Conservation and Analysis of Coins from Badalpur Monastery, Taxila Valley: A Study of Cleaning Methods

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Attiya Malik

All birds find shelter during a rain, but eagle avoids rain by flying above the clouds, problem are common, but attitude makes the difference.

D.r. A. P. J. Abdul Kalam

My This Humble Effort Is Dedicated To My

Baba Jani

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Abbreviations

PIXE	Proton Induce X-ray Emission
RBS	Rutherford Back Scattering
BCC	Body-Centered cubic
FCC	Face-Centered cubic
HCP	Hexagonal Close Packed
BCE	Before Common Era
CE	Common Era
BA	Black Arrow
BB	Black Bullet (BB),
SG	Sharp Gray
GB	Gray Bullet
GSP	Gray Sharp Point
NaCl	Sodium Chloride
PAA	Proton Activation Analysis
IBA	Ion Beam Analysis
PIGE	Particle Impelled Gamma-beam Emission
WD	Wave length-dispersive
ED	Energy-Dispersive
EPMA	Electron Probe Micro-Analysis
NAA	Neutron Activation Analysis
EDXRF	Energy Dispersive X-beam Fluorescence

NCP	National Centre for Physics
NRA	Nuclear Reaction Analysis
Cu	Copper
Fe	Iron
Cr	Chromium
Co	Cobalt
Zn	Zinc

Abstract

The main objective and aim of this research under the title 'Conservation and Analysis of Ancient Coins from Badalpur Monastery, Taxila Valley: A Study of Cleaning Methods' is to establish Archaeometallurgical study of metals. The aim of this research is to investigate the possible benefits and consequence of a conservation system of metal objects through a literature review. This research deals with the analysis of 34 coins and the problems of conserving such material. In this research is to find the most suitable method for the conservation of poorly preserved ancient coins. Firstly the coins analysed by proper documentation and photography before cleaning method. After which comparative experiments of different cleaning methods have been carried out in order to find out the least harmful and most efficient method. Researcher used different techniques like mechanical, chemical and electrolysis techniques normally when researcher conserved 34 coins artefacts. A research also deals with the experiments to determine the necessity and efficiency of stabilizing the surface of the ancient coins after cleaning and make a proper catalogue and chronology of Badalpur site through these 34 coins. Researcher has been found out the elemental composition of copper coin sample which was excavated from Badalpur Site through non-destructive technique Proton Induce X-ray Emission **(PIXE)** and Rutherford Backscattering Spectrometry **(RBS).** Researcher resulted that copper coins were minted during the ruin of Kushan Dynasty (1^{st} century CE-4^{TH} century CE). The elements **Co, Cr, Fe** and **Zn** have been detected in copper coin sample along with the major component of **Cu**. Five elements have been determined quantitatively and examined the correlation between the composition and the minting time period.

CONTENTS

Introduction

Metallurgy is a meadow of materials, Science and building which varies with the physical and substance conduct of metallic basics, their intermetallic mixes and blends are called combinations (Gill, Paul and Shewmon 2017: 1-3). 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 mix of science, material science and mechanics with unique reference to metals. Metallurgy is an ancient subject which is connected to the historical backdrop of humankind. The improvement of civilisations from stone age, bronze age and iron age can be trailed by the discovery of copper and iron (Seshadri Seetharaman, 1996 : 1).

The conservation, analysis and all aspects which concern the research of archaic metals is referred as field of archaeo-metallurgy. 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 metals artefacts (Elmor and Becker 2013: 1-5).

Archaeometallurgy is the study of ancient metals. They can also be used in chemical, physical and anthropological fields. Archaeometallurgy is one of the oldest manifestations of archaeometric research and utilizing science based ways to deal with address social historical question of coins artefacts, isotopes-archaeometallurgy and Archaeometry (Th Rehren, 1994: 1).

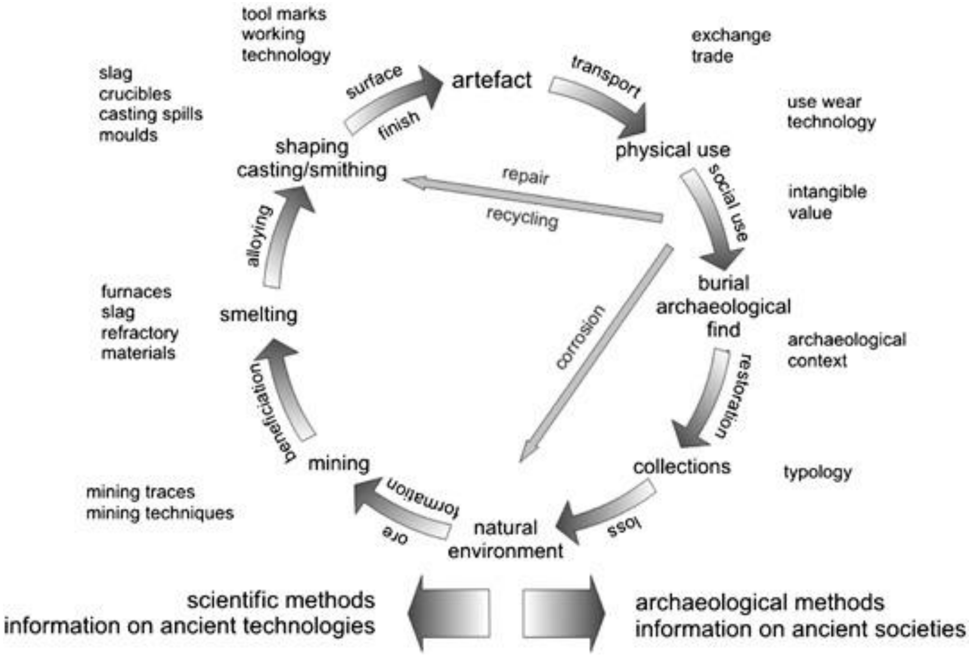


Table 0.1: The archaeometallurgy cycle (after Ottaway 1994)

Metals play an important role in Post Neolithic time period called Copper age, Bronze Age and Iron Age dating back to 10000 BCE. So we can say that archaeometallurgy manages all part of metal generation, conveyance and utilization ever. Before CE, just seven planetary metals were discovered i.e. gold, copper, lead, silver, tin, iron, mercury.

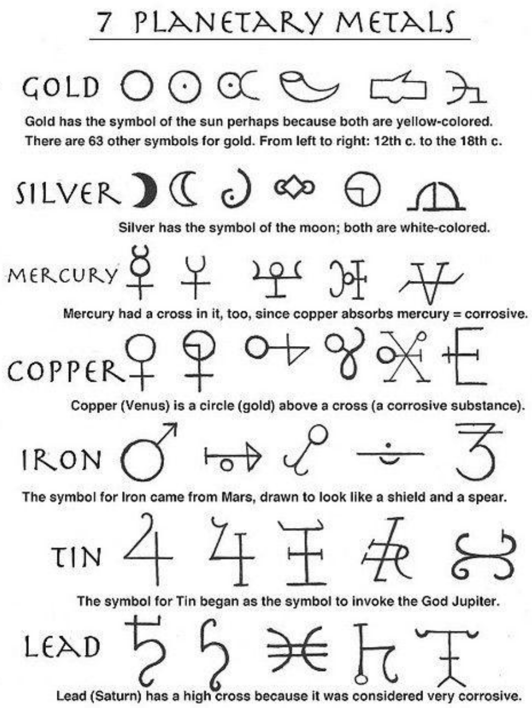


Table 0.2: Seven planetary metals - occult/alchemical symbols (Hilde Heyvaert 1981)

The oldest metal is limited to the particular geological area, the origin of metal not yet clear but seems to have in the late sixth millennium BCE. A Number of civilizations were using methods and exchanging mechanism for the recycling of metals in areas devoid of metal ores such as Egypt, Mesopotamia and Indian Sub Continent. The history of metallurgy in Sub Continent started from 3rd millennium BCE till British Raj. During the reign of Indian Mughal's Empire, India further improved the tradition of metallurgy (Amiteshwar 2001: 269-274).

Taxila is also called Takshashila in Sanskrit (Marshall 1945:1). The name of valley drives from historic city of Takshashila or Taxila. Historic Takshashila is the important point of cultural transformation. Taxila was given a legendary historic city which went back to the remotest antiquity. The earliest settlement of the Taxila Valley in Sarai-Khola which gives information about a cultural sequence dating back from the late Neolithic to Iron Age. So we can say that the history of Taxila dating back from 4th millennium to 5th century CE. The major cities were Bhir Mound dating back to the 6th century BCE belongs to the Achaemenians, Sirkap belongs to Indo Greeks 2nd century BCE, Sirsukh belongs to the Kushan period 1st century CE (Marshall 1960 : 2-3).

The monastery of Badalpur is located in a village named Bhera, It is located 10km north-east of Taxila museum and 2.5 km north-west of Julian monastery, on the left bank of river Haro. The archaeological evidences related to the history of civilization in many aspects. The use of metals in antiquity is one of them. The new metallurgy has multidimensional growth due to adaptation of many metallurgical ideas which are based on ancient practices. The most commonly metals used as antiquity in Taxila are gold, silver, copper, iron, tin, lead and zinc (Ashraf Khan, Mahmood-ul-Hasan and Lone 2005: 2-5).

A group of researchers and understudies from Taxila Institute of Asian Civilizations (TIAC) headed by Prof. Dr. Mohammad Ashraf Khan has found an extensive number of artifacts during the excavation at the Buddhist Stupa and religious community close to Taxila. "The most surprising discovery is metal item and animal bones which opened two new chapters ever. One is that these individuals knew the utilization of various metals and the second rejected the hypothesis that the adherents of Buddhism around then were just vegetarian." The revelation of animal bones at a profound surface and at the kitchen region was a proof that the priests and followers of Buddhism around then were not vegetarian lovers. "This will require revising of the historical backdrop of Taxila in the light of the new and considerable proof." The discovery of the metal items uncovered the craftsmanship of the general population living in the zone between the 1st century and 4th century CE and their insight and use of various metals (Ashraf Khan et. all, 2014: 85).

The cleaning and protection of ancient metals from Europe is an extremely beneficial endeavour. Often though, they are discarded because they are considered as too much complicated and dangerous. As a result, not much development 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 at Taxila valley. Thus, the large amount of both un-conserved artefacts and artefacts in need of re-conservation is badly damaged. This applies to most material categories but due the limitation of this research, researcher will only look into the problems concerning archaeological metal artefacts. The methods currently in use are not very efficient in regards to time management or the preservation of artefacts. Used for cleaning metal artefacts, only scalpels and ethanol.

The aim of this research is to investigate the possible benefits and consequence of a conservation system of metal objects through a literature review. Furthermore, instruments that were previously only used by corrosion scientists are today entering the conservation field. The current trend is to group of electrochemical and analytical techniques in parallel in order to fully understand the behaviour of metal artefacts when conserved (Dillmann, Beranger, Piccardo and Matthiessen, 2014: 1-2).

This research deals with the analysis of coins and the problems of conserving such material. The aim of this research is to find the most appropriate method for the conservation of poorly preserved coins. The researcher reconsiders the origins of metallurgy in Taxila and offers a new representation in which metallurgy began in Badalpur site. The aim of the researcher is therefore not only to reconsider, where and how early metallurgy arised but also to understand the broader methods underlying its diffusion and earliest expansion of coins in Badalpur site. Researcher collected a series of ancient coins and other metal objects such as door bosses, iron-nail, figure ring, iron pan and knives coming from the archaeological excavation of Badalpur site (Taxila) and then analysed them using different analytical techniques looking for a co-relation between the rusted products covering the coins and the chemical-physical features of metal objects.

Firstly the composition of both the metal and the rusted objects of the ancient coins or other metal objects will be analysed by proper documentation and photography before explementary the cleaning method. After which relative experiments of different cleaning methods will be carried out in order to find out the least destructive and most appropriate method. The Researcher will use electrochemical techniques like mechanical and chemical technique normally used when researchers conserve metal artefacts.

This research also deals with the experiments to establish the necessity and effectiveness of stabilizing the surface of the coins/other metal objects after cleaning and make a proper catalogue and chronology of Badalpur site through these ancient metal artefacts. Through PIXE and RBS the researcher will find out the elemental composition of metals. Through the experiments the researcher would decide to try out some of the maintenance procedures found in literature and based on the results will establish their suitability for the conservation of metal objects of the early medieval period.

Research Questions

The following questions are among those that will be addressed in this thesis:

1. What can we imagine to find when looking at coins that have been in storage for decades with different degrees and qualities of conservation?
2. What types of damage do they suffer from?
3. What methods of coins cleaning are best suited for conservation and analysis?
4. What techniques are to be used for the analysis of elemental and chemical composition of ancient coins about to be conserved?

Review of Literature

There are much observation and interpretation about them written by different authors. A lot of literature as a secondary source is given below which are related to the research:

Book *‘Taxila: Archaeological Excavations’* is written by Sir John Marshall. This book deals with the different metal artefacts excavated from different sites of Taxila Valley (Marshall. J: 1945).

Book ‘*Taxila: Archaeological Excavations’* is written by Sir John Marshall. This book describes the topography and historical background of Taxila (Marshall. J reprint 1975).

Book '*Medieval Indian Coinages: A Historical and Economic Perspective'* is written by Amiteshwar Jha. In this book coins belong to three groups. Each group is different from one other either in their source of origin or in their metallurgical operational techniques (Amiteshwar 2001).

The article '*Recent Discovery of coins in the Buddhist Monastery of Badalpur, Taxila Valley Pakistan*' written by M. Ashraf Khan, M. Arif, Gul Rahim Khan, Shakir Ali and Habibullah Khan Khattak. This article deal with the recent excavation of coins at Badalpur site Taxila Valley (Ashraf Khan, Arif, Rahim , Ali and Khattak: 2009).

The article *'Post Kushana Gold Coins in the Cabinet of the National Museum of Pakistan, Karachi'* written by Gul Rahim Khan. Focuses on the gold coins lying in the cabinet of the National Museum (Rahim: 2014).

The article *'Archaeological Survey of India'* written by Alexander Cunningham. In this annual report, discusses geography of Taxila (Cunningham, 1916-17).

Catalogue *'A Catalogue of the Gandhara stone sculptures in the Taxila Museum'* written by Ashraf Khan, Mahmood-ul-Hasan and A.G. Lone. This Catalogue focuses on Gandhara stone sculptures and all types of antiquities on display in the museum. Main aim of this catalogue is to document all Museum objects and establish cultural legacy of Gandhara (Ashraf Khan, Mahmood-ul-Hasan and Lone: 2005).

'Preliminary Report of excavations at Buddhist Monastic Complex of Badalpur, Taxila Valley' written by Shakir Ali, Abdul Azeem and Tahir Saeed. This report discuss is about the Badalpur monastery complex (Ali, Azeem and Saeed: 2009-10).

Book *'The Historic City of Taxila'* written by Ahmad Hasan Dani. This book deals with the study of different excavation reports and guide books which are written on Taxila (Dani: 1986).

The article '*Material Analysis Methods Applied to the Study of Ancient Monuments, Works of Art and Artefacts'* is written by Filip Delalieux, Kouichi Tsuji, Kazuaki Wagatsuma and Rene Van Grieken. In this article material analysis techniques are used to solve a wide variety of cultural heritage related analytical problems (Delalieux, Tsuj, Wagatsuma and Grieken 2002).

The article '*Innovative conservation approaches for monitoring and protecting ancient and historic metals collections from the Mediterranean Basin* is written by V. Argyropoulos a,

E. Angelini b, C. Degrigny. The paper outlines a three-year European funded project, aimed at establishing and promoting a conservation strategy designed for the Mediterranean region by developing an approach to protect metal artefact collections using state of the art portable analytical techniques and new corrosion inhibitors (Argyropoulosa, Angelini b, Degrigny 2004).

The article '*Coins, artefacts, and isotopes – archaeometallurgy and Archaeometry'* is written by Th Rehren. This article discussing the archaeometallurgy is one of the earliest manifestations of archaeometric research, using science-based approaches to address cultural-historical questions. This review first outlines, defining in some detail the main branches of archaeometallurgy, and their specific methodological approaches. It then looks at some of the early publications pioneering archaeometallurgical research (Th Rehren 2008).

The article '*Development of metallurgy in Eurasia'* is written by Benjamin W. Roberts, Christopher P. Thornton and Vincent C. Piggott. The authors reconsider the origins of metallurgy in the Old World. The authors come down firmly on the side of single invention, seeing the subsequent cultural transmission of the technology as led by groups of metalworkers following in the wake of exotic objects in metal (Benjamin, Roberts, Thornton and Piggott 2008).

Thesis '*On the Degradation Mechanism under the Influence of Pedological Factors through the study of Archaeological Bronze Patina'* Presented by Marta Quaranta. The present work is carried out to deepen the study of degradation processes occurring in burial environment involving copper and its alloys (2009).

The article '*Precious metals determination in ancient coins by portable ED-XRF spectroscopy with a* ^{238}*Pu source'* is written by Paulo S. Parreira, Carlos R. Appoloni, Laetitia Le Corre and Maria Filomena Guerra. This article describes a portable X-ray fluorescence system (pXRF) that was employed to analyse a set of gold, silver and billon coins, struck during the *Brasil Colônia* period. The aim of the study was to test the possibilities and limitations of this portable system for the determination of the coins' base alloys, and to verify whether the results obtained were consistent with historical facts (Paulo, Carlos, Corre and Maria 2009).

The article '*Washing and Cleaning of Ancient Coins, an Alternative Method Using Ultrasound and Chemometry'* is written by G. Visco, S. H. Plattner, R. Reale and M. P. Sammartino. In this article a cleaning method is proposed, for bronze coins (Visco, Plattner, Reale and Sammartino 2010).

Dawn Newspaper '*More antiquities discovered in Taxila*'. This is about the most remarkable discovery of an iron nail and animal bones which opened two new chapters in the history of Gandhara. The iron nail revealed the craftsmanship of the people living in the area between the first century and 4th century AD and their knowledge and utilisation of different metals (Dawn Newspaper 2012).

Paper '*Protection of Metal Artifacts with the Formation of Metal–Oxalates Complexes* is written by Joseph E, et al. Front Microbiol. This paper describes the several fungi which are present in high tolerance to toxic metals and some are able to transform metals into metal–oxalate complexes. In this study, growth performance was tested on various copper-containing media. Chromatographic analyses showed that this species produced oxalic acid. The production of metal–oxalates can be used in the restoration and conservation of archaeological and modern metal artefacts (Joseph E, et al. Front Microbiol 2011).

Journal Ancient Coins '*cluster analysis applied to find a correlation between corrosion process and burial soil characteristics'* is written by Rita Reale, Susanne H Plattner, Giuseppe Guida, Maria Pia Sammartino, and Giovanni Visco. They describe a series of ancient coins, coming from the archaeological excavation of Palazzo Valentini (Rome) and then analysed using different analytical techniques looking for a correlation between the corrosion products covering the coins and the chemical-physical soil characteristics (Ritae, Plattner, Guida, Sammartino, and Visco 2 may 2012).

Thesis '*Mass-conservation of Archaeological Iron Artefacts: A Case Study at the National Museum of Iceland*' is written by Sandra Sif Einarsdóttir. The aim of this thesis is to investigate the possible benefits and consequences of a mass-conservation system at the National Museum of Iceland through a literature review (Einarsdóttir 2012).

Research Article '*the Conservation of Early Post-Medieval Period Coins Found in Estonia'* is written by Aive Viljus and Mart Viljus. This article deals with archaeological discovered material and the issues of monitoring such material. The aim of the research was to find the most suitable method for the conservation of poorly preserved coins with varying composition. For this, first, the composition of both the metal and the corrosion products of the archaeological coins were analysed, after which comparative experiments of different cleaning methods were carried out in order to find out the least harmful and most efficient method. A test was also performed to determine the necessity and efficiency of stabilizing the surface of the coins after cleaning (Aive and Mart 20 Feb 2013).

The article '*Excavation at Badalpur Monastery, District Haripur (Khyber Pakhtunkhwa), Pakistan: A Preliminary Report of Season 2014* is written by M.Ashraf Khan, Sadeed Arif, Arslan Butt, Amjad Pervaiz and Muhammad Arif. This article deal with the brief account of the recent excavations conducted on the site of Badalpur. It focuses on the season 2014 excavation (Khan M.A, Arif. S, Butt. A, Pervaiz. A and Arif 2014).

International Journal of Conservation Science '*Evaluating the use of Laser in Analysis and Cleaning of the Islamic Marine Archaeological Coins Excavated from the Red Sea'* is written by Omar Abdel-Kareem, Awad Al-Zahrani, Amal Khedr and Mohamed A. Harith. This study aims to evaluate the use of laser in cleaning and LIBS analysis of the Islamic Marine Archaeological coins excavated in the Red Sea water (Omar Abdel-Kareem, Awad Al-Zahrani, Amal Khedr and Mohamed A. Harith 2016).

The article *'Scientific Study for Treatment and Conservation of Archaeological Iron Artefacts'* is written by Mohamed M. Megahed. This work aims to consider the erosion procedure identified with the nearness of chloride particles (Cl-) in the dirt, and to decide the best techniques for their treatment. To achieve this aim a careful examination was made to determine the condition of the object before treatment. To determine the type of corrosion products XRD was used, while SEM and metallographic examinations were used to assess the internal condition of the object. Also, XRF was used for elemental determination of the object (Megahed).

The article *'PIXE analysis of Greek ancient copper coins minted in Eprius, Illyria, Macedonia and Thessaly'* is written by Kallithrakas-Kontos, A. A. Katsanos, C. Potiriadis, M. Oeconomidou and J. Touratsoglou. This article discusses about the ancient copper coins from Greek cities and analyzed non-destructively proton induce x-ray emission (PIXE) (Kallithrakas-Kontos, A. A. Katsanos, C. Potiriadis, M. Oeconomidou and J. Touratsoglou 1996).

The article '*PIXE analysis of ancient Indian coins'* is written by M. Hajivaliei, M.L. Garg, D.K. Handa, K.L. Govil, T. Kakavand, V. Vijayan, K.P. Singh and I.M. Govil. In this article describes number of coins of Hindu Shahis Dynasty of Kabul (990±1015 A.D.) have been examined using proton induced Xray emission (PIXE) technique. The 3 MeV proton beam from the Pelletron Accelerator at the Institute of Physics, Bhubaneswar, India was used for the manufacture of X-rays. The X-rays were detected by Si(Li) detector (FWHM.180 eV at 5.9 keV) placed at 90° to the beam path. For the dependable calibration of the logical system, thin foils of Micromatter standards of Fe, CuS, KCl, and RbNO3 were used. The computer code GUPIX was employed to get focus of trace elements in these coins. The elements Ca, Ti, Cr, Fe, Ni, Zn, As, Sb, Pb, and Bi were detected in these coins along with the most important elements of Cu and Ag (M. Hajivaliei, M.L. Garg, D.K. Handa, K.L. Govil, T. Kakavand, V. Vijayan, K.P. Singh and I.M. Govil 1999).

The article '*Application of Electrochemical Techniques to the Conservation of Metal Artefacts: a Review*' is written by Christian Degrigny. This paper presented a case studies and research project related to the conservation of metallic alloys involving electrochemical techniques. Emphasis on the build-up of methodologies to the conservation issues and the necessity of a close relation between electrochemists and conservators during a conservation project (Christian Degrigny).

Presentation '*The Art of Cleaning Ancient Coins'* is written, Produced & Directed by Kevin R Sandes CCCE (Certified Coin Cleaning Expert). This presentation provides proper techniques for the conservation of ancient coins including Mechanical, Chemical and Electrolysis techniques (Kevin R Sandes CCCE).

Book '*Corrosion of Metallic Heritage Artefacts: Investigation, Conservation and Preservation'* is written by P Dillmann, G Beranger, P Piccardo, and H Matthiessen. In this book, he tell us about the electrochemical techniques conservators normally use when they conserve metal artefacts. More lately, the latter have recognised the significance of these techniques in understanding of deterioration processes as well as their monitoring and in the solving of exact conservation matters (Dillmann, Beranger, Piccardo, and Matthiessen).

The article '*The Cleaning, Restoration, and Preservation of Ancient Bronze Coins and Artefacts with Some Comments On the Patination of Ancient Silver and Bronze'* written by

Robert Beauford. The article provides only a general overview of a very complex chemical cleaning technique (Robert Beauford).

Stone Crafts of Taxila is written by M. Ashraf Khan and Ifqat Shaheen. Describe the political history of Taxila has been subjected. This publication highlights the magnificent Sculptural art and building crafts of gandhara (Khan, 2015: 15-99). Gandhara (geography, Antiquity, Art and Personalities) is written by M. Ashraf Khan and A.G Lone. Explain Gandhara from the historical, geographical, political, religious and cultural point of view (Khan and Lone, 2004: 45-101).

Hypothesis

Conservation and Analysis of metal artefacts will evolve suitable conservation procedures and preventive conservation of metallic artefacts. It will establish a chronological sequence of Badalpur monastery which will reveal the evolution of the cultural heritage in Gandhara. The application of experimental methods will contribute in the conversion of traditional archaeology into “Experimental Archaeology”.

Statement of the Problem

Archaeology yields information and develops theories about past human activity by means of a study of ancient materials remains. Important archaeological information can be obtained by the investigations of material remains. In this way conservation and analysis skills are essential to archaeological investigations. It is a field of experimental archaeology which studies the conservation and analysis of metal objects and human culture development in the past using input from archaeology, natural sciences and history.

Archaeology has obviously an important task to perform. Briefly considered, its main tasks have been firstly, to initiate and finance field and laboratory researches, conserve ancient artefacts, create and maintain ancient metals objects, and secondly, to control and assist foreign archaeological expeditions. In performing its tasks, the Department of archaeology has been facing many problems; the major ones are concerned with conservation. If these problems are to be solved by systematic archaeological method, careful planning is most essential. In the past some of our ancient metal artefacts have been conserved but certainly not a scientific approach and is most unlikely to produce any significant result.

There is lot of weaknesses in traditional process of human past study and due to which numerous significant archaeological information could not be obtained. Published work about conservation and cleaning process of metal objects is scattered in nature or not enough therefore much more work remains to be done. The proper research has not yet been done on the conservation methods of metal artefacts in Taxila valley due to lack of researchers and laboratories in Pakistan. In Pakistan there are few laboratories associated with museums (Karachi and Lahore) and archaeological institutions. During the early developmental phase, it suffered because of:

(1) Insufficient communication and differences in conceptual orientation between natural science and field archaeology.

(2) Archaeology is more often associated with the discovery of tombs, temples, sites, monuments and palaces than with the conservation and experimental analysis.

(5) Sophisticated, statistical techniques had not been applied to the metal objects which are collected from archaeological sites.

This research explores the conservation techniques in metal artefacts, using case studies from the Gandhara site (Badalpur Monastery) in Taxila. It is to find out whether these metals were made by local material and was any mint present at that time or not. It explains the kinds of metal remains that the researcher can recover and the methods used to analyse them.

A broad experience in the use of these techniques is needed if conservation professionals want to use them. It is clear that the limited use of these techniques in the conservation of metal artefacts is due the lack of practise. Training schools should absolutely include the use of electrochemical and electrolytic treatments in conservation in the curriculum of the students. Furthermore more conservation laboratories specialized in these techniques should offer placements to students in order for them to gain the practical experience that they will never get otherwise.

Aims and Objectives of the Study

The objective of this research is to promote the application of scientific methods for the conservation of metallic antiquities, and the preventive conservation of metallic art objects so as to ensure appropriate preservation of these important elements of the cultural heritage.

Conservation and analysis strategy to protect archaeological metals collections of the ancient metal objects from Gandhara region in Pakistan with the following aims and objectives:

The overall scientific and technological objectives are classified under two major actions:

- Monitoring: To optimize presented portable scientific tools and certification methodologies for the characterization and organization of huge numbers of metal objects. To build up latest non-destructive or on-line micro-destructive analytical methods for analyzing in the compositional difference of metal objects. To recognize the conservational difficulties and needs of metals compilations discovered from the Badalpur monastery. To expand a codified advance in establishing methods for conservation and restoration of metallic artefacts.

- Defending: To find out the long-term effectiveness of past actions (coatings and/or decay inhibitors) used to conserve metals collection and protecting the metal substrate, dullness and reversibility. To establish, by means of a organized scientific approach, the most well-suited, reversible and environmentally-friendly decay inhibitors and/or coatings to defend objects made of valuable metals, copper and iron alloys.

Objectives of this research to develop and promote a conservation policy designed for the Gandhara area by developing moveable monitoring systems and protection methods such as including the identification of degradation phenomena, for collections of valuable metals, iron and copper alloys. Portable techniques, as X-ray Fluorescence (μ-XRF) will be optimized and proposed as diagnostic tools for characterizing metal objects and for recognizing degradation phenomena. These advanced analytical techniques will be applied to analyse collections of archaeological metal objects in the Gandharan region, and to identify the conservation problems.

1. To update and investigate and statistical analysis of different morphometric features of the metal from ancient Gandhara sites through excavation and evaluate the significance of this investigation in systematic and perspective.
2. Some of the metal samples are to be investigate under Scanning Electron Microscope (SEM).

3. The objective of this research is to investigate the likely benefits and consequences of the achievement of a conservation method through a literature review.
4. This work aims to study the corrosion, and to establish the best methods for their treatment. To attain this aim a careful inspection was made to determine the situation of the object before treatment.
5. The aim of the research is to increase the output within the check of little funding and a lack of conservators in the country. This will be done by making a management plan for the conservation method.

Significance of Study

The study and preservation of cultural heritage is a multidisciplinary field where Materials Science and Corrosion Science have a very significant role to play. This research discusses how materials and corrosion scientists can follow a career in cultural heritage. It highlights the particular challenges that these disciplines encounter in the study and preservation of cultural heritage materials and the exciting career paths offered in museums, monuments, and relevant academic and research institutions. The applications for science and designing abilities to social materials are assorted, including the advancement of creative treatment strategies for their future generation and preservation for who and what is to come and prompt specialization inside the sub-fields of archaeological science and protection science.

In conservation discipline the scope is mainly to understand deterioration processes develop treatment protocols, characterise materials for records and decision-making with regards to conservation strategies, and in archaeological materials science the learning of production technologies are intimately connect with the study of past human activities. Conservation science is utilization of scientific information and methods which are described in the preservation and conservation of cultural heritage.

The research will focus on the conservation and analysis of metal artefacts (coins from Badalpur). It will form a more coherent bond between natural science and social science as well. This disciplinary research will place archaeology in the modern sciences. Additionally the significance and scope of this research is that: Metal artefact preservation is one of the most important works because without conservation most artefacts will be damaged, and important historic data will be lost. The loss is not just to the excavator but also to future archaeologists, who may wish to re examine the material.

Methodology

The research is a cross-disciplinary one with conservational techniques used in ancient metal artefacts. In this research primary and secondary sources will be used.

Primary Sources:

The researcher will apply experimental techniques and different scientific methods for the cleaning of metal artefacts (coins). Primary sources include field work, observation, interpretation, photography and different experimental techniques.

Secondary Sources:

Secondary resources will be acquired from articles, seminars, reports of national and international scholars, online data collection including (relevant books, journals, conference paper, magazines news articles and other relevant thesis).

The researcher will use the following different methods for the conservation and analysis of ancient metal artefacts.

- **Quantitative method**

Quantitative methods place greatest confidence on representing developments numerically. Numerical information, of numerous kinds, is valuable in contemplating longer-term improvements, and this sort of research techniques requires quantifiable information including numerical and factual clarifications.

- **Qualitative method**

This type of research methods involves describing in details specific situation using research tools like interviews, surveys and observations.

- **Predictive methods**

Prescient strategies are essentially those that conceive a solitary future considered in all probability, regardless of whether this future is alluring or not based on theory. The strategies coming from the anticipating and from the arranging schools of thought are generally prescient.

- **Meta-Analysis**

This examination strategy is helpful for discovering the normal effect of a few unique investigations on a hypothesis.

- **Experimental Methods**

Investigational research is conducted mainly in laboratories in the framework of basic study. The main benefit of experimental designs is that it provides the chance to recognize unknown specimen and sample. The researcher having following experiments in its own research:

❖ **Observation and Photography** Firstly the written description and photograph of each artefact prior to treatment. Some artefacts were photographed in a more detail to document corrosion and typical, good or detrimental conservation. .

❖ **The art of Cleaning and conservation methods**

Conservation methods will be recognized on those objects that had not been treated. The researcher found the normal process is to apply, treat the object and avoid the traditional treatment methods. After which relative experiments of different cleaning techniques will be carried out in order to discover the least damaging and most well-organized technique Researcher will use three techniques which are given below:

i. **Mechanical Techniques**
ii. **Chemical Techniques**
iii. **Electrolysis techniques**
iv. **Microcrystalline Wax/ Paraloid B72**

A researcher also want to show that a test will carry out to determine the inevitability and good organization of stabilizing the surface of the coins after cleaning and make a proper catalogue and chronology of Badalpur site through these ancient metal artefacts.

❖ **Examinations and Analysis** A suspicious examination is necessary to determine the situation of the object before a course of dealing can be decided.

1. **Proton Induced X – Ray Emission Method (PIXE)**

PIXE will use to determine the kinds of corrosion products and elemental composition of the metal artefacts or ancient coins**.**

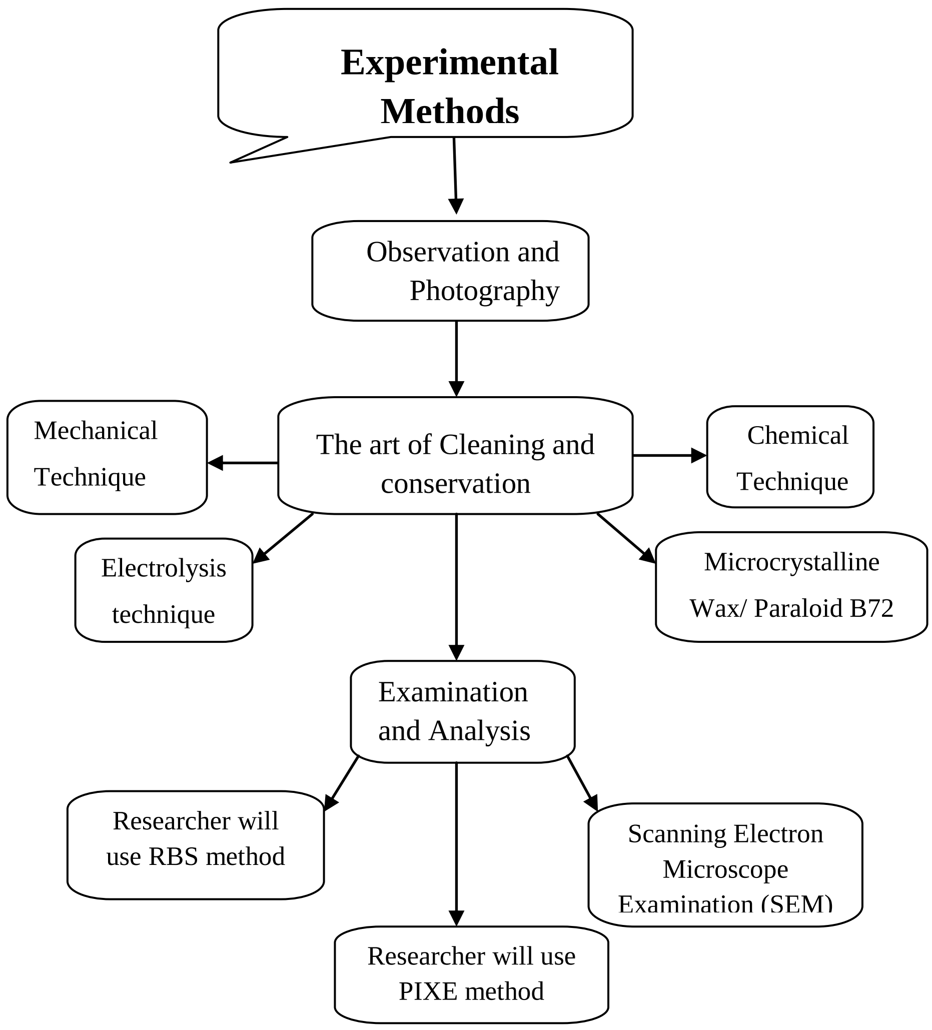
2. **Researcher will use X-Ray florescence**.

RBS Analysis of a sample from the core of object was occurred to determine chemical composition of the metal objects or ancient coins.

3. **Scanning Electron Microscope Examination (SEM)**

SEM examines the elemental composition of artefacts. For assessing the internal condition of the object, metallographic examination and scanning electron microscope have been used.

With the experiments researcher decided to endeavour some of the conservation procedures originate in literature and establish based on the results their appropriateness for the conservation of metal objects.



(By the researcher)

Table 0.3: A flowchart showing the different steps involved in the conservation method recommended in this research.

Chapter 1

Geography and History of Taxila Valley

Geographical Location

For the first time in history, geography of Taxila was recorded by Alexander Cunningham. Taxila is an important archaeological valley which is situated between Indus and Jhelum rivers (Cunningham 1916: 1-2). More clearly, it is located 20 miles north west of the Rawalpindi and 549m above from the sea level. On the world map, Taxila Valley has been one of the important parts of the Gandhara civilization. It lies between north latitudes 32° 42′ 30″ and 33′ 50° and east longitudes 72° 53′ 45′ and 72° 59′. Over all area of the Taxila valley is approximately 375 square kilometres (Marshall 1945: 1).

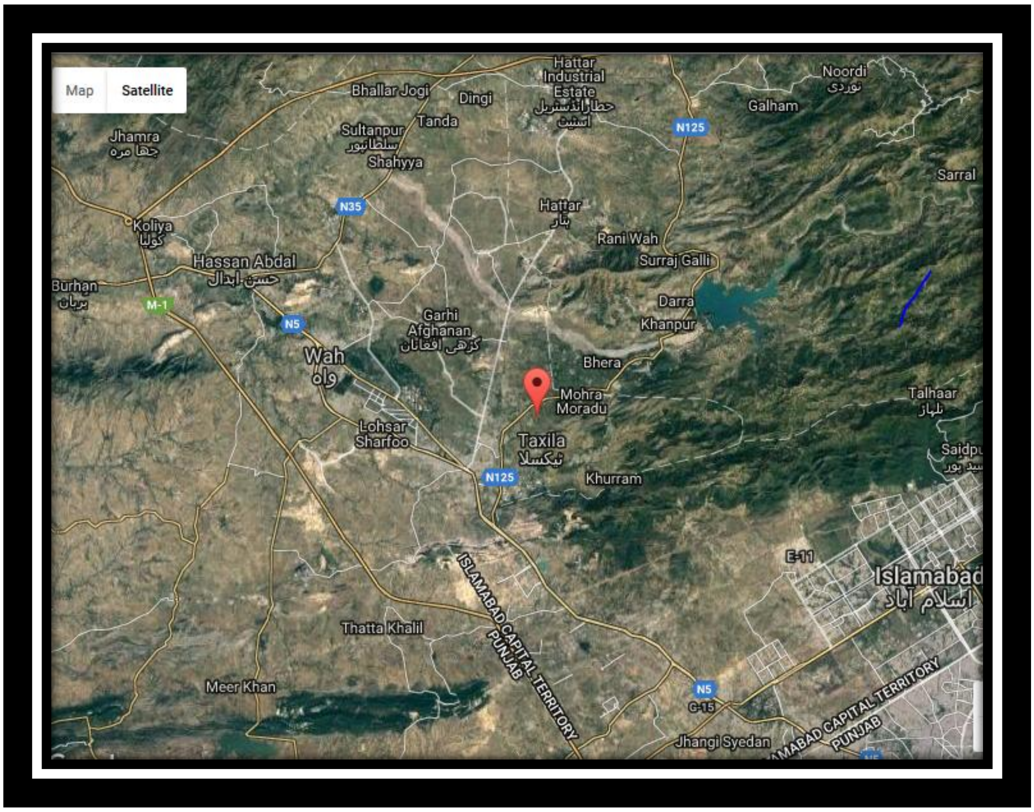


Fig 1.1: Geographical Location of Taxila valley (http://www.earth-3d.com/?eid=1163715_PK_SANS_04&title=Taxila-Pakistan).

Topography

In the archaeology prospective Pakistan is one of the important and famous countries all over the world. Taxila Valley is located 30 kilometres from Islamabad. Its average height from the sea level is between 1700 to 1800 feet. The northern part of the valley is very rich in crops. Eastern side is surrounded by the Muree hills 8000 feet in height and the southern part is less fertile consist of stony areas where number of archaeological sites are present. Due to the Haro River, northern part of the Taxila valley becomes fertile. Haro River consists of two small tributaries (Tamra Nala and the Lundi Nala). Taxila was used as the crossroads of the three trade routes. All of them belonged to the India, Central Asia and Western Asia for different aspects. In Taxila, three particular city sites are located and each site having its own character such as Bhir Mound, Sirkap city and last one is Sirsukh Study of topography showed that Taxila valley was the centre of trade routes and learning (Marshall 1945: 1-6).

Origin of Name Taxila

Taxila is very important part of Gandhara Civilization. Takshasila made by two words Taka means serant and sila means hills. According to some other interpretation, this word can be 'prince of serpent tribe' in pali known as Takkasila. The current spelling Taxila by the Greek and Romans and abbreviated was adopted by European authors (Dani 1999: 1-2). Takshasila was the real name of this city which is a Sanskrit word, composed of two words, Taksha which means serpent and sila means Hills.

Firstly name of Taxila was appeared in the classical sources:

- Tibatans called in rdo-hiog means 'cut-stone'.
- According to Aramic language it was known as naggaruda.
- According to the Chinese pilgrim Hiwn Tsang Taxila valley as 'Ta-cha-shi-lo' which means 'head sacrifice of Buddha' (Ashraf Khan 2002: 13).

In the Puranic Verse, The Taxila expressed as:

'Gandhara-Vishay-esiddhe Tayah-puryau-mahatmonoh

Takshasya-dikshu-vikhyata Ramya-takshasila-puri

In Gandhara district, of the Great cities, the city of Takshasila is beautiful, well known for the consecration of Taksha (Prince of the serpent tribe)'.

-Vayupurana, 88,189-90 (Dani 1999: 1).

Many records and name have been kept about the city. They give different meaning based on an ancient literature (Dani 1984: 11). But there is not much clear and authenticity of the city's name and its origin (Dani 1999: 1).

According to the Jain literature, Taxila is related to the first Tirtharmkara-Rishabha who throne over Taxila and wheel of the Law (Dharmacakra). The name of Taxila derived from Taksa, who was the son of Bharatta, brother of Rama (the hindu Deity). The Kingdom of Taksa's was called Taksa khanda and its capital known as Taxila (Marshall 1918: 10).

According to the Hindu mythology real name of Taxila has been derived from a Sanskrit word Takshasila which means the city of cut stones. In the Puranic Verses 'The name is spelt as Takshasila or Takshasila in the Prakrit epigraphs, but in the Besnagar inscription of the Greek ambassador Heliodorus it is spelt Takkhasila (Dani 1991: 1).

According to the Greek and Romans, this city ruled by takshas, in this way Taxila is also known as rocks of the Takshas. According to other mythology, Taxila was ruled by Naga King, in this way it is given this name which means the hills of the serpents (khan, et, al 1998-2002: 13).

According to the Chu Sha Shi lo. Taxila is a Sanskrit word which means pretty. This is a Buddisht mythology, when Buddha was bodhisattva and gave his head to a man due to a man due to got its name Taxila

History of Taxila Valley

When we move towards to ancient history, Pakistan contains one of the oldest city named Taxila. It is a city of the Gandharan civilization, sometimes known as one of its capitals, Taxila was a hub of mix cultures, namely the Achaemenids, Greeks, Mauryans, Scythians, Parthians, Kushans, Huns and eventually the Muslims.

Ahmed Hassan Dani discussed history of Taxila in his book 'The historical city of Taxila'. Taxila grew to be the most populous and well-groomed city, as it is beautifully described in this quotation that

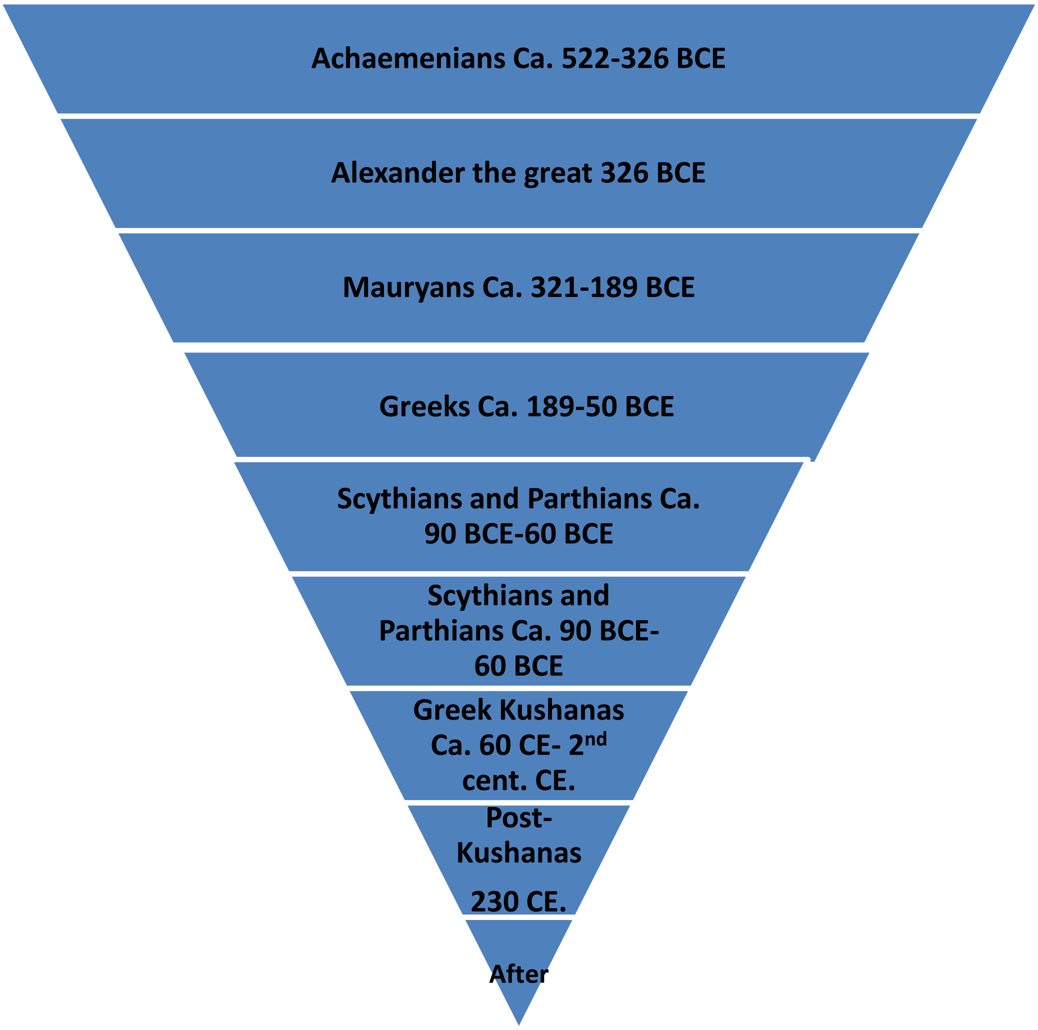
'Between the Indus and the Hydaspesis Taxila, a large city and governed by good laws. The surrounding country is thickly peopled and extremely fertile, as the mountain here begin to subside into the plains. The inhabitants and their king, Taxila, received Alexander with kindness, and in return came be more than they bestowed, so that the Macedonians were jealous and said it appeared as if Alexander had found none worthy of his bounty until he had crossed the Indus. Some says that this country was larger than Egypt' (Strabo 63 BCE).

Early Buddhist books tell the legendary or narrative history of Taxila. According to the Ramayana, Taxila was discovered at the same time when Pushkalavati in Gandhara (Marshall 1960: 11). The city was firstly named after Bharata's son, Taksa, who was its first ruler. Taxila was explored by Sir Alexander Cunningham and Sir John Marshall in the early 20th century. After that the Archaeological survey by Archaeological Survey of India in Taxila valley. Archaeological excavation in Taxila valley uncovered history of this region by Marshall and Later Sir Mortimer Wheeler sustained work for several time (Ashraf khan and Lone 2004: 15).

Political control

Taxila Valley and the area of Gandhara witnessed the rule of several main powers as scheduled here:

Rulers of Taxila Valley



(By the Researcher)

Table 1.1: A Pyramid show the rulers of Taxila City

History of Ancient sites and Major Monuments of Taxila

Fig 1.2: Ancient sites and Major Monuments of Taxila (By Researcher)

During the reign of British raj, Taxila was introduced for the first time. Taxila valley has very rich cultural landscape in term of its structural remains. Different excavations and survey were done during that period. Numerous sites related to Buddhism and other religions such as (Jains and Greek) have been excavated by different archaeologists (Ashraf Khan, 2015: 111). These sites/monuments are listed below:

Archaeological sites in Taxila Valley

Sites and Monuments	Period
Khan-Pur Cave	18000-10000 BCE
Sarai Khola	4000-2800 BCE
Hathial	1500-6th cent. BCE
Bhir Mound	6th-2nd cent. BCE
Sirkap	2nd cent. BCE-2nd cent. CE
The Apsidal Temple	1st cent. CE
Sirsukh	2nd-5th cent. CE
Jundial Temple	8th -1st cent. BCE
Kunala	2nd-5th cent. CE
Dharmarajika	1st cent. BCE to 5th cent.CE
Julian Monastery	2nd-6th cent. CE
Ghai	2nd-5th cent. CE
Mohra Moradu	2nd-5th cent. CE
Bhalar	3rd or 4th cent. CE
Jinnah Wali Dheri	1st-5th cent. CE
Kalawan	2nd-5th cent. CE
Pipplan	2nd-5th cent. CE
Lalchak Stupa	2nd-5th cent. CE
Bhamala	4th-5th cent. CE
Manikyala Stupa	2nd-8th cent. CE
Giri	2nd-5th cent. CE
Badalpur	1st-4th cent. CE
Julian II	2nd cent. CE

By the Researcher

Table 1.2: A list show the Archaeological sites in Taxila Valley

Chapter 2

History and Properties of Metals

Metallurgy is basically an art and scientific method of extracted metals from their ores and slags. This modifying and adopting metals use for different purposes. Metallurgy deals with the physical, chemical and atomic structures and their properties of metals. So researcher can say that metals are made by combination of different material are called alloys (Gill, Shewmon, Charles and Lorig 2017: 1)

Metallurgy is divided into two main types:

Ferrouss Metallurgy (Black Metallurgy)
Non Ferrous Metallurgy (Colored Metallurgy)

Ferrous metallurgy deals with the processes in which alloys are based on iron in the other hand, Non Ferrous metallurgy deal with the processes in which alloys based on the rest of the metals (Encyclopedia 1979:1-2).

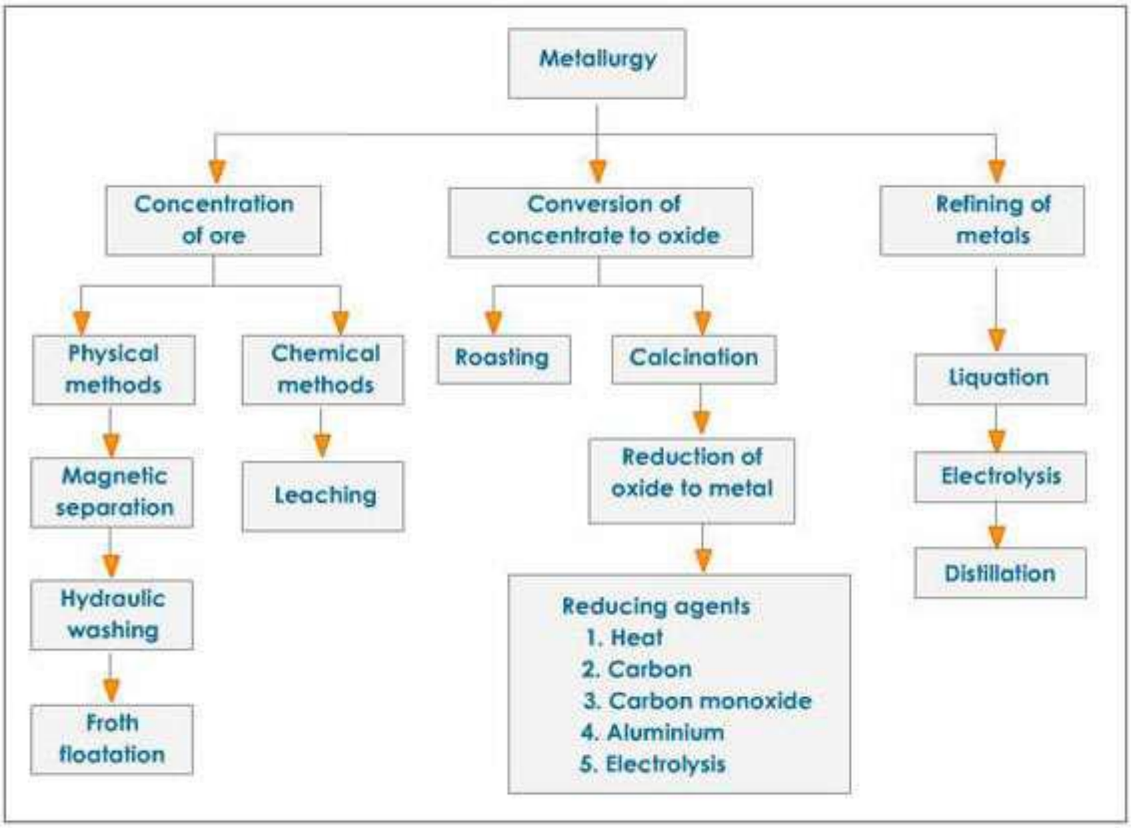


Table 2.1: Flow chart showing the process of Metallurgy (Encyclopedia 1979:1-2).

Definitions of Metallurgy

> The scientific study of extraction refining, alloying and fabrication of metals and their structure and properties are known as metallurgy (Collins English Dictionary 2012)
> The scientific study and technology of extracting metals from ores, refining them for use, and creating alloys and useful objects from them. This is called metallurgy (The American Heritage science Dictionary 2002).

Metallurgy is the procedure which is used for extracting metal from their ores, purifying and then producing objects from metals are called metallurgy. So finally we can describe metallurgy as a material science that deal with the physical and chemical properties of metals and their alloys.

Metals

Metal is an atomic element that is typically a proper hard shape. Metal is good conductor of electricity.

Place of Metals in Periodic Table

The atoms which are declared as metals are shown in periodic table:

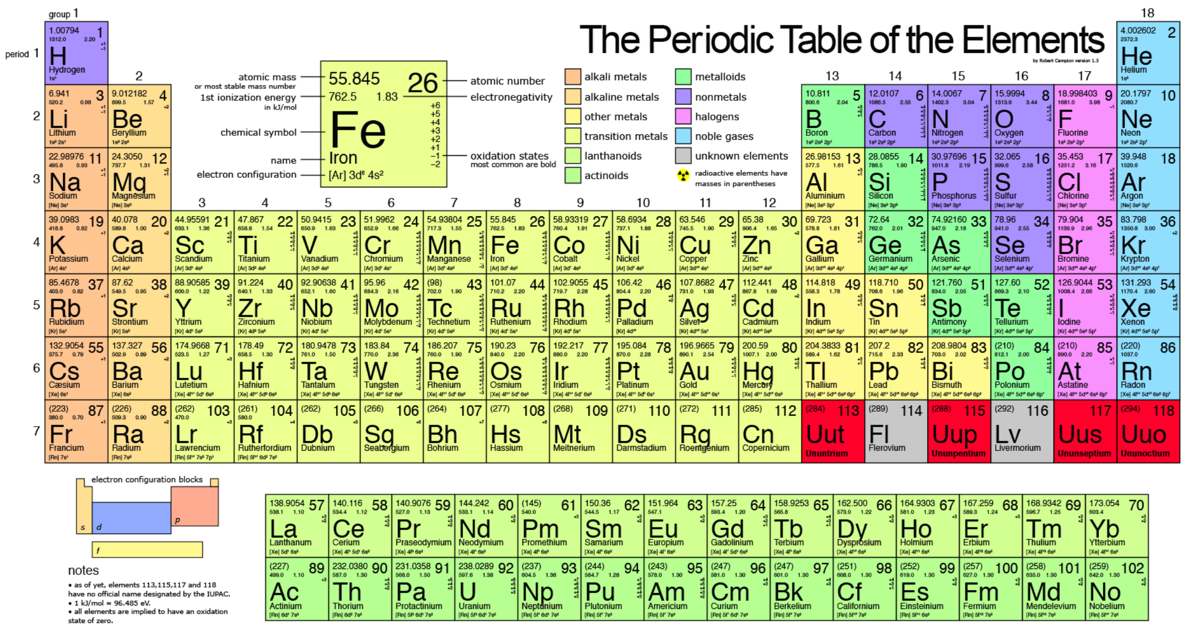


Table 2.2: Table showing the place of metals in periodic table

(https://en.wikipedia.org/wiki/Metal)

Structure and bonding of Metals

Metals are arranged in three crystal structures

- Body-Centered cubic (BCC)
- Face-Centered cubic (FCC)
- Hexagonal Close Packed (HCP)
- **Body-Centered cubic (BCC)**

Each atom is placed at the centre of a cube of eight others.

- **Face-Centered cubic (FCC)**

Every atom is surrounded by twelve others but layers are different. Due to temperature some metals can be change their structure.

Bounding

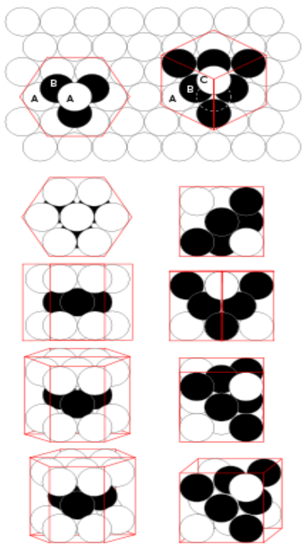


Fig 2.1: Bounding of atoms (Ibid)

Electron of metallic atom willingly removes their outer shell. This movement of metallic electrons to transmit rapidly heat and electricity so researcher can say that metals are good conductor of electricity and electron make bond with other atom so this bounding is called metallic bond (Ibid).

Properties of Metals

Every one of the items around us are made of 100 or so components. These components were characterized by Lavoisier into metals and non-metals by concentrate their properties. The metals and non-metals vary in their properties. Metals having following properties:

Main Group

Al, Ga, In, Sn, Tl, Pb, Bi, Po.

Alkali elements

Li, Na, K, Rb, Cs, Fr

Alkaline earth elements

Be, Mg, Ca, Sr, Ba, Ra

Chemical Properties

Metals can be ionized due rapidly losing electron and form cations (+). They react with oxygen and make oxides.

Examples:

$4\ Na + O_2 \rightarrow 2\ Na_2O$ (sodium oxide)

$2\ Ca + O_2 \rightarrow 2\ CaO$ (calcium oxide)

$4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$ (aluminium oxide).

Metal + Oxygen (from air) Metal Oxide

For example

2 Mg + O2 $\longrightarrow$ 2 MgO (Magnesium Oxide)

MgO + H2O $\longrightarrow$ Mg(OH)2 (Magnesium Hydroxide)

Metal hydroxide changes red litmus blue which shows its basic characteristics.

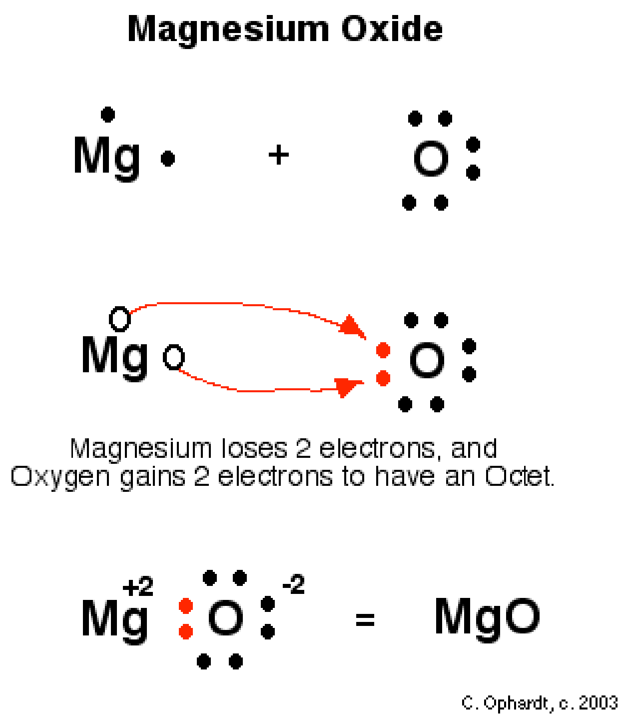


Fig 2.2: Chemical Properties of Metal

(http://www.csun.edu/~jk323784/subjects/chemistry/notes/metal_prop.pdf)

Due to rapid remaining of electrons, they also called a good conductor and high electrical conductivity.

Physical Properties

Metals are generally high density than the rest of atoms in periodic table. They have shining characteristic on the upper surface due to rapid movement of electrons. Silver is a very good reflector. It reflects about 90% of the light falling on it. All modern mirrors contain a thin coating of metals. Most metals are malleable and can beat into thinner sheets. This property is called Malleability such as silver and gold.

Fig 2.3: Shining metal show the physical property Fig 2.4: Thin layer of gold show the physical property

(http://www.csun.edu/~jk323784/subjects/chemistry/notes/metal_prop.pdf)

Metals have high tensile strength that is they can be stretched to some degree without breaking. Metals like tungsten have high tensile strength (http://www.csun.edu/~jk323784/subjects/chemistry/notes/metal_prop.pdf).

Fig 2.5: Metals having high tensile strength.
(http://www.csun.edu/~jk323784/subjects/chemistry/notes/metal_prop.pdf)

Electrical Properties

Metals are good conductor due to their outer most electrons are delocalized and move rapidly called mobile electrons. Metals can make cations (+) ions because they remove and giving electron to very neighbouring atom which require number of electrons to complete their outer most shell for stability (https://en.wikipedia.org/wiki/Metal).

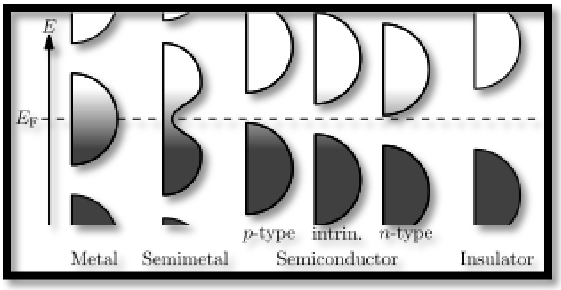


Fig 2.6: Stability of electrons (Ibid)

History of Metals

Metals has involved or captivated with humans for many decades. History of metals is an accomplishment of story of human attempt (Vibha Tripathi 2008: 1). From these metals people made tools and used these metals as a medium of transaction. Ancient writers did not try to classify metals and did not have any concept about their chemical and physical properties. The use of metals is said to be the thing that makes people different from animals. Before the invention of metals people make tools from wood and stones. This time period is known as Stone Age. Nobody can evaluate exact date when metal used in first time but it was probably that native copper was the first metal or founder of metals and people make copper tools.

Vannoccio Biringuccio writes on the arts of mining and something about metal in the first time in history. Georigius Agricola published De Re Metallica in 1555 in which gives clear description of a metal (https://en.wikipedia.org/wiki/Metal). In history, there are six different kinds of metals exist in earth. Most of the metals were naturally discovered or extracted in the form of compound.

- Gold
- Silver
- Copper
- Iron
- Tin
- Lead

Copper was quite soft and flexible then people make alloy from common ores called bronze and that time period called Bronze Age (3300 BC). In Bronze Age people make tools from bronze because bronze are much harder copper. Then in 12000 BCE iron was introduced which was much stronger than bronze and this metal used for war and different machines. Gold and silver were used for trade and money (Encyclopedia 1975: 4).

Development, discovery and application of metals gradually increased by the growth of public societies and the pattern of their live style. So researcher can say that our attraction with metals began when first time people make tools.

Date	Metal	Dominant Location
9000 BC	Earliest references of Wrought Native Copper	Middle East
5000 - 3000 BC	Chalcolithic period: melting of copper; experimentation with smelting	Middle East
2500 BC	Granulation of gold and silver and their alloys	Middle East
2000 BC	Beginning of the Bronze Age	Far East
1500 BC	Iron Age (Wrought Iron)	Middle East
700 - 600 BC	Etruscan dust granulation	Italy
600 BC	Cast Iron	China
200-300 AD	Emergence of Mercury for Gilding Metals (Amalgam gilding)	Roman Empire
1200 - 1450 AD	Introduction of Cast Iron - Start of the Iron Age	Europe
1600's AD	Sand introduced as casting / mold material	France
1709 AD	Cast iron produced with coke as fuel, Coalbrookdale	England
1740 AD	Cast steel developed by Benjamin Huntsman	England
1779 AD	First architectural use of Cast Iron	England
1838	Electroplating of Copper	England/ Russia
1884	Electrolytic refining of Aluminium	US, France

Table 2.3: Approximate chronological and geographical summary of some of the early dominant metals (Azom 2012)

History of Coins

Coins give us a valuable source of information about the kings who issued them. Coins play an important role in chronological sequences of different dynasties. Things are not what they seem, not what people think they are. The insecurely used some accepted definitions of a coin.

Fig 2.7: Coins (https://www.googl.com)

Different Definitions of Coin

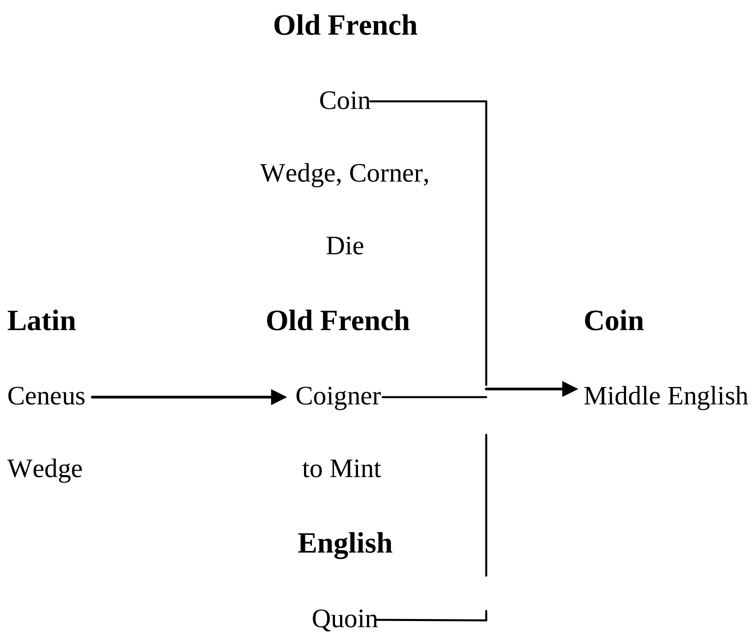
- A flat disc or piece of metal with an official stamp, used as money (oxford living dictionary)
- Coin is define as: something having two different and usually opposing sides usually used in the phrase the other side of the coin (Sinclan Lewis)
- A small piece of metal, usually flat and circular authorized by a government for use as money (A free dictionary)
- A form of money which is usually made from some type of metal which is assigned a specific monetary value by a governing authority is called coin (www.investor words.com/7568.htm).

Numismatics is the study of coins and coin like objects. Coin usually gave a round or circular in shape and imprinted with different symbols. Organized development of the coins study increased with the different methodologies which began 18^{th} century.

Origin of Name

The word coin derives from Latin word ‘Cuneus’ which means wedge because in the history, coins looked like the wedges. Numismatics is an English word which derived from Latin word numisma. Literally numismatics means ‘the study of coins’. According to the Indo-Aryans languages, the word numismatics is known as mudra-vidya, mudra-tattva, mudra-vijnana etc. So in this way history of Sub-continent numismatics was called Pratna-udra-vidya (D. R. Sircar 1968: 1).

Coin Name Origin: Coin have many different spelled such as laynes, coigns, Coigns or quoins.



(Harper. D 2017: 2)

Many words which we associate with coin today come from ancient currency. In these words we can understand how currency systems improved.

1. **Buck**

Early North American depends upon the skin of the deer as a transaction for trade system.

2. **Pecuniary**

This word comes from Latin word **pecus** which means cattle.

3. Fee

This word is derived from the German word used for cattle.

4. Shell-out

Shell-out means to pay, the use of shell as a transaction among native Americans and later the European.

5. Salary

Salary word is also related to coins which derive from Romans (Fleur-de-coin.com).

Beginning of Coins

From the three quarters of a century ago much of communications were occurred through coins. In the history people having different ways to measured their prosperity. Such as herds of cattle, hides, land, gold bars, bonds and stock certificates and some sout 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 have been used as a medium of transaction. But coin growth started when metal objects took a proper shape (Quantum Books, 1999: 6-10).

Importance of Ancient Coins in Archaeology

'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: 7).

One of the most important foundation of information from which archaeologist can try to understand the past is called coins. Relationship between coins and humans since 2700 years ago when people were used coins as a medium of transaction. Ancient Coins tell us the story of king who ruled over different lands. Ancient Coins give information about religious prospective of certain rulers an also give the chronological sequence of dynasties (Lal Gupta, 1969: vi).

Numismatics plays an important role in history of ancient India. Numerous coins have been discovered from different part of Indian country dating back from 300 BCE to 1200 CE (Pai 1976: vii).

Coins interweave the texture of history and serve as historical evidence without coins illustration we does not recognised rulers names, dynasties, their religions, their thought and their work. Coins or numismatics is a multi-disciplinary subject which is related with history and knowledge about palaeography and archaeological epigraphy. So researcher can say that coins have a much importance in a history of our earth. Coins tell us information about the tribal and city states that established in India during Pre-Christian centuries and after. Some written records such as Satavahanas of the Deccan are agreed with and corrected just because of coins. Coins also play an important role in the religious history because almost every ruler depicted their own religious perspective in our coins such as Kushans who ruled in north-western India dating back to 1st century CE and 2nd 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 (Lal Gupta, 1969: vii-x).

Coins save historic records more accurately and authentic than the historic monuments and buildings because coins give information about names and portraits of kings who ruled on that historic period. They provide complete help to identification and sequence about miniatures of dynastic rulers such as Greek, Bactrian, Parthian, Sasanian and Kushan king's portraits, miniatures and Statues etc (Sohail, 1998: 7-8).

Government society, succession of reigns, chronological sequence of dynasty can judge by coins inscriptions. These inscriptions also reflect the image of conquests, political wars, social life, internal work or religious reforms of that dynasty. Ancient Numismatic is a source from which we can analyze the economy of historic society (Collin Discovery Encyclopaedia, 2005).

Coins give enormous contribution to our knowledge and understanding of ancient society after scientific excavation of coins. From this excavation archaeologist can easily reconstruct ancient sites and easy to date. After read all these coin's importance, researcher can say that numismatic is directly related with Archaeology and they both can work hand in hand with the help of ancient coins. These all effort can facilitate more discoveries and analysis that neither discipline could generate in isolation (Archaeological institute of America august 7, 2007).

In early history coins also play an important role in aesthetic and artistic worth. Art of ancient coins reflect an idea about artists and aesthetic taste of those people who were made that coins. In this research researcher wants to tell as far as possible the story of coins. Researcher tries to tell necessary detail about coins in their proper prospective and show image of the historical circumstances (Lal Gupta, 1969: vii-x).

Notion of Coin

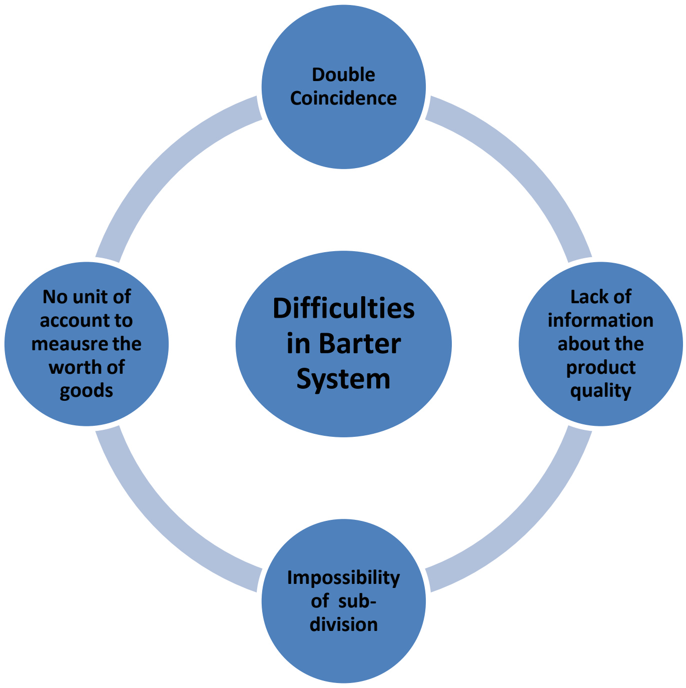
Barter System

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 contact from tribal communities of the other region and developed their life style more accurately. They could make objects by itself necessity to both communities exchange their products with each other so in this stage mutual exchanging system were started within those tribes. Gradually emergence of 'the notion of a unit of value' is an important step for the transaction. This exchanging system within communities and localities were called barter system.

Many things were used as a standard of exchange. Firstly hard stones were used as medium of exchange. Then fur and skins used as money in many ancient countries such as Jews, the Esthonians and North America used furs as a medium of transaction with the Red Indians.

After some time Leather (the earliest currency) used as a medium in Russia, Rome, Sparta and Carthage (Chakrabortity, 1931: 6-7).

Cow as a medium of transaction



By the Researcher

Table 2.4: Flow chart showing the difficulties in barter system

Although barter system was a foundation of medium of transaction but they were not a standard medium so some difficulties were arising soon. Due to development of civilization people felt, they needs enduring and suitable medium as a transaction for trade objects then they seems cow as a unit of wealth. Approximately 3000 BCE Vedic people (Indus Valley) used cows as a medium of transaction till 5th century BCE.

Nishka

After some time, some people thought about one standard value of transaction object because large things could not exchange with small objects vice versa (Lal Gupta, 1969: 1). Then Vedic people found a standard object for exchanging material known as Nishka which means some sout of necklace. Because Nishka was expensive amongst rest of the other ornaments in Vedic society (Ibid: 2).

Metal

After the innovation of small object as a medium of exchanging, metal has been naturally arrived. Metal was an earliest give in value in the monetary pattern or level (Burgess, 1913: 35). 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 our 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 mention in historic literature as raktika and today it is known as ratti. Seeds were irregular in shape and size so they were need proper scale and value for standardization so they started metal round in shape known as Satamanas. This word is also mentioned later in the literature of Samhilas and Brahmanas. One another metallic piece were introduced name 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 and sealing system was introduced many metallic pieces was designed with stamp. This was the time when coin was born (Lal Gupta, 1969: 2-5).

Ancient Coin in Sub-Continent

Firstly coinage was started independently China, Lydia and India. The oldest coins were used by Lydian's in 700 BCE. They also had known as inventors of coins because they issue gold and silver coins first time in history (Chakrabortity, 1931: 11). According to the Vedic literature, coins evolution in 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 sub-continent. During the ruins of Ashtadhayi, dated in 6th century and 7th century BCE, one of the earliest stamping metallic coins were introduced in sub-continent. This was an advanced stage of Indian coinage where first minting coins introduced and they were used freely in India. If they all are correct so researcher can claim that invasion of coins in India at least one century before Lydia or China (Ibid: 5-7).

Number of coins which were found in different part of sub-continent has not yet found an authentic date. Number of the theories arrived by different scholars for the origin of coinage (Kumar and Srivestava 1998: 15).

Number of the European scholars such as H. H. Wilson and Tame Prinsep tells that Indian coins were not an indigenous creation. They were introduced by the Greek of Bactria (Wilson, 1836: 407).

S. R. Goyal describes that origin of coin in sub-continent due to Greek kings. He gives the authentic point that when Greeks spread their hold in India then Greek kings ordered first time to make coins according to artistic merit (Goyal, 1995: 214).

According to the Ephesus, invention of coins in India dating back to 6^{th} century BCE and Lydia in 656 BCE which shows that Indian coins were earliest coins in the whole world (Kokatanur, 2015:2445). Coins can be divided under an economic, legislative, metrological and artistic perspective. Ancient Indian coins started by as punch marked coins (Ibid: 2546).

Punch-Marked Coins

According to the historians and different scholars Punch-marked do not have definite date and year but these coins were evolved first in Bhir Mound in Taxila and same in Indian sites dating back from 4^{th} century BCE to 1^{st} century CE (Ibid: 2546-47). Punch-marked coins have been firstly evolved in two regions of 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: 11).

Earliest Indian coin has not any definite shape and structure. They do not have any particular weight or any type of proper shape inscribed on it. Those type of coins known as Punch-marked coins. In those coins having just irregular shapes which influenced by nature such as animals, trees, human figures and hills etc. these shape struck by stamping device known as punching machine. Name of Punch-marked coin originated from manufacturing technique. Mostly coins are in silver metal and all these characteristics of Indian coins related to Greece (Kokatanur, 2015: 2546). Earliest Indian coins having archaic die-struck pieces are called punch-marked coins (Mukherjee, 2007: 11). Punch marked coins discovered all over in India from strata graphically layers till 2^{nd} century CE. Early coins were only un-inscribed Punch-marked coins.

During the ruins of Satavahana dating back to 2^{nd} century BCE, Romans portrait influence was found on those coins. During the period of Satavahana, coins having different symbol of nature such as animals portrait, mountains etc introduced first time in sub-continent. Punch-marked coins became standard value which replaced barter system (Reddy, 2011: 33). Recent archaeological excavations have proved that coins were more developed in Mauryan Period. These Punch-marked coins proved that during Janapadas in the Buddha’s time, number of silver and copper coins was issued with definite Punch-marked (Raj Pai, 1976:1).

Dynastic Coins

Dynastic coins mostly related to dynastic rulers such as Kushanas, Saka-Pahlavas and Indo-Greeks dating back from 2^{nd} century BCE to 2^{nd} century CE. Mostly portrait of rulers, god and goddess figures depicted on the surface of these coins. All these figures demonstrate that who ruled on that time and which religion they belonged (Kokatanur, 2015: 2546-47).

These earliest Indian coins show culture, architecture, faith, language and worth of those eras from which different rulers ruled (Ibid: 2550).

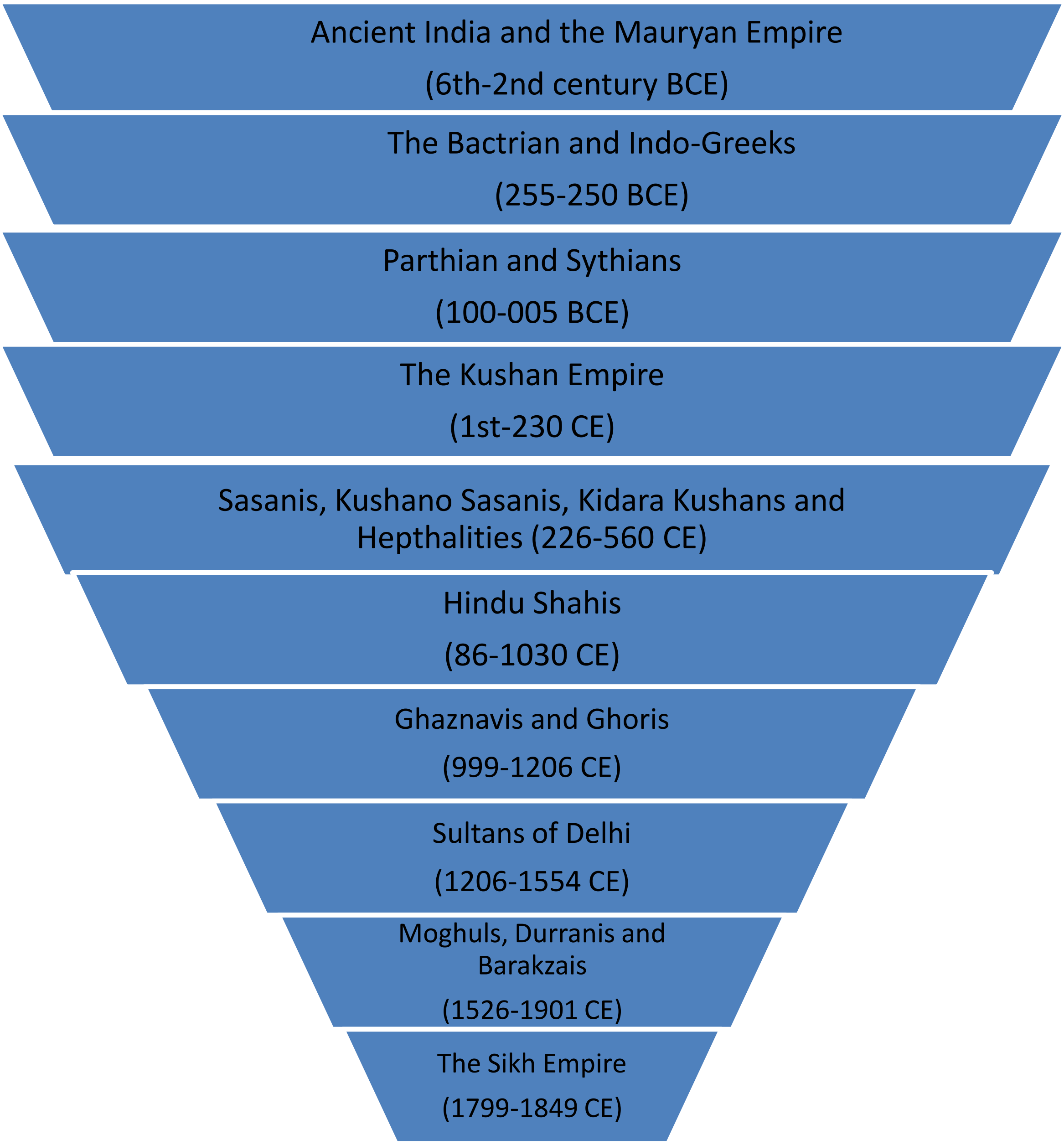


Table 2.5: Flow Chart showing the Chronological Sequence of Dynastic Coins

Coins from Taxila Valley

Taxila is an ancient valley of Gandhara civilization dating back from 6^{th} century BCE to 9^{th} century CE. Coins of Taxila play an important role in the chronological sequence of Taxila Valley. Researcher can get information about local copper coins from the stratum of sites dating back to the 3^{rd} century BCE. Coins of Taxila have been discovered in many varieties and approximately 12000 coins have been exposed from different sites of Taxila valley.

No	Discovered Coins	Sites
1	7665	Sirkap
2	1579	Bhir Mound
3	1546	Dharmarajika
4	396	Kalawan
5	316	Bhamala
6	313	Chir Tope A,B,C,D
7	175	Jaulian
8	106	Sirsukh
9	84	Mahra Moradu
10	81	Jandial
11	43	Mahal
12	27	Pippala
13	18	Lalchak
14	187	Badalpur
15	9	Bhallar Stupa
16	6	Hathial
17	5	Khalay
18	3	Ghai
19	2	Seri
20	1	Ratta Pind

Table 2.6: Discovered Ancient Coins from Taxila (Marshall, 1954: 751)

Mints of Ancient Coins at Taxila Valley

Large number of metals has been found at Taxila Valley of a date earlier than the 4th century BCE. Earlier these were imported from the Indian parts of Barygaza (Broach).

According to the author 'Arun Kumar Biswas' Lothal brass containing 6.04% zinc and bronze-brass having 16.2 % zinc and 20.72% tin which have been attained by cementation process.

According to the Craddock"s in 1981:

'This could have produced only by mixing copper and zinc metals. Hence the overriding importance of the vase excavated from the Bhir Mound at Taxila Valley, dated to the 4th century BCE and shown to contain 34.34% zinc (Marshall, 1951, 1975: 568).'

This is very much important evidence for the availability of metallic zinc in the 4th century BCE. These metals objects were made before the Greeks settlement in Sirkap and Alexander"s invasion of Taxila. So discovering of zinc metal as a separate metal and credit goes to Indians not Greeks.

In Sirkap site number of bangles was found which giving 19.70% zinc. In Dharmarajika bangle and pot containing 12.85% zinc were found. While copper alloy (copper and nickel) which were naturally occurring in province of Yunan and China (Kumar, 1996: 273-274).

The alloy and material were used in the coins of Euthydemus, Agathocles and Panthaleon. They all have been proved that they must have been intimate trade relationship between Greek dynasty in Taxila, Bactria and the Han dynasty of China during the 2nd century BCE. But after the 1st century BCE white copper had been disappeared because the trade was stopped.

After that this process started at Taxila in the manufacture of copper and bronze metals were as follows:

- Hammering, Riverting and Soldering
- Soled eating
- Hollow casting by the cire predue process
- Embossing or repousse work

In Bhir Mound site found 32 copper and bronze objects in which 23 made by hammered and were in solid east. These metal objects further compared with Greek, Sakas and Parthians time dated of the 1st century CE. They yielded large number of copper and bronze objects such as bracelets, bangles, ear-rings, ear-pendants, brooches, neck-pendants and buckles.

In the process of soled casting of high tin, stone or terracotta moulds were used. In the 2nd century BCE, cire predue process was employed for the fabrication of household vessels. Copper, bronze and silver were made by hammering the metal sheet in a solid metal die. These techniques were used only in India, while Greeks, Sakas, Parthians, Kushans etc used new style of art and household objects.

Some surgical instruments like spatula etc which were made of copper and bronze found in the layer of Kushan period at Taxila. Almost 221 numbers of Iron and steel objects were found at Taxila Valley. Such as Bhir Mounds, Sirkap and monastery of Jaulian. These objects were burnt by the invasion of Kushans and White Huns so due to great heat, these objects preserved better against corrosion and disintegration. These objects divided into six groups:

- Household utensils
- Arms and Armour
- Horse-bridles and elephant goods
- Carpenter‟s and black-smith‟s tools
- Agricultural implements
- Miscellaneous articles such as needles, plummets, unwrought ingots etc.

These objects were not prepared at Taxila; they were clearly origin such as ladles, foreign, candelabra, wheeled braziers, heavy iron javelins, helmet, snaffle-bits etc. They all were not common in India and Taxila.

According to the Marshall, ancient steel of Taxila were produced by crucible or wootz process but no clear evidence could be obtained. The archaeological findings from the Maurya, Greek, Parthians, and Scythians and Kushana layers at Taxila explore many aspects of written history. Minerals and metals objects which were found at Taxila, tell us the history of India and its contact with other countries (Ibid: 275-277).

According to the Marshall some group of coins of Maues are resemblance with the Telelephus money at Kapisi. So researcher can say that it was at Kapisi also that coins of the very group were minted. Its follows, so the other group of coins might be expected that was minted at Taxila. This is also known as first and major group of Maues which was minted at Taxila, which was the capital of the new territory. Remaining small groups of coins having crude, rough workmanship in which kharoshti script is written. This indicate the origin where the kharoshti script was less famous than Northern Panjab and Gandhara known as Arachosia district. So Maues coins were found on Taxila, Kapisi and Arachosia but his naturally principal mint were only at Taxila Valley.

Chapter: 3

The Art of Cleaning Ancient Coins from Badalpur Monastery

Cleaning coins is a talent not a science. This is because all the coins are not in equal size and in same condition. Some coins can be cleaned with water while using tooth brush but other coins need proper techniques and methods to clean them properly. Coins should be cleaned relying upon the coin metal as indicated by the earth crustation, or potential oxidation introduced. The researcher used three different cleaning techniques for the coins which were collected from Badalpur monastery during the excavation (Season 2015).

The Basics

The Researcher used three basic techniques to clean the coins of Badalpur Monastery.

- Mechanical Technique
- Chemical Technique
- Electrical or Electrolysis Technique

- **Mechanical Technique**

Mechanical Technique is a long and time consuming method for cleaning ancient coins. In this technique I have used soap, water, a tooth brush, scalpels, dental picks and Diamond Dusted Dremel tools.

- **Chemical Technique**

Chemical Technique in which the researcher used those solvents which are not very harmful for coin patina such as Lye. These coins were in bad state of preservation covered with dirt/ curst/ oxides. Mostly, chemically cleaned coins became clear. The researcher has discussed its state of preservation in detail.

- **Electrical or Electrolysis Technique**

The Researcher used electrical technique in which ancient coins were cleaned through electrolysis process. This cleaning method only took a few hours, but was generally frowned upon. This may take slightly longer time, but it will be easier. It is very comprehensive and damaging technique therefore the researcher has used the technique only for those coins which could not be cleaned by any other methods.

Magnification

Firstly, Instead of microscope, the researcher used hands free magnifying system for the cleaning of ancient coins. Ordinary light and magnifying glass are enough for the observation of ancient coins. Magnifying glasses are generally low-powered; they have a decent-sized handle and a relatively long focal length, to see the fine details of a coin at a sufficient size so they're extremely easy to use.

Fig 3.1: Magnifier

Mechanical Cleaning

Mechanical Cleaning is a valid method to clean the ancient coins. It totally depends upon the scraping and brushing. Different steps which are used by the researcher during Mechanical Technique are given as follow:

1. As we know, from the numerous years prior to all the old coins were cleaned with the help of Olive oil. A strategy for cleaning coins starts with Olive Oil. Olive Oil contains a low corrosive nature that has a tendency to soak encrustations and enter the dust and release them from the coins. Firstly the researcher soaked the coins in Olive Oil and let them rest for seven days to enable the corrosive to do its work (Fig 3.2: Ancient Coins in Olive Oil).

2. After a week the coins were removed from olive oil and wash with tooth brush and liquid soap and scrub under warm running water. Cleanser works by bringing down the surface strain of water enabling the water to infiltrate the soil, by mixing grease, and by engrossing earth into the foam. In the case of cleaning ancient coins, dirt is our first enemy. It is removed before the starting cleaning methods. Almost all the coins are hard enough to clean but small amount of dirt can be removed. There is no specific time limit for cleaning and washing till the end of the process.

Fig 3.3: Wash ancient coins with brush

3. Before starting proper technique and tools the researcher has used another method to remove the mud and dirt from ancient coins known as Gringgott's Wizard Mix 3.

Fig 3.4: Gringgott's Wizard Mix 3.

4. The researcher removed as much dirt and mud as possible with brush and soap under running water. Then examined these ancient coins under magnifying glass.

Fig 3.5: Ancient coin under magnifying light

All the coins were examined carefully and then separated into three categories for better understanding.

Category 1:

Those coins that are cleaned and show clear details. These finally cleaned coins are ready for mechanical cleaning technique.

Category 2:

Those cleaning of coins which contain portrait and details were problematic that may require a additional time to clean with olive oil or Gringgott's Wizard may last for weeks.

Category 3:

Those coins that have very heavy encrustations. They could only be cleaned through electrolysis.

5. **Common Dental Pick Tool**

The Common dental pick with its sharp point and hard steel was the first mechanical tool for cleaning ancient coins from Badalpur site by the researcher. The researcher used Dental Pick Tool to explore the coin's surface. Firstly the dental pick was used on the coins from sideways rather than from the point. By using little pressure the instrument was used in a circular method rather than left-right or up and downwards.

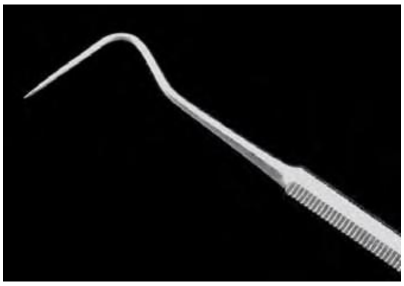


Fig 3.6: Dental Pick Tool

6. X acto-knife

X acto-knif was used as a scaple for cleaning technique. It is very simple craft knife also known as a common house hold tool.

Fig 3.7: X acto-knife

The coin was gripped in the hand and the boundary of the curved blade was used to rub off the mud and corrosions blade was used as plane as possible on the surface and some time in circular motion.

Fig 3.8: Using Craft knife

21st Century Tools

7. Diamond-dusted Dental pick

Diamond-dusted Dental pick is spade-shaped on both-sides. It is a much better tool than the tools used before. It is best used for delicate cleaning. It was used slowly on the surface of the coins at low pressure.

Fig 3.9: Diamond-dusted Dental pick

Never used the Diamond-dusted Dental pick in up down or left-right positions. The researcher only used tip of the tool in circular motion to brush the encrustations otherwise it can destroy the patina of a coin.

Fig 3.10: After using Diamond-dusted Dental pick (Obverse side of the coins)

Diamond-dusted Dental pick is used not only for cleaning dirt but also for rock hard green encrustations with its flat part of the blade.

Fig 3.11: After using Diamond-dusted Dental pick (Reverse side of the coins)

8. The Dremel Mini-Mite

The Dremel Mini-Mite is a battery-powered tool having low weight in the hand and is much responsive. The researcher used it at the lowest speed 5000rpm.

Fig 3.12: The Dremel Mini-Mite Box (by the researcher)

9. Pick-axe

The researcher has used pick-axe tool to clean the ancient coins only is circular motion at low pressure.

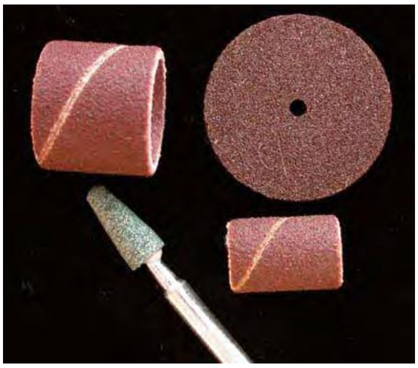


Fig 3.13: Pick-axe

In the case of silver coins, they are too much intact but can be broken easily. These type of coins require large amount of time to clean them. Pointed some small problems that were hidden yet. The three red bits seen on the upper side of the coin (fig: 3.14) must be ignored and avoided in any case. These small eruptions will get destroyed it is tried to remove. At the end, the red circles must also be leaved or ignored.

Fig 3.14: Encrustation on the ancient coins

10. Dremel Soft brass bristle cup brush

The utilization of Dremel instruments for cleaning coins requires not only practice but patience as well. The Dremel soft brass bristle cup brush is a momentous instrument that can be utilized for some purposes. This tool was used to knock off dirt and detail for cleaning and polishing.

Fig 3.15: Dremel Soft brass bristle cup brush

Soft brass bristle cup brush is not only used for scrubber but it is also a polishing tool. Do not develop any pressure on coins but just touch the coin surface with the bristles. Always use the brush under warm running water. Never put the bristles flat-wise alongside the coins surface. It is too abrasive and may cut thin patina layer.

Fig 3.16: The Soft-bristle Brass Brush… the Wrong Way!

Only use tip of the brass bristles because it is not used for cleaning, but for polishing purpose. This tool makes ancient coins smooth and shining.

Fig 3.17: The Soft-bristle Brass Brush… the Correct Way!

Amazing difference can be seen before and after brushing and all the details much clear. Vicious green encrustations disappeared by Soft brass bristle cup brush works. Soft brass bristle cup brush tool works brilliantly for ancient coins.

11.Mechanical Cleaning With Dremel Tools

- **Diamond Dusted Dremel Tools Names**

Left to right, tools are
Flame Tip 55 (F55),
Flame Tip 45 (F45),
Point Tip 80 (P80),
Bullet Tip 10 (B10),
Bullet Tip 15 (B15).

Fig 3.18: Diamond Dusted Dremel Tools (by the researcher)

The researcher used five tiny Diamond Dusted Dremel Tools which easily clean the fix coins of their encrustations. They are slightly damaging to the patina of coins.

- **Diamond Dusted Rubber Dremel Tools Names**

Left to right, tools are
Black Arrow (BA),
Black Bullet (BB),
Sharp Gray (SG),
Gray Bullet (GB).

The researcher has four Diamond Dusted Rubber Dremel apparatus for smoothing the surface of ancient coins.

Fig 3.19: Diamond Dusted Rubber Dremel tools (By the researcher)

- **B10 Dremel tool**

The B10 Dremel instrument is the most excellent method to clean any ancient coin.

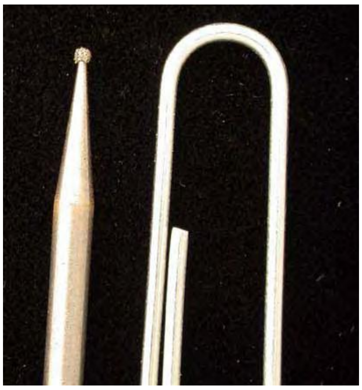


Fig 3.20: B10 Dremel tool Fig 3.21: Wrong way for cleaning encrusted ancient coins

In the above fig (3.20 and 3.21) this is the wrong way to clean the ancient coins so never use Diamond Dusted Dremel tool in a back and forth motions. Always use the Diamond dusted Dremel tool in a circular motions.

Fig 3.22: Right way for cleaning encrusted ancient coins

Remove encrustations with low pressure. Touch the ball tip to the surface and let the apparatuses take the necessary steps. Never use the tool more than 5000 rpm.

Fig 3.23: Cleaning encrusted ancient coins at low pressure

(Fig: 3.23) After the B10 has cleaned the green corrosion. The coin become clear and legends become apparent.

- **The flame Tip55**

The F55 is a broad tipped tool used for the encrustations, fields and specially coin's details.

Fig 3.24: The flame Tip55 of Dremel tool

Now after using F55, we can observe the actual improvement. The field, legends and sketch are coming apparent without damaging patina.

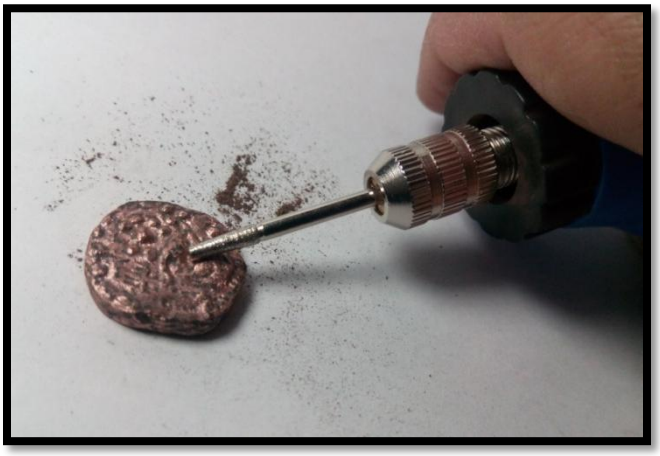


Fig 3.25: legends and portrait are become clear

- **The flame Tip45**

This Tip is smaller but sharp than the F55. This tool is used for more maintenance and smoothing. The tip is pointed as much as necessary to clean legends and details.

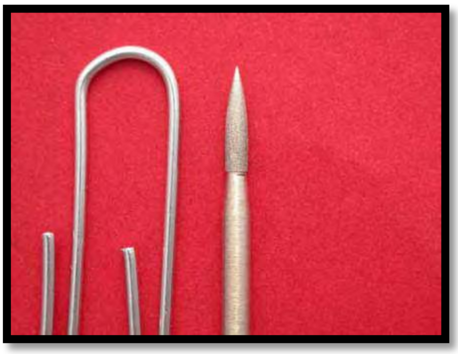


Fig 3.26: The flame Tip45 of Dremel tool

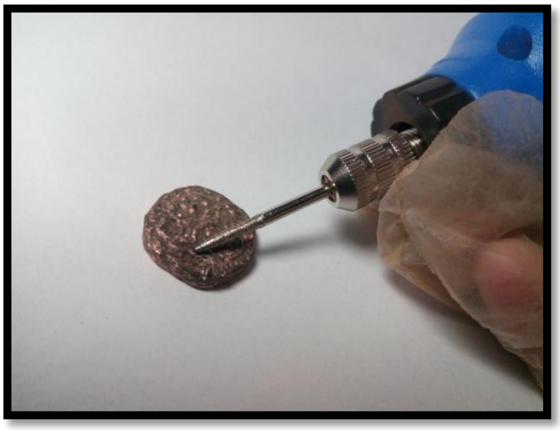


Fig 3.27: legends and portrait are become clear

- **Diamond dusted Dremel tool ' P80'**

Then next step is to use the pointed tip P80. It is best to clean points of interest and legends. The researcher has utilized P80 to expel the majority of the rest of the patina on the two sides of the coins.

Fig 3.28: Diamond dusted Dremel tool 'P80'

Fig 3.29: legends and portrait are become clear

- **EL44 tool**

EL44 tool was merely used because of its massive encrustation properties. It could be harsh so if it is used it only in stiff encrustations of coins.

Fig 3.30: EL44 tool

Fig 3.31: legends and portrait are become clear

- **Diamond dusted rubber tools 'Black Arrow (BA), Black Bullet (BB), Gray Bullet (GB), and Gray sharp Point (GSP)'**

Diamond rubber devices were utilized for cleaning and smoothing. The researcher utilized the Black Arrow (BA) and the Black Bullet (BB).

Fig 3.32: Diamond dusted rubber tools 'Black Arrow (BA), Black Bullet (BB) and Gray Bullet (GB), Gray sharp Point (GSP)'

Firstly the BB was utilized to clean/smooth the representation and the fields and after that the smaller BA was used to characterize the legends. For additional smoothing two elastic bits, the Gray Bullet (GB) and Gray Sharp Point (GSP) were utilized. These instruments work more fine and best after BB and the BA. GB and GSP were smoothing increasingly the field, representation and legends. Now, the coin looks like stripped of all patina but bundles of sharp points of interest are appearing. It is brighter and sparkles.

Fig 3.33: BB to clean/smooth the portrait and the fields

Fig 3.34: BA to clean/smooth the portrait and the fields

Fig 3.35: Obverse side of the Coin

Fig 3.36: Reverse side of coin

- **Lemon Juice**

After all mechanical technique, few bits of encrustations still remained which were needed to be soaked in lemon juice. Lemon juice and Soft brass bristle brush were used under warm running water.

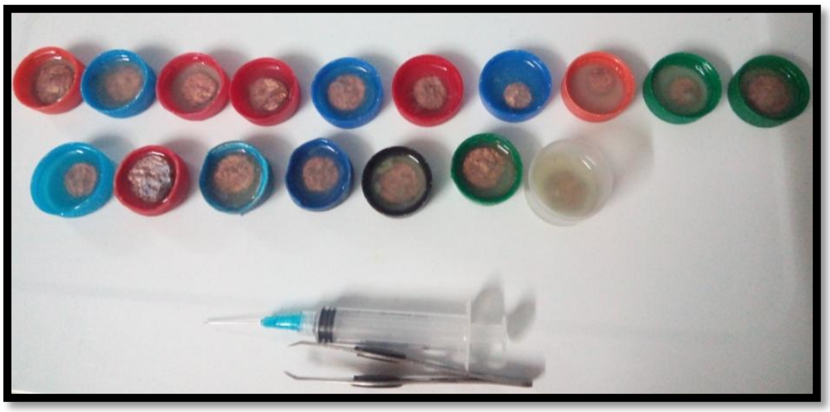


Fig 3.37: Soaked in lemon juice the ancient coins

Chemical Techniques

JAX solutions

After this now it is time to turn repatination products. Many repatination materials are JAX solutions. They are in four types ‘Brown, Brown/Black, Black and Green patina. All JAX solutions were used easily. The coins were soaked for only few minutes in the solution. All the solutions provided different patina to ancient coins because every coin has a different metal content.

Fig 3.38: JAX Solution for repatination products

Brown patina solution was applied to provide the coin further natural look. The solution was poured into a small container and the coins were putted in that solution for a few seconds. The coins were removed immediately from the solution and were brushed under warm running water.

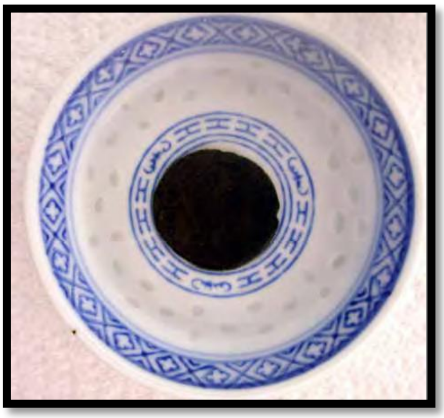


Fig 3.39: Ancient coin in a JAX Solution

Now the coin was placed in a dry area and waited an hour for allowing the solution to complete its work.

Renaissance Wax

Some Renaissance Wax was applied. It is non-reactive Wax and protects coins well.

Fig 3.40: Renaissance Wax

A small amount of Wax was applied with fore-finger and rubbed gently onto the coin's surface. The coins were putted in warm place and waited an hour then were buffed gently with cotton cloth.

Deller's Darkener

After drying the coins Deller's Darkener was used. Deller's is a great chemical for diming small errors. It was rubbed on the coin and waited for the product to do its work. At the end soft bristles brass brush was used for brushing both side of the coin. In this process

Deller's Darkener worked best. It cannot harm ancient coin patina and they work differently on each coin based on their metal content. Sometimes they worked quick, sometimes deliberate and sometimes in a minute. After this application the coins were restored in front of sunlight for few days.

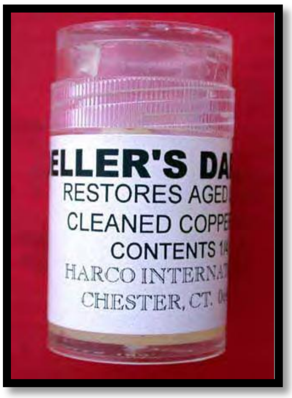


Fig 3.41: Deller's Darkener

By using Deller's Darkener on coins with their unique patina to restore a small number of cleaning mistakes, the ancient coin's surface was restored and it was settled in front of sunlight for two hours extra or less. Deller's captivated into the patina of coin and polished bits became too dim. If the Deller's Darkener failed be engrossed then the coin cleaner process is completed. If not the process is repeated till the patina fails to soak up the darkener. After this process the ancient coins were settled in front of sunlight for many days. When the ancient coins dried simply buffed them with a soft cotton cloth.

Fig 3.42: Before the Cleaning

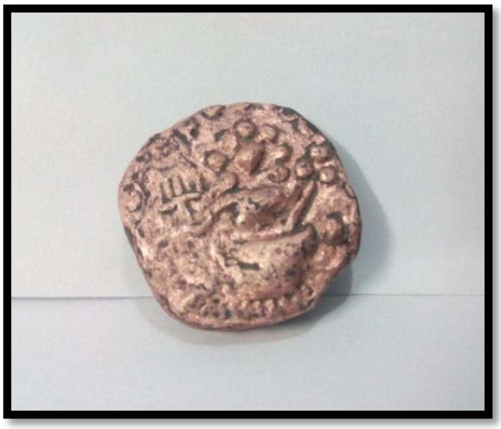
 

Fig 3.43: After the Cleaning

Electrolysis Technique

Electrolysis

The electrolytic process needs an electrolyte, an ionized solution, and electrodes. A cathode having negative charge and anode having positive charge are used in electrolysis. Positive ions move towards the cathode and negatively charged ions move in the direction of an anode in the electrolysis circuit. This movement of ions generate the current in the circuit. This process is called electrolysis.

Creating Our Own Electrolysis Circuit

In the figure (3.44), the researcher made an electrolysis machine for which transformer was needed. 12 volt, 1500 amp transformer from an electronic shop was purchased. The next step was a use of the small size plastic container which can at least grasp two cup of liquid. Joined transformer and clip off power point in at the last part of wiring. Then twisted these two wires and fill plastic container with water.

Fig 3.44: Electrolysis Machine

A coiled 6 inch copper wire was attached to the one end of the transformer’s wire (fig: 3.45).

Fig 3.45: Transformer with Copper wire

In the next step a steel washer was attached to the coiled copper wire.

Fig 3.46: Transformer along with copper wire and steel washer

Restoring ancient coins through Electrolysis

Filled container with hot water then add two table spoon of NaCl and two table of spoon of Baking Soda. Coin must be connected to the alligator clip and the steel washer to the coiled copper wire as shown in fig: 3.47.

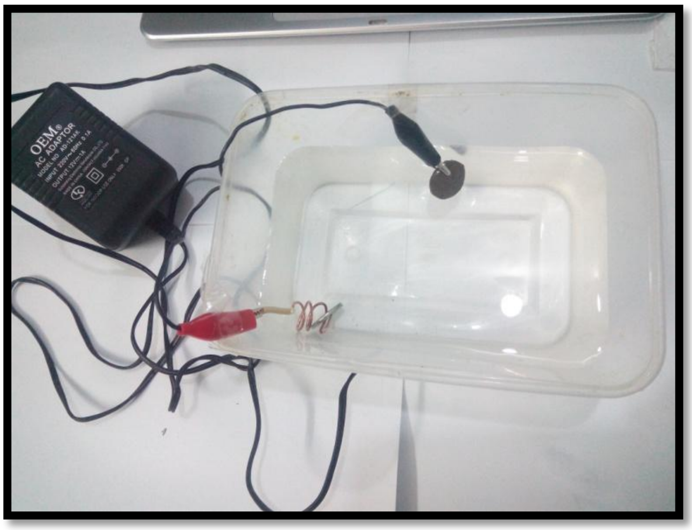


Fig 3.47: Electrolysis Circuit

Fig 3.48: Transformer with ionized solution

Now plugged on the transformer. Within a few seconds, the washer began to fizz and water became dirty.

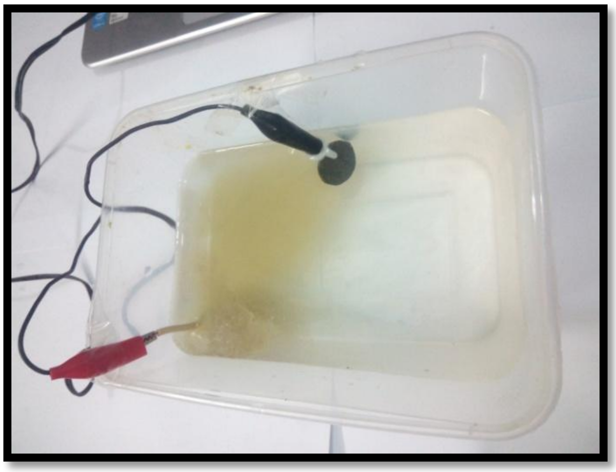


Fig 3.49: Electrolysis Process

Fig 3.50: At the End of Electrolysis Process

After five minutes the coin was removed the clip and then scrubbed it lightly with Soft Bristles Brass Brush under warm running water. The researcher found black residue which was removed from the ancient coin after electrolysis and the observed under magnifying glass. Then the remaining electrolysis crust was removed with Dental pick. All the coins that have undergone the electrolysis procedure needed to be soaked in de-mineralized water for 24 hours.

Smoothing Tools

In this process Diamond Dusted Black Rubber Bullet Dremel apparatus was used to smoothen the coin's surface. The side of the device was utilized for smoothing but not the point.

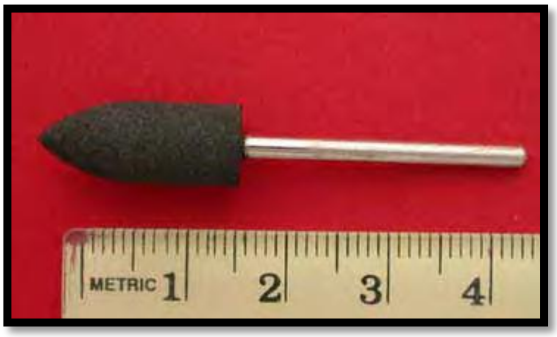


Fig 3.51:Smoothing tool

Before the Cleaning

Fig 3.52: Obverse side of the Coin

After the Cleaning

Fig 3.53: Reverse side of the Coin

Now all the encrustations have been separated and the coin's original surface is relatively clear.

Chapter: 4

Discovery of Coins from the Recent Excavation at Badalpur (2015)

Badalpur History of Excavation

In 1863 First time Sir Alexander Cunningham visit Badalpur Monastery and published the report on the Annual report of Archaeological Survey of India. Natesa Aiyor excavated Badalpur site in 1916-17, followed by M. Arif in 2005 under the supervision of M. Fazal dar Kakar (DG of Archaeological Deparment) and then Muhammad Ashraf Khan in 2009-2015 (Ashraf and Lone 2004: 25). Badalpur stupa is one of the monumental stupa, near the village of Bhera. Badalpur stupa is one of the most imposing monuments in Taxila which measures over 80 feet in length and 20 in height. Two rows of chambers with narrow verandahs and on the eastern side of the stupa, there are the buried remains of a spacious monastery. Badalpur site having number of coins which belonged to the Kushan kings Kanishka, Huvishka and Vasudeva dating back to the 2nd - 3rd century CE (Marshall 1918: 101-102).

Fig 4.2, 4.3: Recent Excavation at Badalpur Monastery (Photo by Researcher)

During the excavation at the monastery, from Natesa Aiyan collected 10 copper coins of Kushan period given below:

1. Soter Megas (1 Coin)
2. Kadphises (2 Coins)
3. Kanishka (4 Coins 2 of Oesho deity and 2 of unknown deity)

4. Vasudeva (2 Coins of Ardoxsho type)
5. Sasanian (1 Coin having bust of king and fire altar) (Ashraf Khan 2007: 178).

Coins discovered from the recent excavation at Badalpur (Season 2015)

Excavations initiated by Federal Department of Archaeology and Museums in 2005 and done their work and excavations in four seasons including the recent diggings in 2009 under the supervision of Prof. Dr. Muhammad Ashraf Khan and Mr. Muhammad Arif.

The gold coins is the quarter dinar of Kanishka, all the rest of coins (copper) belongs to the Kushan rulers except one which is belong to Hindu Shahi dynasty.

The present research focuses on the 34 copper coins found during the 2015 excavation at the Badalpur monastery from trench X-14. The following method has been used while cataloguing these coins.

Conservation of Badalpur Coins Period (220 BCE-271 BCE)

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
1	6.096 g – 5.287 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.4: Obverse side of the Coin 1

Fig 4.5: Reverse side of the Coin 1

After Cleaning

Fig 4.6: Obverse side of the Coin 1

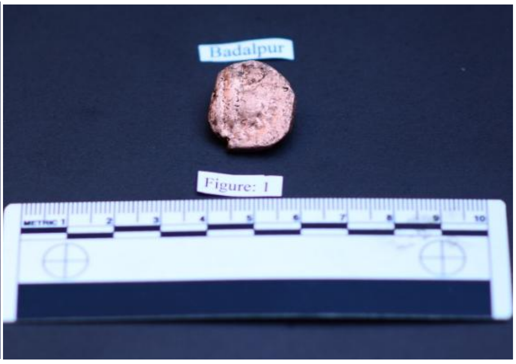


Fig 4.7: Reverse side of the Coin 1

Description A copper coin belong to local Taxila (from about the early quarter of 3rd century (c. 220 BCE) to about the early quarter of the 2nd century BCE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
2	4.003 g – 3.527 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.8: Obverse side of the Coin 2

Fig 4.9: Reverse side of the Coin 2

After Cleaning

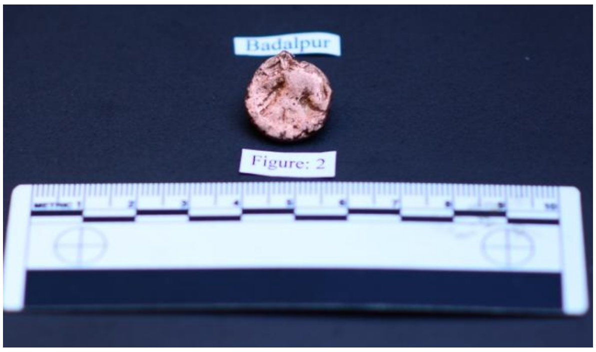


Fig 4.10: Obverse side of the Coin 2

Fig 4.11: Reverse side of the Coin 2

Description

A copper coin of Amitation, Azez II (from about the late quarter of the 1st century CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
3	3.316 g – 2.983 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.12: Obverse side of the Coin 3 Fig 4.13: Reverse side of the Coin 3

After Cleaning

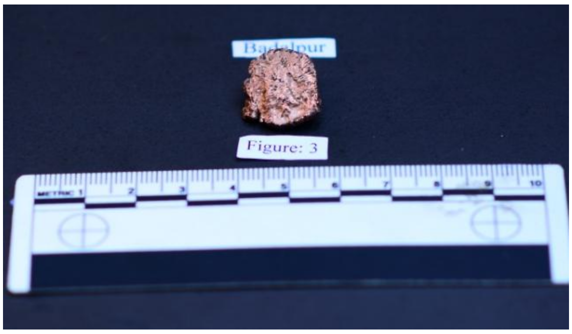


Fig 4.14: Obverse side of the Coin 3

Fig 4.15: Reverse side of the Coin 3

Description

A copper coin of Amitation, Azez II (from about the late quarter of the 1st century CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
4	5.012 g – 4.844 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.16: Obverse side of the Coin 4 Fig 4.17: Reverse side of the Coin 4

After Cleaning

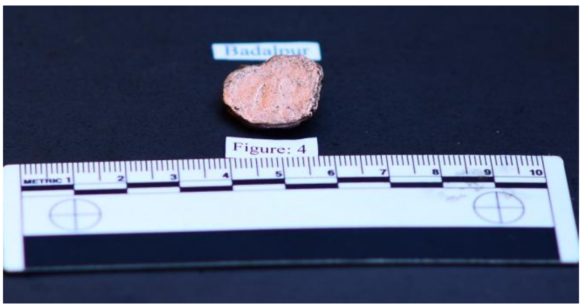


Fig 4.18: Obverse side of the Coin 4 Fig 4.19: Reverse side of the Coin 4

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
5	4.030 g – 3.851 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.20: Obverse side of the Coin 5

Fig 4.21: Reverse side of the Coin 5

After Cleaning

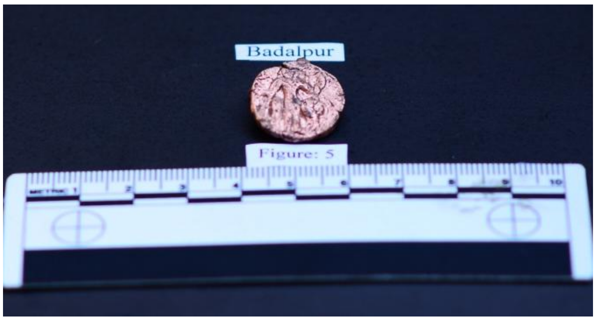


Fig 4.22: Obverse side of the Coin 5

Fig 4.23: Reverse side of the Coin 5

Description

A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
6	2.607 g – 2.411 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.24: Obverse side of the Coin 6

Fig 4.25: Reverse side of the Coin 6

After Cleaning

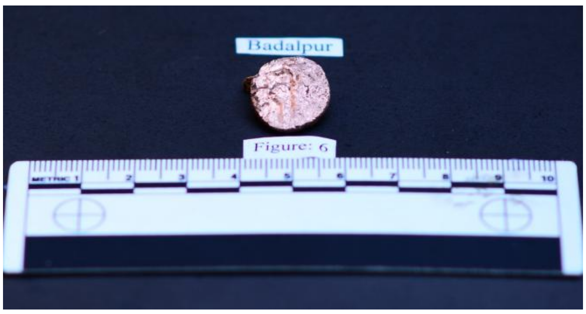


Fig 4.26: Obverse side of the Coin 6

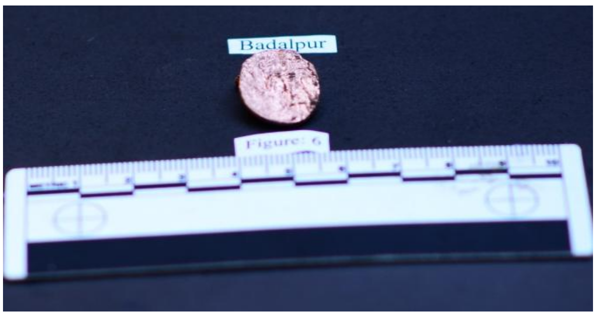


Fig 4.27: Reverse side of the Coin 6

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
7	1.518 g – 1.255 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.28: Obverse side of the Coin 7

Fig 4.29: Reverse side of the Coin 7

After Cleaning

Fig 4.30: Obverse side of the Coin 7

Fig 4.31: Reverse side of the Coin 7

Description

A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
8	2.073 g – 1.834 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.32: Obverse side of the Coin 8

Fig 4.33: Reverse side of the Coin 8

After Cleaning

Fig 4.34: Obverse side of the Coin 8

Fig 4.35: Reverse side of the Coin 8

Description

A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
9	1.980 g – 1.349 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

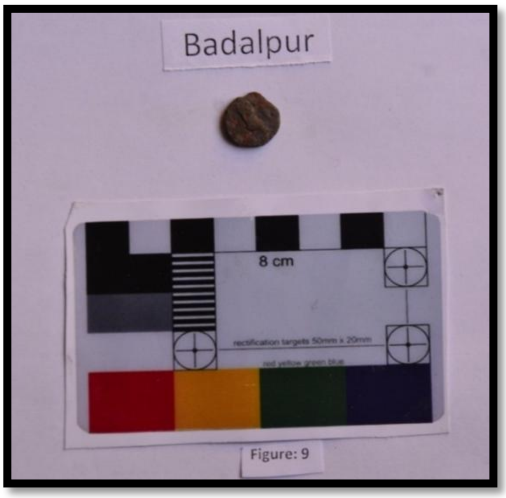


Fig 4.36: Obverse side of the Coin 9

Fig 4.37: Reverse side of the Coin 9

After Cleaning

Fig 4.38: Obverse side of the Coin 9

Fig 4.39: Reverse side of the Coin 9

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
10	6.106 g – 6.006 g	4ft from cell wall	X-14	3	25-11-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

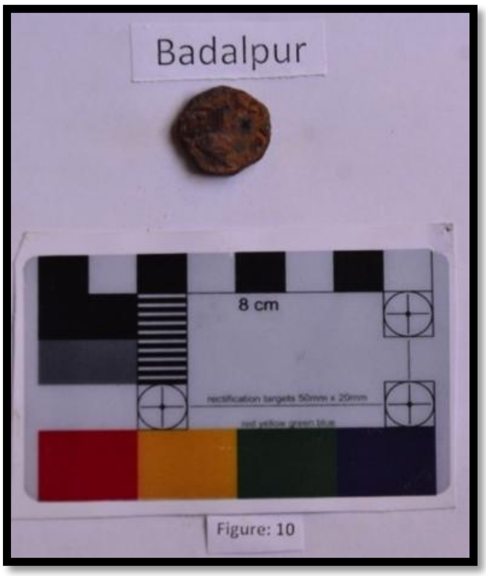


Fig 4.40: Obverse side of the Coin 10

Fig 4.41: Reverse side of the Coin 10

After Cleaning

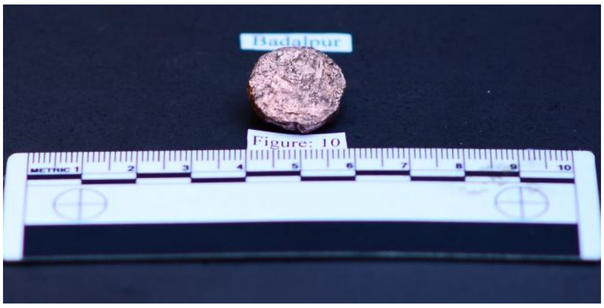


Fig 4.42: Obverse side of the Coin 10

Fig 4.43: Reverse side of the Coin 10

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
11	3.710 g – 3.576 g	E5.3m×N 5.8 D8 ft	X-14	3	25-11-2015	Rusted Intact Copper	Copper	Badalpur Site

Before Cleaning

Fig 4.44: Obverse side of the Coin 11

Fig 4.45: Reverse side of the Coin 11

After Cleaning

Fig 4.46: Obverse side of the Coin 11

Fig 4.47: Reverse side of the Coin 11

Description

A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
12	8.602 g – 6.984 g	E5.3m×N 5.8 D8 ft	X-10	3	25-11-2015	Rusted Intact Copper	Copper	Badalpur Site

Before Cleaning

Fig 4.48: Obverse side of the Coin 12

Fig 4.49: Reverse side of the Coin 12

After Cleaning

Fig 4.50: Obverse side of the Coin 12

Fig 4.51: Reverse side of the Coin 12

Description A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
13	5.732 g – 5.278 g	From N2.65m/ W7.4m	X-14	3	20-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.52: Obverse side of the Coin 13

Fig 4.53: Reverse side of the Coin 13

After Cleaning

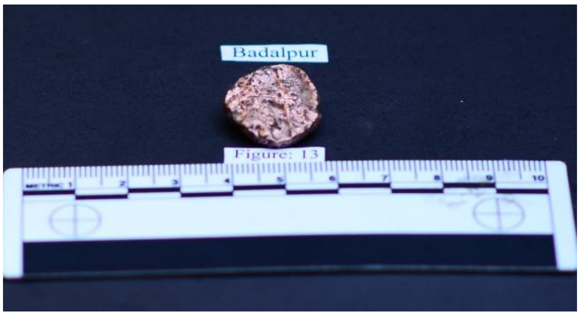


Fig 4.54: Obverse side of the Coin 13

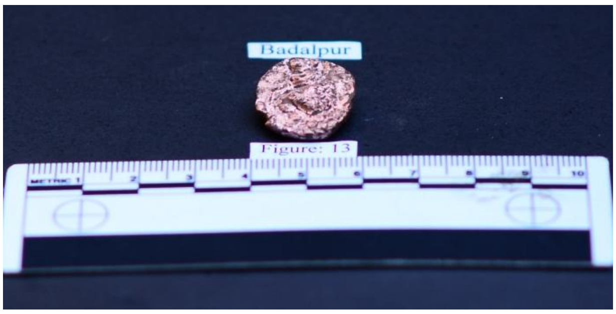


Fig 4.55: Reverse side of the Coin 13

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
14	6.149 g – 4.994 g	E5.3m×N 5.8m D8ft	X-14	3	25-11-2015	Rusted Intact Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.56: Obverse side of the Coin 14

Fig 4.57: Reverse side of the Coin 14

After Cleaning

Fig 4.58: Obverse side of the Coin 14

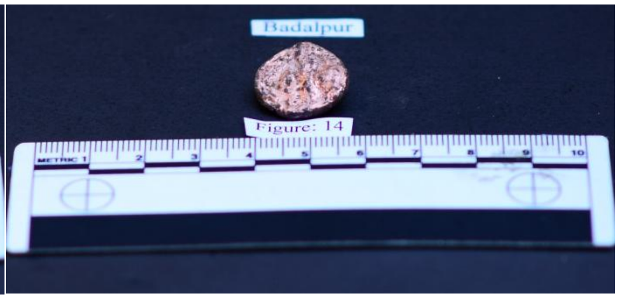


Fig 4.59: Reverse side of the Coin 14

Description A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
15	3.514 g – 3.256 g	From N2.65m/ W7.4m	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.60: Obverse side of the Coin 15

Fig 4.61: Reverse side of the Coin 15

After Cleaning

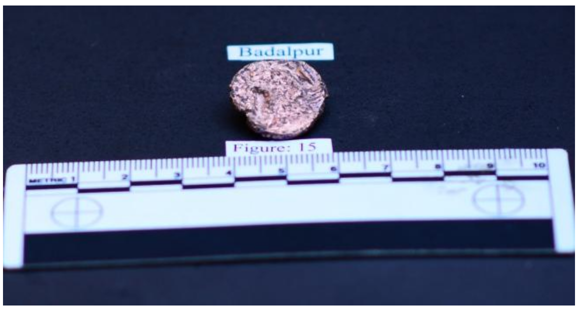


Fig 4.62: Obverse side of the Coin 15

Fig 4.63: Reverse side of the Coin 15

Description A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
16	5.584 g – 5.101 g	N7.6m× W4.2m D8ft	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.64: Obverse side of the Coin 16

Fig 4.65: Reverse side of the Coin 16

After Cleaning

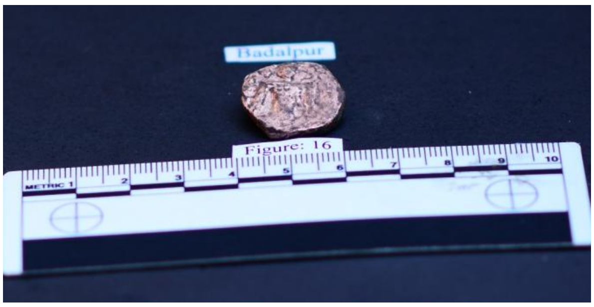


Fig 4.66: Obverse side of the Coin 16

Fig 4.67: Reverse side of the Coin 16

Description A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
17	4.479 g – 4.479 g	N7.6m× W4.2m D8ft	X-08	3	26-11-21015	Rusted Intact Coin	Copper	Badalpur Site

Before Cleaning

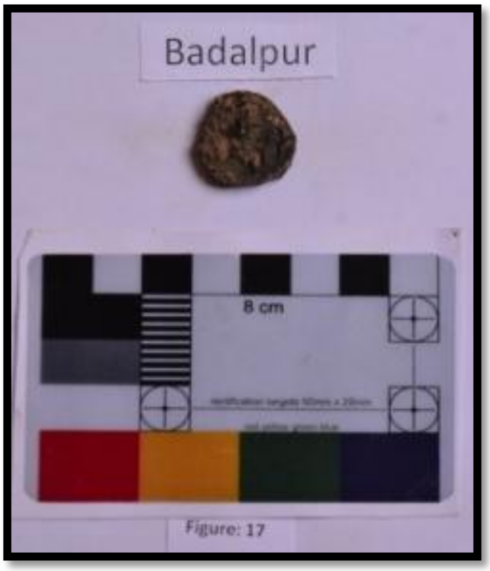


Fig 4.68: Obverse side of the Coin 17

Fig 4.69: Reverse side of the Coin 17

After Cleaning

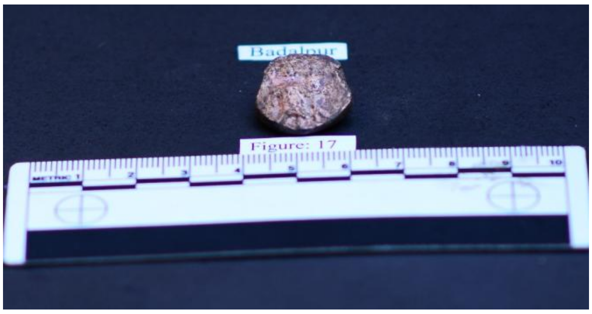


Fig 4.70: Obverse side of the Coin 17

Fig 4.71: Reverse side of the Coin 17

Description

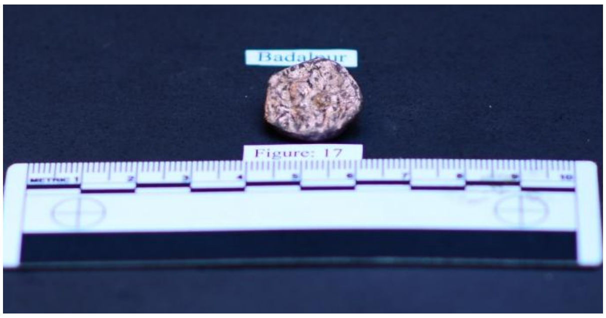
A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
18	6.124 g – 5.954 g	10ft form monastery wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.72: Obverse side of the Coin 18 Fig 4.73: Reverse side of the Coin 18

After Cleaning



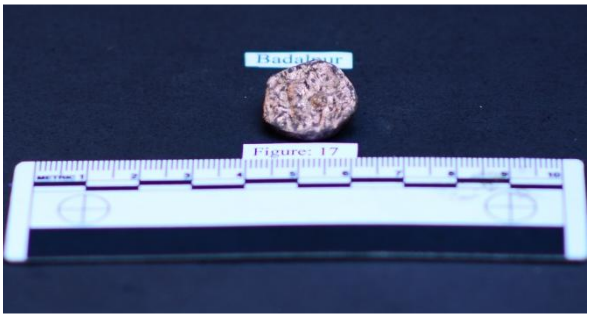


Fig 4.74: Obverse side of the Coin 19 Fig 4.75: Reverse side of the Coin 19

Description

A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
19	4.345 g – 3.769 g	10ft form monastery wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.76: Obverse side of the Coin 19 Fig 4.77: Reverse side of the Coin 19

After Cleaning

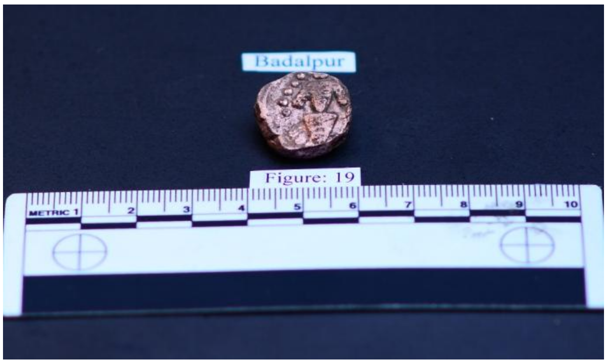


Fig 4.78: Obverse side of the Coin 19 Fig 4.79: Reverse side of the Coin 19

Description

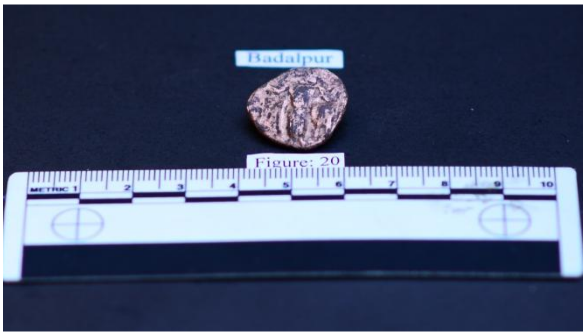
A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
20	5.497 g – 4.143 g	10ft form monastery wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.80: Obverse side of the Coin 20 Fig 4.81: Reverse side of the Coin 20

After Cleaning



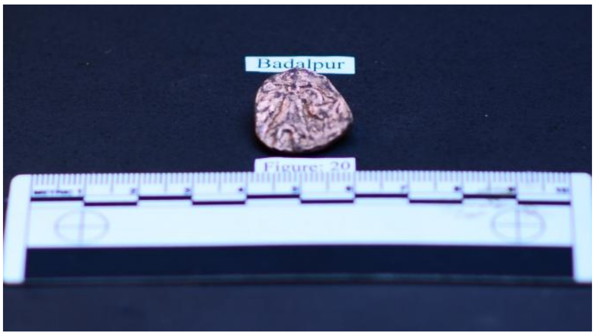


Fig 4.82: Obverse side of the Coin 20 Fig 4.83: Reverse side of the Coin 20

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
21	6.557 g – 5.952 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.84: Obverse side of the Coin 21

Fig 4.85: Reverse side of the Coin 21

After Cleaning

Fig 4.86: Obverse side of the Coin 21

Fig 4.87: Reverse side of the Coin 21

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
22	5.901 g – 5.561 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.88: Obverse side of the Coin 22

Fig 4.89: Reverse side of the Coin 22

After Cleaning

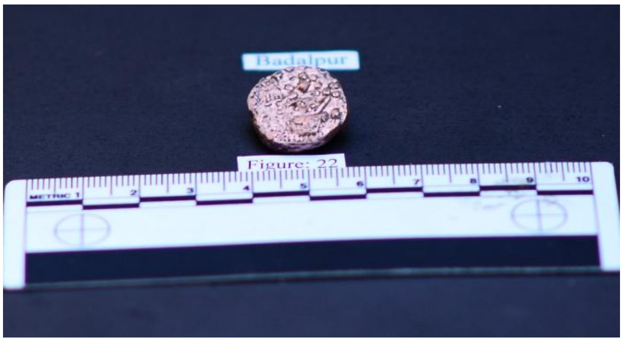


Fig 4.90: Obverse side of the Coin 22

Fig 4.91: Reverse side of the Coin 22

Description

A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
23	4.805 g – 4.391 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.92: Obverse side of the Coin 23

Fig 4.93: Reverse side of the Coin 23

After Cleaning

Fig 4.94: Obverse side of the Coin 23

Fig 4.95: Reverse side of the Coin 23

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
24	5.818 g – 5.495 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

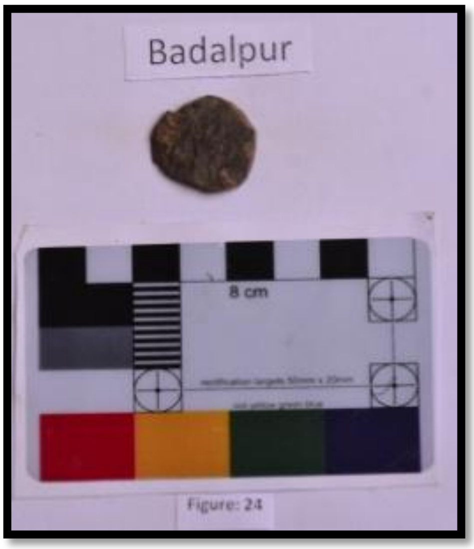
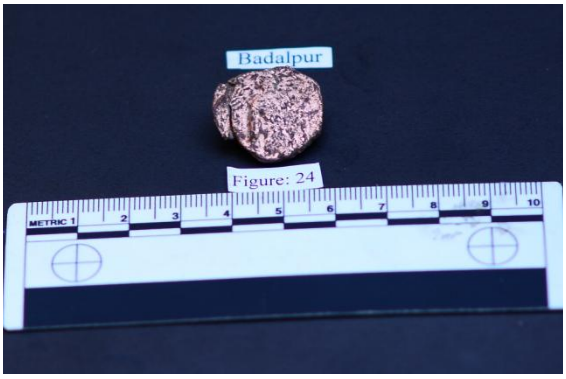


Fig 4.96: Obverse side of the Coin 24

Fig 4.97: Reverse side of the Coin 2

After Cleaning



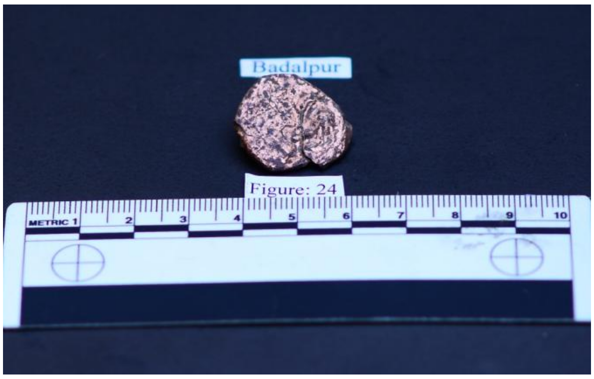


Fig 4.98: Obverse side of the Coin 24

Fig 4.99: Reverse side of the Coin 24

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
25	5.388 g – 4.579 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.100: Obverse side of the Coin 25 Fig 4.101: Reverse side of the Coin 25

After Cleaning

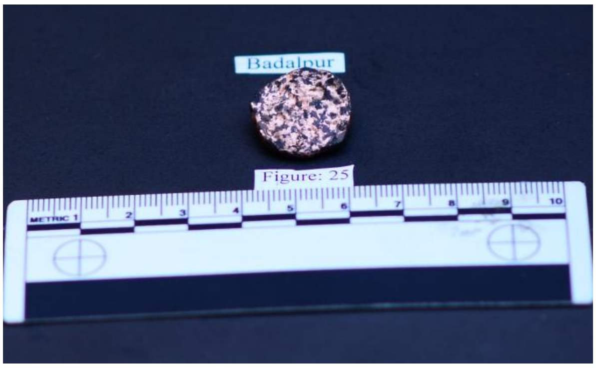


Fig 4.102: Obverse side of the Coin 25 Fig 4.103: Reverse side of the Coin 25

Description

A copper coin of Vasudeva (from about the late quarter of the 2^{nd} century <190> CE to about the middle of 3^{rd} century <227> CE).

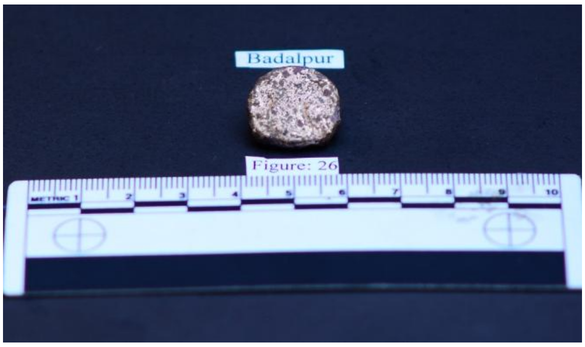
S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
26	6.013 g – 5.643 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.104: Obverse side of the Coin 26

Fig 4.105: Reverse side of the Coin 26

After Cleaning



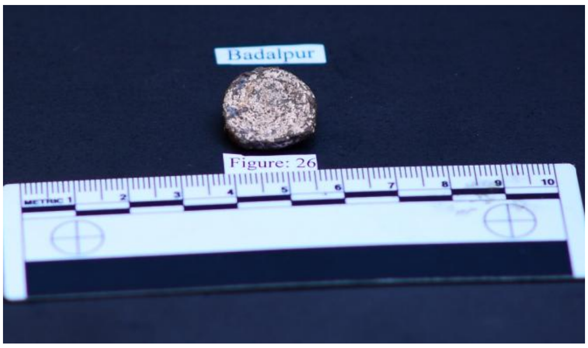


Fig 4.106: Obverse side of the Coin 26

Fig 4.107: Reverse side of the Coin 26

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
27	5.003 g – 4.406 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.108: Obverse side of the Coin 27

Fig 4.109: Reverse side of the Coin 27

After Cleaning

Fig 4.110: Obverse side of the Coin 27

Fig 4.111: Reverse side of the Coin 27

Description

A copper coin of Vasudeva (from about the late quarter of the 2nd century <190> CE to about the middle of 3rd century <227> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
28	5.497 g – 4.058 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.112: Obverse side of the Coin 28

Fig 4.113: Reverse side of the Coin 28

After Cleaning

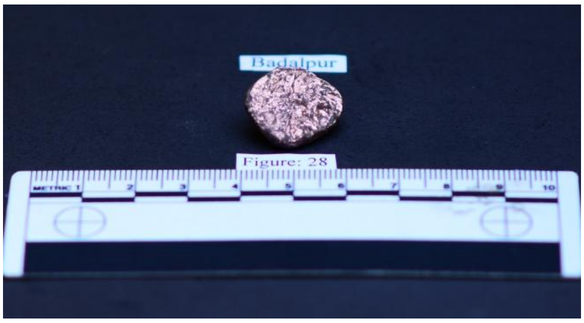


Fig 4.114: Obverse side of the Coin 28

Fig 4.115: Reverse side of the Coin 28

Description

A copper coin of Vasishka (from about the third quarter of the 3^{rd} century <247> CE to about the last quarter of the 3^{rd} century <267> CE).

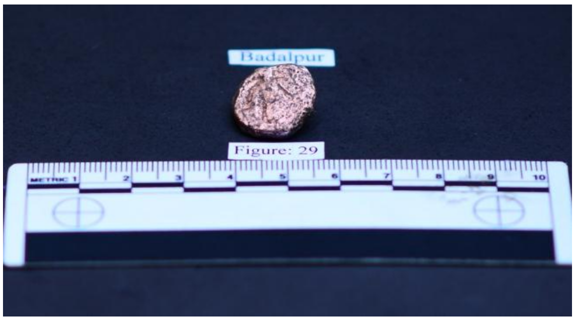
S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
29	7.923 g – 7.069 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.116: Obverse side of the Coin 29

Fig 4.117: Reverse side of the Coin 29

After Cleaning



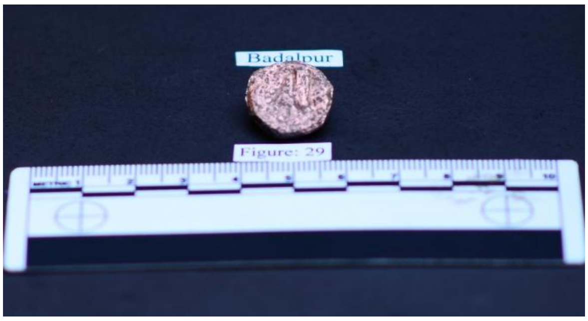


Fig 4.118: Obverse side of the Coin 29

Fig 4.119: Reverse side of the Coin 29

Description

A copper coin of Vasishka (from about the third quarter of the 3rd century <247> CE to about the last quarter of the 3rd century <267> CE).

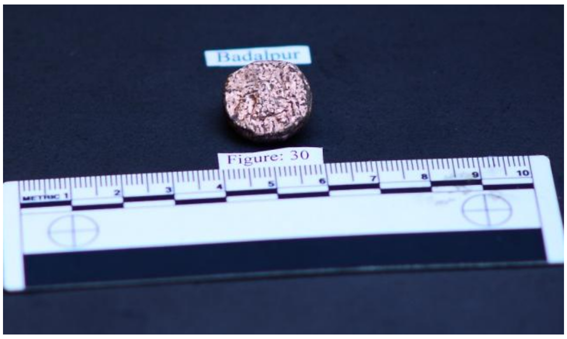
S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
30	6.690 g – 5.559 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.120: Obverse side of the Coin 30

Fig 4.121: Reverse side of the Coin 30

After Cleaning



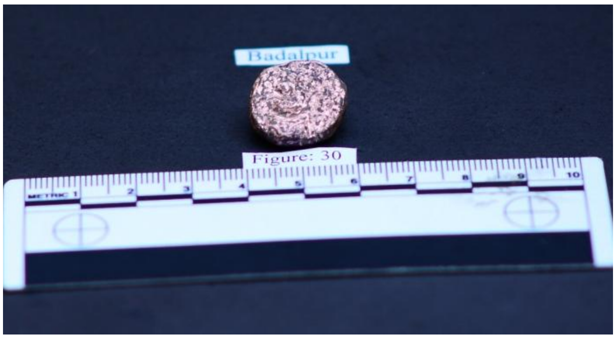


Fig 4.122: Obverse side of the Coin 30

Fig 4.123: Reverse side of the Coin 30

Description

A copper coin of Vasishka (from about the third quarter of the 3rd century <247> CE to about the last quarter of the 3rd century <267> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
31	5.832 g – 5.214 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.124: Obverse side of the Coin 31

Fig 4.125: Reverse side of the Coin 31

After Cleaning

Fig 4.126: Obverse side of the Coin 31

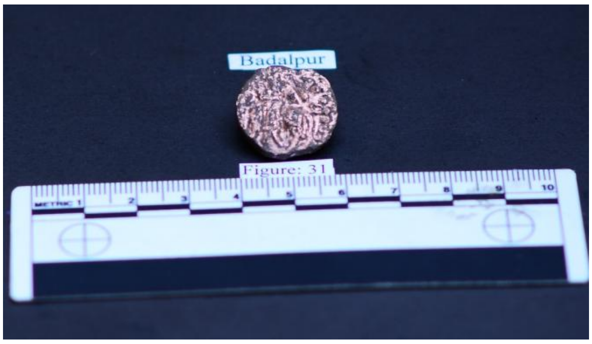


Fig 4.127: Reverse side of the Coin 31

Description

A copper coin of Kanishka III (from about the last quarter of the 3rd century <267> CE to about the end of the 3rd century <271> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
32	5.750 g – 5.382 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.128: Obverse side of the Coin 32

Fig 4.129: Reverse side of the Coin 32

After Cleaning

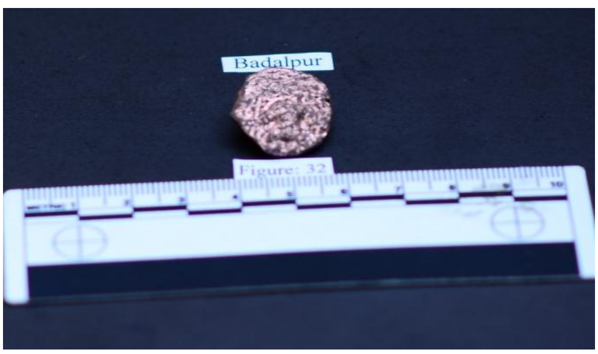


Fig 4.130: Obverse side of the Coin 32

Fig 4.131: Reverse side of the Coin 32

Description

A copper coin of Kanishka III (from about the last quarter of the 3rd century <267> CE to about the end of the 3rd century <271> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
33	5.092 g – 4.435 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.132: Obverse side of the Coin 33

Fig 4.133: Reverse side of the Coin 33

After Cleaning

Fig 4.134: Obverse side of the Coin 33

Fig 4.135: Reverse side of the Coin 33

Description

A copper coin of Kanishka III (from about the last quarter of the 3rd century <267> CE to about the end of the 3rd century <271> CE).

S. No.	Dimension (weight g Before-After)	3D Location	Locus	Layer	Date	Object	Material	Excavated from
34	4.345 g - 3.667 g	4ft from cell wall	X-14	3	22-12-2015	Rusted Coin	Copper	Badalpur Site

Before Cleaning

Fig 4.136: Obverse side of the Coin 34

Fig 4.137: Reverse side of the Coin 34

After Cleaning

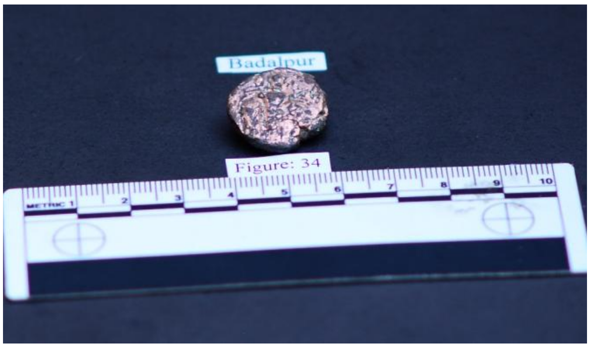


Fig 4.138: Obverse side of the Coin 34

Fig 4.139: Reverse side of the Coin 34

Description

A copper coin of Kanishka III (from about the last quarter of the 3rd century <267> CE to about the end of the 3rd century <271> CE).

Chapter: 5

Analytical Methods for the Determination of Elemental and Chemical Composition of Coins

Compositional study involves measuring the composition of materials to determine the presence and amount of different elements. Elemental analysis is a dominant part of archaeological chemistry from more than a century. All the archaeological objects can be studied by using elemental analysis. These analyses can be best in terms of the history of its development. Compositional analysis equipment has progressed in which instruments measure not only elemental abundances, but also their isotopic rations and providing new dimensions of inquiry in archaeological chemistry (Price and Burton 2011: 78-80).

Introduction

Coins are objects of extraordinary historical fee and they're broadly studied in Archaeometry due to the fact they offer critical statistics about various factors of the historic civilization that used them. The development of ancient coins, several changes occurred in designs, shapes, outlines and epigraphs which give a ocular and realistic representation of different traditions and giving knowledge about chronology and methodology (Vijayan, Rautray, Nayak and Basa 2003: 128). Current analytical chemistry offers numerous strategies which may be hired for archaeometric purposes and a mixed technique of ancient studies and analytical techniques can be very beneficial for decoding statistics approximately the manufacturing strategies, provenance, authenticity, and so on. of those coins.

The compositional study of trace elements of ancient coins provides us significant knowledge regarding the technology, area, politics and historical facts. Elemental analysis of ancient coins provides attention in direct relation between wealth, and metallurgy of the period of minting the coins (Kallithralias-Kontos, Katsanos, Potiriadis, Oeconomidou and Touratsoglous 1996: 662).

The moderately late improvement of non-dangerous expository procedures has opened new possibilities for the examination of coins with no or negligible harm caused. Investigations of chemicals and elemental composition of coins give us valuable data to the archaeologists, students of history and numismatists. This significant data can help us their assembling innovation, age, printing places and the exactness or authenticity. Elemental Composition explore the information about the history, economy, dynastic rulers for specific period of time, kingdom or a whole empire and minting technologies for the production of metal alloys.

The aim of this to research is to explore and analyze the most suitable chemical and elemental composition techniques for the conservation of copper coins of Badalpur Site, Taxila. Firstly, the composition of metal and the corrosion products of the coins were analyzed and then the comparative experiments from different techniques were done.

Non-Destructive Methods for the Analysis of Coins.

The analytical methods can be separated into two most important categories.

1. **Destructive Method**
2. **Non-Destructive Method**

Archaeological finds consisting of coins are treasured artifacts, often particular and irreplaceable, and that they must be analyzed with techniques that cause minimal harm to the sample. In this sense, the improvement of non-destructive analytical techniques has helped to acquire this objective (Jose, Garcia and Maria 2015: 207).

In 1960s, both destructive and non-damaging methods have been utilitarian for the investigation of old coins, essentially for the assurance of their basic and synthetic organization. Everyone of the procedures which are utilized as a part of compositional investigation of old mint pieces are absolutely non-dangerous on the grounds that historical center keepers and gatherers don't approve testing or whatever other method that may demolish the coins and they make extremely restricted harm to the old coins. (Andreas 2017:2-5).

X-rays in Archaeology

X-rays play a vital role in the knowledge about the archaeological artefacts and their composition. Techniques of x-ray provides a particular meadow to physicists, art historians, archaeologists, curators and conservators to gain details about the identification of artefacts (Beckhoff et al. 2006: 1).

Air path system and instruments with the micro-beam of x-rays are applied for the different analysis such as: pigments in paint layers and elemental and chemical composition of metal or coins.

Elemental Composition Study of Coins by Proton Induced X-rays Emission (PIXE) and Rutherford Backscattering Spectrometry (RBS)

X-ray emission techniques had been notably used in several analytical investigations. X-rays are a short wavelength shape of electromagnetic radiation located within the place between gamma rays and ultraviolet radiation. X-rays were first discovered by the German physicist Wilhelm K Rontgen (1845–1923) for which he gained the Nobel prize in 1901, and X-rays had been used for industrial elemental analysis since 1950s.

Coins are essential to study and increase authentic data. In 1953, numerous atomic and nuclear strategies were advanced and carried out to the non-harmful elemental evaluation of archaeological objects. During the 1960s and 70s, improvement of detectors and different methods were accessible to examine metal pieces of coins like proton activation analysis (**PAA**) method, Ion beam examination (**IBA**) techniques **PIGE** (Particle Impelled Gamma-beam Emission), both wave length-dispersive (**WD**) and energy-dispersive (**ED**), Electron probe microanalysis (**EPMA**), **NAA** (Neutron Activation Analysis), **EDXRF** (Energy Dispersive X-beam Fluorescence), Proton induced X-ray emission (**PIXE**) and Rutherford backscattering (**RBS**) were standard as surface methods for the elemental and chemical analysis of ancient coins. They can only analyze a surface layer of limited depth (from a few micrometers up to a few tens of micrometers). Different scientists like V Cojacaru et al, 2000; A C Mandal et al, 2003; P K Nayak et al, 2004; B Constantinescu et al, 2005, 2008; S Santra et al, 2005; M Fayze-Hassan et al, 2011; S An Abd El Aal et al, 2012; R Kumar et al, 2014 had effectively examined distinctive sorts of old coins by utilizing EDXRF and PIXE methods.

The proton-incited x-beam emanation (PIXE) strategy is of one of a kind system for archaeological examples because it is non-dangerous, quick, touchy and equipped for synchronous multi-basic examination.

In this examination, these coins are uses for essential and compound investigation through PIXE and RBS strategies. Minimal scientific work was done in regards to the Badalpur coins.

The procedures of the Proton prompted X-beam discharge (PIXE) and Rutherford backscattering spectrometry (RBS) have been utilized for the investigation of copper coins.

Proton Induced X-rays Emission (PIXE)

PIXE is a Common method which can highlight different artefacts of period under study. The elemental composition can be used as the possible source of metal at that period of time. The Proton Induced X-ray Emission is a non-destructive, multi elemental and quick technique. In this way number of object or ancient artefacts can be analyzed in short period of time. PIXE is standardized, sensitive and comparatively universal method so it can be used for the analysis of ancient objects. PIXE is prevailing technique for ancient copper coins. One copper coin having several elements can be analysed with PIXE within 15min. The variation in the PIXE enables the categorization of the layered formations at the surface of ancient coins (Kallithralias-Kontos, Katsanos, Potiriadis, Oeconomidou and Touratsoglous 1996: 663).

PIXE have ability to offer minimum sensitivity for elements ranging from Ar to Zr (Sodaei and Kashani 2013: 105). Due to variational beam characteristics of PIXE surface metal structure can be determined (Ibid: 106).

Rutherford Backscattering Spectrometry (RBS)

Rutherford Backscattering Spectrometry (RBS) is an atomic procedure which is utilized for the investigation of strong surface. Rutherford Backscattering Spectrometry technique is a quantitative, non-dangerous to break down. This strategy created by Geiger and Marsden. This method was firstly discussing Rubin et al. in 1957 and later by Tesmer and Nastasi.

Aim of this technique is to bombard ions at MeV- range energy and then this energy is recorded by an energy sensitive detector.

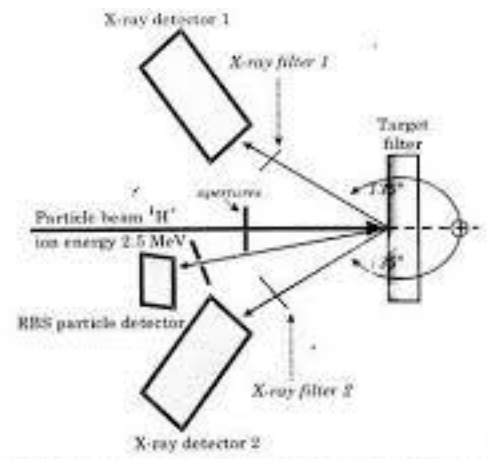


Fig 5.1: Schematic diagram of a Rutherford Backscattering Spectrometer

Rutherford Backscattering Spectrometry technique is quantitative which allows determination of the composition of material and depth profiling of individual elements. They are non-destructive method having better depth resolution of several nm and they carry very well sensitivity for heavy elements as part per-million (ppm) (Mayer 2003: 1-5).

Material and Methods

Sample Preparation

Researcher has selected 34 copper coins of Kushans which were excavated from Badalpur site, Taxila Valley under the supervision of Prof. Dr. Muhammad Ashraf Khan. Coins have been cleaned by three different techniques: one was the mechanical second was chemical and third was the electrolysis technique before submitting to the National Centre for Physics **(NCP)** Laboratory known as Data Analysis Labs. All the coins were analyzed for the elemental composition under the Officer (Mr. Turab Ali Abbas, PSO) of the National Centre of Physics (Data Analysis Labs). The coins were then subjected to Proton Induced X-ray Emission **(PIXE)** and Rutherford Backscattering Spectrometry (**RBS)** analysis.

Experimental Set-up

The trials were performed at the Data Analysis Labs of the National Center for Physics (NCP) 'Islamabad'. A multipurpose scrambling chamber with 20 inch measurement was intended to do Rutherford Backscattering Spectrometry (RBS), Channelling, and Nuclear

Reaction Analysis (NRA) and with an uncommon plan for Proton Induced X-beam Emission (PIXE).

The vacuum acquired inside the test chamber was of the request of 10−7 Torr and in which we can see a wheel target holder (where coins were putted) observed by a PC through a venturing engine. The chamber conveys numerous view ports for multipurpose investigations. Two have been intended to complete Proton Induced X-beam Emission (PIXE) and Rutherford Backscattering Spectrometry (RBS) examination.

From the PIXE viewport of the objective chamber and at 135° to the shaft heading, a retractable collimated ORTEC Si(Li) finder (FWHM 170 eV at 5.9 keV), with 30mm2 dynamic region and 12.7 μm thick Be window, was used to recognize X-beam outflow from targets. To make conceivable the location of light and substantial components in the meantime. The separation between the objective and the locator was 9 cm, out of which 4 cm is noticeable all around (outside the load).

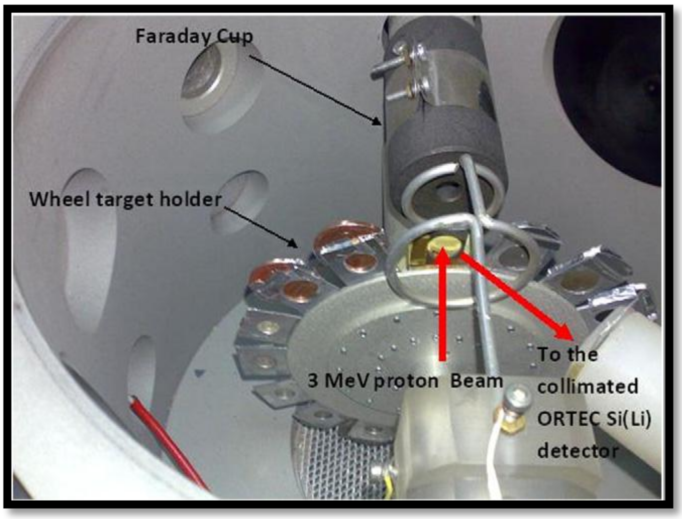


Fig 5.2: Target chamber (National Centre of Physics (Data Analysis Labs)

The shaft charge testimony on the objective is computed through a charge integrator associated with a computerized counter-clock. Scientist decrease high check rate, an aluminised mylar (150 lm) has been utilized as safeguard. This safeguard lessens X-beam forces of low Z components (Si±Ca) considerably more when contrasted with high Z components (Z>25). This empowers the utilization of high shaft streams and gives expanded affectability to overwhelming components. The shaft current was coordinated in the example (for thick targets) and in a Faraday glass behind the objective (thin targets). To get precise charge mix at the example position, an optional electron suppresser framework applying negative _200 volts was utilized. For the solid alignment of the explanatory framework (viz. X-beam yield saw by the finder per unit charge per unit mass of the component) thin Micromatter guidelines were utilized. The finder flag was formed and enhanced lastly, through a heartbeat stature investigation, the vitality range was put away and showed in a multichannel analyzer. Each objective was keep running for a charge of around 3 μC. The shaft current was kept lower than 5 nA to keep away from high tallying rates at the identifier that would lessen the discovery affectability because of increment of the foundation commotion. GUPIX programming was utilized for PIXE range fitting and computation of natural synthesis of the coins.

Data Analysis

For this situation for thick target, GUPIX considers: the vitality loss of the 3 MeV episode protons, the variety of X-beam generation cross-segments with the diminishing proton vitality, the retention of X-beams from various profundities in the objective, and the natural impact (improvement of the X-beam yields). GUPIX utilizes all the inputted detail of the Si(Li) X-beam finder to produce a hypothetical bend for its effectiveness.

As indicated by our analysis setup, the proton bar is barraging the coin surface at an edge φ equivalent to 45°. The X-beam finder is situated at an edge φ equivalent to 135° to the proton shaft bearing, subtending a little strong edge. The hypothetical power of the radiated X-beam line, of component Z gives a mass focus CZ, from a volume of thickness dð at the profundity ð behind the coin surface, because of a number Np of impinging protons.

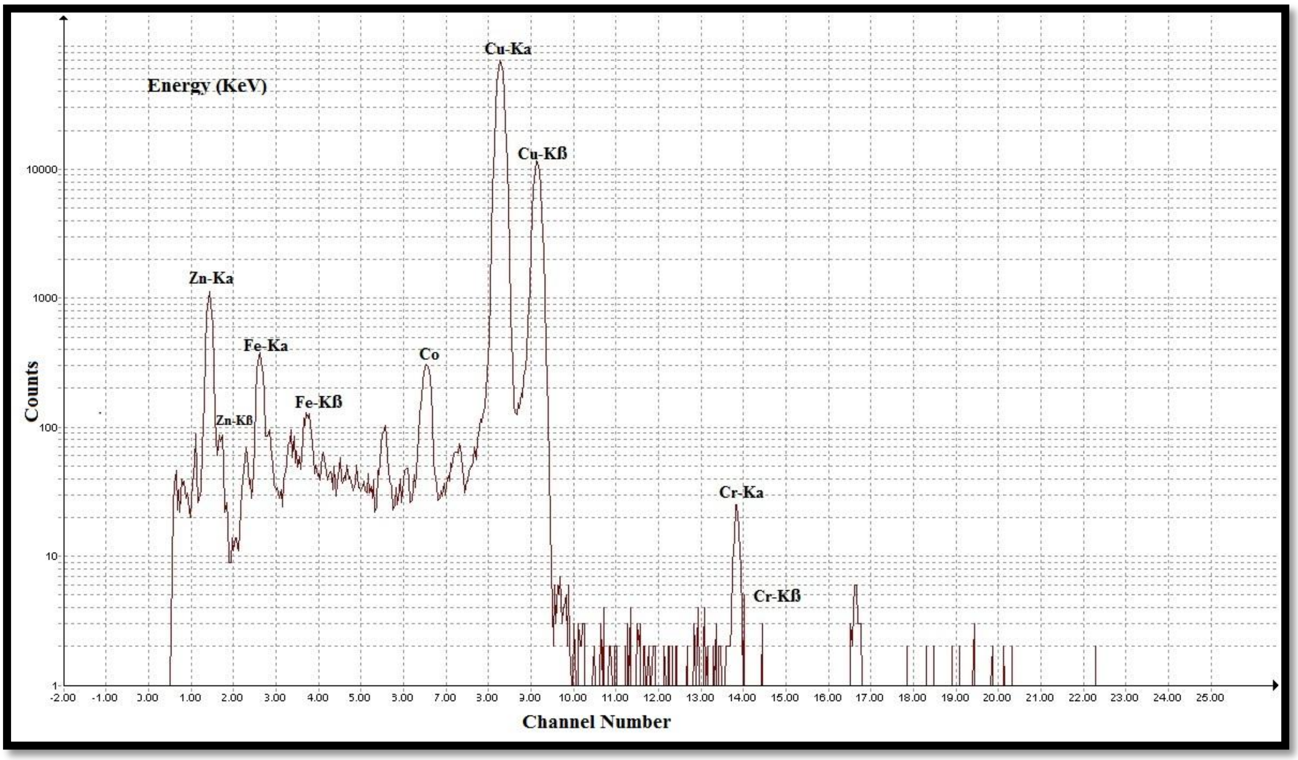


Fig 5.3: PIXE spectrum of Badalpur coin obtained by using 3 MeV protons in front of the detector. The X-ray lines of the elements present in the spectrum are those of Cu, Zn, Fe, Co, and Cr.
(National Centre of Physics (Data Analysis Labs)

At a moment advance of the otherworldly information investigation, we aligned GUPIX by examining copper coin: the internal parts of coin fixation in ppm (2.7Cr, 19821.9Cr, 10.6Fe, 198Zn and 3.2Co). The arrangement of those current coins is very much characterized and could be utilized as reference models. The last advance is the cycle methodology that GUPIX rushes to fit the trial range with the produced one, giving the essential organization on the PC. The after effect of the essential investigation of the two copper coins acquired by GUPIX program is shown in Table: 5.1.

Copper Coin-14

Elements	Area Counts	Filter Trans. (-5)	H Value (-5)	Yeld /uC/ppm	Det. Eff (-3)	Conc. ppm of	% Stat Error	%Fit. Error	FWHM Area	LOD ppm	+1% of Overlap
Cr	71.9	88695	153	3957	1000	2.7	30.68	25.24	20.8	1.1	30.68
Cu	288814	96489	153	1975	1000	19821.9	0.5	2.02	4.3168E +05	6.1	0.15
Fe	325.9	93067	153	4322	1000	10.6	13.06	9.95	492.4	2.2	13.06
Zn	2354.8	97163	153	1603	1000	198	7.10	4.77	3518.09	14.2	7.10
Co	105.4	94510	153	4504	1000	3.2	21.07	19.63	159.2	1.1	21.07

Table 5.1: Elemental Composition of Kushans copper coins-14 obtained by PIXE analysis

Results and Discussion

The ancient period of Kushan Dynasty approximately ended in 4th century CE. The elements Cr, Fe, Co and Zn were detected in the coin along with the major component Copper (Cu) by the present experimental set-up. The elemental compositional analysis was performed using GUPIX software. The concentration of copper is 19821.9ppm and weight of the coin before and after cleaning is 6.149 g – 4.994 g. According to the spectrum, our analyses results came to confirm the fact that copper was rapidly present in the age of Kushana dynasty. High concentration of Cu in coins indicates that, it has been added deliberately to show monetary policy or economic necessity.

To determine our PIXE analytical results of the copper coin that all the coins which have been excavated from Badalpur Site, Taxila Valley has similar elemental composition. In the copper coin, the elements of Co, Cr, Zn and Fe are the most important metallic impurities relating to the original ore. The presence of iron (Fe) as impurity in our sample could be related to the use of the sulphide ore (chalcopyrite) and may be attributed to surface contaminations.

Conclusion

The logical investigation for extraction, cultivating, alloying and assembling of metals and their organization and properties are known as metallurgy. Basically metallurgy is a material science that deals with the physical and chemical properties of metals and their alloys. The oldest metal is limited to the particular geological area, the origin of metal not so far clear but seems to have increased in the late 6th millennium BCE. The most commonly metals used as antiquity in Taxila are gold, silver, copper, iron, tin, lead and zinc.

The disclosure of the metal artefacts uncovered the craftsmanship of the general population living in the territory between the first century CE to fourth century CE and their insight about the distinctive metals. A level plate or bit of metal with an approved stamp, utilized as cash and one of the most important basic information from which archaeologist can try to understand the past is called coins. Numismatics is a multi-disciplinary subject which is related with history and information about palaeography and archaeological epigraphy. So researcher can say that coins have much importance in the history. Coins also play an important role in the religious history because almost every ruler depicted their own religious viewpoint in coins such as Kushans who ruled in north-western India dating back to 1st century CE and 4nd century CE.

Coins of Taxila play a vital role in the chronological sequence of Taxila Valley. Researcher can get information about local copper coins from the stratum of sites dating back to the 3rd century BCE. Coins of Taxila have been discovered in many diversity and roughly 12000 coins have been exposed from different sites of Taxila valley.

The cleaning and preservation of ancient metal artefacts from Europe and other parts of the world is a very valuable undertaking. But not much development in the use of these techniques in conservations and preservation of metal objects. In Taxila no conservator is specialized in archaeological conservation. As a result, a large number of artefacts are without treatment and badly damaged. This applies to most material classes however due the restriction of this research; researcher just investigated the issues concerning archaeological metals (coins).

The goal of this research was to explore the achievable benefits and outcome of a conservation method of metal objects. Cleaning coins is an art not a science. Some coins were cleaned with only tooth brush, soap and water but many coins needed proper techniques and methods to clean them properly. This research has analyzed 34 coins and the issues of monitoring such material. The point of this exploration, the researcher re examined the sources of metallurgy in Taxila and offered us another portrayal in which metallurgy started in Badalpur site. Researcher collected a series of coins and other metal objects such as door bosses, iron-nail, finger ring, iron pan and knives coming from the excavation of Badalpur site (Taxila) and then analyzed using diverse analytical techniques looking for a co-relation connecting the rust products covering the coins and the chemical-physical features of metal objects.

The researcher used different techniques like mechanical, chemical and electrochemical to conserve 34 coin artefacts. At the end of the result the researcher have proved that mechanical cleaning is the best and favourable technique than rest of the others. It does not destroy and damage patina of the coins and through this technique image and legend of the coin were clearer.

Through PIXE and RBS the researcher has found out the elemental composition of metals. With the experiments, the researcher decided to do experiment with a portion of the preservation strategies found in writing for the conservation of metal objects of the medieval period.

The researcher has found out the elemental composition of copper coin sample which was excavated from Badalpur Site through non-destructive technique Proton Induce X-ray Emission **(PIXE)** and Rutherford Backscattering Spectrometry **(RBS).** The researcher resulted that copper coins were minted during Kushan Dynasty (1^{st} century CE-4^{TH} century CE). The elements **Co, Cr, Fe** and **Zn** have been detected in copper coin sample along with the major component of **Cu**. Five elements have been determined quantitatively and examined the correlation connecting the composition and the minting time age.

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