BE CIVIL ENGINEERING PROJECT REPORT

EXPLORATION AND VALIDATION OF PORPHYRY COPPER DEPOSITS USING ASTER DATA IN DATTA KHEL, KHYBER PUKHTOONKHWA, PAKISTAN

Project submitted in partial fulfillment of requirements of

BE Civil Engineering Degree

Project advisor Col Dr. Sajid Mahmood

Submitted By

Capt Muhammad Asif Ullah Khan	**NUST-2018-281044-BMCE (Syn Ldr)**
Capt Muhammad Mansoor Ali Shah	**NUST-2018-281056-BMCE**
Capt Mussadiq Khattak	**NUST-2018-281048-BMCE**
Capt Ali Imran Durrani	**NUST-2018-281085-BMCE**
Capt Salman Tilla	**NUST-2018-281091-BMCE**

Military College of Engineering, Risalpur
National University of Sciences and Technology Islamabad, Pakistan (2022)

DECLARATION

This to certify that

The BE Civil Engineering Project titled

Exploration and validation of Porphyry Copper Deposit using ASTER Data in Datta Khel, Khyber Pakhtunkhwa, Pakistan

Submitted by

Capt Asif Ullah Khan (syn ldr)	**(NUST-2018-281044-BMCE)**
Capt M Mansoor Ali Shah	**(NUST-2018-281056-BMCE)**
Capt Mussadiq Khattak	**(NUST-2018-281048-BMCE)**
Capt Ali Imran Durrani	**(NUST-2018-281085-BMCE)**
Capt Salman Tilla khan	**(NUST-2018-281091-BMCE)**

Has been accepted towards the partial fulfillment of the requirements for

BE Civil Engineering Degree

____

Col Dr. Sajid Mahmood, PhD

Syndicate Advisor

DEDICATION

Dedicated to our beloved Parents and respected Teachers, whose prayers and guidance have always been source of encouragement and inspiration. Especially to our advisor whose support led us to the completion of this project.

ACKNOWLEDGEMENT

All thanks and praise to Allah Almighty.

We concede before Allah Almighty for all His blessings. We thanks MCE for providing us opportunity and resources to give final shape to our research work. This paper and the research behind it would not have been possible without the exceptional support of our advisor, **Col Dr. Sajid Mahmood**. His knowledge, enthusiasm, and exacting attention to project have been an inspiration and kept our work on track.

ABSTRACT

Minerals are the most important natural resources which plays an important role in boosting economy of any country. 'Mineral is compound of naturally available substance with specific chemical composition’. North Waziristan district of KPK consists of mountainous Belt and hosts many mineral deposits in N-W of Pakistan specially Datta Khel region. Conventionally geological information for mineral explorations require the geologists to plan field visits, collect various samples for study and analysis but this is laborious task which requires a lot of experience, practice, in-depth knowledge, equipment and technical experts. Remote sensing is latest technology used for surveying/ mapping of different geological sites. Remote Sensing sensors mounted either on aircrafts or satellites detect the electromagnetic radiation reflected from the earth surface without making any direct contact. Remote Sensing images are used for mineral exploration by recognizing mineral zones by their spectral signatures. For our study ASTER satellite level 1T images were obtained from NASA website for year 2003 and 2018. Year 2003 images were utilized for copper exploration and year 2018 images for validation (Presently copper is being extracted from an existing site which started after 2003, that’s why imagery of year 2003 was used so that validation of proposed method could be done). 9 x Bands were used (3 x VNIR and 6 x SWIR). Image processing techniques of Principal Component Analysis (PCA) and Band Ratioing (BR) were used to identify the potential mineral sites. Interpretation was carried out using Eigen vectors, Eigen values, correlation and covariance matrices. Potential sites were marked and then filtered out by using PCs and BRs. These techniques identified new potential locations of porphyry copper mineralization in our study area of Data Khel, Khyber-Pakhtunkhwa. The potential sites of Copper and Iron Oxide were the final product of this research which were validated using the identification of existing site in imagery of year 2003. Results showed that the assimilation of the image processing techniques has a great ability to obtain comprehensive information for the reconnaissance stages of copper exploration in region. This research results can assist geologists to find new copper porphyry and other mineral deposits, before costly detailed ground investigations. Subsequently, the introduced image processing techniques can create an optimum idea about possible location of new potential sites.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBERIVATIONS

RS	Remote Sensing
GIS	Geographical Information System
GPS	Global Positioning System
PCA	Principal Component Analysis
BR	Band ratio
NDVI	Normalized Difference Vegetation Index
GSP	Geological Survey of Pakistan
USGS	United State Geological Survey
GEOSS	Group on Earth Observations system of systems
REDD	Reducing Emissions from Deforestation and Forest Degradation
ISRO	Indian Space Research Organization
ROC	Receiver Operating Characteristics
SPOT	Satellite for observation of Earth
IRS	Indian Remote Sensing
AHP	Analytical Hierarchy Process
WLC	Weighted Overlay Combination
SMCE	Spatial Multi criteria Evaluation Approach
TIFF	Tagged Image Format File
DEM	Digital Elevation Model
ASTER	Advanced Space borne Thermal Emission and Reflection
Landsat ETM+	Landsat Enhance Thematic Mapper
LIBS	Laser-induced breakdown spectroscopy
ESM	Electromagnetic sounding Multispectral
AVIRIS	Airborne visible infrared imaging spectrometer
SWIR	Short Wave Infrared Radiation

CHAPTER 1: INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Background

Advancement of the modern world is affecting every walk of life. Trend of everyday development in Science and engineering is giving birth to new methods and techniques which is making our lives easier than before. There are many scientific innovations currently in use which are playing vital role to facilitate of our daily life works. Remote sensing is Primary method to obtain data, main function of the remote sensors is that it collects the data from the objects like rocks, minerals and from the earth surface without making any direct contact. These sensors, typically mounted on aircrafts or satellites, performing actions by detecting the radiations reflected from the earth. Remote sensing has great potential to identify the potential mineral zones related to mineral deposits, Progression in the field of remote Sensing is making it more and more convenient to assess and analyze geologic structures and formulate better understanding of minerals exploration. ASTER are successfully applied to highlight the hydrothermal alteration zones. ASTER data is being widely used for an extensive range of geological applications, including structural and lithological mapping, ore mineral explorations, environment geology etc.

In the North West Area of Pakistan, Datta Khel region is located in North Waziristan closer to International border with Afghanistan and around 41 kms South West of Miranshah district. Datta khel Tehsil of North Waziristan District is part of Bannu Division (Khyber Pakhtunkhwa province) in Pakistan. Miranshah is capital city of North Waziristan . Our project location is in data Khel region of North Waziristan which is part of Bannu division.

Geographically, the whole of Waziristan is a single entity. However, for administrative suitability it has been split into two agencies: North and South Waziristan. The area has been defined as a land of high and difficult hills with deep and rocky defiles Datta Khel region has been reported for possessing higher quantity of expensive minerals, specifically Copper and iron minerals have been largely reported in this area. (Geological Survey, 2020)

Figure 1.1 Datta Khel location on Pakistan Map (Karim AM, 2016)

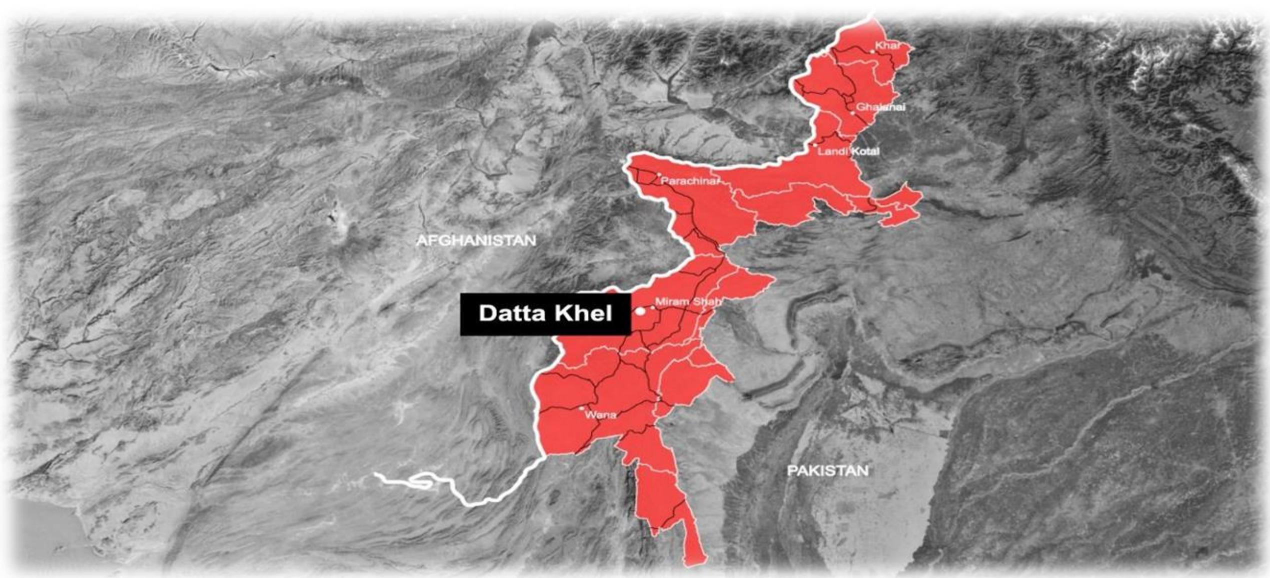

Figure 1.2 Datta Khel Region (Google, n.d.)

Major portion of the Datta Khel Region is located and comes under western area of Pakistan and a smaller portion run towards Northwards. Datta Khel is 21 kms away from Pak-Afghan border belt (which is 2670 kms long).

Datta Khel Region Climate is humid subtropical climate which make it suitable for using Remote Sensing technique for Mineral Exploration. Hydrothermal alteration data can be mapped using the ASTER data and can be compiled into hydrothermal alteration polygons for use in an assessment of porphyry copper mineral resource potential in the Datta Khel Region. In this Final Year Project, an effort has been made to find out various possible hydrothermal alterations zones present in the general area of Datta Khel Region in North Waziristan, Pakistan.

The first detailed geologic mapping and hydrothermally altered minerals survey was done at Datta Khel region by U.S Geological Survey. They were working under a project sponsored by the Agency for International Development (USAID) involving US department of State and the Government of Pakistan. The information available about specific mineral localities in their report references is sketchy and the size of deposit is seldom given, an indication that the investigation reported was very brief.(Geological Survey, 2020)

1.2 Problem Statement

When the geological information is required for mineral explorations, various course of actions are required to be carried out in the field. To achieve this, geologists are required to carry out the conventional methods, i.e. visit the site areas, collection of various samples for study, analysis and performance of geophysical and geospatial surveys. However geological study in the field requires a lot of experience, practice, in-depth knowledge of different technical methods, equipment and technical experts. Many regional geologic features such as major faults, major folds, far off area etc. cannot be studied only by conventional methods. It is sometimes difficult to locate some of these features by conventional surveys. Geoscientists were among the first to use the remote sensing data like aerial photographs a few decades ago for surveying/mapping operations. Distinctive features like hydrothermally altered zones can be easily picked up on the satellite imageries/aerial photographs and further analyzed in different softwares, which help us determining ore minerals in the area. Thus, Remote Sensing images are used for mineral exploration by recognizing hydrothermally altered zone by their spectral signs. The current research project encompasses, the applicability of ASTER data to identify potential minerals sites in AOI, using Remote Sensing techniques for identifying hydrothermal alteration porphyry copper minerals, and Iron oxide sites in Datta Khel region of

North Waziristan, Pakistan.

Figure 1.3 Datta Khel Project Pin Point Location (NASA, n.d.)

1.3 Conceptual framework

Introduction of remote sensing in the field of Geological surveys during the last few decades have largely influenced minerals exploration. ASTER satellite data processing for mineralization mapping was used to detect alterations and identify mineral exploration sites. To achieve this various techniques have been introduced which are being used in satellite imageries processing for identification of hydrothermally altered zones and mapping of minerals deposit zones.

By using Remote Sensing, for mapping and mineral explorations, we get hyperspectral datasets which provide explicit ground covers with hundreds of bands. Filtering contiguous hyperspectral datasets potentially discriminates surface features. So, with the help of transformation techniques and dimensionally reduction methods, a number of spectral bands are minimized without losing original information through a process known as Dimensionality Reduction (DR). The benefits of using and transforming original data is to remove the correlation among bands. For images processing in GIS, we will use major techniques of DR i.e., Principal Component Analysis (PCA) and Band Ratio (BR). The major principle of these dimensionality reduction techniques is to reduce the complexity of the data, various techniques have been applied to scale and adjust the image data and thus eliminating the noise from each band.

During the process of current study, all of these techniques will be applied on the ASTER data to see and evaluate their effect in image processing and results will be compared and integrated specifically for hydrothermally altered zone at Datta Khel.

PCA is the most efficient method among others as an identifier in terms of time and provides a better accuracy in the acquired imageries in remote sensing. Due to the better efficiency and capability, PCA handles multiple image which is capable of reducing data dimensionality and complexity. For verification and validation of the results of the present study, field surveys and investigations will also be carried out to ensure the comprehensive validity of results of AOI. The main objective of this study is to adopt a methodology, for Identification of mineral exploration in Datta Khel Region, which would be highly efficient and economical.

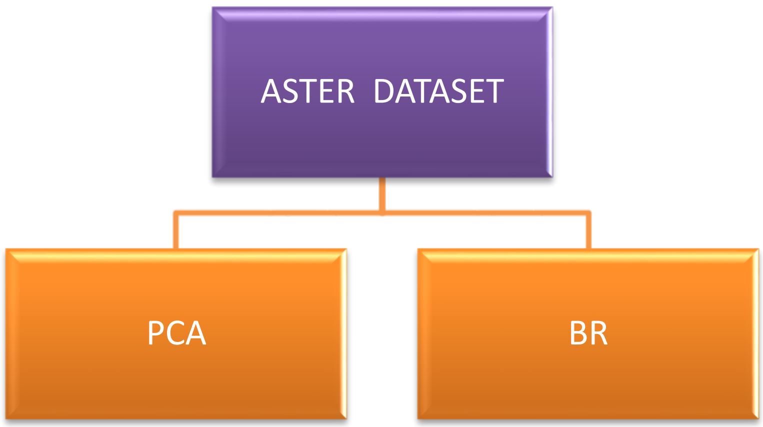

Figure 1.4 Conceptual framework of the study

1.4 Scope and Objectives

Scope of this study is to highlight the context, applicability of Remote Sensing techniques and results of data for Mineral Exploration by using ASTER data to identify hydrothermally altered zones of Datta Khel Region (North Waziristan, Pakistan). In addition, these results will be used to identify the potential sites of porphyry of Copper in Datta Khel and surroundings.

The objectives of this paper are to:

- To identify potential sites of hydrothermally altered zones using ASTER data.
- To examine the correlation between the spectral reflectance of SWIR, VNIR and identification of hydrothermally altered mineral accumulation associated with porphyry copper deposits in Datta Khel Region of North Waziristan.
- To determine the potential sites for further explorations and ground truthing in the area.

1.5 Research Questions

- Whether the remote sensing techniques are applicable to create a mineral/ore exploration map for the area of interest Datta Khel in North Waziristan, Pakistan?
- What is the layout, classification and pattern of the mineral deposits of Copper in Datta Khel?
- How effective RS technique is for the exploration of minerals in comparison to Conventional Field Exploration Techniques?
- What will be the limitations of using the ASTER data for minerals mapping?

1.6 Significance

- This project focuses on analyzing the quality and accuracy of ASTER data, to identify areas of porphyry copper deposits in Datta Khel region of North Waziristan, for mineral exploration.
- When a spectral emission is made the corresponding details will be revealed according to the local lithology, which will help to define areas that have been hydrothermally altered for mineral exploration and characterization and the identification of mineral rocks in a particular area.
- Spatial distribution can easily be detected by ASTER data which is the major source of mineral potential identification in hydrothermally altered zones.
- For lithological mapping of hydrothermally altered zone ASTER data image evaluation will performed with splendid concertation.

1.7 Methods of Exploration Currently in Use worldwide

- Remote sensing
- Controlled Source Audio-Magneto Telluric (CSAMT)
- Radiometric surveys
- Spontaneous potential (SP)
- Borehole geophysics
- Portable Infrared Mineral Analyzer (PIMA)
- Satellite imagery

- Use of radars especially GPR (Ground penetrating radar)
- Time-domain electromagnetic (TEM)
- Electromagnetic (EM, EMI)
- Imagery spectrometry
- Short Wave Infrared Radiations (SWIR)
- ASTER (Advanced space-borne thermal emissions reflection radiometer)
- Airborne visible infrared imaging spectrometer (AVIRIS)
- Laser-induced breakdown spectroscopy (LIBS)
- Electromagnetic sounding Multispectral
- Magnetic surveys
- Induced polarization (IP)

1.8 Remote Sensing

Science and art of obtaining information about an object, area or phenomenon through an analysis of data acquired by a device that is not in direct contact with the area, object or phenomenon under investigation

There are three distinct attributes of Remote Sensing.

- To understand the relation between the Spatial Features and individual features; remote sensing is there to provide us the aerial outlook of the earth surface.
- To capture the visible information is relatively an easy job but remote sensing is facilitating us more like capturing Shortwave Infra-Red (SWIR), Mid IR, Far IR and Thermal IR (TIR) information which a normal naked eye can't observe.
- To make it convenient and possible to gather information about areas inaccessible to normal field surveys and existing at a well far distance.

Every type of rock and minerals possess different chemical composition. Due to this peculiar characteristic, they absorb and reflect the light in different wavelengths. Each feature exhibits a unique spectral characteristic. Rocks and minerals possess a crystalline lattice structure. Such interactions produce identifiable features in the reflectance spectrum of the material. The reflectance spectra of few minerals are shown below in fig (1.5).

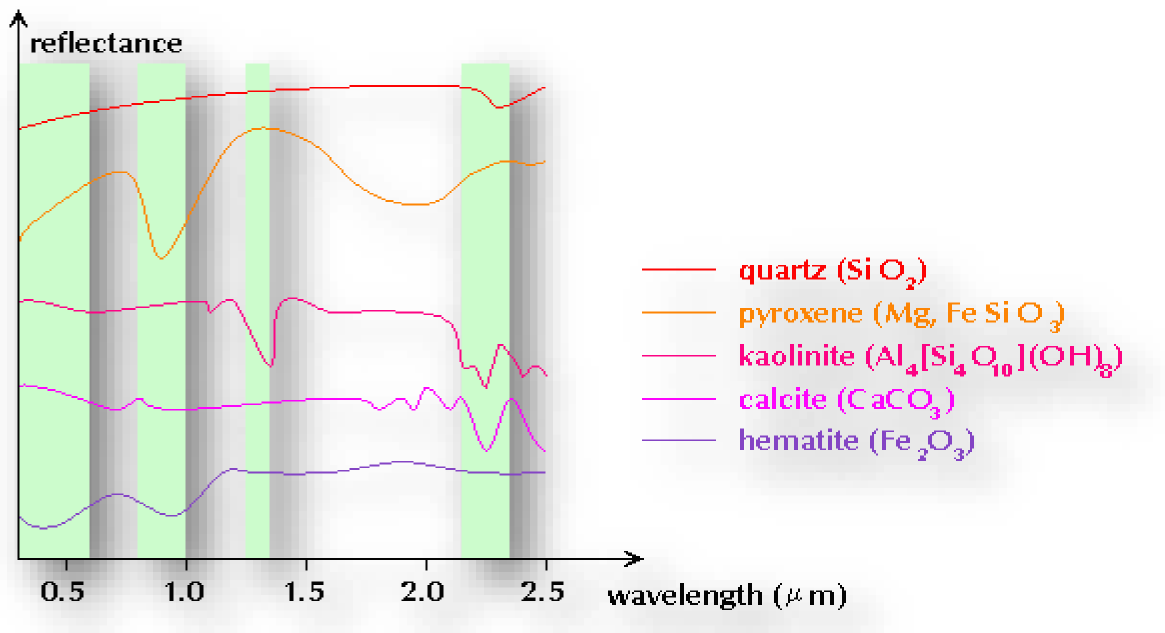

Figure 1.5 Reflectance Spectra of few minerals in different wave lengths (“*Hunt* 1977.Pdf,” 1977)

1.9 Remote Sensing and its Techniques

Field in which spectral information is acquired, processed, and interpreted remotely about the surface of earth and relation between energy of electromagnetism and matter, which further taken down for analysis. Satellite and airborne sensors are used for collection of data, which then gauged and authenticated using a field spectrometry. Remote sensing is defined as extraction of data and information about the somatic features of earth by estimating electromagnetic radiation associated with field indicators and matter particles that originates from different objects. Main advantage of remote sensing, contrary to on site observation is that in this information about object is gathered without making physical contact with said object, particularly remote and inaccessible areas of the Earth. Remote sensing is a collective term which is combination of different techniques, methodologies, processes, tools, and technologies i.e. Radar, spectrometry, Band spectrum, Sonar, GIS.

These tools and techniques of remote sensing are then utilized to combine visual and spectral attained data for further process, insights are created through further analysis in entire exploration process of mineral deposits. Exploration is done by images created through remote sensing as described:

- Physical Features like faults, cracks, fractures, geology, faults, and ore deposit are mapped and analyzed.
- Spectral signature of rocks is used to recognize Hydrothermal altered zones.

Remote sensing records information in visible as well as in the SWIR, Mid IR, Far IR and TIR regions of electromagnetic spectrum. Optical and/or synthetic aperture sensors are used to get images. Spectral and spatial data of sunlight which is reflected from surface of earth is measured by optical sensors and likewise, electromagnetic spectral data is measured through synthetic aperture sensors by sending microwave radiation and receiving the scattered back waves from the crust of earth. Since rock and mineral features depending upon their chemical composition reflect in specific wavelengths, so each feature exhibits a unique spectral characteristic. Remote sensing may help to discriminate geological features depending upon their color, tone, texture, composition, stratigraphic position, and interrelations between features. First step in exploration of minerals consist of collection of data in field which is relevant and useful for further process of translating above data in orderly and process-able form for explorers, i.e. image classification. Spectral signatures used in remote sensing as every mineral, material, and substance has unique way of reflection, absorption, transition, and emotion of solar radiation depending upon wavelengths of these radiations. When the amount of the connected points produces a curve called the Material's specific spectral signature can be obtained by plotting a curve between wavelengths of different ranges and radiation or electromagnetic energy from an object. If spectral signature of two objects are same, they will be of similar specifications, in other words every object will have specific unique signature depending on how this object behave and interact with radiations. With identification of spectral signature of an object, other data sets can be searched for same vary signature to find objects of similar patterns. Sensors are calibrated, and manipulation i.e. (spectral color bands is altered in the image) and processing of data sets are done to identify spectral signature.

1.9.1 Remote Sensing satellites

- Thematic Mapper (TM) Landsat
- National Oceanic and Atmospheric Administration – Advanced Very High-Resolution Radiometer (NOAA-AVHRR)

- ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) (14 spectral bands)

1.10 Knowledge Gaps

Remote sensing techniques provides great help in the field of geology which includes hydrothermal mapping, mineral exploration and other phenomena related to this. Remote sensing makes it easy to study, analyze and differentiate between different rock types however multispectral analysis of rocks under wideband multispectral sensor are somehow impossible as every rock has its own type of spectral signature, wavelength absorption and reflection capacity and characteristics so delineation based on these terms are not preferably suitable. From all above mention reasons hydrothermal mapping used entirely indirect method that's is data obtain from satellite map or manipulate the image based on weathering and geotectonic characteristics. So, keeping in mind all these circumstances it's impossible to construct a conclusive and detailed map based remotely sensed data. More ever it's possible to prepare a geological map from Data obtain from satellite by comparing and considering the ground realities comparing the satellite-based map with regionally developed geological map and with field work analysis at relatively local scale. Keeping all the facts and figures in mind current work of ours based on ASTER data complementary to ground realties helps in mapping and exploring mineral porphyry in Datta Khel region.

1.11 Conclusion

This project will provide an economical mean for the exploration of mineral deposits of hydrothermally altered zones in Datta Khel region, using ASTER satellite data. Relevant ASTER data will be processed through various remote sensing techniques, to attain desired results including Principal Component Analysis (PCA) and Band Ratios techniques (BR). In the BR evaluation process, results will be obtained after evaluation and calculations for bands of both VNIR and SWIR regions among the nine ASTER bands. Detailed images processing and evaluation techniques shows that vegetation and deposits of Iron-oxides ores are mainly spotted near VNIR regions and its subsystems in addition to this hydrothermally altered regions with higher probability of copper deposits are spotted and distinguished based on its peculiar characteristic of absorbing SWIR for ASTER data at regional scale.

CHAPTER 2: LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To find out knowledge gaps in the research and to study the existing knowledge including substantive findings, as well as theoretical and methodological contributions towards the research, this literature review provides solid platform and desired knowledge. Predominantly, basing on principles and methodologies of photo interpretation the techniques of remote sensing used produced successful Results.

2.1.1 ASTER based remote sensing investigation of gypsum in the Kohat Plateau,

north Pakistan. An attempt was been made to map the outcrops of gypsum through several remote sensing mapping techniques. These techniques include band ratio 4+8/6, stretch RGB-468 composite and Principle Component PC4.ASTER is a powerful tool to map different rocks units in arid, remote and inaccessible areas. PC4 results exhibited higher degree of accuracy compared to other methods. In the VNIR and SWIR sections of the electromagnetic spectrum, gypsum has major spectral absorption features caused by overtones and combination tones of water molecules in gypsum crystals. (Khan et al., 2020)

2.1.2 Mapping of manganese potential areas using ASTER satellite data in parts of

Sultanate of Oman, The company studied the image of 14 ASTER spectral bands based on the spectral absorptions characters of manganese minerals, they processed the 9 ASTER VNIR-SWIR spectral bands using the band ratio ((1 + 3)/2, (3 + 5)/4, (5 + 7)/6) to discriminate the occurrences of manganese and associated lithological information.(Rajendran & Nasir, 2013).

2.1.3 Further to confirm their occurrences, we studied the application of Principal

Component Analysis on satellite data of study region. In the PCA technique, the relationship between the spectral responses of target minerals or rocks and numeric values extracted from the eigenvector matrix is used to calculate the Principal component (PC) images. Using this relationship, one can determine which PCs contain the spectral information due to the minerals and whether the digital numbers (DNs) of pixels containing the target minerals had high (bright) or low (dark) values. (Loughlin, 1991)

2.1.4 In the PCA of 9 ASTER VNIR and SWIR spectral bands, the first three high order principal components (PC1, PC2, and PC3) have over 99% of the spectral information; hence these have been widely used for lithological mapping rather than the subsequent low order principal components (PC4, PC5, PC6, etc.) which usually contain less than 1% of spectral information and they contain low signal-to-noise ratios. The principal component analysis is proved powerful in discriminating the occurrences of manganese ore in Wahrah formations and the associated rock units of the study region.

2.1.5 Spectral resolution of ASTER falling in the SWIR bands poses enough potential to map mineral zones of hydrothermally altered epithermal gold and porphyry copper rocks which enhanced the usefulness of SWIR data of ASTER in field of remote sensing. Hydrothermally altered rockes were differentiated and distributed into argillic, phyllic, and propylitic zones based on absorption of each alteration zones. VNIR and SWIR bands of ASTER data was successfully utilized to analyze the potential of mineral deposits in study area. A major characteristic associated with mineralization of copper is its distribution in different zones. Argillic zone potassic zone, phyllic zone, and propylitic zones are the zones in which Copper deposits are present. Identification of these zones are done based on type and geology of mineral present; identification of these deposits associated with different mineral zones can easily done by using ASTER data and remote sensing techniques. (Berger et al., 2008)

2.1.6 Mineral exploration is revolutionized by the advent of Remote sensing techniques as it not only help to map land surface minerals but also eradicate the cumbersome complications faced during early stages of exploration i.e. reconnaissance and survey. (Di Tommaso & Rubinstein, 2007)

2.1.7 Dimensionality reduction techniques are used in the field of mineral detection and exploration by Siddiqui et al., (2018) reduced the cost and effectiveness of initial stage of mineral detection/exploration. Dimensionality reduction techniques includes PCA, ICA, MNF these transformation techniques used in multivariate statistical analysis and converts the correlated variables into uncorrelated variables. The results showed that the most appropriate method for generation of hydrothermally altered zones is ICA. Results clearly represents that differentiation and alteration of hydrothermally altered zones derived from the dimensionality techniques gathered from remotely sensed data is very economical and reliable for mapping purpose at the site of metalorganic study. (Siddiqui et al., 2018)

2.1.8 World's Seventy five percent of Copper, fifty percent Molybdenum, and roughly twenty five percent Gold, and large quantity of Rhenium, and small quantity amount of other metals such as silver, zinc, palladium, tellurium, selenium. (Sillitoe, 1972)

2.1.9 Hydrothermally altered zones can be easily identified based on their specific absorption property and their measure of reflectiveness that is specified for different minerals. Absorption was measured in visible and near infrared zones. Multispectral and hyperspectral techniques were used for measuring copper and gold deposits through SWIR. PCA is a powerful statistical technique that can be used to compress images and eliminate the unwanted effects. This technique summarizes the variability of complex datasets, and has gained an unprecedented popularity in the remote sensing studies. (Gabr et al., 2010)

2.1.10 ASTER data analysis was done using transformation techniques band rationing and principle component analysis in addition SAM and SID was applied to detect the difference of ground truthing and laboratory analysis directional filtering was also done to find out the linear direction for old exploration. New techniques SAM, SID, and directional filtering applied suggested the great potential for gold mining (Sheikhrahimi et al., 2019)

2.1.11 ASTER data analysis for copper porphyry using specialized band ratio, PCA, was done at volcanic belt site for hydrothermal mapping. Data was specifically taken from two zones VNIR and SWIR. Analyzation techniques were evaluated for both regions. Results have two ajor finding that is identification of new mineral lands without investing much and second is techniques applied gives the optimum land idea for possible areas for copper and gold mining and mapping. (Pour & Hashim, 2011)

2.1.12 Hydrothermally altered rockes were differentiate and distributed into argillic, phyllic, and propylitic zones based on absorption of each alteration zones. VNIR and SWIR bands of ASTER data was successfully utilized to analyze the potential of mineral deposits in study area. Moreover, mineralized Cu–Au area of Reko Diq, Pakistan containing hydrothermally Silicified rocks were mapped using bands of TIR region ASTER data. (Rowan et al., 2006)

2.1.13 ASTER is best implicated to map hydrothermally altered zone and explains the lithology of different minerals specified for gold and copper deposits. Key findings suggest that ASTER data is useful in lithological mapping and discrimination of hydrothermally altered and geological different zones based on the wavelength emitted. Hence remote sensing is a technique with low cost and high accuracy for exploration of minerals. Differentiation between hydrothermally altered zones are significant in identification of mineralization and exploration of copper. Zones of Phyllis deposits known for its high concentration of copper mineral having great economical value, this zone can be explored through analysis of ASTER data. (Pour & Hashim, 2011)

2.1.14 Remote sensing techniques of Principal component analysis and Band ratio for analysis of ASTER data were compared. Data obtained from SWIR and VNIR can be used to study mineral regions of dolomite, clay, iron oxide and calcite. The data for various bands often correlate. The correlation between the images of the bands demonstrates that there is some common information or, in other words, they have a repeated information. The transformation of the principal component is a method to remove or reduce such ancillary information, which is done by compressing the multi-spectral data into a new coordinate system. The information in the multispectral bands is often less than the number of bands, and therefore, the objective of PCA is to determine the number of dimensions in an information collection. (Asgher Ali Daahar Hakro et al., 2016)

2.1.15 For differentiation between mineral rocks that from VNIR and SWIR regions of ASTER was analyzed via PCA to reduce the ambiguity in related bands. PCA is applied to all 9 bands of ASTER except TIR region. The study concludes that ASTER data is best for used in lithological studies as its higher rate of accuracy both spatially and spectrally areas can be easily defining with different lithology with the help of remote sensing and GIS tools. ASTER data analyzed by VNIR gives best image at 15m resolution which is validated by comparing ground level data with laboratory spectra which resembles. (Arivazhagan & Anbazhagan, 2017)

2.2 **Knowledge Gaps**

Remote sensing techniques provides great help in the field of geology which includes hydrothermal mapping, mineral exploration and other phenomena related to this. The use of ASTER multispectral data in mineral exploration and lithological mapping has increased in recent years due to spectral characteristics of unique integral. Remote sensing makes it easy to study, analyze and differentiate between different rock types. It is cost effective and highly accurate. It can be utilized in far flung and remote areas which are underdeveloped and have been unexplored. From all above mention case studies we can predict that copper and iron minerals can be explored using ASTER data in band ratio and PCA. In Pakistan there has been very rare work on copper and iron mineralogy identification which can be maximized using remote sensing techniques. The studied techniques are time effective as well in the mapping of different rock occurrences and associated formations and thus we recommend to use the techniques in the arid region anywhere in the Pakistan. Moreover, this work demonstrates the sensor capability of ASTER in providing information on the occurrences of different rocks, which is valuable for mineral prospecting and exploration activities. The preliminary remote sensing study recommends for a large scale detailed exploration work on the occurrences of different rocks in this region. however multispectral analysis of rocks under wideband multispectral sensor are somehow impossible as every rock has its own type of spectral signature, wavelength absorption and reflection capacity and characteristics so delineation based on these terms are not preferably suitable. From all above mention reasons hydrothermal mapping used entirely indirect method. The data was obtained from satellite map or manipulated the image based on weathering and geotectonic characteristics. Based on characteristic every geological structure has its own unique mapping trend e.g. some fragile and weak structures required surface to be mapped, in addition to this elastic or flexible structure cannot be differentiated from satellite data. So, keeping in mind all these circumstances it's impossible to construct a conclusive and detailed map solely based on remotely sensing data.

CHAPTER 3: METHODOLOGY

CHAPTER 3
METHODOLOGY

3.1 Data Collection

ASTER data available on NASA official website (fig 3.1) and USGS official website (fig 3.2) was of numerous types. For our project our requirement was of ASTER Level 1B data (VNIR and SWIR bands), which was not available at any of above mention sites. However, on probing through USGS website, we were only able to download ASTER Level 1 (Level 1T) Precision Terrain data with all VNIR, SWIR and TIR bands.

The difference between both data is as following:

- ASTER Level 1B data is radiometrically processed and geometrically adjusted and contains i.e. 3 bands of VNIR, 6 bands of SWIR, and 5 bands of TIR
- Level 1B data is only available on NASA official website but it doesn't contain short wave infrared (SWIR) band having spatial resolution of 30m.
- ASTER Level 1B data measurements for every sensor (VNIR, SWIR, and TIR) stay stable starting with one scene then to next
- In ASTER Level 1T image measurements vary by scene on account of the pivotal interface
- The ASTER Level 1T is a multi-file data product generated with single resampling from the ASTER Level 1A info scene to give low-quality result of image resolution.
- Creation of login account on USGS and NASA website by providing necessary information
- Study area (AOI) of this project was selected on the map to obtain ASTER Level 1T data.
- Latitudes and Longitudes were taken from Google Earth pro for our AOI and then these were converted to decimal degrees on earth data (fig 3.3).
- These Latitudes and longitudes were entered/used in USGS earth data website

to get data files. (fig 3.4)

- Data files were selected which contained our AOI and processed for downloading. (fig 3.5)
- Data processing for downloading was carried out and a link was sent on provided email address, which was having 10 days of expiry time.
- 10 Gaga bite data was downloaded on the link provided on the email address from LPDAAC. Which comprises of more 50 granules of data, contained TIF, HDF and Met files.

3.2 Image Processing Software & Tools

To determine effectiveness of technology in mineral exploration following softwares and tools were used in conducting the present study.

- Global Mapper 17
- ArcGIS 10.3
- Erdas Imagine 13

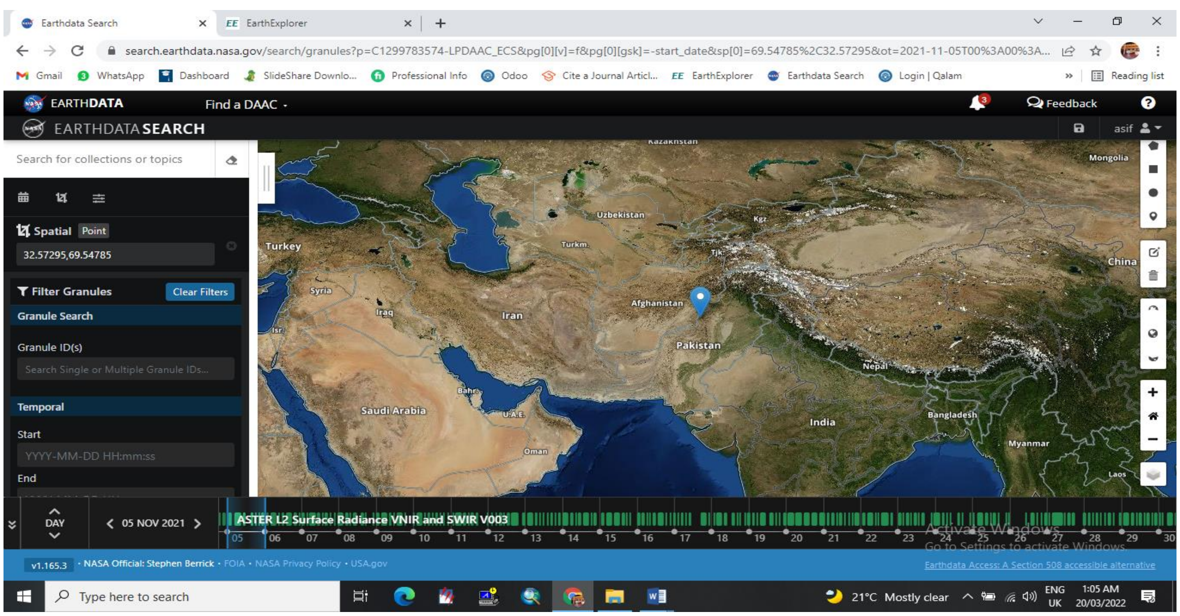

Figure 3.1 NASA Earth Data Site (NASA, n.d.)

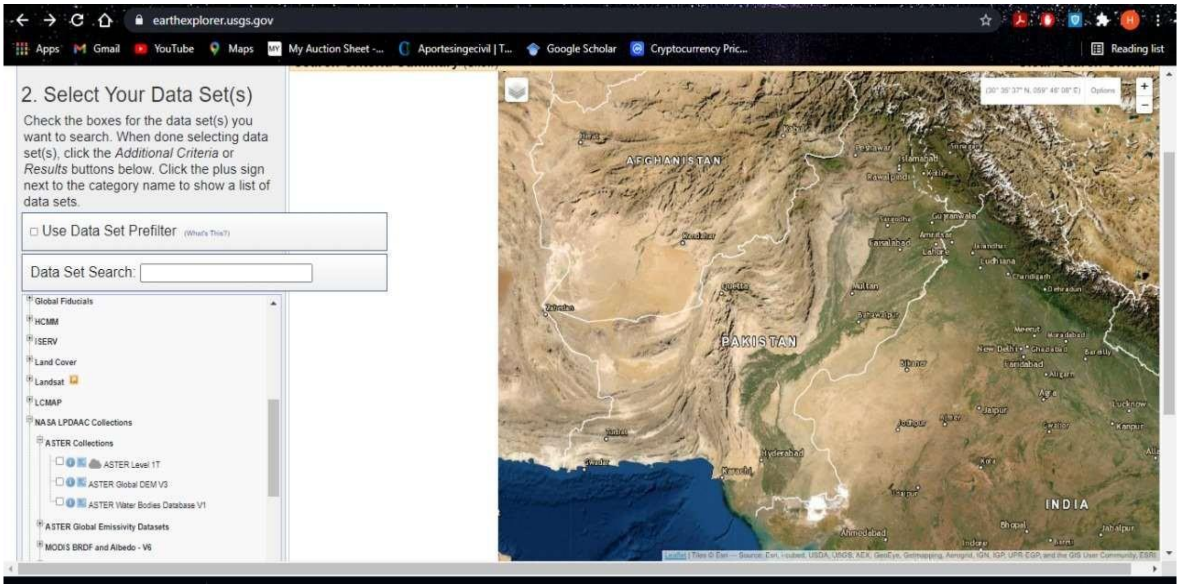

Figure 3.2 USGS Earth Data Search Site (USGS, n.d.)

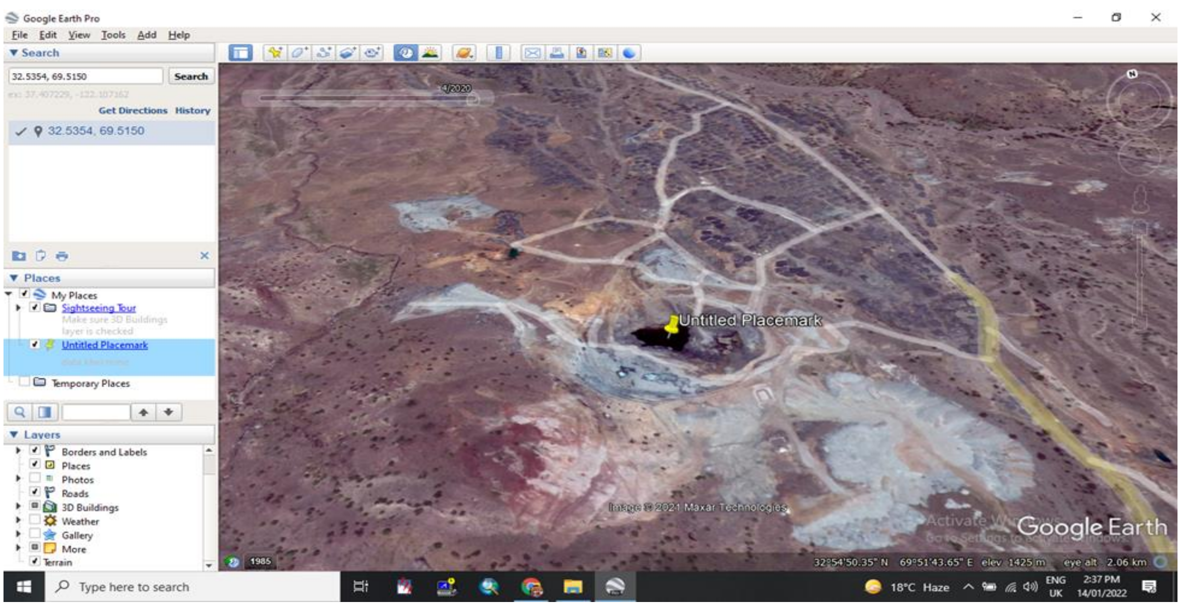

Figure 3.3 Selection of latitude and longitude in DMS in Google Earth (GOOGLE Earth, 2003)

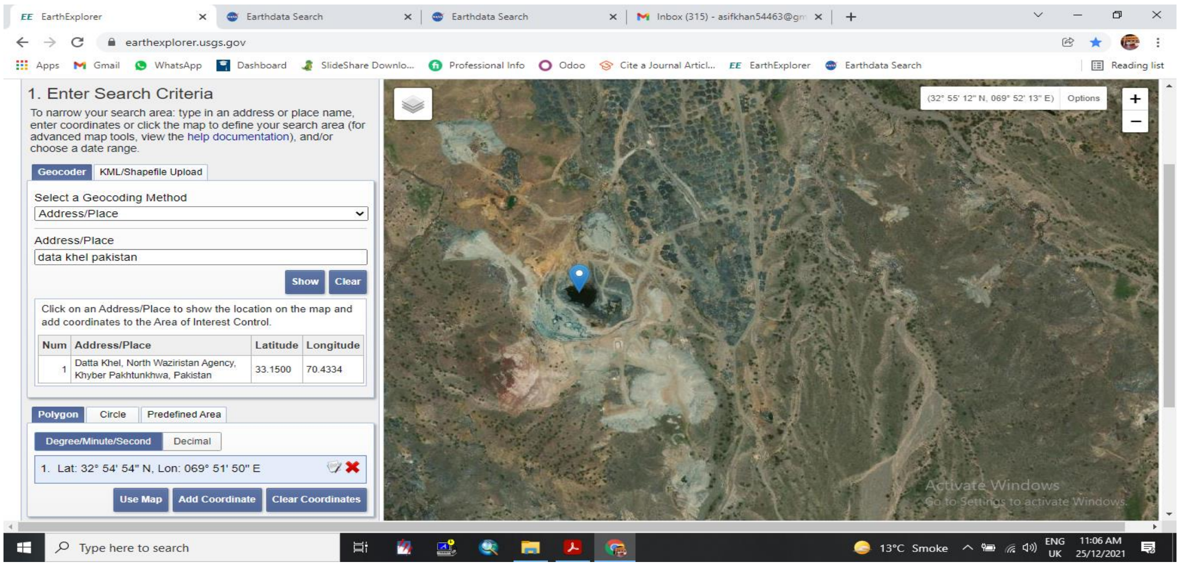

Figure 3.4 Selection of latitude and longitude in degree decimal in earth data website (USGS, n.d.)

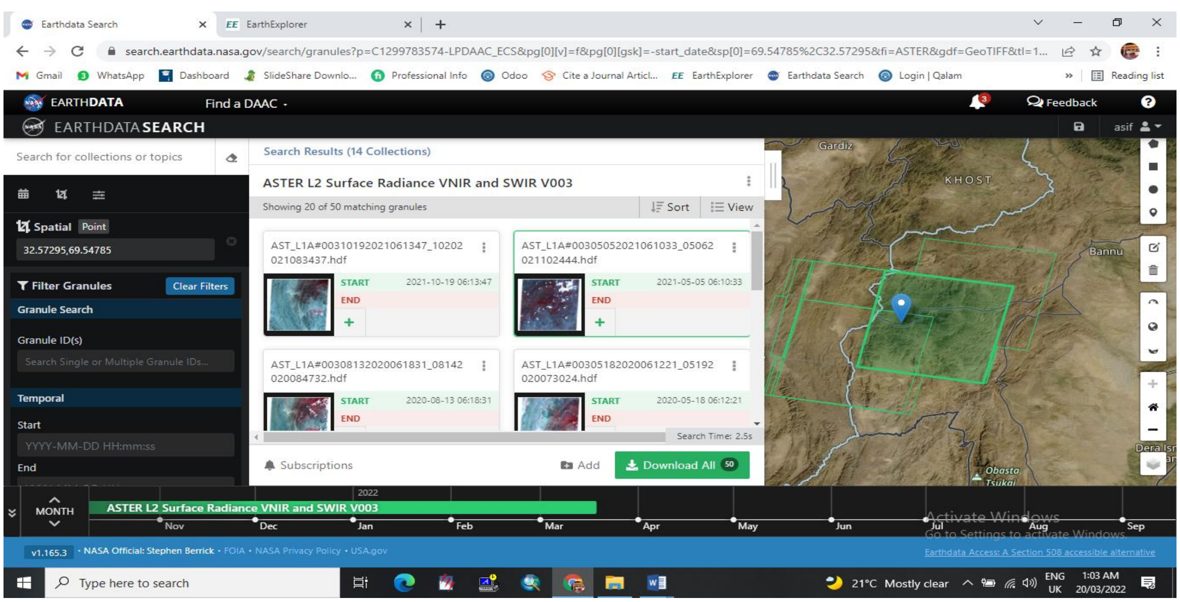

Figure 3.5 Tile selection on NASA Earth Data website (NASA, n.d.)

3.3 Geological Settings

Datta khel tehsil of North Waziristan District is in Bannu Division of Khyber Pakhtunkhwa province in Pakistan. It is the northern part of Waziristan, a mountainous region of northwest Pakistan, bordering Afghanistan and covering 4,707 square kilometers (1,817 sq mi). The capital city of North Waziristan is Miranshah. Our project location is in data Khel region of North Waziristan which is part of Bannu division.

Geographically, the whole of Waziristan is a single entity. However, for administrative suitability it has been split into two agencies: North and South Waziristan. The area has been defined as a land of high and difficult hills with deep and rocky defiles. The mountains of North Waziristan are geographically distinct from the larger mountain systems of Koh-e-Sufaid in the north and Sulaiman in the south. The highly mineralized Razmak zone is connected with it. The average height of the Waziristan Mountains is 1,500–2,500 meters (4,900–8,200 ft) above mean sea level.

This region of province has vast mineral underground reservoirs which can be estimated using remote sensing techniques. In Fig 3.5, imagery acquired from NASA earth data site shows our study area of data Khel, KPK.

Several significant minerals including porphyry (Cu-Mo-Au), copper, iron, gold- silver, sulfur, zinc-silver-copper relate to the magmatic rocks of north Waziristan. The average precipitation is about 66.8mm, in which maximum rain fall occurs in the months of July and August. Due to well-exposed earth surface and nonexistent vegetation cover this area is suitable for remote sensing studies. Study regions incorporate copper and gold stores situated in data Khel region.

3.4 Pre-processing of data

Data used in our project examination site were obtained from the NASA (USA) and USGS earth data website, which consists of level 1T (cloud-free) ASTER data of datta khel region. They were acquired on Nov 12, 2021 for the datta khel region, two forms of data set were downloaded for project. For processing to get potential sites, ASTER L1T data of 2003 was downloaded and for ground truthing data set of 2018 was downloaded. Correction/alteration was performed by Crosstalk program.

- The data comprise of all fourteen bands in single file, for our project there was requirement of nine bands (VNIR and SWIR) which were extracted from Raw data file.
- Spatial Resolution of 30 m of SWIR of Aster data was converted to the spatial dimensions of 15m of the VNIR using resample tool available on ArcGIS.
- The resolution acquired was weak. Pan sharpening technique is used to augment resolution without effecting pixel digital numbers. ArcMap Software is used for the processing and evaluation/analysis of reflectance of this ASTER data.
- Individual product obtained comprises of two HDF-EOS files: one VNIR, and the other SWIR, then this HDF file is converted into TIF using ArcGIS for processing
- Data obtained from NASA site contained dark edges which have been eliminated using ArcGIS software, as it was going to affect our PCA and BR results
- AOI is clipped using clipped tool in ArcGIS which was available/Overlapping in all bands (VNIR and SWIR)
- The data is atmospherically corrected and formed developing the bands of the corresponding ASTER L1T image.

3.5 Techniques used for image processing

Techniques selected were primarily based on their reliability, robustness & how quick they produce results. All techniques were basically sited on properties of spectral resolution of alteration minerals for designed mining location of data which concerns our study. Two main methods which are PCA, & BR were executed on ASTER data. layout of methodology is given in fig (3.6).

3.5.1 Principal Component Analysis

The technique used for amplitude of datasets, by increasing effectiveness of dataset and simultaneously reduces data loss. PCA is statistical technique that selects non-correlated eigenvector loadings of variables in a way that each component sequentially extracted linear combination and has a smaller variance. Standard PCA Transformation has applied to the ASTER data scenes of datta Khel, KPK. It happens when it exploit on variance with the help of new uncorrelated variables. It is the way towards figuring the main sections and utilizing them to Sort out difference in evidence on the available data. Nine new image components are generated from the original nine bands (VNIR + SWIR) ASTER dataset.

3.5.2 Band Ratio

The technique in which DN values of different bands are divided by DN values of other bands known as Band Ratio. It helps in identification of certain materials which cannot be seen in raw bands. In the recent years Aster BR technique is well accepted and considered very useful in geological mapping and minerals exploration in recent time frame.

In the recent years, ASTER BR method has enticed worldwide recognition acknowledgment in geographical mapping (“(Are et al., 1800)). Selected ASTER bands (VNIR and SWIR) were utilized for analysis using Band Ratio technique. Selected ASTER VNIR and SWIR bands have used for BR in this study. Three BRs have performed

- Stabilized vegetation index (StVI) = (band 3/band 2) / (band 1/band 2) for detecting vegetation features (Ninomiya, 2003)
- Ratio of band 4/2 for identifying iron oxides (Abdelsalam et al., 2000)
- Ratio of band 7/6 for identifying muscovite (Hewson et al., 2005).

The methodology of the BR is aimed to recognize vegetation (crops etc.), iron oxides, and mineral zones (having OH ions), which leads to the general region planning of the hydrothermal alteration regions related with porphyry copper deposits. Relative Absorption Band Depth (RBD) is a useful proportional technique of using three-point definition which shows absorption intensities of minerals (Al– O – H, Fe, Mg – O – H, and CO3). In every absorption, numerator is the Sum of bands addressing the shoulders, while the band that is found closed to least absorption is represented by the denominator (Crowley et al., 1989) Three RBD ratios have implemented in this study (RBD_5, RBD_6, and $RBD_{8)}$ were assigned for RGB (red, green, and blue) color combination to define argillic, phyllic and propylitic hydrothermal alteration zones.. The RBD proportions have been inferred considering Crowley et al. (1989). It is given below:

$$RBD5 = (B4 + b6) / b5$$

$$RBD6 = (b5 + b7)/b6$$

$$RBD8 = (b7 + b9) / b8$$

Here b4, b5, b6, b7, b8 and b9 shows ASTER bands 5, 6, 7, 8 and 9, separately

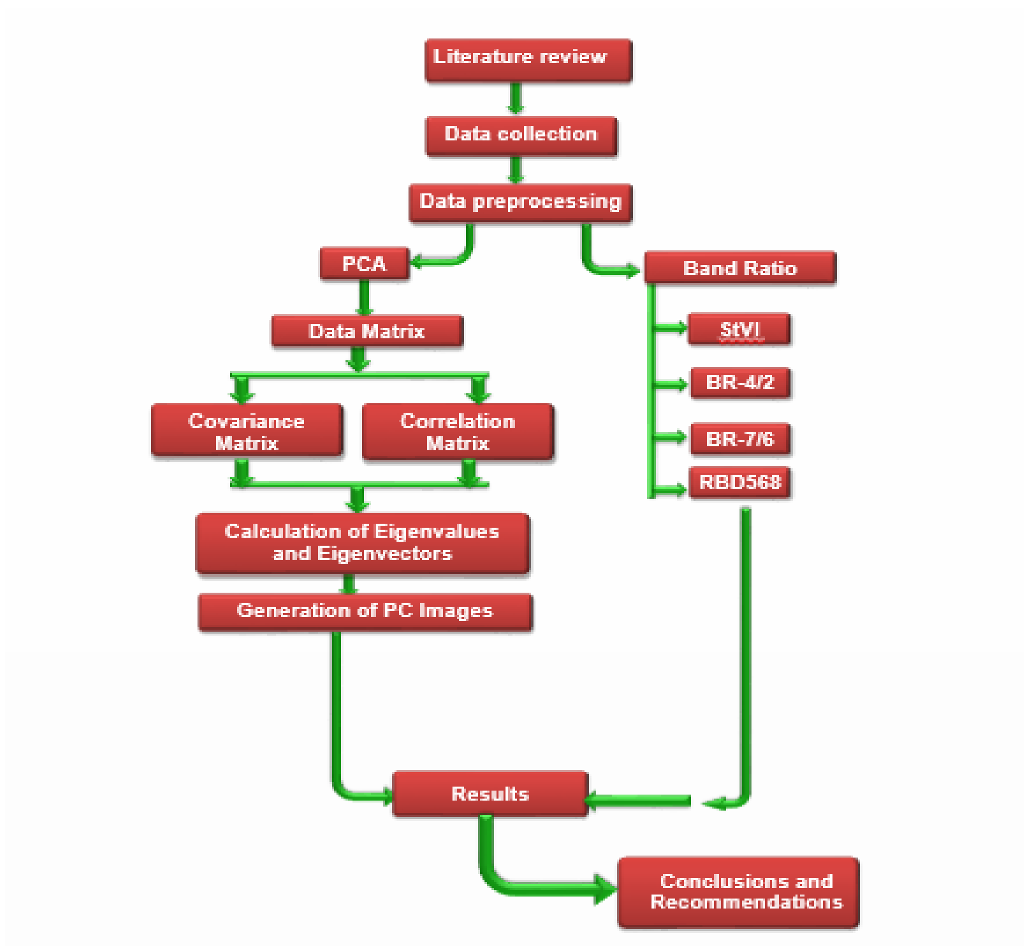

Figure 3.6 Conceptual Framework of the study

CHAPTER 4: RESULTS AND ANALYSIS

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Principal Component Analysis (PCA)

The outputs from aster data using PCA method are statistic facts written in table form below. The selected tile imagery from the transformations after using PCA are in figures below. The eigenvectors values of the image and the eigenvalues of the image as derived after using PCA, by using utilizing covariance on each of the nine bands of the imagery from the tiles of a part of the Datta Khel North Waziristan region are shown in Tables below. PC1 is made from a positive weighting of all of the nine bands (VNIR+ SWIR).

Table 4.1 : Covariance Matrix Of The Tile

LAYER	PC LAYER NUMBER								
	1	2	3	4	5	6	7	8	9
1	199.7503	208.4505	108.8997	98.47633	111.9748	124.533	112.2380	92.46726	93.87282
2	208.4505	229.2106	117.9561	110.7442	126.6506	142.1117	127.6755	105.2198	108.6344
3	108.8997	117.9561	112.2690	91.57183	75.96118	86.57934	78.69291	80.86047	63.82272
4	98.47633	110.7442	91.57183	154.4825	104.2846	116.3013	109.4279	143.1003	87.84213
5	111.9748	126.6506	75.96118	104.2846	103.8274	114.9834	105.9691	100.2945	88.99599
6	124.5334	142.1117	86.57934	116.3013	114.9834	130.0366	118.3525	111.3460	99.83902
7	112.2380	127.6755	78.69291	109.4279	105.9691	118.3525	111.3962	106.9892	92.69127
8	92.46726	105.2198	80.86047	143.1003	100.2945	111.3460	106.9892	143.1457	86.84199
9	93.87282	108.6344	63.82272	87.84213	88.99599	99.83902	92.69127	86.84199	80.31014

Table 4.2: Correlation Matrix of the Tile

LAYER	PC LAYER NUMBER								
	1	2	3	4	5	6	7	8	9
1	1.00000	0.97419	0.72720	0.56059	0.77754	0.77270	0.75242	0.54683	0.7411
2	0.97419	1.00000	0.73531	0.58852	0.82098	0.82315	0.79902	0.58089	0.80069
3	0.72720	0.73531	1.00000	0.69533	0.70357	0.71656	0.70367	0.63785	0.67214
4	0.56059	0.58852	0.69533	1.00000	0.82343	0.82056	0.83417	0.96230	0.78864
5	0.77754	0.82098	0.70357	0.82343	1.00000	0.98957	0.98534	0.82268	0.97461
6	0.77270	0.82315	0.71656	0.82056	0.98957	1.00000	0.98335	0.81612	0.97697
7	0.75242	0.79902	0.70367	0.83417	0.98534	0.98335	1.00000	0.84726	0.97998
8	0.54683	0.58089	0.63785	0.96230	0.82268	0.81612	0.84726	1.00000	0.80994
9	0.74116	0.80069	0.67214	0.78864	0.97461	0.97697	0.97998	0.80994	1.00000

Table 4.3 Eigenvalues of PCA layers

PC layer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	1018.57	151.535	51.5230	28.2017	5.84387	4.64070	1.69762	1.38666	1.02554

Table 4.4 Eigenvector of PCA on VNIR + SWIR bands of ASTER data

LAYER	PC LAYER NUMBER								
	1	2	3	4	5	6	7	8	9
1	0.38867	-0.5135	- 0.09986	-0.34336	-0.24941	0.59748	0.11695	0.14496	-0.05875
2	0.43007	-0.4953	-0.0206	-0.2051	-0.26424	0.65057	-0.08456	-0.15909	0.04032
3	0.26894	-0.0591	-0.72993	0.61073	0.11612	0.05626	0.02129	0.01185	-0.03374
4	0.33051	-0.47295	0.29077	0.30150	0.55911	0.30271	-0.28672	-0.0719	-0.00308
5	0.30735	-0.08787	0.28487	-0.19504	0.23107	0.10268	0.35869	-0.07734	0.76161
6	0.34391	-0.09517	0.30436	-0.28146	0.22708	-0.10589	-0.39807	0.44229	-0.53287
7	0.31678	-0.1295	0.28356	-0.21207	0.08281	0.23317	0.14572	-0.75766	0.31778
8	0.31549	-0.47210	0.13635	-0.40254	-0.59809	0.21990	-0.27380	-0.12597	0.00795
9	0.26416	-0.0852	0.31539	-0.22772	-0.26900	-0.02231	0.71637	0.39603	-0.16949

Table 4.5 Percentage and Accumulation Eigenvalues

PC Layer	EigenValue	Percent of EigenValues	Accumulative of EigenValues
1	1018.57466	80.5561	80.5561
2	151.53505	11.9845	92.5406
3	51.52300	4.0748	96.6154
4	28.20172	2.2304	98.8458
5	5.84387	0.4622	99.3079
6	4.64070	0.3670	99.6750
7	1.69762	0.1343	99.8092
8	1.38666	0.1097	99.9189
9	1.02554	0.0811	100.0000

PC1 accounts for 80.55 % of the complete fluctuation as is visible from eigenvalues. PCA has adequately mapped brightness into the conversion of PC1. As for PC2, all values lie in negative zone of Eigenvector (Table 4.4). These negative values shows that it might be noisy and may have no significant data. In PC3, Eigenvector loadings shows that PC3 shows the contrast between the visible channels i.e. the bands with negative eigenvector loadings (Band 1,2 & 3) and the infrared channels whose eigenvector loadings are positive (Bands 4,5,6,7,8 & 9). The remaining six PCs can be required to contain data because of the changing reflectance of oxides of Fe and hydroxyl minerals (Loughlin, 1991). On looking for moderate or larger eigenvector loadings for layer 1, 2 & 4 where eigenvector loadings are in inverse sign, we can hint those oxides of iron can be separated by bright pixels in PC4 (Tables 4.4)

Oxide (Fe) minerals have lesser reflectance in visible and higher reflectance in infrared. This feature of Absorption in the VNIR is produced by using electronic processes (0.4 – 1.1 lm) because of the presence of transition components, for example, Fe^{2+}, Fe^{3+}, Mn, Cr, and Ni in the crystal form of minerals. The bright pixels in PC4 shows iron oxides due to the positive influence from layer 4 (0.3015). PC4 picture shows iron oxide minerals that showed as brilliant pixels with circular shape around porphyry copper deposits and new possibilities in the investigation regions (Fig 4.1). Considering the bright pixels of iron oxide in PC4, it has lower loading of band 2 (-0.2051) that shows that there is less vegetation related with Fe oxides in the PC imagery. One of the significant minerals associated with hydrothermal modified rocks are iron oxides Pour & Hashim,(2011) Near surface processes and their modification of product results in the creation of Fe oxides. It has a yellowish or ruddy tone that is adjusted to the rocks that are named gossan (Abdelsalam et al., 2000).

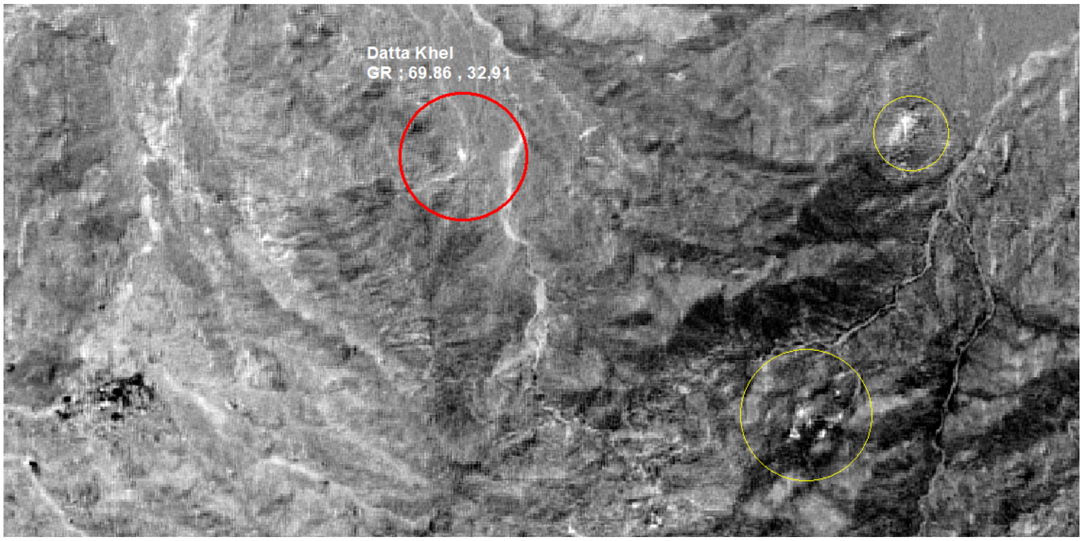

Figure 4.1 PC4 image shows iron oxide minerals as bright pixels with circular and semicircular shapes

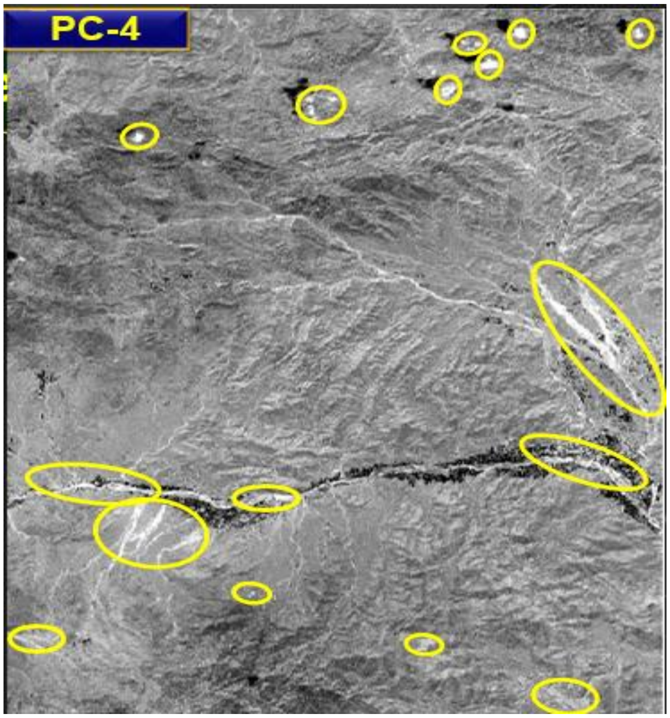

Figure 4.2 PC4 image shows iron oxide minerals as bright pixels with circular and semicircular shapes in the vicinity of our AOI , these sites can be referred as potential sites

Loading of Eigenvector for PC5 shows domination of vegetations . Higher reflectance of band 3 and low reflectance of band 2 is the reason behind the indication of vegetation (Ninomiya, 2003)

In PC5 image vegetation pixels appear as bright . Vegetation pixels are following the drainage systems and some patches as field form in flat plain (Fig 4.3). Variance percentage of vegetation PC is 0.46% , indicating slight green bushy vegetation surface in study area. Spectral absorption of Iron oxide deposits in infrared (visible to middle) electromagnetic spectrum from 0.4 to 1.1 m. (Hunt & Ashley, 1979)

Absorption from 0.45 to 0.68 lm indicates presence of Vegetation. It's reflectance is very high in near infrared. High reflectance of iron oxide deposits in the range of 0.63– 0.69 lm are observed during analysis, variety of vegetation shown as red edged reflectance in near infrared lies in range varying from 0.76 to 0.90 lm, basing on these reflectance qualities of iron oxide minerals can be differentiated from vegetation (Crósta & Moore, 1989)

Iron oxide deposits can be differentiated from vegetation using characteristic of ASTER band 2 (0.63–0.69 lm) and 3 (0.78–0.86 l m). PC5 bright signature indicates pixels of vegetation and dark signature shows iron oxide pixels. (Fig. 4.1). Layer 8 & 9 have distinctive absorption (2.29– 2.43 lm) of ASTER data shows presence of chlorite, carbonates, calcite and dolomite and other Mg(OH)-, Fe bearing minerals (Fig. 4.3) ((Hunt & Ashley, 1979; Wright & Ramsey, 2006)

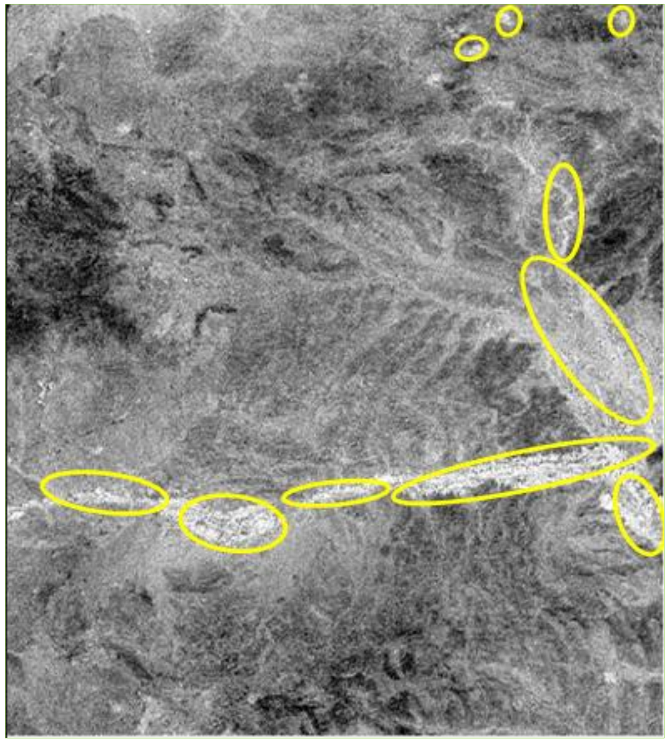

Figure 4.3 PC5 image shows vegetation as bright pixels that follow the drainage

Noisy and uninformative data of PC8 and PC9. Scale and indications of the percentage variance and eigenvector loadings analysis suggest that PC6 & PC7 comprises of some anticipated information. According to Crósta & Moore, (1989) and (Loughlin, 1991)a PC image with moderate and high eigenvector stacking for reflective and absorptive groups of mineral or mineral gathering with inverse signs enhances that mineral. On the off chance that the stacking are positive in reflective band of a mineral the picture tone will be bright, and in the event that they are negative, the picture tone will be dull for the upgraded target mineral. In this way, eigenvector measurement in each PCA would recognize the PC picture in which the spectral data of mineral under test is stacked. Considering the indication of the eigenvector loadings of band 4 and furthermore groups 5, 6, 7 & 8 in PC6, there is presence of Al (OH) bearing minerals (Fig 4.4). PC6 can be marker of argilic and phylic modification zones as a result of the size and indication of the eigenvectors loadings of layer 5, 6, 7 in PC6. In PC7, the analysis of PCA shows signs of Fe, Mg (OH) bearing minerals (Table 4.4). The consequences of PC image for ASTER scenes for OH-bearing minerals in PC6 shown in dull pixels in light of the fact that the band 6 has eigenvector stacking with negative sign (-0.10589) as is shown in (Table 4.4). These inconsistencies can be because of a PCA result which is scene dependent, transform coefficient from one scene to another.

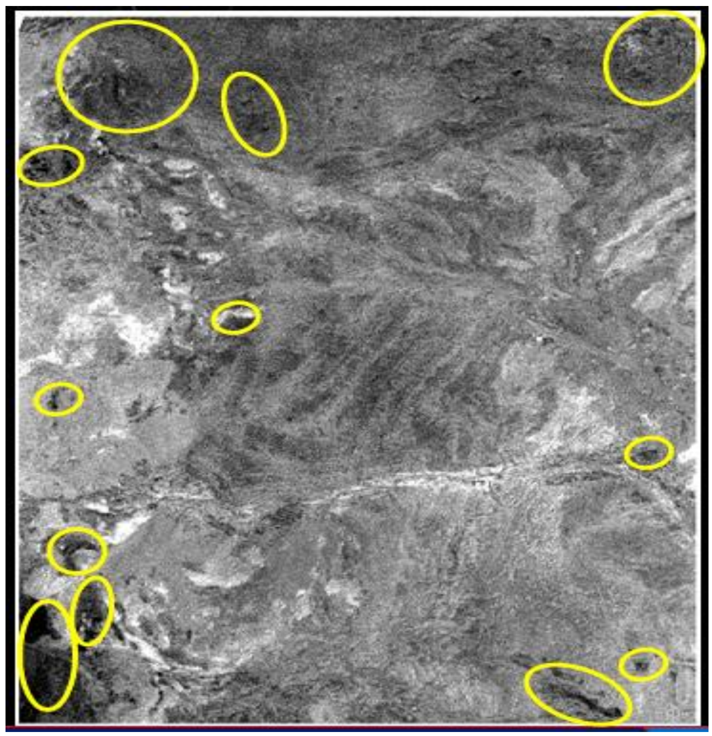

Figure 4.4 PC6 shows signs of Al (OH)-bearing minerals and indicator of Argillic and Phyllic zones

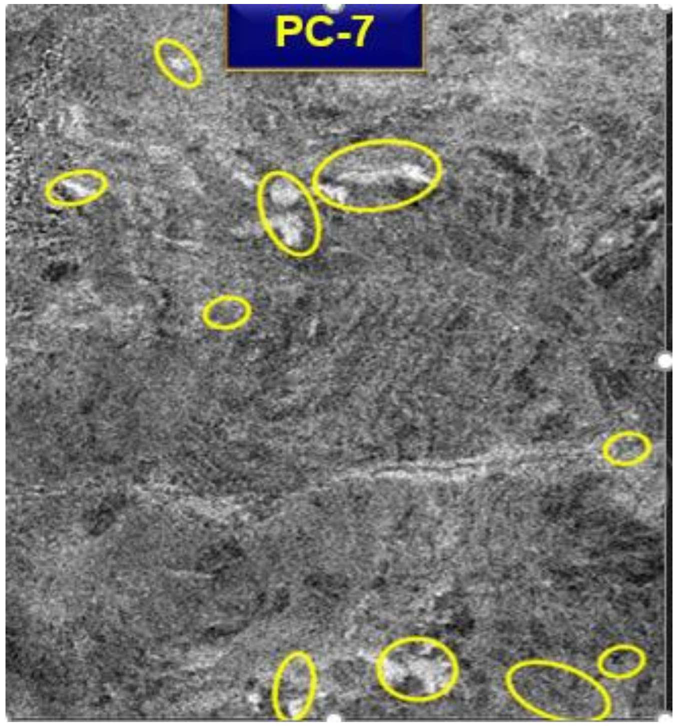

Figure 4.5 PC7 image shows signs of Fe, Mg (OH)-bearing minerals as bright pixels

Fig. (4.6) show RGB shading composites of PC5 (Vegetation pixels), PC6 (Al (OH)- bearing minerals' pixels), and PC7 (Fe, Mg (OH)- bearing minerals' pixels) pictures of Datta Khel. The RGB color composites were generated to show vegetation covers and hydrothermal alteration zones in study areas. Vegetation is visible and indicated as light yellow color. The RGB appearances for alteration halos in Study area are showed in blue (Phyllic and Argilic zones) and maroon tones Propylitic zone that encircle phyllic and argillic zones. In this manner, hydrothermally changed areas about cooper deposits are identifiable.

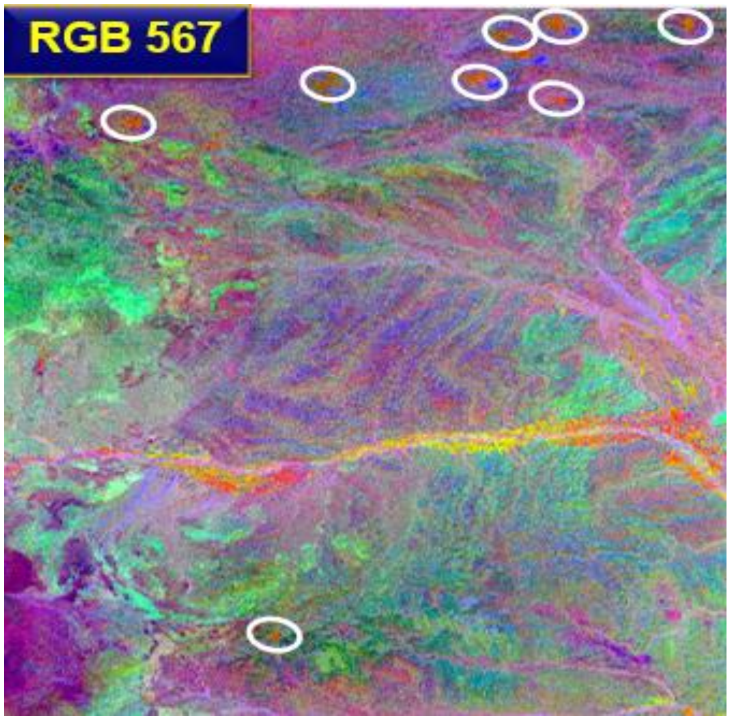

Figure 4.6 RGB color composite of PC5, PC6, and PC7 images, showing hydrothermal alteration halos around known copper deposits, shown by white circles around the known copper deposits and identified prospects

4.2 BR

The BR conversion assists with accomplishing of detecting qualitative hydrothermally changed minerals. High numerical values on the scene shows spectral signature of spectral image for minerals they were designed to map. NDVI is the most widely acknowledged vegetation index in the world. It is used as following

$$NDVI = \frac{NIR - red}{NIR + red}$$

In above equation, NIR is the datum in near infrared and its value correlates to band 3, and red correlates to band 2. It is steady and touchy enough for examining vegetation on the off chance and is applied to reflectance data which is atmospherically corrected. StVI is determined by following

$$StVI = (band\ 3 / band\ 2) * (band\ 1 / band\ 2)$$

This technique is utilized in recognizing vegetation in 4 full image making a scene of ASTER in the investigation regions. Fig 4.7 represents the outcome of stabilized Vegetation Index as white pixels which are quite similar to PC5 of PCA analysis

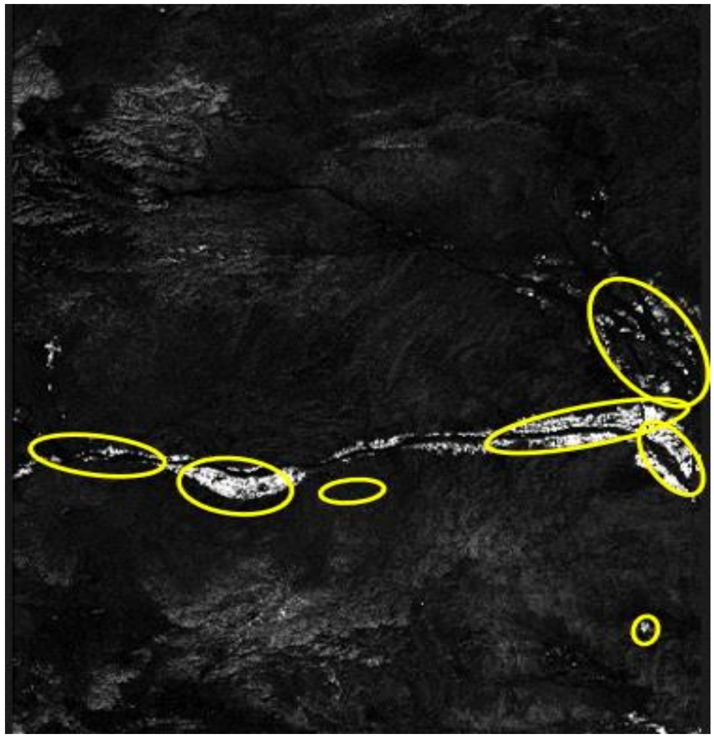

Fig 4.7 ASTER StVI= (Band 3/Band 2)(Band 1/Band 2) image shows vegetation as bright pixel

Putting ratio of band on one subscenes band4/band2 was indicated as bright pixels (Fig 4.8). Band ratio band 4/band2 is also identical to PC4 of PCA technique used. Past investigations have recorded the distinguishing proof of explicit modified minerals of hydrothermal characteristics by the examination of BR (SWIR region).

BR of 7/6 for is used for recognizable proof of muscovite. The features BR were used for muscovite in the investigation region since it is a helpful instrument in planning the overall impacts on the altered effects on hydrothermal sources. (Fig 4.9) shows the result of BR in our selected location. Zones of modified hydrothermal sources are appearing as white pixels in the BR since reflectance of muscovite is higher in band 7 and lower in band 6.

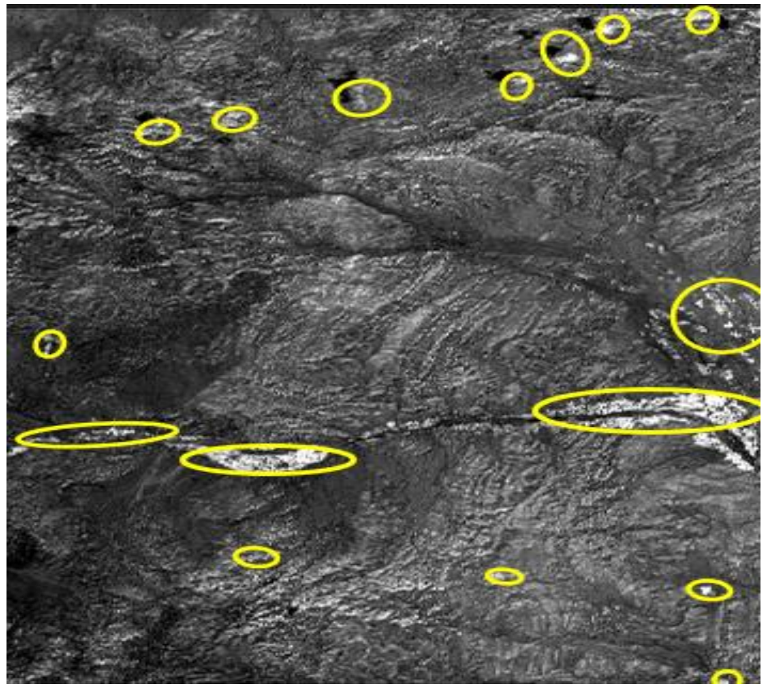

Figure 4.8 ASTER band ratio image of 4/2 shows Iron oxide minerals (Gossan) as bright pixels

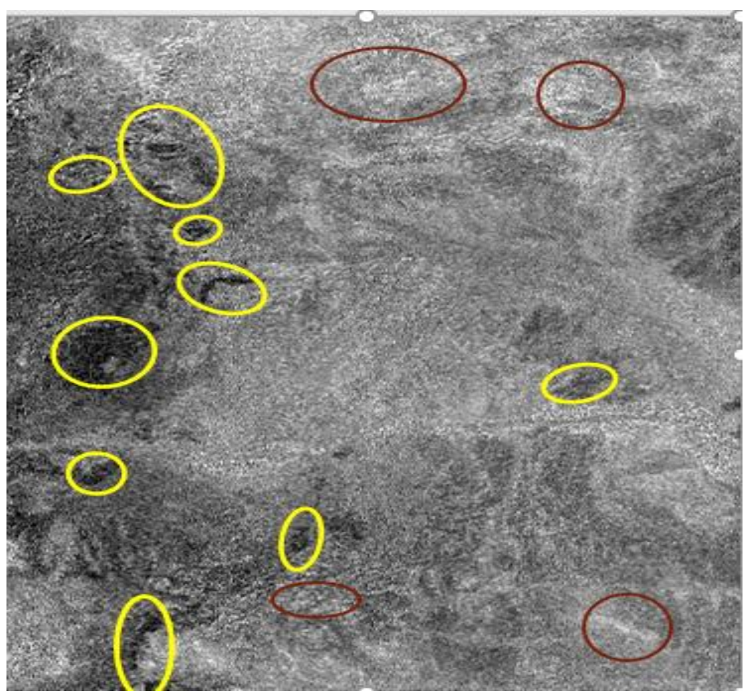

Fig 4.9 ASTER band ratio image of 7/6 shows hydrothermal altered zones

RBD Relative Absorption Band Depths images have been utilized in this examination to portray mineral collections utilizing SWIR Bands. Argillic adjustment zone is comprised of Kaolinite and alunite that showcases ingestion highlights at 2.09 lm (concur band 5). Phyllic alteration spectral qualities incorporate muscovite and illite reflectance spectral showing concentration of Al-OH absorption features. Similarly Al- OH assimilation include and is commonly focused at 2.19 lm (concur with band 6). Propylitic mineral array reflectance spectra are described by Fe, Mg-OH retention highlights and CO3 highlights brought about by sub-atomic vibrations in epidote, chlorite and carbonate minerals. These retention highlights are situated in the 2.35 micrometer region (concur with band8). One ASTER image is applied over by RBD. RGB guns were used to stack and generate outcome. Its colour shading combination were allocated to introduce the yield. In such manner, mineral accumulations are shown with different colors, narrow argillic areas as bluish green and wide phyllic as yellow shading that involved significant area of the hydrothermal modified mineral haloes, and propylitic zone as pinkish purple (Fig 4.11). The modification area of haloes is compared with featured ellipsoidal polygons in the images of PCA. Nonetheless, distinguished hydrothermal modification sectors are better conspicuous in correlation with PCA outcomes.

The image obtained from NASA website shows the presence of phyllic in yellow and argillic in red zones in (figure 4.11) . This infers that there is further need to investigate the region as many potential sites are present in the area . Thus validates the conclusions drawn from present study.

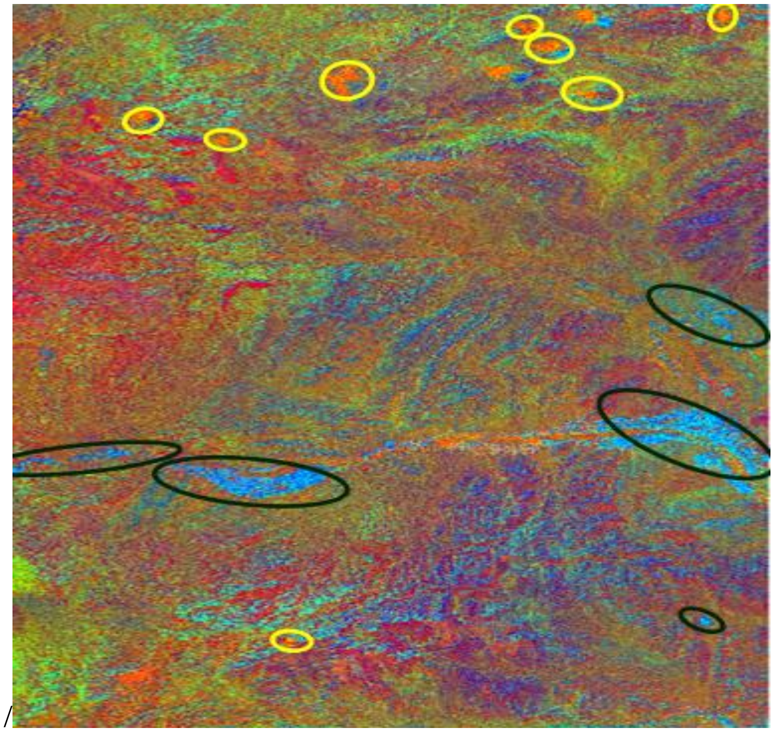

Figure 4.10 ASTER RBD-ratio image of RBD-5, RBD-6, RBD-8 in RGB. Argillic alteration zines manifest as dark blue and phyllic alteration zones as light purple color and prophyllitic alteration zone as maroon color in Datta Khel area

4.3 Ground truthing and validation

PC4 image is identical to BR 4/2 image depicting locations of Iron Oxide as bright colors (fig 4.12)

PC4 BR 4/2

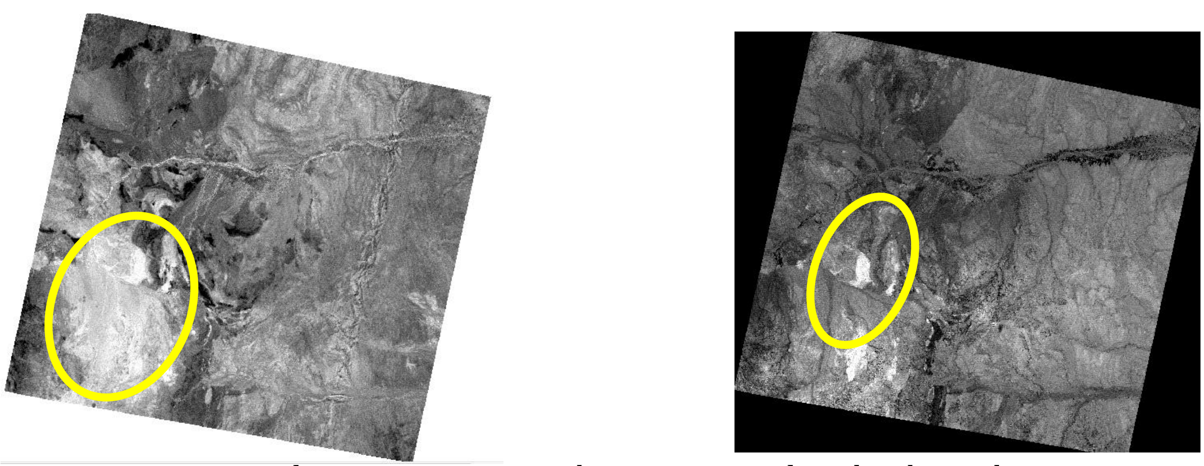

Figure 4.11 PC4 and BR 4/2 comparison showing iron oxide as bright pixels

PC5 image is identical to StVI image depicting locations of Vegetation as bright pixels (fig 4.13)

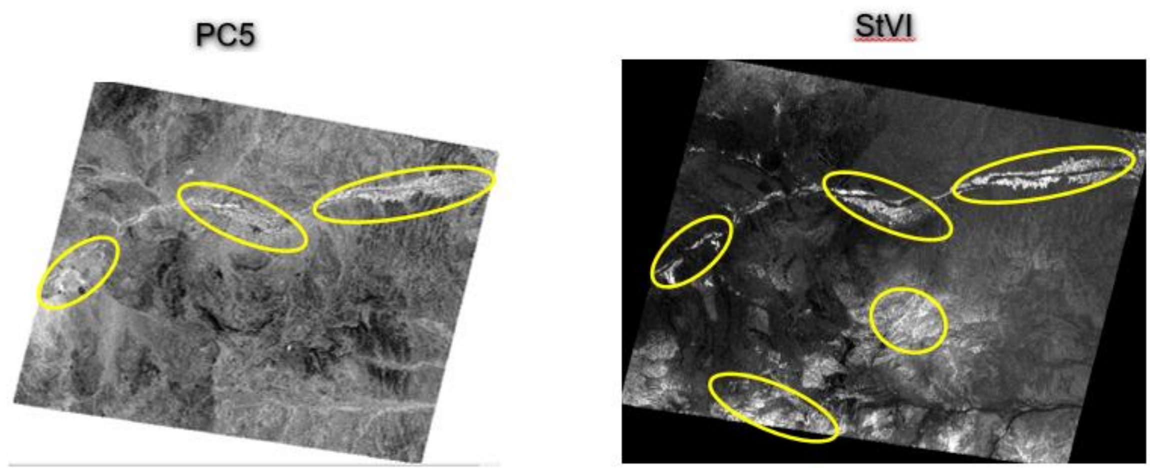

Figure 4.12   PC5 and STVI comparison showing vegetation as bright pixels

PC567 composite image in RGB shows hydrothermal zones where as RBD also shows hydrothermal zones

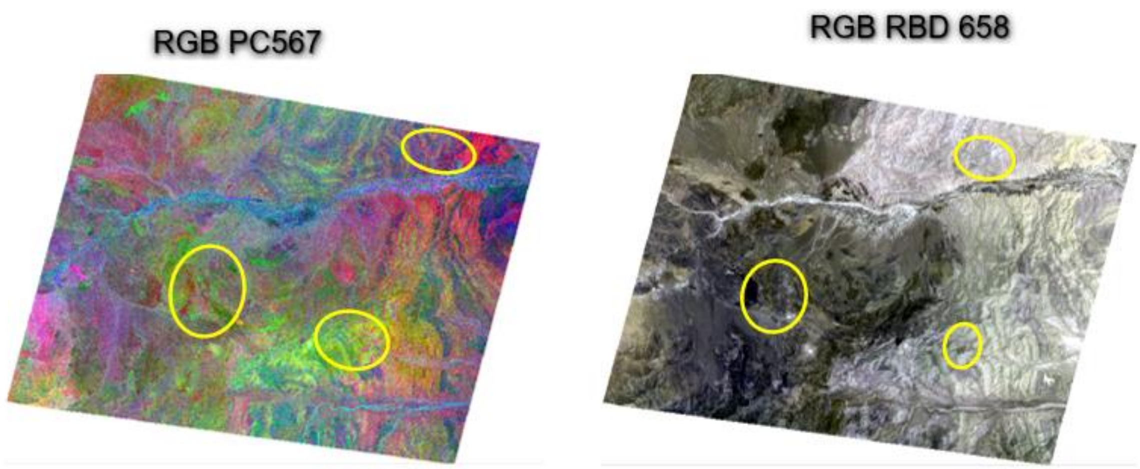

Figure 4.13   RBG 567 and RBG 658 comparison showing hydrothermal zones

CONCLUSION

Increasing demands for mineral resources with simultaneous depletion of the existing mineral resources requires very quick exploration of new and larger areas by obtaining the necessary geological and mineral anomalies information so that target areas for more detailed exploration can be identified. This is very difficult to be achieved solely by the usual conventional methods of exploration. Therefore, satellite based remote sensing and GIS based techniques need to adopted for quick and efficient completion of the mineral exploration. This research bestows ASTER data to recognize the porphyry copper mineralization related to hydrothermal alteration zones. Datta Khel region area of KPK has great economic significance and important for the country's overall future development. It has tremendous potential in the field of minerals which needed to be explored. Modern image processing techniques are used to explore new potential sites. Following techniques were used:

- PCA
- BR

For thorough hydrothermal alteration mapping, which direct us to the recognition of economically valuable zones for copper mineralization. ASTER level 1T data was acquired from earth data site of NASA USA. Examination and analysis of Data was subsequently done using Global Mapper, Erdas Imagine and Arc GIS 10.3 which provides standard data & information for hydrothermal mineral mapping.

Datta Khel area was classified by image processing techniques for mapping the existing hydrothermal alteration zones. The PC images were yielded using PCA transformation, which are valuable for distinguishing the spatial distribution of different materials which are present in VNIR + SWIR groups & dependent on their spectral properties. Iron oxides & vegetation which are available in the VNIR subsystem their distribution was uncovered by PC4, PC5, separately. All distinct pixels for minerals bearing OH- were recognized in PC6 and PC7 images of the SWIR subsystem. The PCA is based on measurements and with variable results in similar region with various geologic extents. Stabilized vegetation index (StVI) and band ratio of 4/2 portrayed iron oxides, individually. The results of band proportion (7/6) infers the effects of alteration through hydrothermal solutions and can be used as a distinct tool in mapping high-potential alteration zones. The color composites of RGB (6,5 and 8 images) were advantageous in identifying of the argillic, phallic, prophylactic mineral assemblages utilizing ASTER SWIR groups. This research proves that image processing techniques has great ability to assist economic geologists during reconnaissance stages of mineral exploration, and can be extrapolated to new regions for exploring high-potential copper/iron mineralization.

Recommendations

- Pakistan is filled with rich minerals like copper porphyries, iron oxide and gold minerals etc, therefore, Remote sensing can be a valuable tool in locating, mapping and evaluating these mineral deposits, As this method is inexpensive and require little knowledge and practice.
- Extensive education and training should be conducted at different national universities, so that the use of remote sensing technology and software use such as Global Mapper and Arc GIS etc. becomes a common practice for identifying and working on mineral deposits and general geological data/information.
- Further exploration and research should be conducted in view of this research work, in order to identify other mineral deposits, as Pakistan in general and Waziristan's mountainous belt in particular are rich in mineral deposits.
- Survey of Pakistan and SUPARCO, should work in close coordination, as some ASTER data types which are generally readily available for other developed countries are missing for Pakistan. Availability of different types of data, can enable us in locating, mapping and evaluating mineral deposits in every corner of the country, at different spatial resolutions, so that the physical need in initial stage is limited to none.
- Survey of Pakistan, should induct its own air craft mounted remote sensors for collection of all types of geological data, in order to facilitate remote mineral exploration.
- Awareness and education cadres should be conducted for the locals of these areas. As NASA data is freely available on the Internet. Locals, can conduct similar research on the land they own through this technology and can make a living out of it,
- It can be inferred that the various computer softwares along with the latest technologies of remote sensing and information technology, are highly valuable and essential for the understanding and assessment of the present or current status of the existing geological resources in any part of the world. Use of computer softwares be maximized in interpretation of the past and present data

as well as predicting the future status of these resources in any region which help in exploration of these mineral resources.

REFERENCES

Abdelsalam, M. G., Stern, R. J., & Berhane, W. G. (2000). Mapping gossans in arid regions with Landsat TM and SIR-C images: The Beddaho Alteration Zone in northern Eritrea. *Journal of African Earth Sciences*, *30*(4), 903–916. https://doi.org/10.1016/S0899-5362(00)00059-2

Are, T., Laborers, N. O. T., Survey, G., Wide, H. A. S., Of, S., & One, A. (1800). *Pn* . _ ~~. *2*.

Arivazhagan, S., & Anbazhagan, S. (2017). ASTER Data Analyses for Lithological Discrimination of Sittampundi Anorthositic Complex, Southern India. *Geosciences Research*, *2*(3). https://doi.org/10.22606/gr.2017.23005

Asgher Ali Daahar Hakro, Adnan Khan, & Sadaf Naseem. (2016). Mineralogical Investigation of the Bara Formation from Lakhra Anticline, Sindh province, Pakistan. *Journal of Basic & Applied Sciences*, *12*, 1–7. https://doi.org/10.6000/1927-5129.2016.12.01

Berger, B. R., Ayuso, R. a, Wynn, J. C., & Seal, R. R. (2008). Preliminary model of porphyry copper deposits. *Open-File Report - U. S. Geological Survey*, 55. http://search.proquest.com/docview/50492319?accountid=163493%5Cnhttp://pubs.usgs.gov/of/2008/1321/ http://pubs.usgs.gov/of/index-water.html

Crósta, A. P., & Moore, J. M. M. (1989). Geological mapping using landsat thematic mapper imagery in almeria province, South-East Spain. *International Journal of Remote Sensing*, *10*(3), 505–514. https://doi.org/10.1080/01431168908903888

Di Tommaso, I., & Rubinstein, N. (2007). Hydrothermal alteration mapping using ASTER data in the Infiernillo porphyry deposit, Argentina. *Ore Geology Reviews*, *32*(1–2), 275–290. https://doi.org/10.1016/j.oregeorev.2006.05.004

Earth, G. (2003). *Google Earth* (Vol. 32, Issue 1).

Gabr, S., Ghulam, A., & Kusky, T. (2010). Detecting areas of high-potential gold mineralization using ASTER data. *Ore Geology Reviews*, *38*(1–2), 59–69. https://doi.org/10.1016/j.oregeorev.2010.05.007

Geological Survey, U. (2020). Advanced Spaceborne Thermal Emission and Reflection Radiometer Level 1 Precision Terrain Corrected Registered At-Sensor Radiance (AST_L1T) Product, AST_L1T Product User’s Guide. *Open-File Report*, *1*(July), 1–68.

Google. (n.d.). *datta khel*. https://www.google.com/search?q=datta+khel+pic&sxsrf=ALiCzsa6vQkuN1man1l7SDPP8LYRSsOOFw:1655579459538&source=lnms&tbm=isch&sa=X&ved=2ahUKEwiB49SM2rf4AhXEi_0HHTQiBrsQ_AUoA3oECAEQBQ&biw=1517&bih=631&dpr=0.9

Hunt 1977.Pdf. (1977). In *Geophysics* (Vol. 42, pp. 501–513).

Hunt, G. R., & Ashley, R. P. (1979). Spectra of Altered Rocks in the Visible and Near Infrared. *Economic Geology Lancaster, Pa.*, *74*(7), 1613–1629.

Karim AM, et al. (2016) . (2016). *pakistan*. Epidemiology and Clinical Burden of Malaria in the War-Torn Area, Orakzai Agency in Pakistan. https://doi.org/https://doi.org/10.1371/journal.pntd.0004399.g001

Khan, A., Faisal, S., Shafique, M., Khan, S., & Bacha, A. S. (2020). ASTER-based remote sensing investigation of gypsum in the Kohat Plateau, north Pakistan. *Carbonates and Evaporites*, *35*(1). https://doi.org/10.1007/s13146-019-00543-x

Loughlin, W. P. (1991). Principal component analysis for alteration mapping. *Photogrammetric Engineering & Remote Sensing*, *57*(9), 1163–1169.

NASA. (n.d.-a). *datta khel pin location*. https://search.earthdata.nasa.gov/search?fi=ASTER&lat=50.297190954227894&long=108.26806640625&overlays=referenceFeatures%2Ccoastlines%2CreferenceLabels&zoom=3

NASA. (n.d.-b). *NASA site*. https://search.earthdata.nasa.gov/search?fi=ASTER&lat=62.08606049921281&long=138.7265625&overlays=referenceFeatures%2Ccoastlines%2CreferenceLabels&zoom=3

Ninomiya, Y. (2003). A Stabilized Vegetation Index and Several Mineralogic Indices Defined for ASTER VNIR and SWIR Data. *International Geoscience and Remote Sensing Symposium (IGARSS)*, *3*(August 2003), 1552–1554. https://doi.org/10.1109/igarss.2003.1294172

Pour, A. B., & Hashim, M. (2011). Identification of hydrothermal alteration minerals for exploring of porphyry copper deposit using ASTER data, SE Iran. In *Journal of Asian Earth Sciences* (Vol. 42, Issue 6). https://doi.org/10.1016/j.jseaes.2011.07.017

Rajendran, S., & Nasir, S. (2013). Mapping of manganese potential areas using ASTER satellite data in parts of Sultanate of Oman. *International Journal of Geosciences and*

Geomatics, *1*(2), 92–101.

Sheikhrahimi, A., Pour, A. B., Pradhan, B., & Zoheir, B. (2019). Mapping hydrothermal alteration zones and lineaments associated with orogenic gold mineralization using ASTER data: A case study from the Sanandaj-Sirjan Zone, Iran. *Advances in Space Research*, *63*(10), 3315–3332. https://doi.org/10.1016/j.asr.2019.01.035

Siddiqui, R. H., Aftab, S. M., & Chaudhry, A. H. (2018). Hydrothermal Alteration in Porphyry Cu-Mo-Au Mineralizations of the Chagai Arc, Balochistan, Pakistan. *IOP Conference Series: Materials Science and Engineering*, *414*(1). https://doi.org/10.1088/1757-899X/414/1/012033

Sillitoe, R. H. (1972). Model for Porphyry Copper Systems. *Economic Geology*, *67*(7), 1010-. http://ezproxy.utas.edu.au/login?url=http://search.proquest.com/docview/742899977?accountid=14245%5Cnhttp://www.segweb.org/

USGS. (n.d.-a). *usgs lat,long*. https://earthexplorer.usgs.gov/

USGS. (n.d.-b). *usgs site*. https://earthexplorer.usgs.gov/

Wright, S. P., & Ramsey, M. S. (2006). Thermal infrared data analyses of Meteor Crater, Arizona: Implications for Mars spaceborne data from the Thermal Emission Imaging System. *Journal of Geophysical Research: Planets*, *111*(2). https://doi.org/10.1029/2005JE002472