impurities in the final product.

The analysis of Late Kushan copper coins offers valuable insights into the economic and technological context of the Kushan Empire. The evolution of coin manufacturing techniques, from the quality of the dies to the alloy compositions, highlights a dynamic period of innovation and adaptation. The gradual reduction in coin weight can be seen as a response to economic challenges, possibly reflecting a decline in resource availability or an attempt to address inflationary pressures. The comparison with contemporary coinage from neighboring regions can further elucidate these trends, providing a broader understanding of the Kushan economic strategies. Overall, this study underscores the intricate relationship between technology, economics, and resource management in ancient coinage practices.

The high concentration of copper in Late Kushan coins, as indicated by spectrum analysis, points to a deliberate policy by the Kushan authorities. This increase in copper content reflects an intentional shift in monetary policy likely driven by economic necessity. As copper was more readily available and less expensive than precious metals like silver and gold, its use in coinage would have allowed the Kushan rulers to produce a larger quantity of coins, thereby facilitating trade and daily transactions. This strategy would have been particularly important in an expansive empire like the Kushan, where a stable and abundant currency was crucial for maintaining economic stability and supporting commercial activities. The deliberate addition of copper also suggests a pragmatic approach to resource management. By utilizing a metal that was abundant in their territory, the Kushan authorities could ensure a steady supply of coinage without over-relying on more scarce and valuable metals. This move could also be seen as an effort to control inflation by increasing the money supply in a controlled manner. By issuing coins with a high copper content, the Kushans could meet the growing demand for currency driven by economic expansion and increased trade activities across their empire. This approach indicates a sophisticated understanding of monetary economics and resource utilization.

The multi-analytical investigations of Late Kushan copper coins provide significant insights into the smelting practices and material sources used during the Kushan period. The analysis confirms that sulfide ores of copper were smelted to extract the metal. However, the presence of impurities like silica, iron, and sulfur indicates that the smelting processes were not highly refined. This suggests that the Kushan metallurgists either lacked advanced technology or prioritized efficiency and cost over purity. The poor quality control during smelting, as evidenced by the compositional gradients observed, points to a possible reliance on less sophisticated smelting techniques, which failed to fully remove these impurities.

The presence of sulfur, which acts as a corrosion accelerator, highlights the long-term implications of the smelting impurities. Sulfur's high volatility and its segregation on isolated spots likely contributed to its loss during coin circulation, reducing the overall corrosion observed on the coins. Nonetheless, the fact that sulfur and silica were detected on the coin surfaces through WD-XRF analysis underscores the incomplete removal of these impurities. The existence of isolated corrosion spots aligns with this finding, suggesting that while the coins were generally in good condition, certain areas were more vulnerable due to localized concentrations of impurities.

The choice to use pure copper instead of common alloys like bronze or brass for this hoard of coins is particularly noteworthy. Typically, alloys such as bronze (copper and tin) or brass (copper and zinc) were used to lower smelting temperatures and reduce costs. The absence of zinc or tin in these coins indicates a deviation from standard practices, which might reflect specific economic or resource conditions faced by the Kushan minting authorities. This decision could have been driven by the availability of raw materials, the specific requirements of the hoard, or a strategic choice to produce a certain type of coin.

The improper smelting and the presence of impurities like silica, phosphorus, and sulfur highlight the technological constraints of the Kushan metallurgy. The high silica content, particularly in selected spots, indicates issues with the refining process, such as improper poling. This suggests that the Kushan metallurgists either lacked the knowledge or the means to effectively refine the metal. Economically, the use of pure copper, despite the poor workmanship, might have been a necessary compromise. The cost savings from not fully refining the metal and the potential availability of sulfide ores could have driven this decision.

When compared to other Indian Kushan coins, the studied hoard shows significant differences in composition and fabrication. The use of pure copper, the presence of impurities, and the specific smelting issues distinguish these coins from other reported Kushan coins, which often employed alloys. This difference could indicate regional variations in metallurgical practices, resource availability, or economic conditions within the Kushan Empire. It also underscores the importance of localized studies to understand the diversity and complexity of ancient coinage practices.

In conclusion, the multi-analytical investigations of Late Kushan copper coins reveal a nuanced picture of Kushan metallurgy and economic strategies. The reliance on sulfide ores, the presence of significant impurities, and the use of pure copper instead of alloys reflect both technological limitations and strategic choices. These findings offer critical insights into the economic and material conditions of the Kushan Empire, highlighting the interplay between resource availability, technological capabilities, and economic necessities. The distinctive characteristics of this coin hoard, compared to other Kushan coins, underscore the regional diversity in ancient coinage practices and the adaptive strategies employed by the Kushan minting authorities (Appendix-VI a).

4.7 Comparative Analysis of Late Kushans with special reference of economic, political and minting practices of Great Kushans

The transition from the Early to Late Kushan period marks a distinct shift in the empire’s trajectory, particularly when examining economic strength, political authority, and minting practices. During the heydays of the Early Kushans, especially under the rule of Wima Kadphises and Kanishka the Great, the empire exhibited remarkable economic vitality. This prosperity was largely driven by their control over extensive trade routes, including key segments of the Silk Road, which allowed for the movement of luxury goods, gold, and cultural influences across the Roman empire, Central Asian states and the Indian subcontinent. Coinage from this era struck predominantly in gold and heavy unit copper attest the wealthy economic condition of the Kushans. The coins were not only abundant in high-value metals but also bore intricate artistic designs, cosmopolitan iconography, and bilingual inscriptions that reinforced the Kushans' position as a powerful and culturally integrative force (Kennedy, 2011).

In stark contrast, the Late Kushan period reflects the consequences of prolonged internal fragmentation and mounting external pressures. As Sassanian incursions from the west and the rise of the Gupta Empire in India greatly challenged the Kushan dominance, the central government's ability to control vast territories and manage economic networks deteriorated. The western part comprised Central Asian states, Afghanistan and Gandhara was lost to the Sasanian after Vasudeva I rule. In mid of 3rd century CE, the Sasanians firmly established their in the occupied territory which was called as Kushanshahr. This decline is evident in the changing nature of their coinage. Gold coins became debased, and the copper coins devalued by weight progression. The coins of this period were marked by uniform design, crude engravings, simplified imagery, and a noticeable drop in metallurgical quality. Such changes are symptomatic of a strained treasury and reflect the breakdown of long-distance trade systems that had once fueled the early empire's affluence.

Politically, early Kushan rulers projected a strong centralized monarchy with divine associations, seen in the form of regal portraits and representation of numerous deities on their coins. These images served not only as currency but also as instruments of imperial ideology and legitimacy. By the late phase, however, this coherence dissolved. The quality of portraiture on coins diminished significantly, and the depiction of rulers became more symbolic than propagandistic. Inscriptions increasingly favored regional scripts like Brahmi over the earlier Hellenistic Greek and Kharosthi combinations, pointing to a shift from cosmopolitan rule to more localized, perhaps fragmented, political control. The minting practices also became decentralized, with multiple, regionally-based mints producing coins of inconsistent quality, further reflecting the weakening of a unified imperial apparatus.

Thus, a comparative analysis of the Early and Late Kushan periods reveals a stark contrast: from economic vigor and expansive political control supported by refined and symbolically rich coinage, to economic contraction, political disintegration, and the production of debased, locally influenced coinage. This transformation encapsulates the broader arc of the Kushan Empire's evolution from a dominant transregional power to a fractured entity succumbing to regionalism and decline (Ibid).

The Late Kushan rulers notably Vasudeva-II, Shaka, and Kipunadha present a clear departure from refined to debased coinage, good to crude style, excellent to simple manufacturing technique, and adoption of uniform design and symbols when compared them to their early Kushan predecessors such as Wima Kadphises, Kanishka-I, Huvishka, and Vasudeva-I. This contrast reflects not just evolving minting practices but deeper political, economic, and cultural shifts within the Kushan empire (Khan, 2008).

Economic Declining of Kushan Empire

The economic history of the Kushan Empire, as seen through its coinage, reflects a trajectory of rise, prosperity, and gradual decline. A comparative analysis between the Late Kushans, particularly from Vasudeva I onward, and their earlier counterparts such as Kanishka-I, Huvishka, and Wima Kadphises, reveals a significant shift in the empire's fiscal and monetary landscape. This change is most clearly illustrated through the quality, weight, and distribution of their coinage (Khan, 2010). Wima Kadphises introduced a gold coinage system based on the Roman pattern, indicating a vibrant trade with the Roman world and a stable internal economy (Göbl, 1984 and Puri, 1984).

During the climax stage of the Great Kushans ruled by like Kanishka-I and Huvishka presided over a thriving empire with access to abundant trade routes, including the Silk Road, and established strong connections with the Roman Empire, Central Asia, and China. This prosperity was reflected in their coinage, which included high-purity gold dinars and well-crafted heavy copper coins. The gold coins typically weighed around 7.8 to 8 grams, and their meticulous artistry, diverse iconography, and inscriptions in Bactrian script demonstrated the empire's cosmopolitan outlook and financial strength. Kanishka's coins, for instance, featured a vast pantheon of deities from Greek, Zoroastrian, and Indian traditions, showcasing the wealth, religious inclusivity, and imperial ambition of the period (Khan, 2010). Under Kanishka and Huvishka, the Great Kushans maintained this prosperity, with significant state investment in monumental architecture and religious patronage, which further fueled urban growth (Göbl, 1984 and Puri, 1984).

In contrast, the Late Kushans, beginning with the rule of Vasudeva-I, faced growing economic and political pressures. These included territorial losses, declining trade volumes, and encroachments from emerging powers such as the Sassanian Empire in the west and the Gupta Empire in India. Vasudeva-I's copper coinage shows a shift toward conservatism and uniformity. While he retained traditional iconography such as the two-armed Oesho and Bactrian inscriptions, his coins marked a reduction in artistic complexity and metal weight, generally ranging from 11 to 9 grams. This indicates a deliberate attempt to maintain symbolic continuity in the form of diminishing economic capability (Khan, 2010). The Kushan coinage, hence forth Late Kushans, from this era onwards reflect debasement in gold contents and weight reduction in copper, a clear sign of dwindling economic resources. Although Mathura and parts of the eastern empire retained some prosperity under later Kushan rulers. In general, the economic decline was progressively developed during the time of Late Kushans (Göbl, 1984 and Puri, 1984).

At the time of Vasishka, Kanishka-III and Vasudeva II, the economic decline repeadly developed. The gold coins of this period became increasingly crude and debased, both in purity and composition. Later copper coins often weighed less than 6 grams, and the reduction in detail and quality suggests the use of lower-grade metal alloys and possibly unskilled minting. This degradation in coinage reflects monetary inflation, weakened centralized control, and shrinking access to bullion sources. Furthermore, the reduction in active mint centers and the emergence of regional variations in coin types point to fragmentation of the imperial economy and reliance on recycled or overstruck coins, all hallmarks of a weakening fiscal structure (Khan, 2010). Trade shrank, tax revenues dropped, and this is mirrored in the debasement of coinage. The gold coins of this period were produced in less purity, and copper coins in reduced weight and crude style of execution. The economic decentralization is evident from localized coinage and a loss of uniform minting standards, suggests a week regional autonomy and reduced centralized control of the Late Kushans (Bracey, 2012).

The introduction of the Soter Megas copper coinage**,** followed by a full imperial currency system under Wima Kadphises, reflects their intent to create monetary coherence across a vast and culturally diverse empire. In contrast, the period of the Late Kushans, Kanishka II and successors is marked by drastic economic devalution. Both gold and copper coinage saw steady debasement; in the case of gold the purity seen under Wima Kadphises (beginning of 2nd century CE) was nearly 99% which later dropped below 25% at the time of Kipunadha (mid-4th century CE). Likewise, the weight of copper coins was gradually reduced from a standardized tetradrachm unit (17g) to barely reduced weight tetradrachm unit (2g) at the end of the Late Kushan rule. These changes reflect dwindling access to resources, shrinking trade revenues, and the collapse of centralized economic control. Additionally, rampant imitation coinage in this period hints at a breakdown in monetary authority and a desperate attempt to continue circulation under deteriorating economic conditions (Cribb & Jongeward, 2014).

The gold coins of Wima, Kanishka-I, and Huvishka were typically struck at a purity of 97–98%**,** indicating strong control over precious metal sources and standardized minting practices. However, during the Late Kushan period, we witness a gradual but marked debasement of the gold coinage. The early coins of Vasudeva I maintained high purity of gold around 92–96%**,** but subsequent issues such as the nandipada series began to drop, ultimately reaching at low level as 68–80%**,** and later even 50% or less under-the rule of Shaka and Kipunada (Oddy and Cribb, 1995).

Political Perspective of Kushan Empire

From a political perspective, the transition from the early to late Kushan period marks a shift from centralized imperial authority to fragmented regional rule, a change that is deeply reflected in the evolution of Kushan coinage. Early rulers such as Wima Kadphises, Kanishka I and Huvishka maintained a strong central administration, with coinage serving as a powerful tool of imperial propaganda. Their coins consistently featured a standing king in regal attire paired with a wide array of deities, projecting messages of divine legitimacy, political stability, and cosmopolitan inclusiveness. The uniformity in inscriptions, minting techniques, and iconography across a vast territory highlighted a cohesive and centralized state apparatus (Khan, 2010).

The Early Kushans adopted the Indo-Greek and Indo-Parthian system of satrapal governance but maintained strong central authority through a network of loyal provincial governors (kshatrapas and mahakshatrapas). The divine kingship ideology (e.g., *devaputra*) underpinned their authority, blending Hellenistic, Indian, and Central Asian concepts of sovereignty. Kanishka's reign marked the empire’s zenith, characterized by military conquests, diplomatic ties with China and Rome, and religious pluralism (Göbl, 1984 and Puri, 1984).

Kanishka-I further elevated Kushan coinage with detailed depictions of divinities and standard Bactrian legends, highlighting the ruler's divine endorsement and imperial authority. Huvishka continued these traditions, adding complexity to coin imagery and script while maintaining high gold contents and aesthetic quality (Khan, 2008). Kanishka-I is known not only for consolidating a vast empire but also for his imperial ideology, which was codified in official documents like the Rabatak inscription**.** This record affirms dynastic legitimacy and showcases Kanishka's divine right to rule through a wide pantheon of deities. The Early Kushan kings styled themselves as *"King of Kings"*, issuing coins that projected both military power and religious authority. The presence of centralized mints and consistent royal portraiture across vast regions reflects a high degree of state control and bureaucratic uniformity (Cribb & Jongeward, 2014)**.**

In contrast, the Late Kushan rulers, including Kanishka-II, Vasishka, Vasudeva-II, and Shaka, operated within a context of declining central power and increasing regionalization. Their coinage, while still borrowing earlier motifs such as the Oesho-and-bull design of Vasudeva-I, began introducing new religious and political symbols, such as the design of enthroned Ardoxsho by Kanishka II, a deity associated with fortune and legitimacy. This change in iconography suggests an attempt to forge a new visual language of authority in response to shifting allegiances and possibly Sasanian influence. The introduction of pendant coins and ornamental pieces at the time of Shaka further points to a departure from purely economic utility; coinage was now being used for ceremonial display or elite circulation, reflecting a weakened monetary economy and a need to assert prestige symbolically in a fractured political environment. Thus, while early Kushan coins were tools of unified imperial rule, Late Kushan coinage reveals a fragmented polity, where rulers relied on symbolic assertion and local religious motifs to maintain legitimacy in the face of declining centralized control (Khan, 2010).

The Late Kushans operated under fragmented authority. While still using the title of 'devaputra', the later rulers lacked the same central control. Political authority became more symbolic than real in many regions, with increasing autonomy of local governors and a rise in semi-independent polities. The empire had been significantly reduced in size, and Late Kushan rulers like Kanishka II and Vasishka often ruled over smaller territories and sometimes overlapped in Gandhara. The emergence of Kushano-Sasanians in the northwest and the rise of regional powers like the Guptas and Western Satraps overshadowed the declining Kushan polity (Puri, 1984).

Vasudeva-II coins also begin to write his name *Vasu* in Brahmi with addition of individual letters such as *ga* and *bha*, likely attempts to maintain bureaucratic tracking amid deteriorating governance. The use of such symbols was initiated by Vasudeva I when he began to issue coins from eastern mint. Shaka and Kipunadha, the successors of Vasudeva II further developed this pattern. The evidence of pendant-style coins with ornamental attachments of Shaka from Taxila, indicates a ritual or decorative purpose and further distancing them from the practical monetary utility of earlier Kushan issues (Khan, 2008).

Minting Practices of Kushan Empire

From a minting perspective, the contrast between the early and late Kushan periods is striking and indicative of broader administrative and political changes. During the reigns of early emperors like Wima Kadphises, Kanishka-I, and Huvishka, the minting practices were marked by high technical standards, consistency in design, and complete Bactrian inscriptions. Coins from this period were struck on well-prepared flans with balanced iconography, enabling easy identification of rulers and deities. The uniformity of legends and symbols across vast regions highlights the presence of a centralized minting authority, likely regulated by the imperial court to ensure standardization and control over currency production (Khan, 2010).

Kujula Kadphises' early copper coins mimic Indo-Greek styles and Indo-Scythian types but soon moved toward distinct Kushan iconography, while Wima Takto, second ruler of the Kushans, began standardized coinage on a new pattern. Wima Kadphises introduced heavy gold coinage with Roman stylistic influence, denoting political sophistication and economic strength. He introduced a major innovation in the form of the *sacrificing king* motif, while Kanishka-I further transformed the coinage by adopting the Bactrian language and labeling divine figures. The coins of this ruler and successor (Huvishka) shows an unprecedented array of deities, reflecting an assertive religious-political message and the use of divine figures for batch identification and mint control. Coins were struck with high artistic quality and a careful consistency of weight and metallic contents, pointing to well-managed mints likely based at Begram, Peshawar, Kashmir, and later Mathura **(**Cribb and Jongeward, 2015)**.** Kanishka's coins are particularly rich in religious imagery, depicting a pantheon of deities from multiple traditions Greek, Iranian, Indian emphasizing the cosmopolitan nature of Kushan rule (Göbl, 1984 and Puri, 1984).

The coinage of the Early Kushans were not only the economic tools but vehicles of religious and political messaging. Coins of Wima Kadphises and especially Kanishka-I depicted a pantheon of deities related to Iranian, Greek, Indian, and Buddhist traditions including Helios/Miiro, Mao, Athsho, Nana, Oado, and Siva. This was not a random eclecticism but was an intentional imperial ideology aimed at unifying a vast, multicultural empire by acknowledging local religious traditions. The high artistic quality and consistency in weight and inscriptions reflect centralized mints with imperial oversight (Bracey, 2012).

In contrast, under Late Kushan rulers especially after Vasudeva-I there is clear evidence of declining minting quality. Although legible Bactrian legends and structured layouts still found on the coins of Vasudeva I and Kanishka II, but on the coins of other rulers such as Kanishka III, Vasudeva-II, and Shaka, the Bactrain legend became off-flan and represent blurred details and irregular flan shapes. These depreciations of coins make challenges to the scholars for their proper attributions. This deterioration suggests a loosening of central control over minting operations, as local authorities or semi-independent regions began producing coins with minimal oversight. The emergence of regional styles, the inconsistent use of legends, and the increasing crudeness of strikes all reflect the fragmentation of Kushan power and the rise of autonomous minting centers. Thus, while early Kushan coinage exemplified imperial coherence and technical precision, late Kushan minting practices reveal a period of disorganization, decentralization, and administrative decline (Khan, 2010).

Vasudeva-I, too, issued coins with consistent symbols like trident behind altar on the obverse and for-pronged *tamga*, marking stability and continuity in minting. However, later coins of this period show hint at stylistic decline. Besides this, the emergence of new control marks like *nandipada* symbol and Brahmi letters simultaneously appeared on the coins of two different mints.

Kipunadha's coins retain similar motifs but are divided into two sub-types, *bhadra* and *basata*, based on legends under the left arm suggest either regional minting or internal fractionalization. The rise of cast and debased copies, particularly under Kipunadha and Kushano-Kidarite series, underscores a breakdown in centralized minting practices. While early coins adhered to standard weight and set pattern of dies but later issues, particularly of Kipunadha and those Kidarites show degradation in fabric, irregular legends, and increasing use of Brahmi. These changes reveal both linguistic and administrative shifts and a loss of the trans-regional coherence that had characterized early Kushan minting (Khan, 2008).

The Late Kushans issued their copper coins in reduced weight and gold in lower purity. Regional variations appeared in style and weight depreciation point to decentralized minting practices and reduced quality control. Their inscriptions, while continuing the Kushan titulature, suggest a diminished authority. The shift also indicates shrinking imperial revenues and the loss of access to gold sources and major trade hubs. Late Kushan coins are also more prone to imitation and debasement, with a noticeable decline in artistic and technical quality compared to the richly executed coins of the early period (Göbl, 1984 and Puri, 1984).

The socio-religious and political strength of the Late Kushans greatly diminished. Along with this, the diversity and quality of their coinage substantially contracted. Later coins frequently featured only simplified images of deities such as Osheo and Ardoxsho lacked the earlier breadth of religious representation. The use of debased coinage also suggests a shrinking state budget and weaker propaganda machinery. The earlier ideological goal of representing unity through religious pluralism had eroded, replaced by more localized or narrowly sectarian symbolism. Furthermore, inconsistent legends and devaluation of the weight of copper across regions reflect the loss of a centralized minting authority and the decline of the Kushan state's integrative vision (Bracey, 2012).

The main Kushan series under the early rulers employed refined minting technology and a consistent iconographic program featuring deities and the king in regal poses. In contrast, Late Kushan minting was far less consistent. New symbols (such as swastika**,** nandipada**,** Brahmi letters, and clusters of dots) appeared frequently and were likely indicative of mint identity, sequences of production and religious affiliation**.** The coins of Shaka, for instance, were issued at multiple fineness standards (75%, 60%, 50%), often within overlapping series, suggesting purity controls was deteriorating**,** or such variations were perhaps consciously manipulated to address regional economic needs. The introduction of copper alloys and progressive debasement also suggests experimentation or adaptation to declining resources or inflationary pressures (Oddy & Cribb, 1995).

CHAPTER-5

CONCLUSION

This study provides a comprehensive analysis of the Late Kushan copper coins from the Islamabad Museum's collection, focusing on their conservation, elemental composition, and the technological practices employed in their production. The research employs advanced archaeometallurgical techniques, including X-ray Fluorescence Spectroscopy (XRF), and Rutherford Backscattering Spectrometry (RBS), to thoroughly investigate the material and structural characteristics of these coins.

5.1 Key Findings

5.1.1 Corrosion Analysis and Conservation Approaches

The research methodology employed in this study is comprehensive and systematic, combining meticulous fieldwork with rigorous scientific analysis to investigate Late Kushan copper coins. Despite the limited availability of advanced conservation laboratories in Pakistan, the study leverages the well-equipped facility at Islamabad Museum, which provides essential digital and physical tools for the conservation process. By documenting the coins' physical attributes, applying non-destructive conservation techniques, and analyzing their metallurgical composition, the research aims to preserve these historical artefacts while deepening our understanding of Late Kushan coinage and ancient metallurgical practices. The study's approach ensures that both the preservation and scholarly analysis of these coins are carried out with precision, contributing significantly to the field of archaeometallurgy and cultural heritage conservation.

5.1.1.1 Conclusion of RBS technique

The research effectively combines elemental analysis techniques such as Rutherford Backscattering Spectrometry (RBS) with practical conservation efforts. The coins exhibited signs of corrosion, with compounds such as malachite, azurite, attacamite, and copper oxides (cuprite and tenorite) identified. These findings indicate significant environmental impacts on the coins over time. The study on the deterioration of Late Kushan copper coins reveals the complex interplay of environmental and material factors influencing their corrosion over time. The corrosion process is driven by various elements, such as oxygen, moisture, and carbon dioxide, leading to the formation of patina layers, including copper oxides like Cuprite and Tenorite. The research highlights the critical role of proper storage and conservation practices, as the absence of these has resulted in significant degradation, including the complete mineralization of coins stored under suboptimal conditions. Analytical methods, such as Rutherford backscattering spectrometry (RBS), have identified the elemental composition of these coins, with copper being the primary element alongside impurities like iron, silicon, and calcium. The presence of these impurities and corrosion compounds like malachite and azurite underscores the need for targeted preservation strategies. Ultimately, this study offers essential insights into the corrosion mechanisms at play, providing a foundation for more effective conservation efforts to protect these valuable cultural artefacts (Appendix-V).

5.1.1.3 Physical Conservation technique

The decision to focus on uncleaned coins allows for a more authentic assessment of their original composition and condition, which is crucial for both historical understanding and the development of effective conservation methods. The conservation approach proposed in this study includes pre-treatment investigations, stabilization treatments, and meticulous documentation. These steps are crucial for ensuring the long-term preservation of these historical artefacts. The study emphasizes the importance of using non-destructive methods, where possible, to clean and conserve the coins, thereby preserving their historical value.

In conclusion, while dental pick tools are invaluable for the precise, non-destructive cleaning of Late Kushan copper coins, their limitations highlight the need for a more comprehensive conservation strategy. These tools allow for meticulous removal of dirt and rust without damaging the coin's surface, preserving its historical integrity. However, they fall short in restoring the original luster of the coins and are ineffective against bronze disease, a common issue requiring chemical intervention. Therefore, to fully preserve and protect Late Kushan copper coins, it is essential to combine physical cleaning with chemical treatments. This integrated approach ensures that both surface grime and deeper, chemically-induced corrosion are addressed, thereby safeguarding the coins' historical and monetary value for future generations (Appendix-I).

5.1.1.4 Chemical Techniques

5.1.1.4.1 Ultrasonic Treatment

Ultrasonic cleaning is a highly effective and versatile method for removing contaminants from various materials, particularly in the metals industry. Its ability to use high-frequency sound waves to generate cavitation bubbles in an aqueous medium allows for thorough cleaning, even in the most intricate and hard-to-reach areas. For ancient artefacts like Late Kushan copper coins, ultrasonic cleaning is especially valuable as it can remove rust and surface corrosion without compromising the coins' integrity. This method strikes a delicate balance between effective contaminant removal and preservation, ensuring that the historical and numismatic value of such artefacts is maintained. In summary, ultrasonic cleaning is an ideal solution for preserving valuable or delicate items, offering both precision and protection (Appendix-III).

5.1.1.4.2 Stabilization and Reinforcement Treatment

The BTA treatment and Paraloid B72 reinforcement methods for Late Kushan copper coins are essential for their preservation, effectively inhibiting corrosion and enhancing structural integrity. BTA treatment forms a protective layer that stabilizes the coins but requires careful handling due to health risks associated with benzene. Similarly, the Paraloid B72 vacuum impregnation process provides deep reinforcement, though it relies on volatile solvents and raises concerns about long-term reversibility. These techniques highlight the balance between effective conservation and safety, emphasizing the need for careful management and potential exploration of safer alternatives to ensure the coins' preservation while maintaining their historical and cultural integrity (Appendix-IV).

5.1.1.4.3 Bronze Disease Treatment

The challenge of combating bronze disease in copper-based artefacts, such as Late Kushan copper coins, underscores the need for targeted and effective preservation strategies. While current treatments can mitigate corrosion and even restore some artefacts' original appearance, their success is inconsistent, particularly in addressing deeply embedded corrosion. This variability highlights the limitations of existing methods and the necessity for a more nuanced approach tailored to each artifact's specific condition. To safeguard culturally and historically significant artefacts from the destructive effects of bronze disease, preservationists must continue refining existing treatments and developing new, more effective strategies. Only through these dedicated efforts can we ensure the longevity and integrity of our shared heritage.

5.1.2. Elemental Composition and Alloying Practices

The elemental analysis revealed that the coins were primarily composed of copper with the presence of various impurities such as silica, nickel, phosphorus, and silver.

The inclusion of alloys like tin, lead, and nickel indicates advanced alloying practices, aimed at enhancing the durability of the coins.

The use of sulfide ores in smelting processes, coupled with significant impurities like iron, sulfur, and silica, points to less refined smelting techniques. These impurities suggest that the smelting processes likely operated at lower temperatures, and improper poling might have contributed to the incomplete removal of these impurities.

The multi-analytical investigation of Late Kushan copper coins provides a comprehensive understanding of the Kushan Empire's metallurgical practices and economic strategies. The findings highlight the use of sulfide ores, significant impurities like silica, phosphorus, and sulfur, and the deliberate choice to use pure copper instead of common alloys such as bronze or brass. These characteristics reflect both the technological constraints and strategic decisions made by the Kushan minting authorities, likely driven by resource availability and economic pressures (Appendix-VI b).

The presence of impurities suggests limitations in refining technology, while the use of pure copper points to a pragmatic approach to coin production, balancing cost with the need for a stable currency. The differences between this hoard and other Kushan coins emphasize regional variations in metallurgical practices, showcasing the empire's adaptability in response to local conditions.

Overall, these investigations reveal the intricate relationship between technology, resources, and economic policy in the Kushan Empire, offering valuable insights into the complexities of ancient coinage and the empire's broader economic strategies. The study underscores the importance of localized analyses in understanding the diverse and dynamic nature of historical minting practices.

5.1.3 Minting Techniques

The study offers valuable information on the minting processes and the economic implications of the coinage, it could have benefited from a more comparative approach, examining coins from different regions or periods to contextualize the findings within broader numismatic trends. The study explored the socio-political factors that may have influenced the observed economic devaluation, such as shifts in trade routes or political instability, to provide a more comprehensive understanding of the Kushan Empire's economic history.

The study concludes that the Late Kushan coins were predominantly struck rather than cast, which reflects sophisticated minting techniques. The presence of striations and micro-cracks within the coin interiors, likely caused by mechanical stress during minting, supports this conclusion.

The decision to use pure copper instead of more common alloys such as bronze or brass suggests an economic strategy that reflects resource management within the Kushan Empire. The choice of copper, a relatively abundant resource, might have been driven by the need to optimize available resources while maintaining the integrity of the coinage.

5.1.4 Technological and Economic Insights

The study highlights the technological sophistication of the Kushan Empire in terms of coin production. The use of advanced alloying and minting techniques, despite the presence of impurities, reflects a nuanced understanding of metalworking processes. The economic considerations of using pure copper, as opposed to alloyed metals, suggest a strategic approach to resource management and economic challenges faced by the Kushan Empire.

The research on the Late Kushan copper coins offers significant insights into the technological, economic, and metallurgical practices of the Kushan Empire. The findings suggest that the Kushans employed sophisticated minting techniques, possibly influenced by both technological advancements and economic considerations. The conservation strategies proposed in this study aim to preserve these coins for future generations, ensuring that they continue to provide valuable historical and cultural insights. This study not only enhances our understanding of ancient coinage practices but also contributes to the broader field of archaeometallurgy by highlighting the importance of integrating conservation efforts with scientific analysis.

The Kushan Empire's monetary system initially demonstrated economic strength and stability, with gold coins minted in the standard dinar weight of 8.00 grams and copper coins based on the Greek tetradrachm unit of 17.00 grams. The issuance of these coins in various denominations reflects a well-structured economy capable of supporting diverse commercial activities. However, during the mid-reign of Huvishka, the fifth ruler, a uniform reduction in the weight of copper coins marked the beginning of economic strain. This deliberate reduction indicates growing fiscal pressures, likely stemming from military expenditures, administrative costs, or difficulties in accessing raw materials. In the following reigns, the copper coinage continued to decline in weight, eventually reaching critically low levels due to the progressive depletion of resources. This deterioration was compounded by poor fabrication techniques and the intentional addition of impurities to stretch limited metal supplies, further eroding the coins' intrinsic value. The declining quality and weight of the coins reflect systemic economic mismanagement and resource scarcity. This monetary debasement not only undermined public confidence in the currency but also signaled the empire’s weakening economic foundations, contributing to its gradual decline.

The coinage of early Kushan rulers emphasized imperial ideology, religious patronage, and monetary stability, whereas Late Kushan issues reflect a period of political fragmentation, artistic decline, and decentralization. The transition from high-quality struck gold coins with

Hellenistic-Bactrian influences to localized, often cast and debased issues, signals not only a weakening empire but also the gradual absorption of Kushan territories by regional powers and successor states.

The comparison between the Late Kushans and their early imperial predecessors reveals a clear trajectory from imperial cohesion to regional fragmentation, as reflected in the evolution of their coinage. While early rulers like Wima Kadphises, Kanishka-I, and Huvishka used coinage to project imperial grandeur, religious inclusivity, and economic strength, the Late Kushan period beginning with Kanishka II signals a shift toward symbolic conservatism and administrative decline. Before the coinage of Vasudeva-I served as a transitional phase, preserving earlier traditions but adapting them to a more constrained political and economic reality. The subsequent rulers further diverged from imperial norms, introducing new iconographic elements, lower minting standards, and increasingly illegible inscriptions, all pointing to weakened central authority and growing regional autonomy. Thus, the numismatic record of the Kushans not only charts artistic and monetary changes but also encapsulates the rise, maturity, and eventual disintegration of one of Central Asia's most influential empires.

The comparative study of the Early and Late Kushans underscores the trajectory of a powerful, centralized empire that gradually devolved into a fragmented polity facing external pressures and internal decay. While the Early Kushans epitomized imperial grandeur, economic integration, and sophisticated minting, the Late Kushans reveal the strains of maintaining imperial legacies in the face of regional challenges and shifting political dynamics. The contrast in coinage alone provides a tangible record of this transition from flourishing rule to gradual disintegration.

The economic comparison between early and late Kushan rulers underscores the shift from a vibrant, globally connected empire to a shrinking, economically strained polity. The early Kushans projected wealth, stability, and religious diversity through their high-valued artistically rich coinage. In contrast, the Later coins` design by Vasudeva-I, adopted a more cautious and symbolic monetary approach, aiming to project continuity while grappling with the realities of economic contraction and political decentralization. The numismatic evidence thus offers a tangible reflection of the empire's broader economic transformation.

The conclusion of this research underscores the importance of developing non-destructive and efficient cleaning and conservation methods tailored to the specific challenges posed by ancient copper coins, particularly those from the Kushan period. The study's focus on the hard patina that often forms on these coins highlights a significant conservation issue, and its efforts to find a remedy are commendable. By identifying the causes of patina formation and proposing appropriate treatments, the research offers practical solutions that could benefit not only the Islamabad Museum's collection but also other institutions dealing with similar artefacts. The findings emphasize the need for ongoing collaboration between archaeologists, conservators, and materials scientists to ensure that these historical objects are preserved for future generations. Ultimately, the study makes a valuable contribution to both the understanding of ancient Kushan metallurgy and the field of conservation, offering a model for how scientific analysis can inform and enhance cultural heritage preservation.

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APPENDICES

APPENDIX – I

Catalogue of the 390 selected group of copper coins from Islamabad Museum

S. No	Classified King	Dimensions (weight Before Conservation)	Measurement (Diameter and Width)	Object	Material	Collection
1	Vasudeva (Nandipada)	8.5g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
2	Vasudeva (Short Figure)	8.0g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
3	Vasudeva	8.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
4	Vasudeva	6.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
5	Azes II	7.3g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
6	Vasudeva (Trident-axe)	8.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
7	Huvishka	3.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
8	Vasudeva	8.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
9	Huvishka	6.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
10	Vasudeva Limitation	9.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
11	Kanishka II (Stylized))	9.2g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
12	Vasudeva Limitation	8.5g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
13	Vasudeva (Tamga)	8.0g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
14	Vasudeva	6.1g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
15	Vasudeva	8.1g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
16	Kanishka II	6.6g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
17	Vasudeva Limitation	7.8g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
18	Vasudeva	7.8g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
19	Vasudeva Limitation	8.3g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
20	Kanishka II	8.5g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
21	Vasudeva	8.7g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
22	Vasudeva	8.0g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
23	Vasudeva (Short Figure)	8.8g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
24	Vasudeva (Short Figure)	7.9g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum

25	Kanishka II (Oesho))	8.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
26	Kanishka II (Br. Vi)	8.6g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
27	Kanishka II (Oesho))	7.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
28	Vasudeva (Tall Figure)	5.2g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
29	Vasudeva	7.8g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
30	Vasudeva	8.2g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
31	Vasudeva (Tall Figure)	3.6g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
32	Vasudeva	8.1g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
33	Vasudeva Limitation	7.9g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
34	Vasudeva	5.4g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
35	Vasudeva	8.9g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
36	Kanishka II (Fine)	7.9g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
37	Vasudeva Limitation	8.8g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
38	Uncertain	9.0g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
39	Vasudeva	8.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
40	Vasudeva (Early Trident)	9.0g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
41	Vasudeva (Tall Figure)	7.5g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
42	Vasudeva	8.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
43	Kanishka II	6.6g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
44	Kanishka II	7.4g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
45	Vasudeva	4.0g	2.2-0.6cm	Rusted Coin	Copper	Islamabad Museum
46	Vasudeva	8.0g	2.6-0.4cm	Rusted Coin	Copper	Islamabad Museum
47	Vasudeva (Tall Figure)	7.7g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
48	Vasudeva Limitation	7.6g	2.5-0.4cm	Rusted Coin	Copper	Islamabad Museum
49	Kanishka II (Fine)	9.1g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
50	Vasudeva	8.4g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
51	Vasudeva	8.9g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
52	Vasudeva Limitation	8.5g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
53	Vasudeva	8.2g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum

54	Kanishka II	3.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
55	Vasudeva	7.4g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
56	Kujula	8.3g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
57	Vasudeva	8.7g	2.3-0.6cm	Rusted Coin	Copper	Islamabad Museum
58	Vasishka	8.3g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
59	Vasudeva (Tamga)	8.4g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
60	Vasudeva	8.7g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
61	Vasudeva	8.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
62	Vasudeva (Short Figure)	7.0g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
63	Vasudeva (Tamga)	4.9g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
64	Vasudeva (Short Figure)	8.6g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
65	Vasudeva	7.8g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
66	Vasudeva	8.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
67	Vasudeva (Tall Figure)	7.2g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
68	Uncertain	6.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
69	Vasudeva Limitation	8.3g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
70	Kanishka II (Oesho))	10.2g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
71	Vasudeva Limitation	7.6g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
72	Vasudeva	5.1g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
73	Vasudeva	8.6g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
74	Vasudeva	8.7g	2.1-0.6cm	Rusted Coin	Copper	Islamabad Museum
75	Kanishka II (Stylized))	3.8g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
76	Kanishka II	6.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
77	Vasudeva	8.0g	2,4-0.5cm	Rusted Coin	Copper	Islamabad Museum
78	Vasudeva	6.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
79	Vasudeva	5.4g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
80	Vasudeva Limitation	4.7g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
81	Kanishka II	6.8g	2.2-0.6cm	Rusted Coin	Copper	Islamabad Museum
82	Vasudeva	8.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum

83	Kanishka II	7.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
84	Vasudeva	7.5g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
85	Vasudeva	5.8g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
86	Vasudeva	8.3g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
87	Kanishka II	8.6g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
88	Vasudeva Limitation	9.2g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
89	Vasudeva	8.3g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
90	Vasudeva	6.6g	2.6-0.4cm	Rusted Coin	Copper	Islamabad Museum
91	Kanishka II	7.4g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
92	Vasudeva	4.0g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
93	Kanishka II	8.0g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
94	Vasudeva	7.7g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
95	Vasudeva	7.6g	2.1-0.6cm	Rusted Coin	Copper	Islamabad Museum
96	Kanishka II	9.1g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
97	Vasudeva	8.4g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
98	Kanishka II (Khar. Vi))	8.9g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
99	Vasudeva Limitation	8.5g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
100	Vasudeva Limitation	8.2g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
101	Kanishka II	3.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
102	Vasudeva (Nandipada)	7.4g	2.5-0.4cm	Rusted Coin	Copper	Islamabad Museum
103	Uncertain	8.3g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
104	Kanishka II (Oesho))	8.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
105	Kanishka II (Fine)	8.3g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
106	Kanishka II	8.4g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
107	Kanishka II	8.7g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
108	Vasudeva	8.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
109	Vasudeva (Trident-axe)	7.0g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
110	Vasudeva	4.9g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
111	Kanishka II	8.6g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum

112	Vasishka	7.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
113	Vasudeva	8.1g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
114	Vasudeva (Nandipada)	7.2g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
115	Vasudeva	6.3g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
116	Vasudeva	8.3g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
117	Kanishka II	10.2g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
118	Vasudeva	7.6g	2.7-0.4cm	Rusted Coin	Copper	Islamabad Museum
119	Kanishka II (Fine)	5.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
120	Vasudeva (Short Figure)	8.6g	2.2-0.3cm	Rusted Coin	Copper	Islamabad Museum
121	Vasudeva	8.7g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
122	Vasudeva	3.8g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
123	Vasudeva	6.1g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
124	Vasudeva	8.0g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
125	Kanishka II (Oesho))	6.4g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
126	Vasudeva Limitation	5.4g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
127	Kanishka II (Fine)	4.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
128	Kanishka II (Br. Vi)	9.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
129	Kanishka II (Stylized))	8.3g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
130	Kanishka II (Br. Vi)	7.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
131	Vasudeva	7.5g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
132	Uncertain	5.8g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
133	Kanishka II	8.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
134	Vasudeva (Barred Trident)	8.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
135	Kanishka II	9.2g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
136	Kanishka II (Br. Vi)	8.7g	1.9-0.5cm	Rusted Coin	Copper	Islamabad Museum
137	Kanishka II	8.3g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
138	Vasudeva Limitation	8.4g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
139	Vasudeva Limitation	8.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
140	Kanishka II	8.4g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum

141	Vasudeva Limitation	7.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
142	Vasudeva Limitation	8.8g	1.9-0.4cm	Rusted Coin	Copper	Islamabad Museum
143	Vasudeva	9.0g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
144	Kanishka II	5.4g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
145	Vasudeva (Nandipada)	7.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
146	Kanishka II	8.3g	2.5-0.4cm	Rusted Coin	Copper	Islamabad Museum
147	Vasudeva	8.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
148	Vasudeva	8.1g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
149	Vasudeva	7.2g	2.0-0.5cm	Rusted Coin	Copper	Islamabad Museum
150	Uncertain	6.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
151	Kanishka II	8.6g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
152	Vasudeva (Pronged)	7.8g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
153	Vasudeva	8.1g	2.6-0.4cm	Rusted Coin	Copper	Islamabad Museum
154	Azes II	8.7g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
155	Vasudeva	8.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
156	Kanishka II (Stylized))	8.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
157	Vasudeva	8.7g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
158	Uncertain	8.4g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
159	Vasudeva (Short Figure)	7.0g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
160	Vasudeva	4.9g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
161	Vasishka	8.6g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
162	Kanishka II (Stylized))	8.2g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
163	Vasudeva	3.8g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
164	Kanishka II	7.4g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
165	Vasudeva (Short Figure)	8.3g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
166	Vasudeva (Short Figure)	8.7g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
167	Vasudeva	8.7g	2.2-0.6cm	Rusted Coin	Copper	Islamabad Museum
168	Kanishka II	8.8g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
169	Vasudeva	9.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum

170	Vasudeva	8.6g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
171	Kanishka II (Stylized))	7.8g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
172	Vasudeva Limitation	8.1g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
173	Vasudeva	7.7g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
174	Vasudeva (Tamga)	7.6g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
175	Vasudeva	9.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
176	Kanishka II	8.4g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
177	Vasudeva	8.9g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
178	Vasudeva	8.5g	2.5-0.4cm	Rusted Coin	Copper	Islamabad Museum
179	Kanishka II (Fine)	8.2g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
180	Vasudeva Limitation	3.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
181	Vasudeva (Nandipada)	7.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
182	Vasudeva (Short Figure)	8.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
183	Kanishka II (Fine)	8.7g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
184	Vasudeva Limitation	4.9g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
185	Vasudeva Limitation	8.4g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
186	Kanishka II (Fine)	8.7g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
187	Vasudeva	8.4g	2.3-0.6cm	Rusted Coin	Copper	Islamabad Museum
188	Kanishka II	7.0g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
189	Vasudeva Limitation	4.9g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
190	Kanishka II	8.6g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
191	Vasudeva (Short Figure)	7.8g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
192	Vasudeva (Barred Trident)	8.1g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
193	Kanishka II	7.2g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
194	Vasudeva Limitation	6.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
195	Vasudeva (Nandipada)	8.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
196	Vasudeva	8.4g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
197	Vasudeva	8.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
198	Vasudeva (Short Figure)	8.4g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum

199	Uncertain	7.0g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
200	Kanishka II	4.9g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
201	Vasudeva	8.6g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
202	Kanishka II (Br. Vi)	7.8g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
203	Vasudeva	8.1g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
204	Vasudeva	7.2g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
205	Kanishka II (Khar. Vi))	6.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
206	Kanishka II	7.1g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
207	Vasudeva	9.0g	2.2-0.6cm	Rusted Coin	Copper	Islamabad Museum
208	Vasudeva	9.2g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
209	Vasudeva (Barred Trident)	8.5g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
210	Vasudeva (Nandipada)	8.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
211	Kanishka II (Stylized))	6.1g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
212	Vasudeva	8.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
213	Vasudeva	9.1g	2.3-0.6cm	Rusted Coin	Copper	Islamabad Museum
214	Vasudeva	8.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
215	Kanishka II (Stylized))	8.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
216	Kanishka II	8.2g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
217	Vasudeva Limitation	6.2g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
218	Kanishka II (Br. Vi)	7.0g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
219	Kanishka II	7.5g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
220	Vasudeva	7.5g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
221	Vasudeva Limitation	4.5g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
222	Vasudeva Limitation	6.1g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
223	Vasudeva (Short Figure)	8.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
224	Vasudeva (Short Figure)	6.6g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
225	Huvishka	7.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
226	Vasudeva Limitation	4.0g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
227	Vasudeva	8.0g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum

228	Vasudeva (Nandipada)	7.7g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
229	Kanishka II (Khar. Vi))	7.6g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
230	Kanishka II (Oesho))	9.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
231	Vasudeva Limitation	8.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
232	Vasudeva	8.9g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
233	Vasudeva	8.5g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
234	Vasudeva	8.2g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
235	Vasudeva Limitation	3.8g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
236	Kanishka II	7.4g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
237	Vasudeva (Short Figure)	8.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
238	Kanishka II (Br. Vi)	8.7g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
239	Vasudeva	8.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
240	Vasudeva (Short Figure)	8.4g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
241	Vasudeva (Short Figure)	8.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
242	Kanishka II (Stylized))	8.4g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
243	Kanishka II	7.0g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
244	Vasudeva (Short Figure)	4.9g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
245	Vasudeva (Tamga)	8.6g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
246	Vasudeva	7.8g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
247	Vasudeva	8.1g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
248	Kanishka II (Stylized))	7.2g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
249	Kanishka II	6.3g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
250	Vasudeva (Nandipada)	8.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
251	Kanishka II	10.2g	2.2-0.6cm	Rusted Coin	Copper	Islamabad Museum
252	Vasudeva	7.6g	2.6-0.4cm	Rusted Coin	Copper	Islamabad Museum
253	Kanishka III	5.1g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
254	Vasudeva	8.6g	2.5-0.4cm	Rusted Coin	Copper	Islamabad Museum
255	Vasudeva	8.7g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
256	Vasudeva Limitation	3.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum

257	Kanishka II	6.1g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
258	Huvishka	8.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
259	Vasishka	6.4g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
260	Vasudeva Limitation	5.4g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
261	Vasudeva Limitation	4.7g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
262	Kanishka II	9.0g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
263	Vasudeva	8.3g	2.3-0.6cm	Rusted Coin	Copper	Islamabad Museum
264	Vasudeva	7.4g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
265	Vasudeva (Short Figure)	7.5g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
266	Vasishka	5.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
267	Vasudeva	8.3g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
268	Vasudeva	8.6g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
269	Vasudeva	9.2g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
270	Vasudeva	8.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
271	Vasudeva (Short Figure)	8.0g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
272	Kanishka II (Fine)	7.2g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
273	Kanishka II (Stylized))	5.7g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
274	Vasudeva (Tamga)	7.2g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
275	Vasudeva (Short Figure)	3.8g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
276	Vasudeva Limitation	4.8g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
277	Vasudeva Limitation	8.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
278	Vasudeva	8.0g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
279	Kanishka II	7.1g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
280	Kanishka II	7.7g	2.1-0.6cm	Rusted Coin	Copper	Islamabad Museum
281	Vasudeva	8.9g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
282	Vasudeva	8.5g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
283	Vasudeva (Nandipada)	7.6g	2,4-0.5cm	Rusted Coin	Copper	Islamabad Museum
284	Vasudeva (Nandipada)	8.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
285	Kanishka II	6.6g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum

286	Kanishka II (Br. Vi)	7.0g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
287	Vasudeva Limitation	7.3g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
288	Kanishka II	7.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
289	Vasudeva	8.1g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
290	Vasudeva	7.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
291	Kanishka II	8.7g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
292	Kanishka II (Stylized))	5.9g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
293	Kanishka II	7.5g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
294	Kanishka II	6.8g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
295	Vasudeva	8.7g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
296	Vasudeva	7.8g	2.6-0.4cm	Rusted Coin	Copper	Islamabad Museum
297	Vasudeva	8.6g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
298	Kanishka II	5.7g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
299	Vasudeva	8.2g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
300	Vasudeva	8.2g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
301	Vasudeva	8.3g	2.1-0.6cm	Rusted Coin	Copper	Islamabad Museum
302	Vasudeva (Tall Figure)	7.8g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
303	Kanishka II	5.4g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
304	Kanishka II	6.8g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
305	Vasudeva	7.7g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
306	Vasudeva	8.7g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
307	Kanishka II	7.0g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
308	Vasudeva	8.0g	2.5-0.4cm	Rusted Coin	Copper	Islamabad Museum
309	Kanishka II	6.6g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
310	Vasudeva	9.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
311	Vasudeva (Barred Trident)	5.1g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
312	Vasudeva	6.9g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
313	Uncertain	5.2g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
314	Kanishka II	7.1g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum

315	Vasudeva	8.4g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
316	Vasudeva (Pronged)	8.2g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
317	Vasudeva	8.3g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
318	Vasudeva Limitation	5.2g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
319	Vasudeva Limitation	3.4g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
320	Vasudeva Limitation	4.6g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
321	Vasudeva Limitation	5.5g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
322	Kanishka II (Stylized))	6.5g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
323	Kanishka II (Br. Vi)	8.5g	2.2-0.6cm	Rusted Coin	Copper	Islamabad Museum
324	Kanishka II	6.6g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
325	Vasudeva Limitation	7.8g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
326	Kanishka II	7.8g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
327	Kanishka II (Fine)	8.3g	2.2-0.6cm	Rusted Coin	Copper	Islamabad Museum
328	Vasudeva	8.5g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
329	Kanishka II (Br. Vi)	8.7g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
330	Vasudeva (Nandipada)	8.4g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
331	Uncertain	8.0g	2.7-0.4cm	Rusted Coin	Copper	Islamabad Museum
332	Vasudeva	8.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
333	Vasudeva Limitation	4.8g	2.2-0.3cm	Rusted Coin	Copper	Islamabad Museum
334	Uncertain	8.5g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
335	Vasudeva (Pronged)	8.9g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
336	Vasudeva (Short Figure)	7.5g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
337	Vasudeva (Short Figure)	8.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
338	Vasudeva	5.4g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
339	Vasudeva (Tamga)	8.7g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
340	Vasudeva Limitation	8.5g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
341	Vasudeva	8.2g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
342	Vasudeva	7.8g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
343	Kanishka II (Br. Vi)	8.4g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum

344	Vasudeva	7.7g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
345	Kanishka II (Br. Vi)	7.3g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
346	Vasudeva (Nandipada)	8.1g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
347	Vasudeva Limitation	3.5g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
348	Vasudeva (Barred Trident)	8.6g	2.4-0.4cm	Rusted Coin	Copper	Islamabad Museum
349	Vasudeva	5.6g	1.9-0.5cm	Rusted Coin	Copper	Islamabad Museum
350	Vasudeva	8.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
351	Vasudeva Limitation	6.1g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
352	Vasudeva Limitation	8.5g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
353	Kanishka II	6.2g	2.1-0.5cm	Rusted Coin	Copper	Islamabad Museum
354	Uncertain	7.3g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
355	Vasudeva Limitation	3.9g	1.9-0.4cm	Rusted Coin	Copper	Islamabad Museum
356	Vasudeva Limitation	4.3g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
357	Vasudeva Limitation	5.1g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
358	Vasudeva Limitation	8.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
359	Vasudeva	7.4g	2.5-0.4cm	Rusted Coin	Copper	Islamabad Museum
360	Kanishka II (Br. Vi)	7.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
361	Vasudeva	7.9g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
362	Vasudeva Limitation	5.7g	2.0-0.5cm	Rusted Coin	Copper	Islamabad Museum
363	Vasudeva	8.2g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
364	Vasudeva Limitation	4.7g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
365	Vasudeva Limitation	8.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
366	Vasudeva	8.8g	2.6-0.4cm	Rusted Coin	Copper	Islamabad Museum
367	Vasudeva	7.9g	2.4-0.5cm	Rusted Coin	Copper	Islamabad Museum
368	Vasudeva (Short Figure)	8.3g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
369	Kanishka II (Br. Vi)	8.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
370	Vasudeva Limitation	4.0g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
371	Vasudeva	5.2g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
372	Vasudeva Limitation	7.8g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum

373	Vasudeva (Nandipada)	8.2g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
374	Vasudeva Limitation	3.6g	1.8-0.4cm	Rusted Coin	Copper	Islamabad Museum
375	Vasudeva	8.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
376	Vasudeva (Short Figure)	7.9g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
377	Vasudeva Limitation	5.4g	2.2-0.4cm	Rusted Coin	Copper	Islamabad Museum
378	Vasudeva	8.9g	2.5-0.5cm	Rusted Coin	Copper	Islamabad Museum
379	Vasudeva (Nandipada)	8.5g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
380	Vasudeva (Nandipada)	8.8g	2.2-0.6cm	Rusted Coin	Copper	Islamabad Museum
381	Vasudeva (Nandipada)	9.0g	2.2-0.5cm	Rusted Coin	Copper	Islamabad Museum
382	Kanishka II (Oesho))	8.1g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
383	Vasudeva	9.0g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
384	Vasudeva Limitation	7.5g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
385	Vasudeva Limitation	5.0g	2.0-0.4cm	Rusted Coin	Copper	Islamabad Museum
386	Vasudeva	8.4g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
387	Vasudeva (Nandipada)	8.1g	2.3-0.4cm	Rusted Coin	Copper	Islamabad Museum
388	Vasudeva	8.6g	2.3-0.5cm	Rusted Coin	Copper	Islamabad Museum
389	Kanishka II (Br. Vi)	5.6g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum
390	Vasudeva Limitation	4.7g	2.1-0.4cm	Rusted Coin	Copper	Islamabad Museum

APPENDIX – II

Physical appearance of the Late Kushan Copper Coins before conservation techniques

Fig 82: obverse side of 217 coin

Fig 83: reverse side of 217 coin

Fig 84: obverse side of 231 coin

Fig 85: reverse side of 231 coin

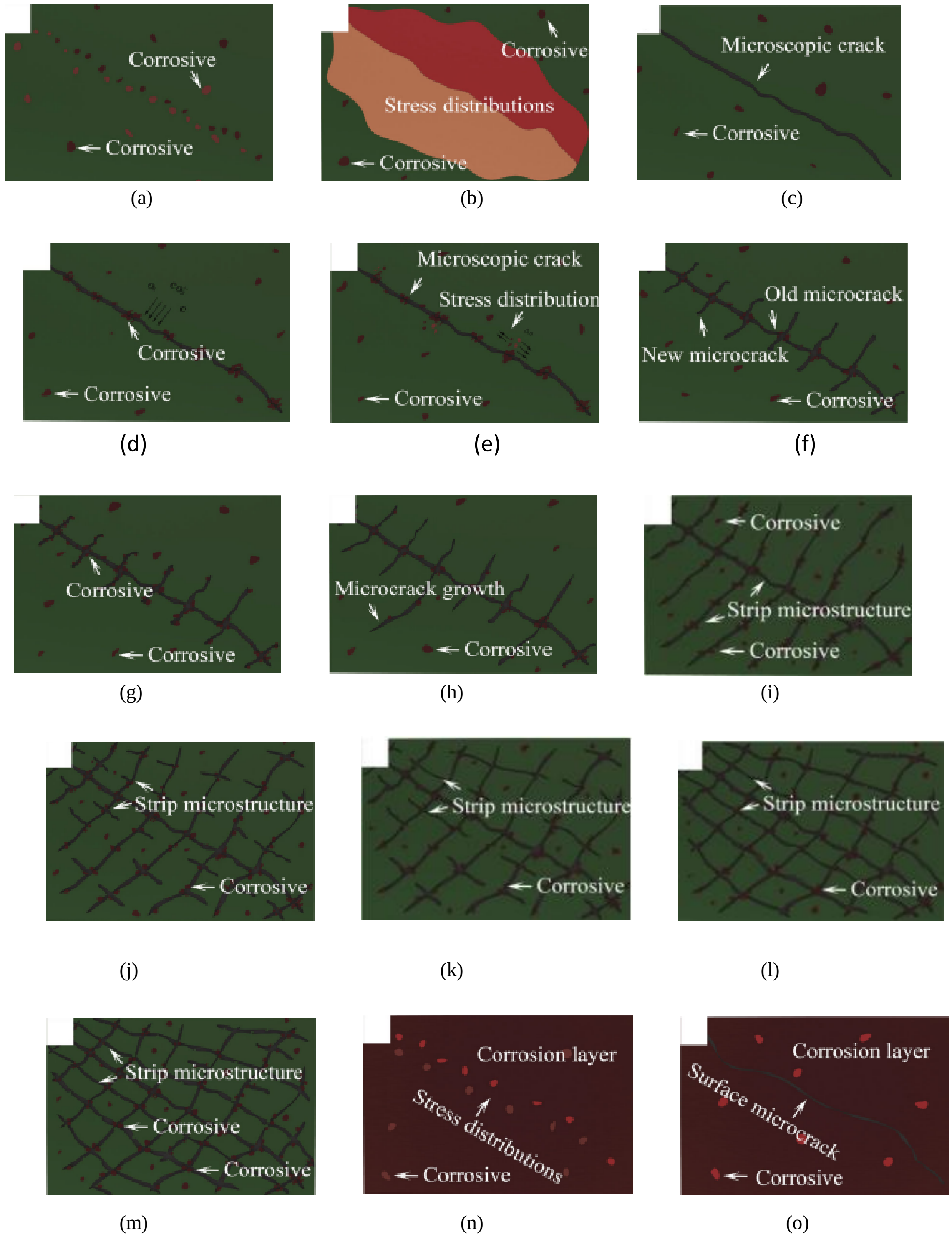
Fig 86: obverse side of 287 **Fig 87: reverse side of 287**

Fig 88: obverse side of 340 coin **Fig 89: reverse side of 340 coin**

Fig 90: obverse side of 372 **Fig 91: reverse side of 372**

APPENDIX – III

Typical model established for the growth of corrosion layers starting from micro-cracks generation to formation of corrosion features of Late Kushan copper coin surface:



APPENDIX – IV

Catalogue of Late Kushan Copper Coins after Ultrasonic Treatment

S. No.	Dimension (weight Before-After)	Size (Diameter and Width)	Object	Material	Classified	Description
1	8.5 – 8.1g	2.2-0.5cm	Rusted Coin	Copper	**Vasudeva (Nandipada)**	Islamabad Museum

Before Ultrasonic Treatment

Fig 92: obverse

Fig 93: reverse

After Ultrasonic Treatment

Fig 94: obverse

Fig 95: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter and Width)	Object	Material	Classified	Description
7	3.8– 3.7g	2.2-0.4cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 96: obverse

Fig 97: reverse

After Ultrasonic Treatment

Fig 98: obverse

Fig 99: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter and Width)	Object	Material	Classified	Description
8	8.7-7.5g	2.3-0.5cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 100: obverse

Fig 101: reverse

After Ultrasonic Treatment

Fig 102: obverse

Fig 103: reverse

S. No.	Dimension (weight Before -After)	Size (Diameter - Width)	Object	Material	Classified	Description
26	8.6-8.5g	2.1-0.5cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 104: obverse

Fig 105: reverse

After Ultrasonic Treatment

Fig 106: obverse

Fig 107: reverse

S. No.	Dimension (weight Before -After)	Size (Diameter - Width)	Object	Material	Classified	Description
27	7.4-7.3g	2.3-0.5cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 108: obverse

Fig 109: reverse

After Ultrasonic Treatment

Fig 110: obverse

Fig 111: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
36	7.9-7.7g	2.2-0.5cm	Rusted Coin	Copper	Kanishka II	Islamabad Museum

Before Ultrasonic Treatment

Fig 112: obverse

Fig 113: reverse

After Ultrasonic Treatment

Fig 114: obverse

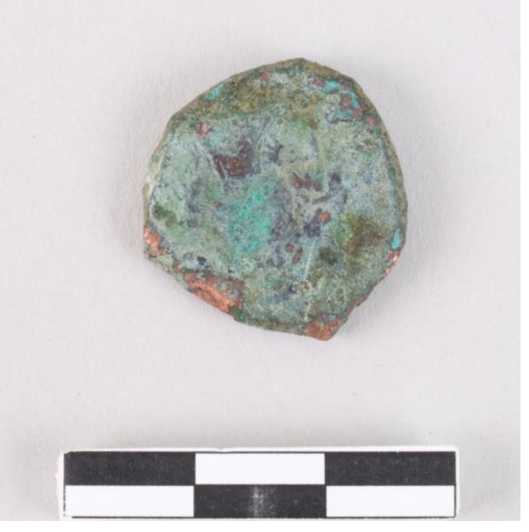


Fig 115: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter-Width)	Object	Material	Classified	Description
81	6.8– 6.4g	2.2-0.6cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 116: obverse

Fig 117: reverse

After Ultrasonic Treatment

Fig 118: obverse

Fig 119: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
129	8.3-8.1g	2.4-0.5cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 120: obverse

Fig 121: reverse

After Ultrasonic Treatment

Fig 122: obverse

Fig 123: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
134	8.1–7.9g	2.3-0.5cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 124: obverse

Fig 125: reverse

After Ultrasonic Treatment

Fig 126: obverse

Fig 127: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
184	4.9– 4.5g	2.0-0.4cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 128: obverse

Fig 129: reverse

After Ultrasonic Treatment

Fig 130: obverse

Fig 131: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
237	8.4– 8.3g	2.3-0.5cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 132: obverse

Fig 133: reverse

After Ultrasonic Treatment

Fig 134: obverse

Fig 135: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
245	8.6– 8.1g	2.3-0.5cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 136: obverse

Fig 137: reverse

After Ultrasonic Treatment

Fig 138: obverse

Fig 139: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
259	6.6– 6.4g	2.4-0.4cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 140: obverse

Fig 141: reverse

After Ultrasonic Treatment

Fig 142: obverse

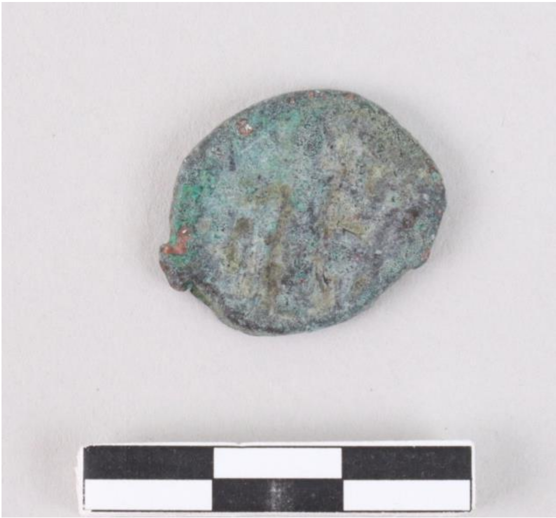


Fig 143: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
302	7.8–7.5g	2.4-0.5cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

Fig 144: obverse

Fig 145: reverse

After Ultrasonic Treatment

Fig 146: obverse

Fig 147: reverse

S. No.	Dimension (weight Before-After)	Size (Diameter - Width)	Object	Material	Classified	Description
313	5.2– 5.0g	2.2-0.4cm	Rusted Coin	Copper	Havishka	Islamabad Museum

Before Ultrasonic Treatment

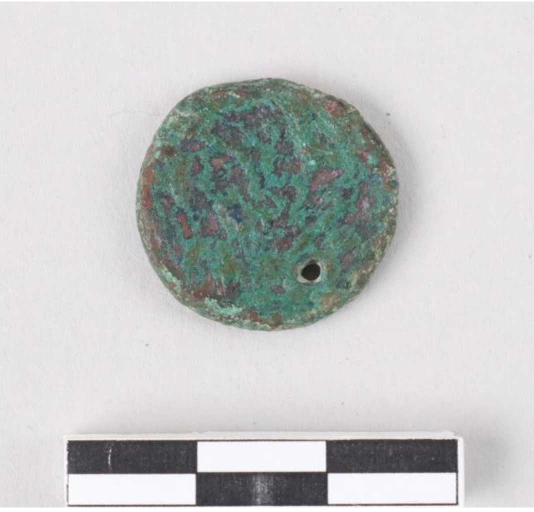


Fig 148: obverse

Fig 149: reverse

After Ultrasonic Treatment

Fig 150: obverse

Fig 151: reverse

APPENDIX – V

Catalogue after Reinforcement of Late Kushan Copper Coins

Fig 152: obverse

Fig 153: reverse

Fig 154: obverse

Fig 155: reverse

Fig 156: obverse

Fig 157: reverse

Fig 158: obverse

Fig 159: reverse

Fig 160: obverse

Fig 161: reverse

Fig 162: obverse

Fig 163: reverse

Fig 164: obverse

Fig 165: reverse

Fig 166: obverse

Fig 167: reverse

Fig 168: obverse

Fig 169: reverse

Fig 170: obverse

Fig 171: reverse

Fig 172: obverse

Fig 173: reverse

Fig 174: obverse

Fig 175: reverse

Fig 176: obverse

Fig 177: reverse

Fig 178: obverse

Fig 179: reverse

Fig 180: obverse

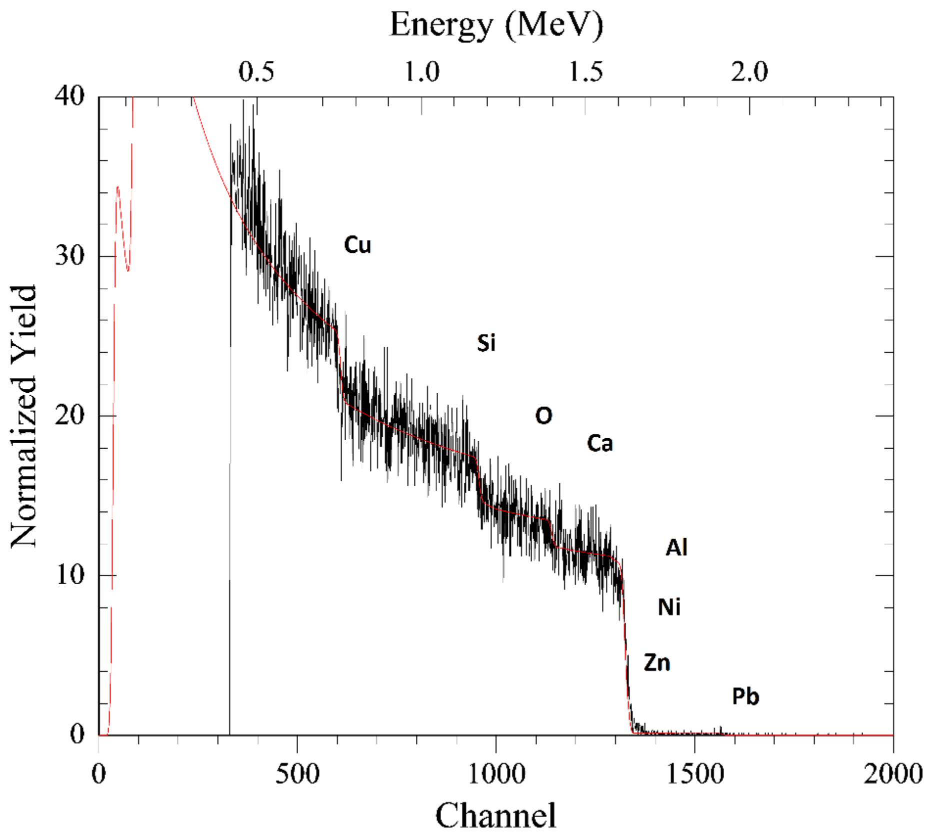
Fig 181: reverse

Fig 182: obverse

Fig 183: reverse

APPENDIX – VI

Rutherford Backscattering Spectroscopy Results



1.

Fig 184: Calculated RBS spectrum of coin 217. 1.9 MeV 4He, 170◦

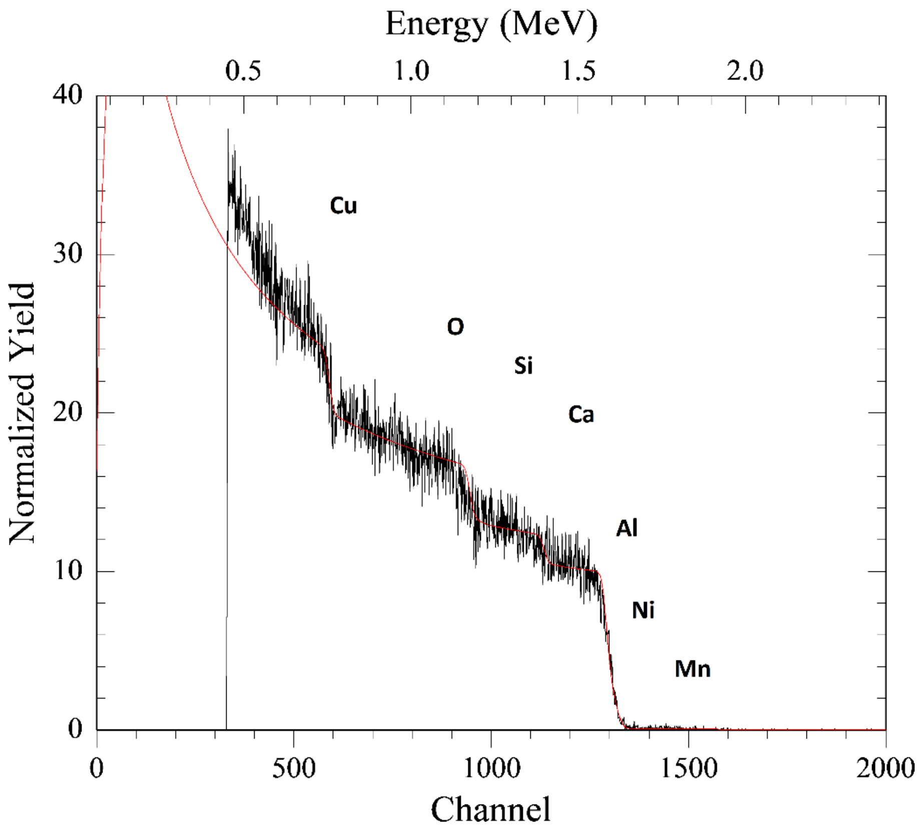
Description Coin 217

Sim Reset
Layer 1
Thick 4000 nm
Composition:

Elements	Cu	O	Si	Pb	Ca	Ni	Al	Zn
Composition	**2.790352**	**0.918221**	**1.17296**	**0.00114656**	**0.256687**	**0.0284803**	**0.02904**	
Percentage	**54%**	**17.6%**	**22.66%**	**0.02%**	**4.8%**	**0.3%**	**0.561%**	**0.04%**

Table 1: elemental composition of coin217

Maxpth 200; Foil disable



2.

Fig 185: Calculated RBS spectrum of coin 231. 1.9 MeV 4He, 170◦

Description Coin 231

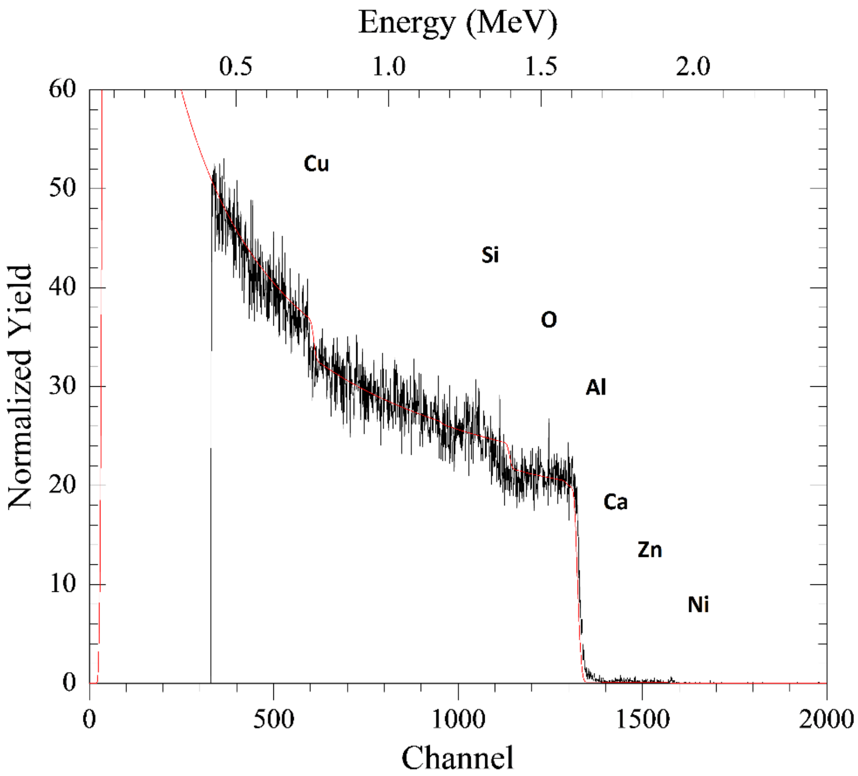
Sim Reset
Layer 1
Thick 4000 nm

Composition:

Elements	Cu	O	Si	Pb	Ca	Ni	Al	Mn
Composition	**4**	**1.7314**	**0.451037**	**0.00114656**	**0.184734**	**0.05176**	**0.06213**	**0.01124**
Percentage	**54%**	**26.6%**	**6.94%**	**0.017%**	**2.84%**	**0.79%**	**0.95%**	**0.17%**

Table 2: elemental composition of coin231

Maxpth 200; Foil disable



3.

Fig 186: Calculated RBS spectrum of coin 287. 1.9 MeV 4He, 170◦

Description Coin 287

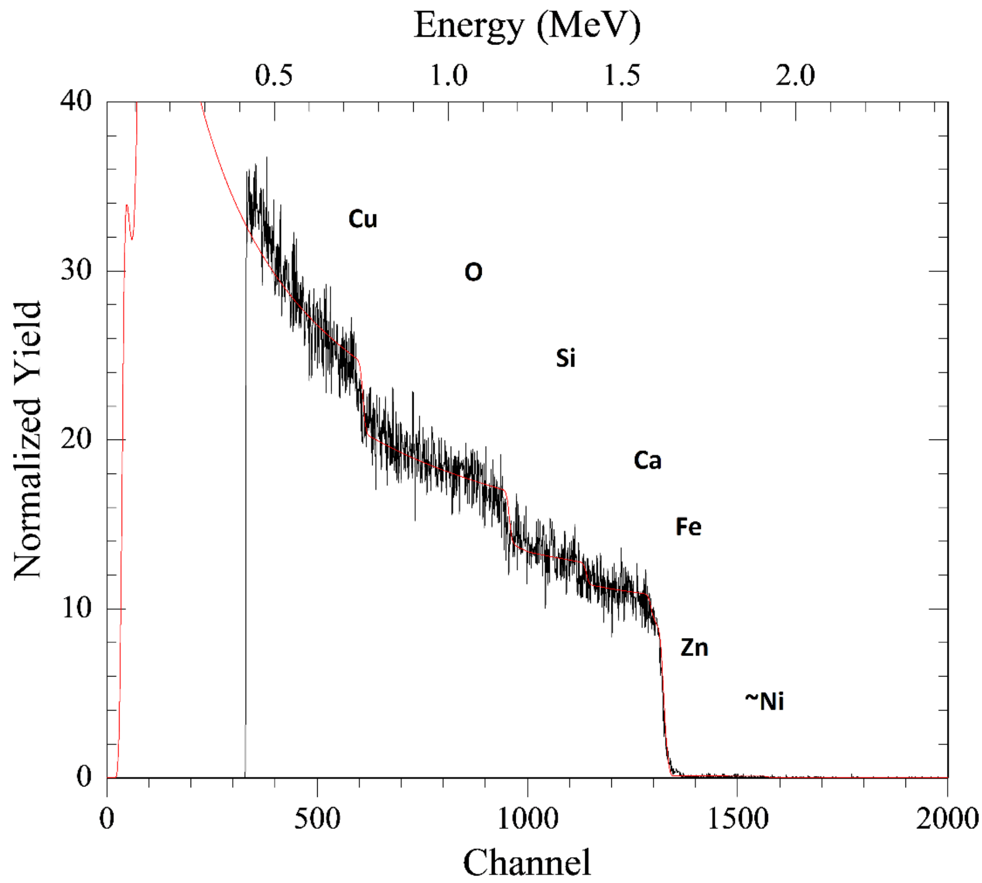
Sim Reset
Layer 1
Thick 4000 nm

Composition:

Elements	Cu	O	Si	Ca	Ni	Al	Zn
Composition	4.3	0.5	1.83	0.1	0.00114656	0.2	0.06
Percentage	61.50%	7.15%	26.17%	1.43%	0.01%	2.86%	0.85%

Table 3: elemental composition of coin287

Maxpth 200; Foil disable



4.

Fig 187: Calculated RBS spectrum of coin 340. 1.9 MeV 4He, 170◦

Description Coin 340

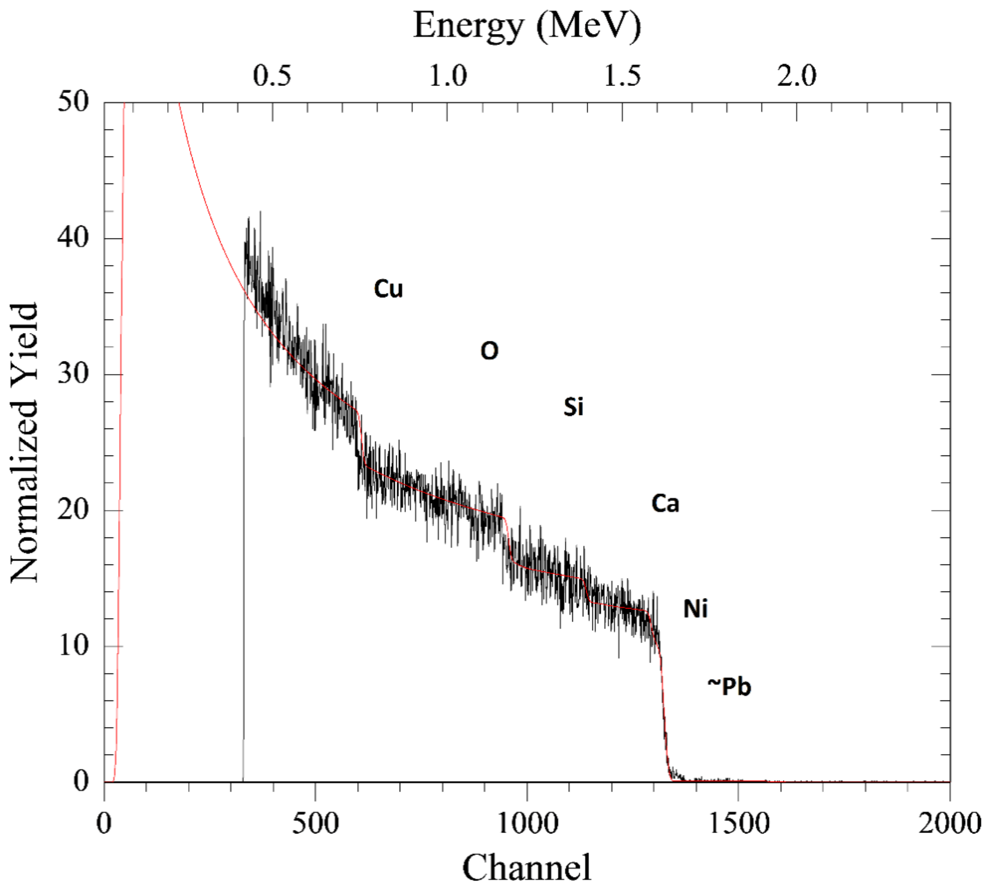
Sim Reset
Layer 1
Thick 4000 nm

Composition:

Elements	Cu	O	Si	Ca	Ni	Fe	Zn
Composition	4.9	1.3	0.8	0.25	0.00114656	0.2	0.1
Percentage	64.89%	17.21 %	10.59%	3.31%	0.01%	2.64%	1.32%

Table 4: elemental composition of coin340

Maxpth 200; Foil disable



5.

Fig 188: Calculated RBS spectrum of coin 372. 1.9 MeV 4He, 170◦

Description Coin 372

Sim Reset
Layer 1
Thick 4000 nm

Composition:

Elements	**Cu**	**O**	**Si**	**Pb**	**Ca**	**Ni**
Composition	**6**	**1.77201**	**1.2**	**0.00114656**	**0.438961**	**0.380271**
Percentage	**61.32%**	**18.08%**	**12.26%**	**0.01%**	**4.39%**	**3.88%**

Table 5: elemental composition of coin372

Maxpth 200; Foil disable

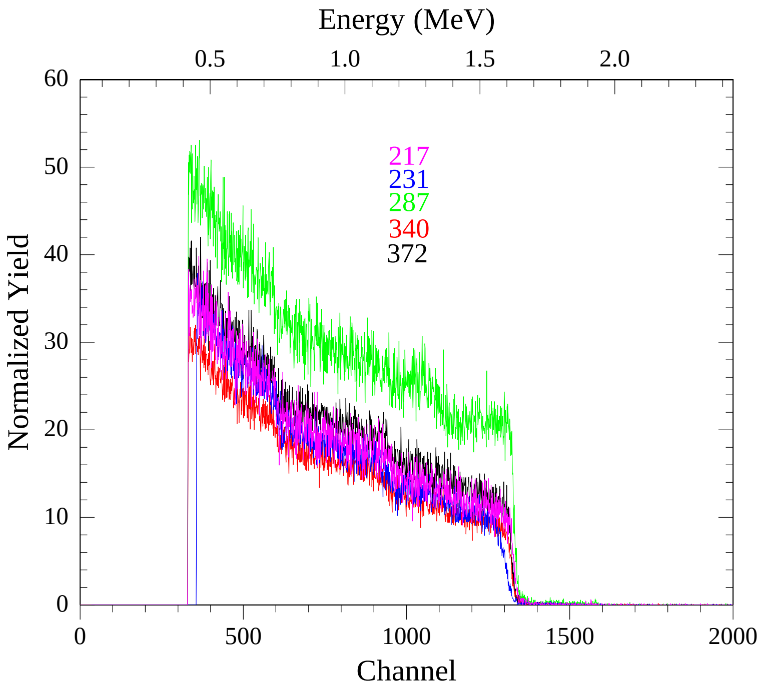


Fig 189: Calculated RBS combined spectrum of coins. 1.9 MeV 4He, 170

APPENDIX – VII (a)

Obverse and Reverse view of the Late Kushan copper coins for XRF analysis

Fig 190: coin 1

Fig 191: coin 5

Fig 192: coin 7

Fig 193: coin 26

Fig 194: coin 27

Fig 195: coin 36

Fig 196: coin 40

Fig 197: coin 56

Fig 198: coin 81

Fig 199: coin 98

Fig 200: coin 109

Fig 201: coin 129

Fig 202: coin 134

Fig 203: coin 184

Fig 204: coin 237

Fig 205: coin 245

Fig 206: coin 253

Fig 207: coin 259

Fig 208: coin 265

Fig 209: coin 302

Fig 210: coin 313

Fig 211: coin 335

APPENDIX – VII (b)

Results of XRF Spectroscopy

No	Element		Cu	Si	P	S	Ni	Pb	Ag	Co
1	Coin 1	Obverse	98.692	0.821	0.025	0.058	_	_	_	_
		Reverse	90.632	8.88	0.023	0.095	_	_	_	_
2	Coin 5	Obverse	77.339	15.591	0.021	0.101	0.022	0.135	4.768	_
		Reverse	75.916	15.668	0.021	0.105	0.037	0.273	5.014	_
3	Coin 7	Obverse	95.404	3.813	0.024	0.023	_	_	_	_
		Reverse	87.298	11.648	0.022	0.072	0.001	_	_	_
4	Coin 26	Obverse	98.568	0.873	0.025	0.06	_	_	_	_
		Reverse	79.713	18.0	0.02	0.089	_	_	_	_
5	Coin 27	Obverse	98.386	0.924	0.025	0.036	_	_	_	_
		Reverse	86.509	12.587	0.022	0.069	0.004	_	_	_
6	Coin 36	Obverse	98.594	0.893	0.025	0.035	_	_	_	_
		Reverse	89.277	10.032	0.022	0.166	_	_	_	_
7	Coin 40	Obverse	90.228	9.255	0.023	0.177	0.002	_	_	_
		Reverse	90.518	8.684	0.023	0.169	0.005	_	_	_
8	Coin 56	Obverse	81.671	14.578	0.021	0.121	0.043	_	_	_
		Reverse	77.721	17.305	0.021	0.094	0.044	_	_	_
9	Coin 81	Obverse	98.69	0.852	0.025	0.02	_	_	_	_
		Reverse	88.638	10.691	0.022	0.041	_	_	_	_
10	Coin 98	Obverse	94.934	4.088	0.024	0.045	_	_	_	_
		Reverse	84.648	14.431	0.021	0.02	_	_	_	_
11	Coin 109	Obverse	84.868	14.051	0.021	0.123	_	_	_	_

		Reverse	87.399	11.815	0.022	0.159	–	–	–	–
12	Coin 129	Obverse	97.18	2.067	0.024	0.054	–	–	–	–
		Reverse	90.358	8.404	0.062	0.068	–	–	–	–
13	Coin 134	Obverse	95.113	3.749	0.024	0.052	0.001	–	–	–
		Reverse	88.464	10.42	0.022	0.105	–	–	–	–
14	Coin 184	Obverse	97.956	0.967	0.025	0.02	–	–	–	–
		Reverse	87.661	11.345	0.022	0.087	–	–	–	–
15	Coin 237	Obverse	95.033	4.277	0.024	0.033	0.001	–	–	–
		Reverse	85.799	13.584	0.022	0.048	–	–	–	–
16	Coin 245	Obverse	97.548	1.691	0.025	0.039	–	–	–	–
		Reverse	86.28	12.955	0.022	0.051	–	–	–	–
17	Coin 253	Obverse	90.898	8.747	0.023	0.048	0.004	–	–	–
		Reverse	91.769	7.806	0.023	0.018	0.001	–	–	–
18	Coin 259	Obverse	96.284	3.008	0.024	0.058	0.006	–	–	–
		Reverse	90.321	8.689	0.023	0.106	0.004	–	–	–
19	Coin 265	Obverse	89.849	8.978	0.023	0.124	–	–	–	–
		Reverse	91.419	7.389	0.023	0.14	–	–	–	–
20	Coin 302	Obverse	96.608	2.862	0.024	0.031	–	–	–	–
		Reverse	89.47	9.963	0.022	0.092	0.002	–	–	–
21	Coin 313	Obverse	95.806	3.223	0.024	0.05	0.05	–	–	0.169
		Reverse	90.628	8.486	0.023	0.094	0.043	–	–	0.145
22	Coin 335	Obverse	86.62	12.95	0.022	0.06	–	–	–	–
		Reverse	92.35	7.046	0.023	0.102	–	–	–	–

Table 6: Elemental Analysis (mas. %) by WD-XRF of Late Kushan Copper Coins from Obverse and Reverse View

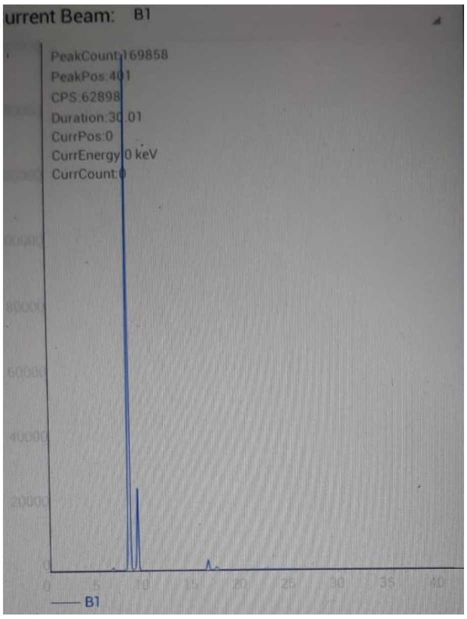


Fig 212: obverse spectrum of coin 1

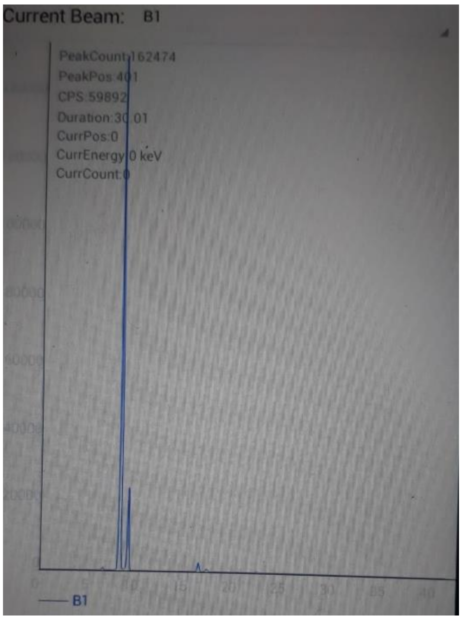


Fig 213: reverse spectrum of coin 1

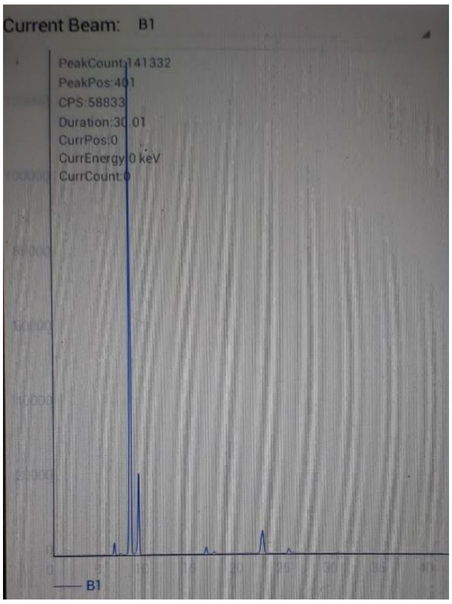


Fig 214: obverse spectrum of coin 5

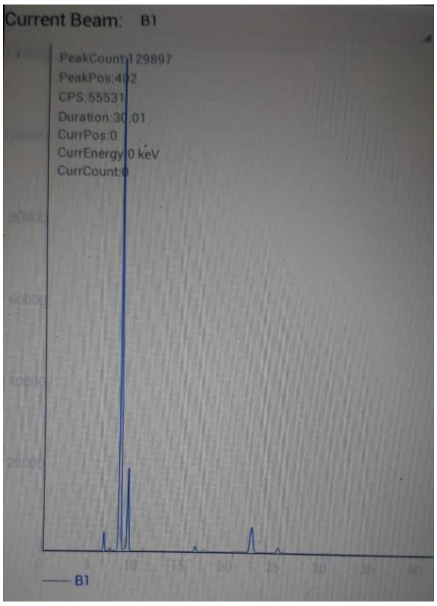


Fig 215: reverse spectrum of coin 5

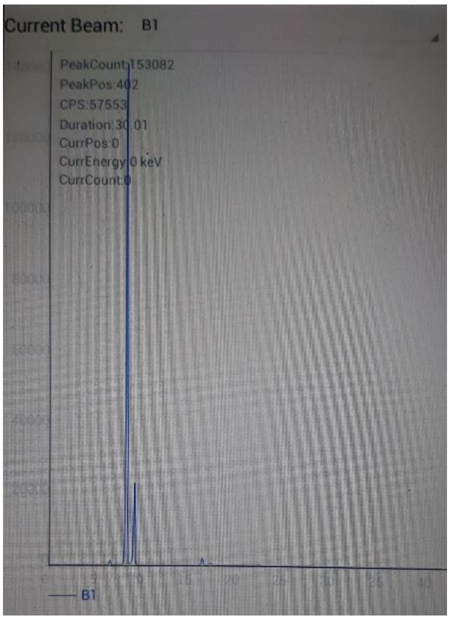


Fig 216: obverse spectrum of coin 7

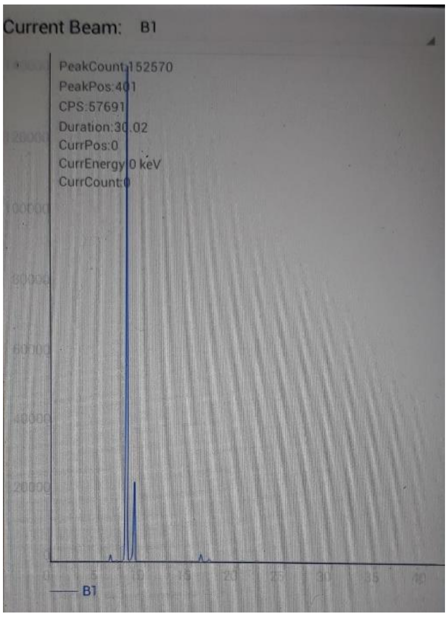


Fig 217: reverse spectrum of coin 7

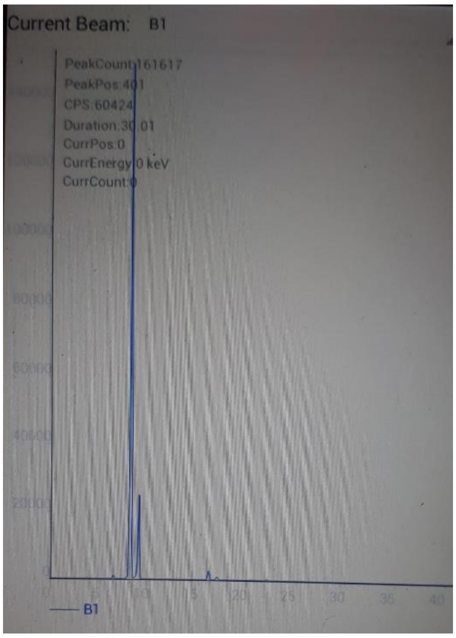


Fig 218: obverse spectrum of coin 26

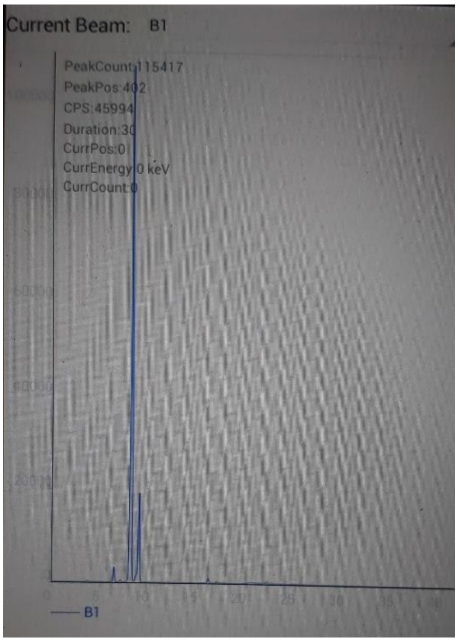


Fig 219: reverse spectrum of coin 26

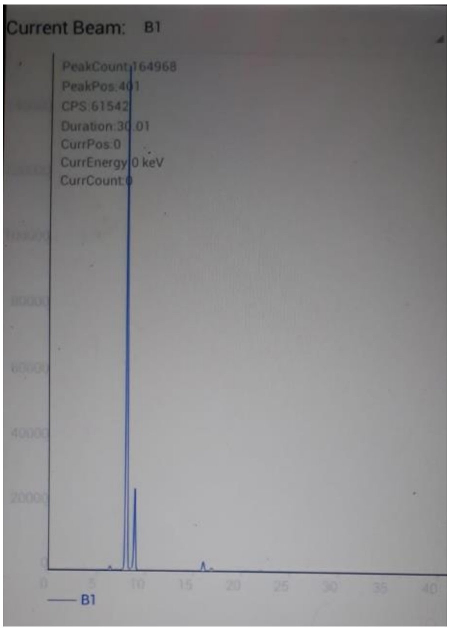


Fig 220: obverse spectrum of coin 27

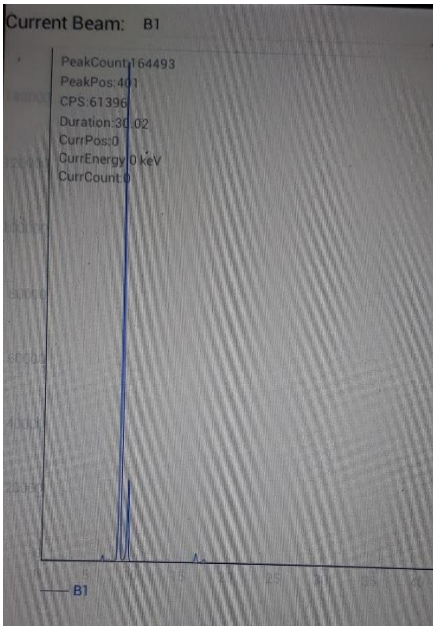


Fig 221: reverse spectrum of coin 27

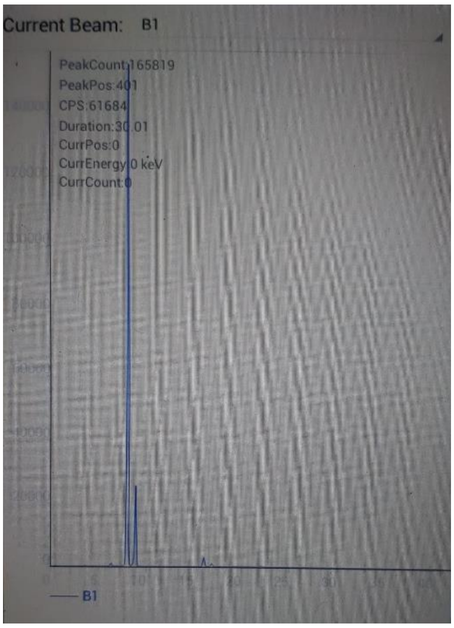


Fig 222: obverse spectrum of coin 36

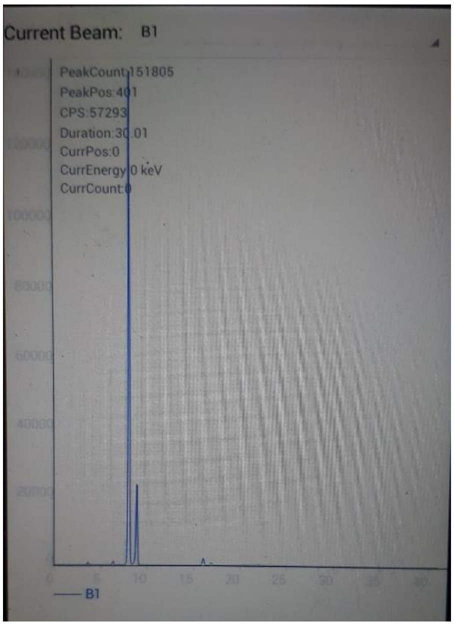


Fig 223: reverse spectrum of coin 36

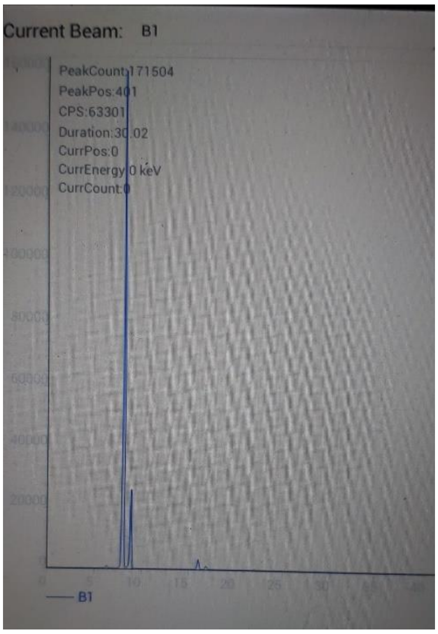


Fig 224: obverse spectrum of coin 40

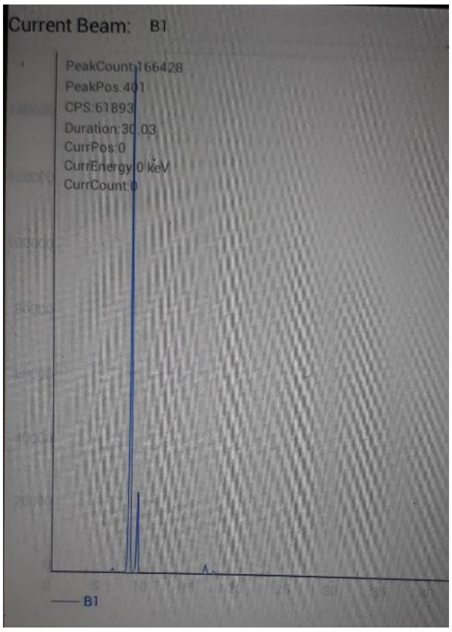


Fig 225: reverse spectrum of coin 40

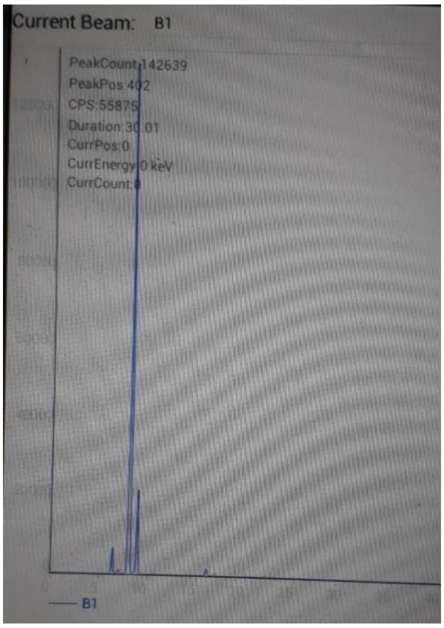


Fig 226: obverse spectrum of coin 56

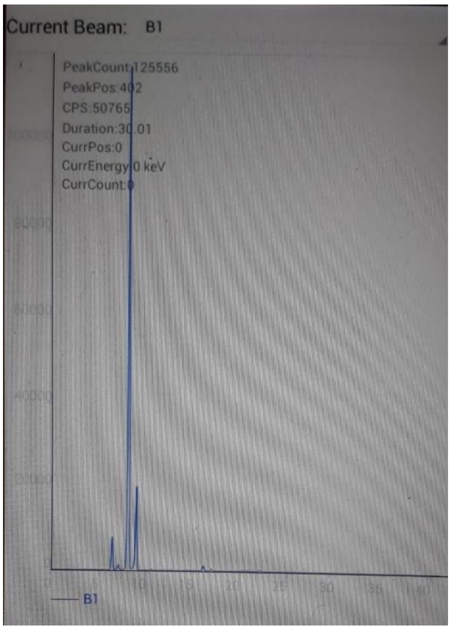


Fig 227: reverse spectrum of coin 56

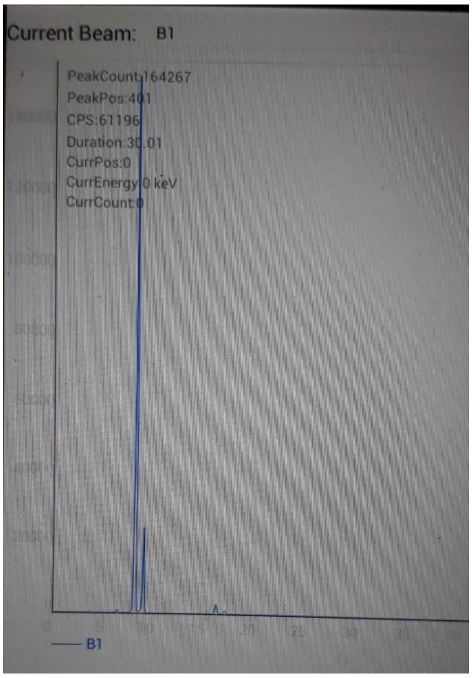


Fig 228: obverse spectrum of coin 81

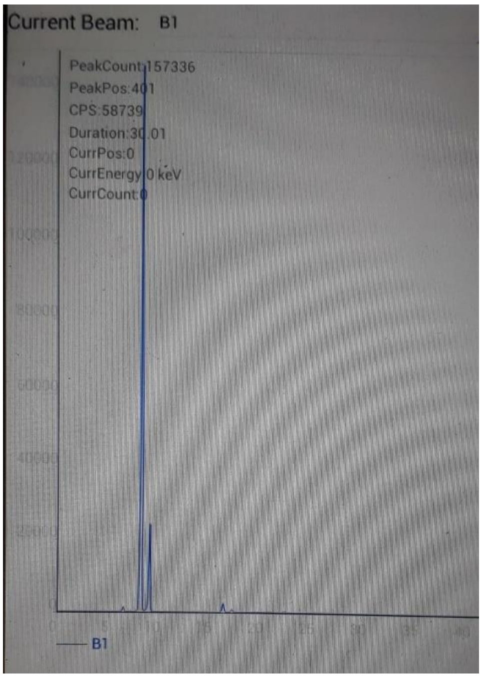


Fig 229: reverse spectrum of coin 81

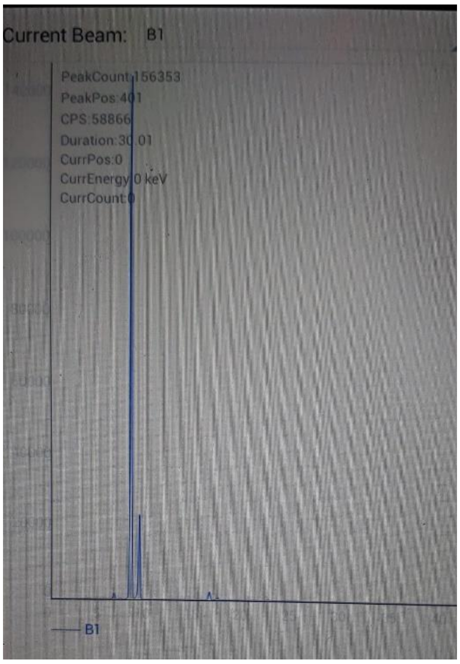


Fig 230: obverse spectrum of coin 98

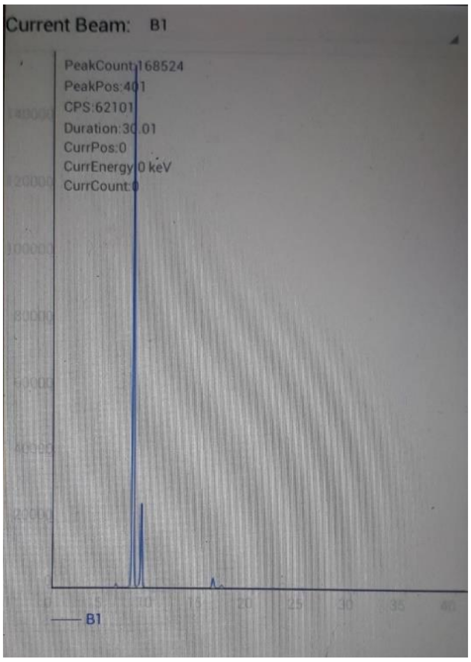
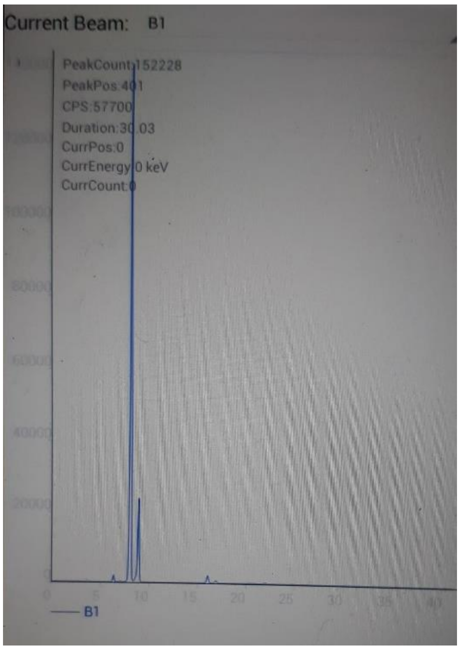


Fig 231: reverse spectrum of coin 98



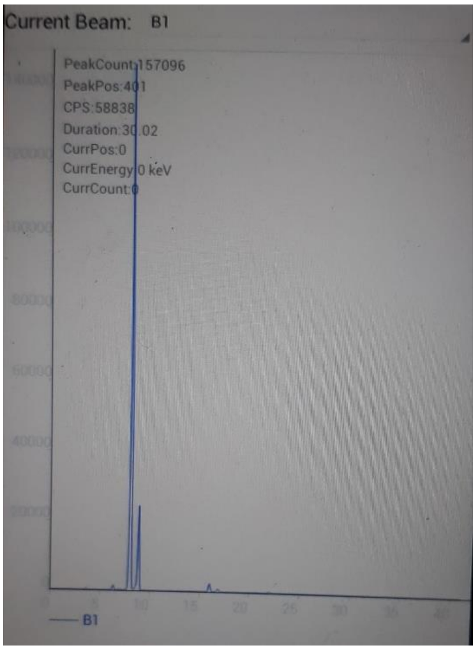
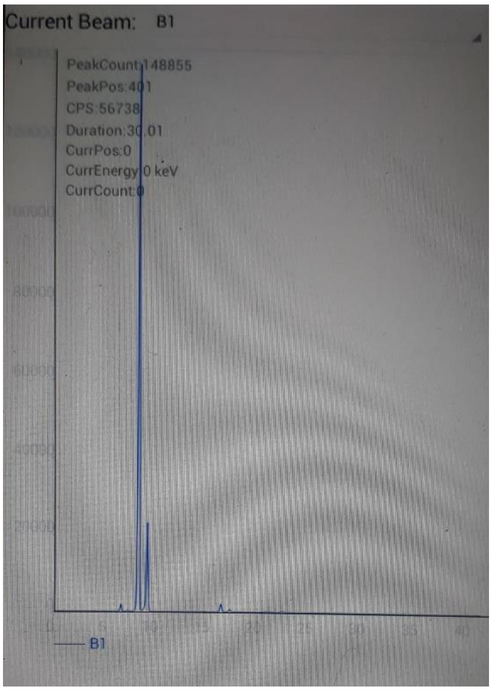


Fig 232: obverse spectrum of coin 109

Fig 233: reverse spectrum of coin 109



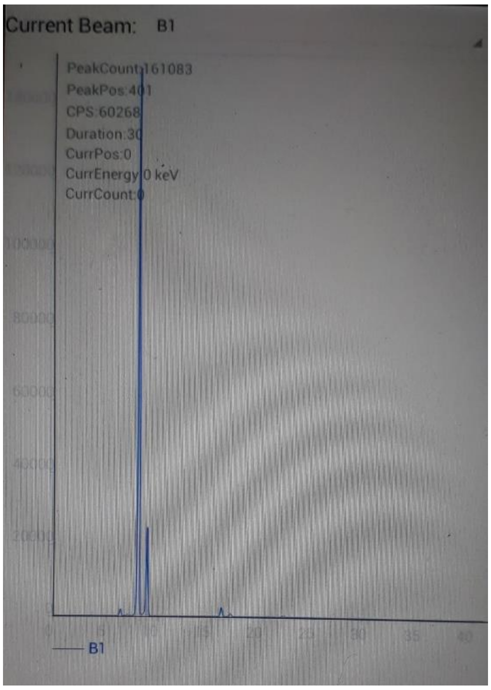


Fig 234: obverse spectrum of coin 129

Fig 235: reverse spectrum of coin 129

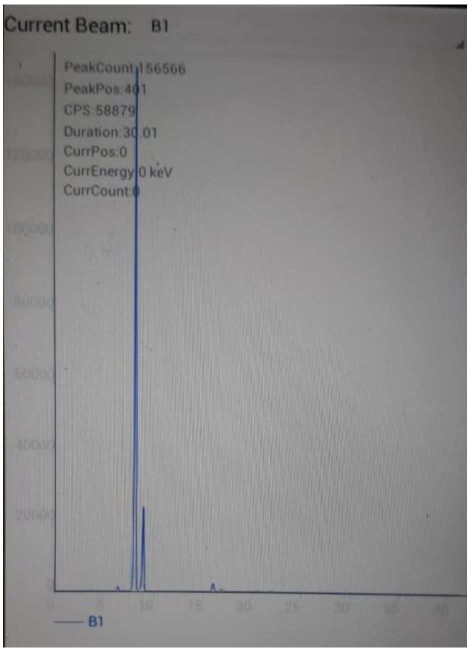


Fig 236: obverse spectrum of coin 134

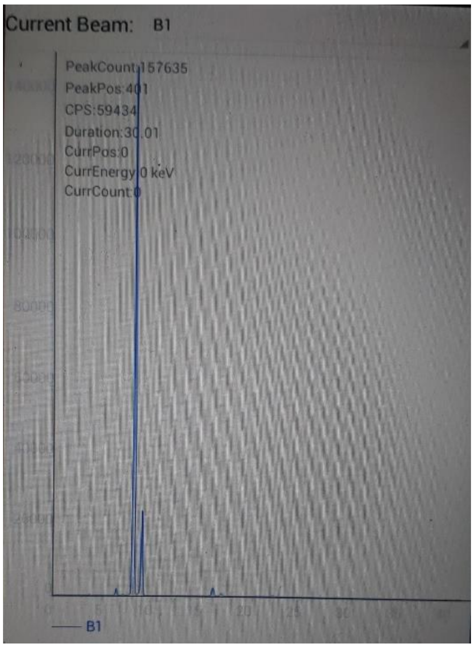


Fig 237: reverse spectrum of coin 134

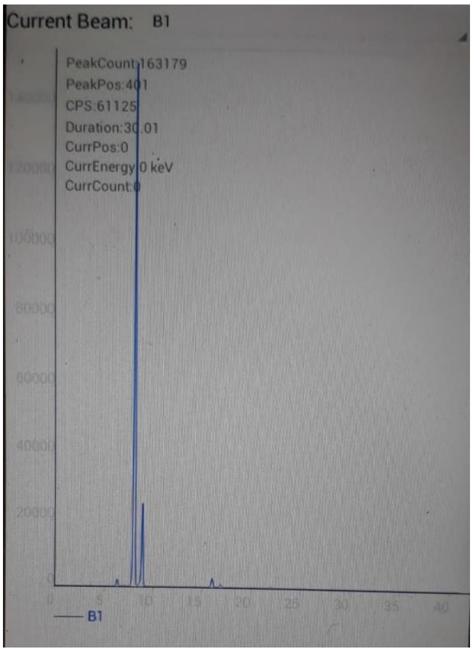


Fig 238: obverse spectrum of coin 184

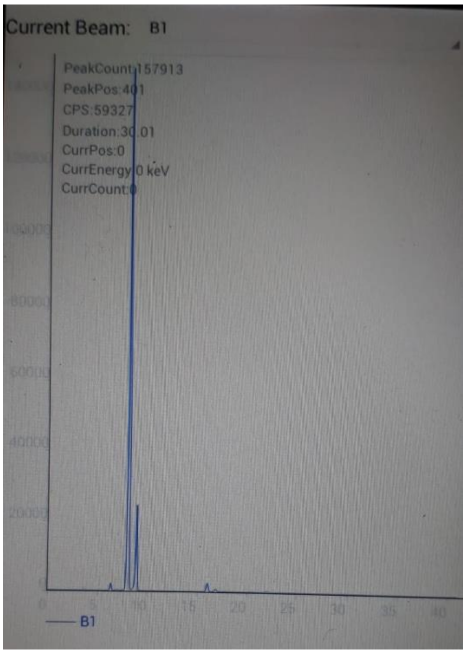


Fig 239: reverse spectrum of coin 184

Fig 240: obverse spectrum of coin 237

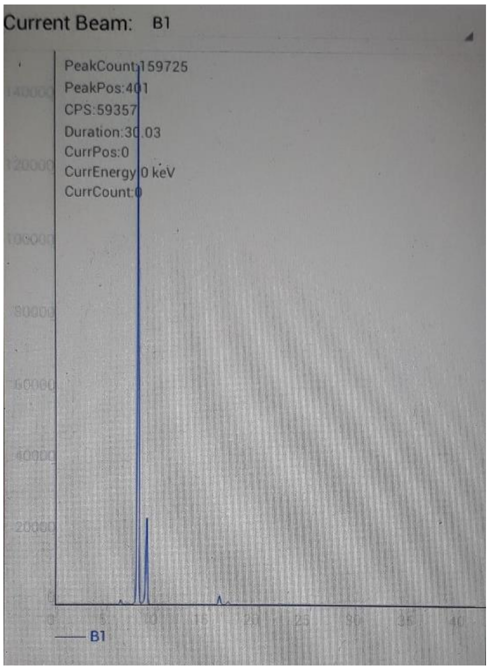


Fig 241: reverse spectrum of coin 237

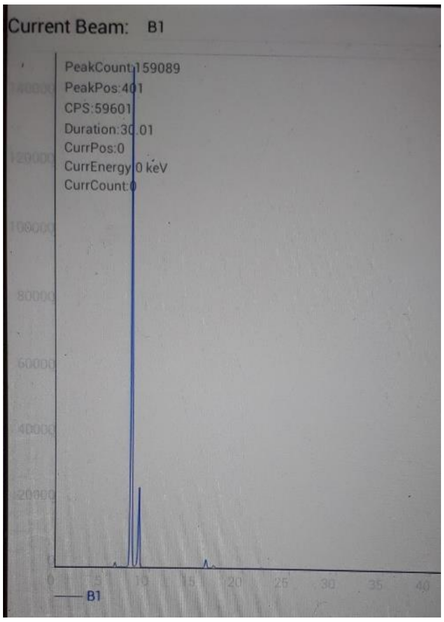


Fig 242: obverse spectrum of coin 245

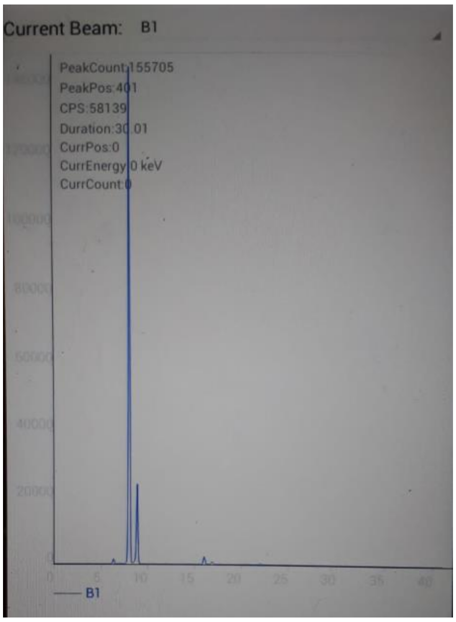
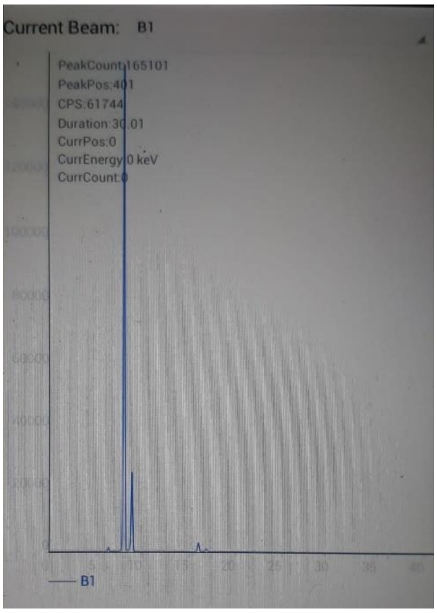


Fig 243: reverse spectrum of coin 245



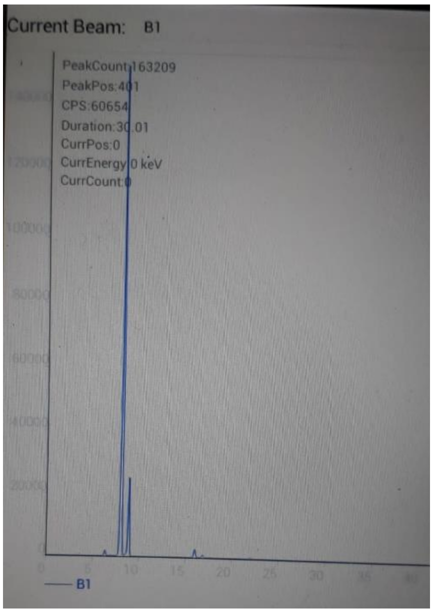
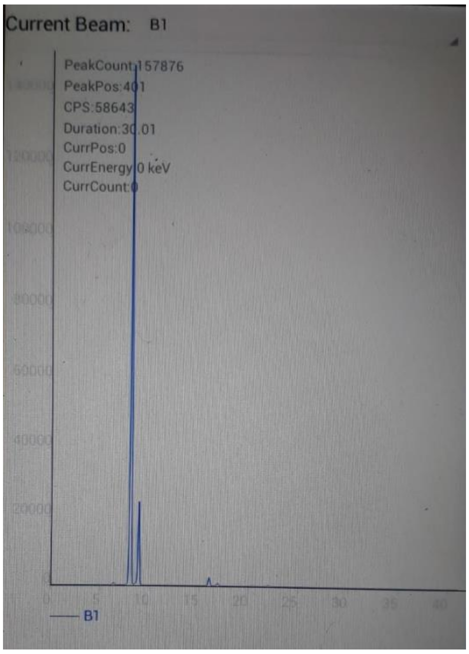


Fig 244: obverse spectrum of coin 253

Fig 245: reverse spectrum of coin 253



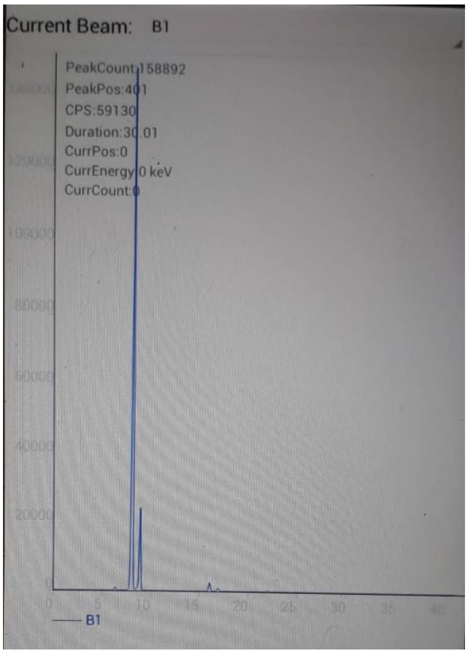


Fig 246: obverse spectrum of coin 259

Fig 247: reverse spectrum of coin 259

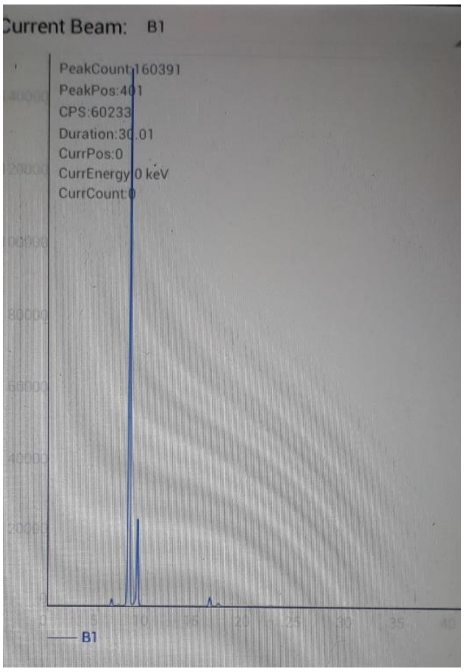


Fig 248: obverse spectrum of coin 265

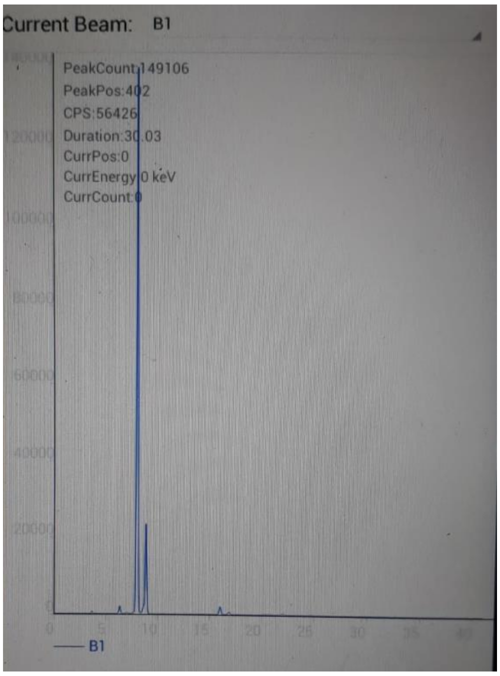


Fig 249: reverse spectrum of coin 265

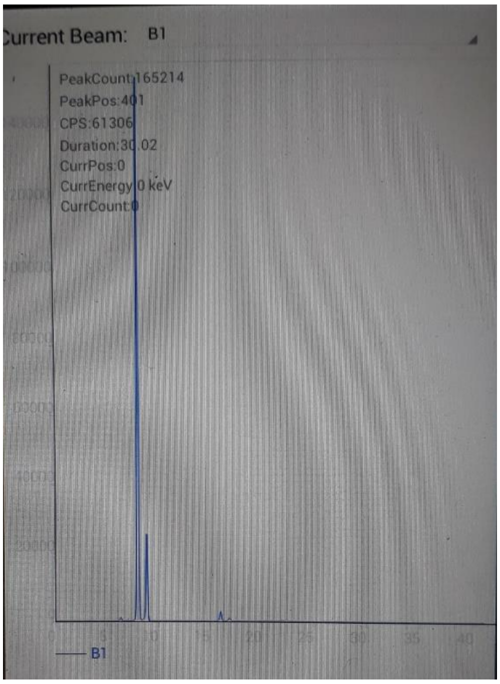


Fig 250: reverse spectrum of coin 302

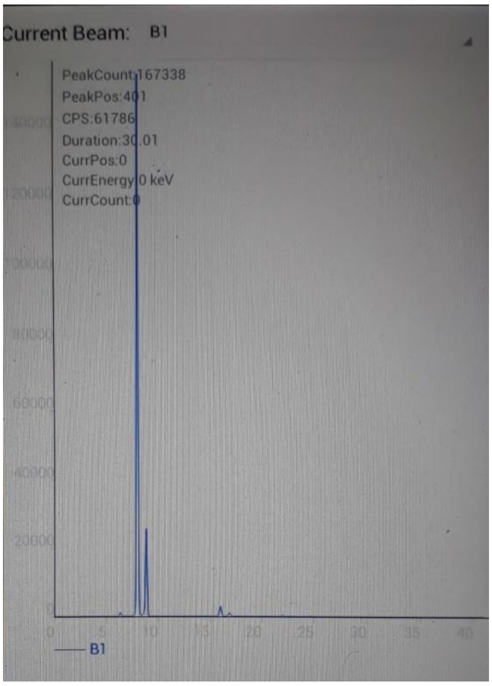
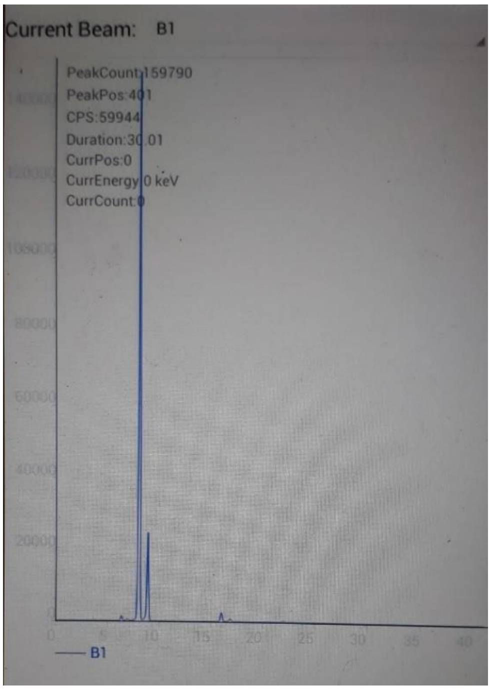


Fig 251: obverse spectrum of coin 302



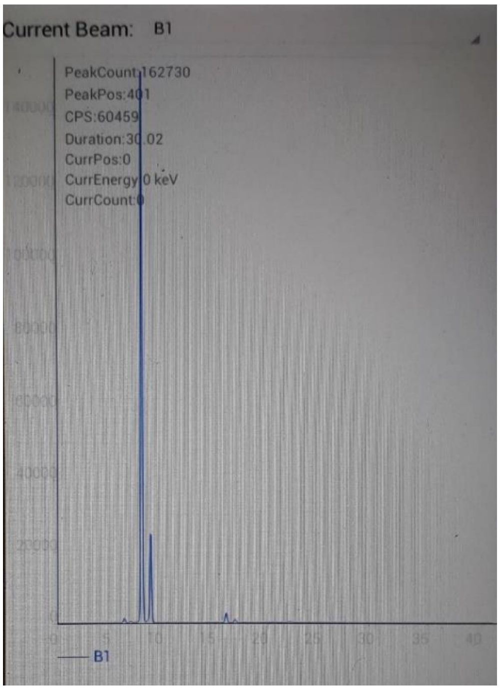
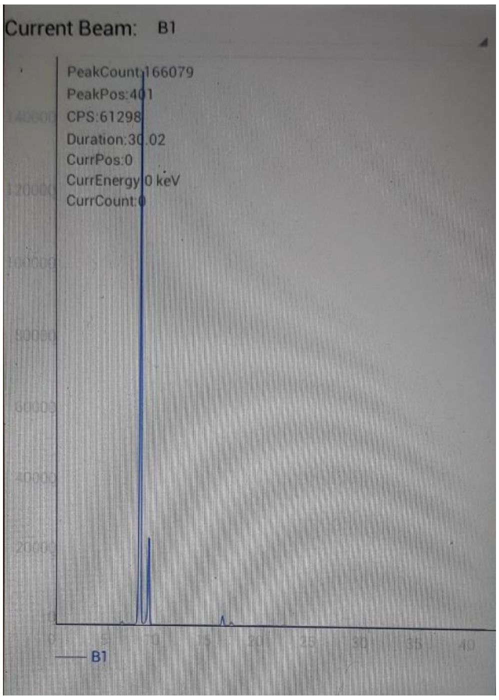


Fig 252: obverse spectrum of coin 313

Fig 253: reverse spectrum of coin 313



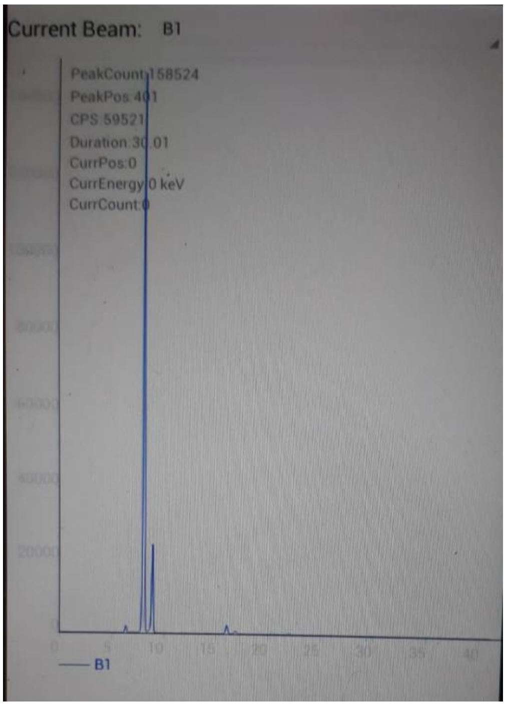


Fig 254: obverse spectrum of coin 335

Fig 255: reverse spectrum of coin 335