



Thesis

Mineral Exploration Using Satellite Imagery

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Declaration

We hereby declare that we have complied this thesis on our own based on the study on the topic of Mineral Exploration Using Satellite Imagery. This thesis was submitted to the Department of Electronics & Communications Engineering to fulfill the partial requirement of the degree of B.Sc. in Electronic & Communication Engineering.

We claim that this work which is demonstrated in this compilation is our own work. We also declare that this work has not been submitted anywhere for publication.

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Mineral Exploration Using Satellite Imagery

Letter of Acceptance

The thesis entitled by the “Mineral Exploration Using Satellite Imagery “submitted by Mirza Mahdi (2015-1-50-011) &Rakibul Hafiz Ridoy (2015-2-50-016) to the department of ECE, East west University , Dhaka , Bangladesh is granted by the department. In some achievement of assertion for the Reward of the Degree of Bachelor of Science in Information & Communication Engineering in April 2019.

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Thanks you all for supporting us.

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Approval

This thesis on Mineral Exploration by Using Satellite Imagery submitted by Mirza Mahdi ID : 2015-1-50-011 & Rakibul Hafiz Ridoy ID: 2015-2-50-16 to department of Electronics and Communication Engineering , East West University . It is submitted in partial fulfillment of the requirements for the degree of B.Sc. in Electronic and Telecommunication Engineering.

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Abstract

Minerals and some crucial rock exploration techniques have been described in this thesis. Mineral exploration is the process where Satellite or remote sensing instrument are necessary. Satellite image processing is used for mineral detection. For finding mineral, several satellite like Landsat satellite, Terra satellite band technology and some advanced sensor like TM, OLI, TM have their usages. Satellite active and passive sensors are very important for sensing minerals. This sensor supports in to collect electromagnetic spectral band extraction. Satellite spectral band 1 to band 9 have usage in Landsat 8 satellite. Landsat 8 is more effective to find out the minerals. This band are the part of electromagnetic spectrum which help to distinguish the mineral reflectance characteristic and absorption band features. The earth object spectral characteristics is different which contain several color combinations like True color, False color and Band ratio technique help to identify the minerals. Some remote sensing software are used to understand the picture and enhance the picture quality. Thermal imaging is another method which identifies the earth surface minerals temperature. Thermal behavior of altered minerals can detect by Satellite Thermal sensor camera and record the information and it can display different color for different mineral and help us to distinguish minerals.

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Chapter 1

Introduction

1.1 Introduction to mineral exploration

Minerals exploration is one of the most primitive human activities, that has been promoted during the last 6000 years in the industry, with modern technology. Exploration means finding unknown mineral source. Many scientific techniques and are used for mineral exploration. The exploration is principally a process of gathering information. Mineral exploration means identify the alteration rock and some minerals. There are many precious minerals and rock exists in earth surface and under the soil. Mineral is a blessing for us and it can be used in many ways. Mineral exploration is very difficult because of it will not exist everywhere. Mineral exploration is very important because minerals are rare and it has huge demand for his extraordinary characteristics. In early mineral exploration procedure was very hard and take more time because of technological issue. All the step had been taken by manually and it took more time but at present technology has been developed. Mineral exploration has many techniques but most three popular techniques is Geological technique, Geophysical technique and Geochemical technique. In geological technique geologist spend time in the possibility area and looking minerals and rocks This is called mapping technique. In geochemical system geologist collect rock, soil and vegetation sample and analyses in laboratory. The geophysical technique is a technique where the system set some property of minerals for identify the specific minerals and rocks. Satellite remote sensing is one of the best and effective technique for mineral exploration. Remote sensing first began in 1840 and inventor Balloonist took picture by the newly invented camera. satellite Remote sensing is a technique where satellite or any aircraft has been used to find geographical information, mineral mapping, lithological mapping, radiometric data, thermal spectral information by specific sensor. Remote Sensing is the technology of acquiring spectral, spatial, temporal information about physical objects, area, without coming close to the physical objects. In remote sensing method, information assignment is accomplished by use of electromagnetic radiations. Sensor is used to collect the earth surface information which is reflected, refracted or Scattered by atmosphere. This technique uses to gather information of any object and radiation of any particular object indicate different characteristic. For mineral exploration by Satellite image remote sensing is one of the greatest technique all over the world. Satellite has many sensor and multispectral camera for detecting surface object and identify different characteristics of those type of object. Satellite active and passive sensor is very useful to collect information. Basically in remote sensing technology Electromagnetic energy has been use. The satellite active and passive sensor use the electromagnetic energy for mapping mineral. When the electromagnetic energy is incident on any earth surface object, three vital energy interactions with the object are conceivable those are reflection, absorption and transmitted. The characteristics of energy reflection, absorption and transmitting will differ for different earth features, depending on their material type. These changes authenticate us to discriminate different features on an image. The part of reflection, absorption and transmitting energy will

differ at different wavelengths. Hence, two landmarks can be distinguishable in one spectral range. For mineral exploration many Satellite has been usages. Most popular satellite which have been usages for minerals identification are Landsat 8, Landsat 7 , TerraSaar -X . All of the mineral exploration satellite consists with advanced technologies and powerful sensor. The sensor consists of camera and it also has capability to distinguish thespectral reflectance of earth surface object. All of the mineral exhibit different kinds of spectral characteristics. Only mineral can't show spectral behavior earth surface all of the object show spectral reflectance and their spectral band also unique.satellite sensor can detect and distinguish the electromagnetic spectral reflectance and mapping with different color. electromagnetic visible band can detect vegetation area, Water and some rock. This type of object shows their true color. The object which can't visible for human eye those object can detect by the electromagnetic SWIR, LWIR, NIR band. This type of mineral can't show their original color .BY using False color imaging it can be possible to see invisible image.Satellite image processing is most important part for mineral exploration During image data collection satellite can't collect proper data due to atmospheric absorption. Earth surface atmosphere consists of ionosphere,troposphere, ozone layer and many other materials like water,Hydrogen, Oxygen etc. This type of layer absorb radiation which has been transmit by earth object. As a result, minerals originals spectral characteristics can't detect by the satellitesensor. The image data which has been collect it can't contain proper information so that image processing is necessary.Image processing help to enhance the picture quality. For image processing Band ratio technique, principle component analysis has been usages. This are the most popular and effective technique. Many image processing software like QGIS,SAGA,OASIS, GIMP have been used for satellite image processing and mineral identification.

Chapter 2

Satellite

2.1 Satellite

Satellite is an object that is moving in a curve path around a planet orbit. Basically Satellites are intentionally placed on the orbit. It is moving all over the earth. There are two types of satellite natural & artificial. Natural satellites are moon, earth, Jupiter, Venus etc. and many artificial satellites are manmade satellite like Sputnik-1, Sputnik-2, Explorer-1, Omed, Viking etc. First Satellite Sputnik-1 was launched by the Soviet Union 4th October 1957. Since then there are 8100 satellite are launched by 40 countries all over the world. The main purpose of satellite is developing better communication link in all over the earth. Satellite communication is much faster and reliable than other technology. Satellite has different kind of activities in all over the world like navigation, military battle zone performance, rescue operation, reconnaissance information, weather observation etc.



Figure 2.1 : Satellite. [26]

2.2 Components of Satellite

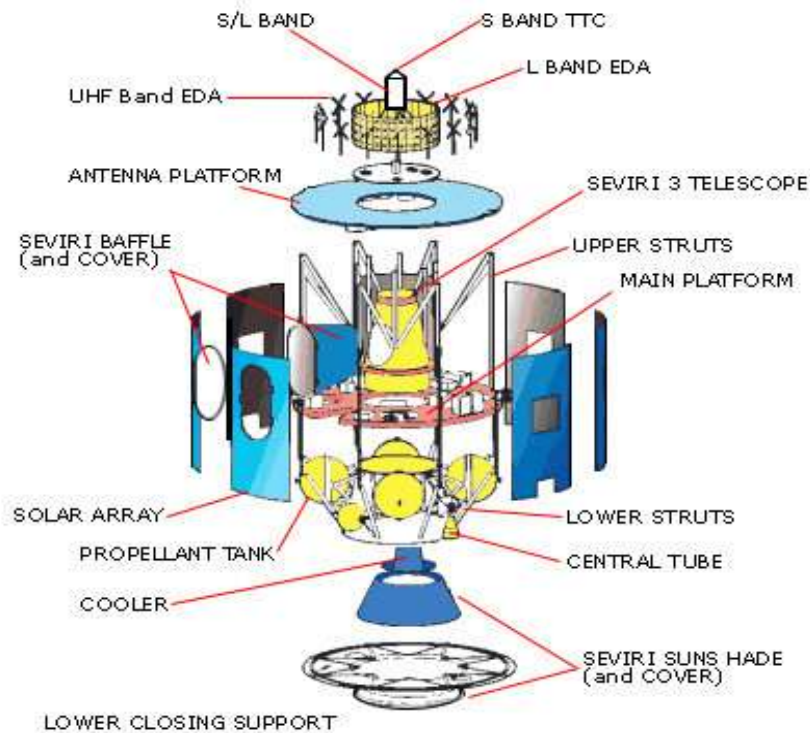


Figure 2.2 : Satellite architecture.[27]

Satellites are very complicated machine that have very perplexing components. Cost of making satellite is very expensive. Satellite components producing is very complex and expensive. The high quality components make satellite more efficient and strong coverage capability. Every satellite component plays an important role for operation. There are many components in a satellite. Subsystem is a major component of satellite and subsystem has different groups. Command and satellite data handling subsystem consists of computer and process data by computer instruction. Satellite also has a power subsystem which produce, distribute and store electric power. Satellite also has a solar cell system this solar system extract energy from sun light. The solar system help satellite for power supply distribution, Communication system and navigation system. Satellite has a transponder which help to shift uplink frequency and downlink frequency. Transponder can transmit and receive simultaneously so that it is called transponder. A communication satellite can have 12 to 24 transponder. Another component are antenna, Propellant tanks, cooler, central tube, upper structure and lower structure.

2.3 Some important Parts of Satellite

Basically Communication Satellite Need Uplink antenna and Downlink antenna for data communication between earth station and satellite. These are the vital parts of satellite,

Transponder: Transponder receives and transmits radio signal any specific frequency range. After receiving the radio signal it will retransmit or broadcast data by different frequency range. Transponder is used in satellite for navigation, location identification, data transmission etc. The transponder circuit helps convert 6 GHz uplink frequency to 4 GHz Downlink frequency.

Antenna: Antenna helps to receive and transmit signal from earth station. There are various types of antennas fixed on satellite based applications such as dipole horn, monopole, reflector, parabolic, micro strip etc. Most commonly there will be reflector antenna along with beam to cover one earth station on earth.

Solar System: It will help satellite to keep running on orbit. This is a power system which helps to keep active on the planet earth. Solar cell helps convert solar energy to electric energy. During the sunlight it is very useful and it has a battery backup system.

2.4 Orbits of Satellite Orbit is an object where the satellite exists and operates all over the planet. Generally, there are three types of Satellite orbit: High Earth Orbit, Low Earth Orbit, Medium Earth Orbit. Basically weather satellite and some of the communication satellites are used in High Earth Orbit. Navigation and GPS tracking satellites are used in Medium Earth Orbit. Low Earth Orbit is used by the Scientific satellite and NASA's Earth Observing satellite uses this type of orbit.

2.4.1 Geo-stationary orbit

This orbit distance from the earth is around 36000 km. The satellite which exists in this orbit can cover all over the earth. Weather observing satellite operates from this Geo-stationary orbit. The orbit height and distance consider how fast and quickly satellite moves around the earth. Earth orbiting satellite generally controlled by the earth gravity. When satellite gets close to the earth the pull of gravity gets more strong and satellite moves more quickly. Weather satellite exists from earth around 36000 km and it takes 23 hours 54 minutes to complete an orbit.

2.4.2 Medium earth orbit

This orbit distance from the earth is around 26500 km. This is the medium range orbit. Satellite in a medium earth orbit moves more quickly. A satellite in this orbit travels at approximately 7.3 km per second. Another two Medium Earth Orbit are notable which are semi-synchronous orbit and Molniya

orbit. Semi synchronous orbit exist around 26500 kilometers above from the earth surface as a result satellite need 12 hours to complete the orbit. This orbit used by the Global Positioning System satellites. This Orbits mainly used for telecommunications based satellite operation. Molnia orbit invented by Russia and it is very effective to observing high latitudes. It is basically use for alternative of Geostationary orbit.

2.4.3 Low earth orbit

This orbit is located from the earth is around 1000 km. This is the lowest distance orbit from the center of earth. Satellites in this circular orbit travel at a speed of around 7.80 km per second. A satellite takes approximately 90 minutes to circle the Earth. Most scientific satellite and many weather satellite are use this orbit This orbit are generally used for remote sensing, military purpose, communication and satellite image sensing. this orbit allows to rapid communication between satellite and earth.

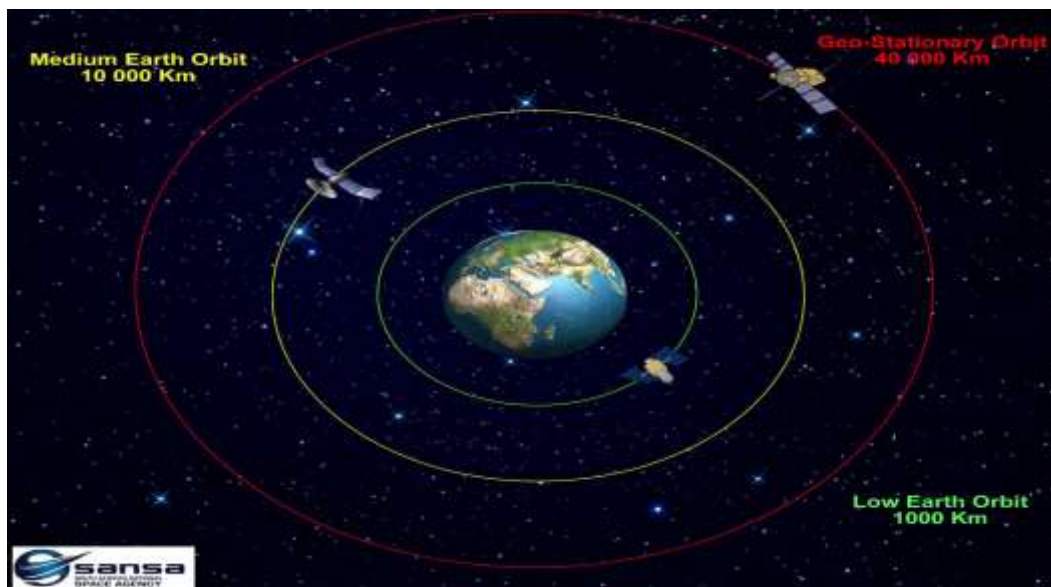


Figure 2.3 : Satellite Orbit. [28]

2.5 Types of Satellite

Satellites are used for many different purposes. These types of satellites are very crucial for better communication and earth observation.

Communication satellite

A communication satellite is nothing but an artificial body that is placed in Earth's orbit. It is used for the purpose of both sending and receiving data between a source and destination. It can also be used to provide data communication and for relaying televisions, radio, weather telecommunication and internet services. Typically, a communication satellite works using electromagnetic waves when it receives data from earth-based stations. Using large satellite antennas, the data is usually sent. It can also be said to be a wireless communication device in Earth's orbit to send and receive data from Earth. From one earth-based communication station to another it is primarily used to redirect communication. The communication satellite redirects the wave to the correlated destination based on the intended station.

Astronomy Satellite

The Astronomy Satellite is in orbit above the Earth; it also makes up the Earth's atmosphere, not clouded by the gases. It is not confused by the heat of the Earth because of infrared imaging equipment. This is a telescope similar in strength to the best on Earth, but in space it is ten times better.

Atmospheric studies satellite

Very first satellites launched into space were atmospheric studies satellites. They are pretty low Earth orbits so that they can study Earth's atmosphere. The first satellite launched, named Alouette by Canada, was also the world's first atmospheric studies satellite. The study of the ionosphere by the Alouette Canadian scientists were trying to learn more about the aurora borealis, which create brilliant lights in the northern skies at night.

Navigation satellite

Nowadays, navigation systems like GPS tracking have become a useful part of our daily modern life, such as driving across unknown roads, video games on our smartphones, finding the nearest outlets. Let's start about what are the satellite navigation systems. The full form of GPS global positioning systems is one of the most popular navigational systems. It consists of a group of satellites crossing orbits above the Earth. Basically, satellite navigation is used for military applications but in time dependency it has become popular in civilian applications.

especially in road navigation. Without proper navigational system like GPS does not decades after introduction, many of the functions in aviation, logistics, shipping etc.

Reconnaissance satellite

Reconnaissance satellite, launched by a country to provide intelligent information to the military activities of foreign countries. The major four types satellite missile launching to detect enemy. The nuclear-explosion detection satellite is designed for detecting also identify nuclear explosions. For the photographs to enemy military activities are detect by photo-surveillance satellite. There are two sub types: the high resolution photographs that are returned to earth via a reentry capsule, which is called close look satellites, another lower-resolution photographs that are transmitted to earth via radio is called area-surveysatellite. Later satellites are combined this two major functions. The another satellite use radar that provide images of enemy activity when it is dark also cloud cover. in addition while passing over a foreign country pickup and record radio and radar transmissions is done by electronic-reconnaissance.

Remote sensing satellite

Global dimensions satellite remote sensing provides a unique reason on the state and dynamic changes occurring in coastal, and oceanic ecosystems and land also. This satellite also provides detailed global observations of both natural a and anthropogenic ally induced changes in land surface, so the determine ecological health, sustainability and dislocations.

Search and Rescue satellite

The weather satellite programmers were helped to established of search and rescues satellite. BY monitors weather patterns from direct observation. By analyzes signals sent out from buoys floating in the ocean. Then the buoys collect the local information and transmit that to the satellite. The satellite uses the Doppler effect to find out the particular buoy. This is the main mechanism to the used for search and rescue.

Weather satellite

The first weather satellite to be considered a success was TIROS-1, launched by NASA on april 1, 1960. TIROS operated for 78 days and proved successfully than Vanguard 2 much more. The weather satellite is primarily used to monitor the weather and the climate of the earth. Weather satellite images helped in monitoring the volcanic ash cloud from Mount St. Helens and activity from other volcanoes. Other environmental satellites can detect changes in the Earth's vegetation, sea state, Ocean color and ice field.

Recovery satellites

The recovery satellite has been used in several fields. TT& C operation for recovery of the satellites is most important for reentry braking maneuver. This satellite finishing appointed missions, its needs to reenter into the atmosphere, land on the pointing area. The satellite control center on ground transmitted commands receives telemetry parameters from the satellite, and calculate reentry trajectory. After receiving some commands, the satellite performs some maneuver operations.

Earth observation satellites

Hemant Photonic explored the idea of using orbiting spacecraft for detailed peaceful and military observation of the ground realities in his 1928 book, *The Problem of Space Travel*. Now a days Earth observation has become Technologically sophisticated increasingly.

Chapter 3

Remote sensing Satellite & Sensor

3.1 Geological Information

In remote sensing mineral exploration Geological setting is very important. Earth surface show different kind of geological characteristics. Different location has a different kinds of features. Two third of the earth surface consist of water. There are so many hill, forest and vegetation area exist in all over the world. Soil characteristics and type are different from one area to another area. Atmosphere are also different from different location. If one area has winter another area can have sunny weather. Earth surface has many several type of area like desert area, tropical area, mountain area, deep water sea, dense forest area, ice with snow area. Each geographical area consists of different characteristics. Earth surface different location carry different kinds of material. Earth surface material or object always radiate, reflect. The material or mineral use sun light for reflection. Which is collected by satellite sensor. Satellite has active and passive sensor for extracting information. For atmospheric change of different location reflection and scattering is also different. Remote sensing data can help to distinguish different pattern of different location. It is help to geological mapping for mineral exploration or other different kinds of activities. It helps to find out the geomorphological information, earth surface motion, earthquakes. All Mineral characteristics are different. Every geographical area can't contain all mineral. Specific types of mineral can find in a certain location. For example, the possibility of getting Petroleum and Gold area is desert. In snow area it is not possible to get this type of mineral. The mineral which is found in mountain area it is less possible to get in desert area. Remote sensing data is visualizing by Geological Information System. Satellite generally use shorter wavelength to detect the mineral. Longer wavelength express thermal exception, large scale information and surface area roughness. Geologic mapping provides many types of information about mineral deposit area and exploration.

3.2 Lithology

Lithology is originally mean rock. In all over the world the research of rock and its information data is called lithology. Lithology study help to know and understanding about rock type. Lithology also helps to know about the different color, size, shape, grain size, rock unit, material, properties and characteristics of rock type. Lithology is the proper physical description of rock and mineral. There are many mineral and rock in all over the world which has different characteristics. Rock types can be change by natural alteration. Rock and mineral alteration is an important part of lithology which help us to know about the changes of rock characteristics. Naturally altered mineral and original mineral has different characteristics. Lithological study helps us to know about the thing. In satellite mineral

exploration technique this is a vital term to know about the lithological information. Every rock and mineral has a different characteristics and they show different types of radiation. Satellite use different kind of wavelength to detect the mineral and rock. If we don't know about the lithology it is not possible to explore the mineral and rock. Lithology science data is a blessing for satellite mineral exploration.

Generally, three types of rock are existing in all over the world. Those are metamorphic, sedimentary and Igneous.

3.2.1 Metamorphic Rock

Metamorphic rocks are consisting of under the earth surface and this rock transformation occur due to intensity heat and pressure. This type of rock arises from the transformation of existing rock. Metamorphic rock covers a huge part of the Earth surface approximately 14%. Metamorphic rock produce by the tectonic collision of soil. The perusal of metamorphic rocks provides information about the temperatures and pressures which occur at great depth in the Earth's lithosphere. Example of some metamorphic are slate, marble, quartzite, schist, kyanite, garnet, sillimanite, staurolite etc.



Figure 3.1 : Metamorphic Mineral.[29]

3.2.2 Sedimentary Rock

Sediment rocks are called because they are consisting of sediment. Generally, four primary procedure reengaged in the formation of a sedimentary rock those are erosion, transportation, deposition, and compaction. Sediment rock are generally made from broken material of surface. It is also produce for collision and weather change of earth. Sedimentary mineral is made from shell, sand, ballast and other material that is why all these material are named as sediment. These material can contain fossils. Normally sedimentary rocks are soft and fragment easily. Sediment rock mineral are very difficult to align. 75 percent rock of earth surface are sedimentary rock. There are some common example of sedimentary rock like argillite, breccia, chalk, chert, claystone, coal, conglomerate, dolomite, limestone, gypsum, shale, turbidit, siltstone, greywacke etc.



Figure 3.2 : Sedimentary Rock. [30]

3.2.3 Igneous Rock

Igneous mean fire. Igneous rock is consisting from Induration and cooling of magma and lava. Lava or magma can be made from the melt of an earth rock. Melting of rock is an another process. Three process is use to melt rock those are temperature increasing, pressure decreasing and composition change. Generally, 1200° Celsius temperatures are needed to form an Igneous type rock. Igneous rock consists by the crystallization after these process produce granular. When lava cool very quickly it can't produce crystal form as a result rocks are look like shine and glass. Two types of Igneous rock are existing in all over the world intrusive and extrusive rock. Intrusive rocks are build when lava or magma cool gradually and Extrusive rock are build when molten magma drop over the terra surface. Andesite, Basalt, Dacite, Gabbro, Granite, Scoria, Tuff, Peridotite, Nepheline, Pegmatite, Fire opal are the example of Igneous rock.

Igneous Rocks



Figure 3.3 : Igneous Rock.[31]

3.3 Passive sensor

These sensors collect data by using reflected or transmitted parts of the electromagnetic (EM) spectrum. They rely on solar illumination of the ground and natural thermal radiation for their source of energy respectively. This sensor does not create electromagnetic energy it is use natural light source to detect and collect information from earth. The passive satellite is a reflector which is receive the signal from the transmitting earth station and scatters the signals in all the direction.

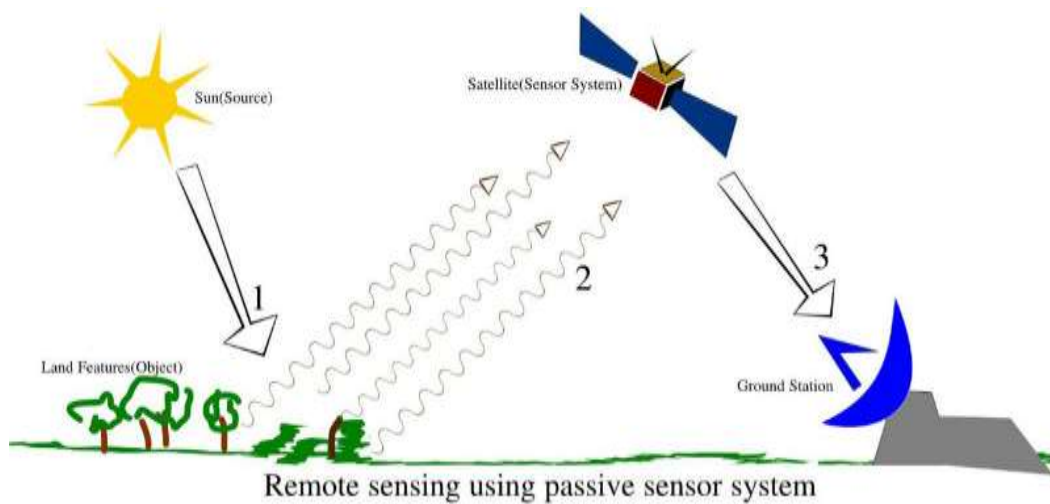


Figure 3.4 : Passive Sensor.[32]

3.4 Active Sensor

These sensors use their own source of energy. They emit energy and measure the intensity of energy reflected by a target. Active sensor creates own electromagnetic energy and transmit by sensor on the earth surface and collect the radiation data and restore the information. It has own transmitting & receiving antenna. Activesensor isLidar, Radar, GPS Sonar.

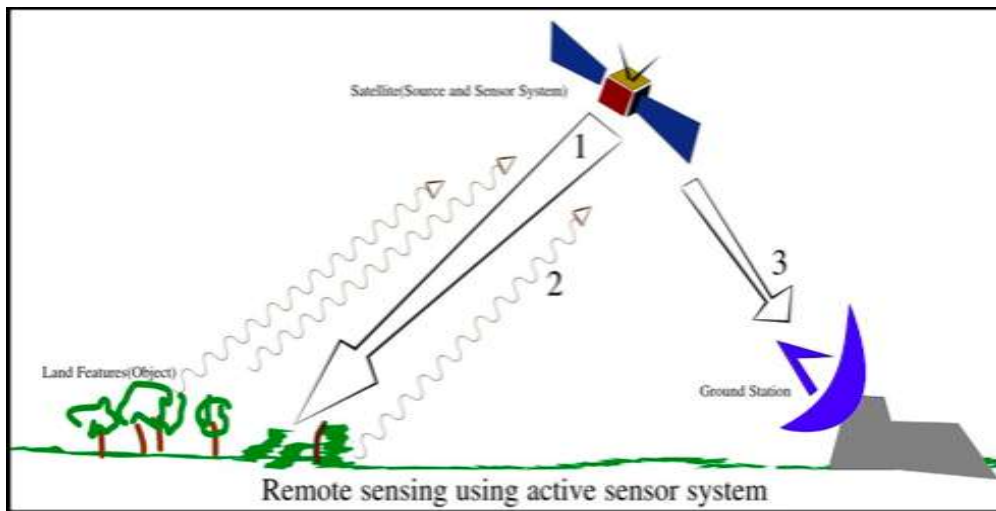


Figure 3.5: Active Sensor. [33]

3.5 Landsat

Landsat are the Satellite which used for gathering information and location mapping and extract ground surface data by remote sensing technique. Landsat use multispectral image for gather data. The Landsat program consists of a series of infrared remote sensing satellites for land observation. Exploration, mapping mineral and GPS and Location tracking are the main purpose of invention of Landsat series satellite. Landsat Satellite consists of different kind of sensor, camera and and Spectral Band. Landsat Satellite has the spectral band and optical ground resolution for track land. Basically this type of satellite was inventing for mineral exploration. Landsat. Landsat satellites have been prepared with digital electromagnetic sensors like MSS, TM, ETM, OLI is used to sense earth surface. This sensor has camera and specific Band to detect earth object.

3.5.1 Landsat Multispectral Scanner

This is the previous version Landsat sensor which had been used Landsat 1 to 5 use Multispectral Scanner and this MSS image consist of four spectral band with 60 m spectral resolution. The coverage area of MSS sensor is 170 km north-south and 187 km east west. MSS has optomechanical sensor system and spectral range in 0.5-1.1 micrometer. Image size is 185 km x 185 km. Multispectral Scanner collect data by green, red, blue and two near infrared band with 60-meter pixel size and the swath width is 185 km. The sensor can Detect visible, non-visible object.

Landsat 3 , 2 , 1 Multispectral Sensor Band

Band Number	Description	Wavelength	Resolution
Band 4	Visible green	0.5 to 0.6 μm	60 meter
Band 5	Visible red	0.6 to 0.7 μm	60 meter
Band 6	Near infrared	0.7 to 0.8 μm	60 meter
Band 7	Near infrared	0.8 to 1.1 μm	60 meter

3.5.2 Thematic Mapper

Thematic Mapper is progressive and Multispectral scanning and it has sophisticated image resolution, improved geometric reliability, sharper spectral separation and superior radiometric accuracy. Landsat Thematic Mapper sensor used by Landsat 4 and Landsat 5 satellite. Thematic mapper image consists of six spectral band and with a spatial resolution of 30 meter. Thematic mapper has optomechanical sensorsystem. Band 1 to 5 and 6 ,7 band is use in this sensor. The coverage area of Thematic Mapper is 170 km north-south and 183 km east-west. Thematic mapper uses 7 spectral band and it has night scenes in band 6. The spectral range of this sensor is 0.45 – 12.m micrometer. Thematic Mapper sensor collect image in visible, near infrared, mid infrared and thermal bands with spatial resolution 30 m. The sensor can Detect visible, non-visible object.

Landsat 5 & 4 Thematic Mapper Band

Band number	Wavelength	Description	Resolution
Band 1	0.451 to 0.521 μm	Visible blue	30 meter
Band 2	0.521 to 0.601 μm	Visible green	30 meter
Band 3	0.63 to 0.69 μm	Visible red	30 meter
Band 4	0.76 to 0.90 μm	Near-infrared	30 meter
Band 5	1.55 to 1.75 μm	Short-wave infrared	30 meter
Band 6	10.4 to 12.3 μm	Thermal	120 meter
Band 7	2.08 to 2.35 μm	Short-wave infrared	30 meter

3.5.3 Enhanced Thematic Mapper plus

Landsat 7 satellite carries ETM plus sensor and it is consisting of seven spectral band. Landsat 7 ETM plus is consist of thermal infrared band. panchromatic band 8 added for gather higher spatial image resolution. The Band 8 resolution is 15 meters All band can gather more than one gain settings for high or low radiometric sensitivity. Band 6 of Landsat collect both low and high gain picture. The coverage area of Landsat ETM plus sensor is 170 km north-south and 183 km east-west. This sensor detects spectral radiation by the electromagnetic spectral band LWIR, SWIR, VNIR from the form 700 km above earth surface. Landsat Enhanced Thematic Mapper plus sensor type is opto-mechanical and its spectral range is 0.45 to 12.5 micrometer. The sensor can detect visible, non-visible object.

Landsat 7 Enhanced Thematic Mapper Band

Band Number	Wavelength	Description	Resolution
Band 1	0.45 to 0.52 μm	Visible blue	30 meter
Band 2	0.52 to 0.60 μm	Visible green	30 meter
Band 3	0.63 to 0.69 μm	Visible red	30 meter
Band 4	0.76 to 0.90 μm	Near-infrared	30 meter
Band 5	1.55 to 1.75 μm	Near-infrared	30 meter
Band 6	10.4 to 12.3 μm	Thermal	60 meter
Band 7	2.08 to 2.35 μm	Mid-infrared	30 meter
Band 8	0.52 to 0.90 μm	Panchromatic	15 meter

3.5.4 Landsat 8 OLI and TIRS Sensor

OLI is an advanced Landsat sensor Technology that was first used in Nasa's EO-1 satellite. OLI is more reliable and performance is better than other Landsat sensor. OLI and TIRS sensor consists of nine spectral bands and spatial resolution of 30 meters. Ultra blue Band 1 is use for coastal area. Band 9 is useful for cloud detection. OLI is basically use for mineral exploration. Thermal band 10 and 11 are used for gather accurate surface temperature. The coverage area of OLI and TIRS are 170 km north-south and 183 km east-west. Landsat OLI image can distinguish vegetation, cultural feature, vigoreasily. TIRS is consist of two thermal band and those spatial resolution is 100 meters. TIRS can measure earth's Thermal energy and it can track the earth object like water, soil, hill, vegetation area, minerals. TIR temperature sensor sense electromagnetic wave in 700 nm to 1400 nm range. TIR sensor can detect moving and small object.

Landsat-8 Operational Land Imager & Thermal Infrared Sensor Band

Band Number	Wavelength	Description	Resolution
Band 1	0.433 to 0.453 μm	Coastal / Aerosol	30 meter
Band 2	0.450 to 0.515 μm	Visible blue	30 meter
Band 3	0.525 to 0.600 μm	Visible green	30 meter
Band 4	0.630 to 0.680 μm	Visible red	30 meter
Band 5	0.845 to 0.885 μm	Near-infrared	30 meter
Band 6	1.56 to 1.66 μm	Short wavelength infrared	30 meter
Band 7	2.10 to 2.30 μm	Short wavelength infrared	60 meter
Band 8	0.50 to 0.68 μm	Panchromatic	15 meter
Band 9	1.36 to 1.39 μm	Cirrus	30 meter
Band 10	10.3 to 11.3 μm	Long wavelength infrared	100 meter
Band 11	11.5 to 12.5 μm	Long wavelength infrared	100 meter

3.5.5 ASTR Satellite Sensor

Aster means Advanced Space borne Thermal mission and Reflection and Radiometer. It is an imaging sensor of Terra satellite which was first launched in December 1999. Aster was made to collect and monitor earth surface temperature, radiometric data monitor, reflectance. The aster sensor can cover the area around 60 km. It has three resolution VNIR, TIR, SWIR. VNIR has 15m a spatial resolution with 3 bands like green, red, Near Infrared. SWIR has a 30 m spatial resolution with 6 band and TIR has 90 m spatial resolution with 5 band. A complete aster scene consists of 14 band multispectral resolution instrument. Aster is only high spatial resolution sensor of Terra satellite which has zoom lens to detect the target and collect information. Aster Satellite image data is used to wide area of global change related application. Aster is used for Vegetation, soil, hazard monitoring, geology, hydrology mapping. High Resolution ASTER can be able to create stereo imagery.

AsterSatellite Band

Band	Label	Resolution (m)	Wavelength (μm)	Description
Band 1	VNIR Band1	15	0.520 - 0.60	Visible green/yellow
Band 2	VNIR Band2	15	0.630 - 0.690	Visible red
Band 3	VNIR Band3	15	0.760–0.860	Near infrared
Band 4	VNIR Band3	15	0.760–0.860	
Band 5	Band	Band	Band	Band
Band 6	SWIR Band5	30	2.145–2.185	
Band 7	SWIR Band6	30	2.185–2.225	
Band 8	SWIR Band7	30	2.235–2.285	
Band 9	SWIR Band8	30	2.295–2.365	
Band 10	SWIR Band9	30	2.360–2.430	
Band 11	TIR Band10	90	8.125–8.475	Long-wave infrared or thermal IR
Band	TIR Band11	90	8.475–8.825	
B12	TIR Band12	90	8.925–9.275	
B13	TIR Band13	90	10.250–10.950	
B14	TIR Band14	90	10.950–11.650	

3.6 Multispectral Image

Multispectral image is a technique that capture image within some specific wavelength around the electromagnetic spectrum. Multispectral image can take by using image sensor. Multispectral image is very useful for identify visible and invisible object of earth surface. Invisible light like SWIR, NIR, TIR can be detect by using multispectral image. Multi spectral image is generally use for remote sensing and mineral mapping. Multi spectral image take several image by different wavelength at the same location for finding the characteristics of those location Every multispectral image indicates as a band. Multispectral image measure small number of spectral band. Multispectral image has 11 band and this bands are obtaining by remote sensing. Band Wavelength is distinguishingby filtering. Multispectral image is used in Landsat series satellite and Aster satellite sensor camera. This sensor camera can capture earth surface data by multispectral imaging and use different band for different object. Multispectral image helps to find out the mineral detection by satellite remote sensor.

3.7 Multispectral Band

Red: Red spectral band use to find out the manmade object in water, soil and vegetation area. This band can capture information from 30 feet depth. Red band has a 600 nm to 690 nm wavelength.

Green: Green spectral Band use to imaging deep water structure and vegetation up to 90 feet in earth surface. Green band has a 515nm to 600 nm wavelength.

Blue: Blue spectral band is use to monitor atmosphere and deep water. This band can capture information from 150 feet depth. This spectral band has a 450 nm to 520 nm wavelength.

Near-Infrared: Near infrared spectral band is used for vegetation area detection. This spectral band has a 750 nm to 900 nm wavelength.

Mid-Infrared: Mid-infrared spectral band is used for vegetation, soil, moisture and forest area remote sensing. 1555 nm to 1760 nm wavelength use for sensing.

Thermal Infrared: Earth surface object temperature, firing area, mineral or other object radiometric infrared data and earth surface emitted ray can detect by Thermal Infrared. Thermal infrared is a part of electromagnetic spectrum which has a wavelength of between 3 micrometers to 20 micrometers. Remote sensing use 8 to 13 micrometer range.

3.8 Multispectral Camera

Multispectral camera is a part of multispectral image processing. This type of camera making is more difficult than general camera. The architecture of this camera is very complex. There are many advanced quality lens, sensor, filter and RGB, NIR band use to build up a Multispectral camera. Red, Green and Blue are the common edge of multispectral camera. This type of camera can identify invisible SWIR, NIR and IR Band which is not seen by human eye. Multispectral RGB image can help to see this type of image. Basically this type of camera has 12.5 million pixels with a sampling rate of 2.5 frame/second. This type of camera has a huge storage capacity for extract the information in his own storage after collecting the image data. Multispectral camera has a network access and control system it has also wireless connection quality. Multispectral camera's is very useful in satellite communication. In remote sensing technique satellite use multispectral camera from space to sense the earth surface. The multispectral camera can distinguish vegetation area, water, soil, forest etc.



Figure 3.6 : Multispectral Camera.[34]

3.9 Thermal Infrared camera

In Satellite mineral exploration thermal infrared camera has been used. The thermal camera can record the earth object temperature and it also has a capability to provide different color for different object. Thermal cameras perceive temperature by identifying and taking different levels of infrared light. This infrared light is invisible for human eye but it can be understood by monitor. The earth surface object which emit infrared radiation Infrared camera can sense. Each object has different emission characteristics such as Cold temperatures given a resemblance of green, blue or purple. whereas hot temperatures exhibit a resemblance of yellow, red or orange.



Figure 3.7 : Thermal Infrared Camera.[35]

Thermal cameras basically have four component lens system, basic detection system, signal processing and display. Thermal camera detects electromagnetic emission of object by this component. The Infrared camera lenses focus on incoming infrared radiation on the target object. Infrared camera consists of material like silicon, germanium zinc. The detector of IR determines the level of thermal and spatial resolution. Generally, two types of Infrared detectors are used those are thermal detectors and photon detectors. The quantum detectors measure incident photon interact through the material of the detector at a molecular level. Normally, interaction includes an electron absorbing moving from one quantum energy level to another. After detection electronic output generate a thermal image. Signal processing element discard the background radiation signal component and it convert electrical output to ordinary graphical image format.

3.10 Satellite image color

The image produce by the satellite image processing component will show different kinds of display on computer monitor.

3.10.1 True Color Image

An image is called a true color image when it is show his original or natural color after collecting by the camera from surface. Generally, human eye can't see the image light without Red, Green and Blue in monitor. This are the RGB visible colorimage. NIR,SWIR,UV, ray can't observe by human eye. After taking the image if it shows green as a green, red as a red, blue as blue so we can say it is a true color of image.For better understanding we include an image below which show the variation of different color where vegetation indicatesgreen, water indicate blue and red color refer some mineral or object.



Figure 3.8: True color image. [36]

3.10.2 False color image

False color image is necessary when an image can't show his original or natural color after collecting by the camera from surface. Generally human eye can't see without red,green and blue light.Ultraviolet, X ray, NIR, SWIR can't detect by the human eye. When any multispectral camera take image and it can't show RGB original color it is very difficult to realize human what is indicate those image. As a result, False color image is used in raw

image. This is also the RGB combination image. Three spectral band use to create False color image. At least two spectral band require for creating False color image. This spectral band combination help human to see invisible light. False color image is use in remote sensing and mineral exploration for identify mineral material. The radiometric image can't explain the original color of mineral so False color image use. Basically Near infrared, Red and Green use for False color imaging. In this picture vegetation area indicate by red color, Green color indicate water.



Figure 3.9: False color image. [37]

3.10.3 Gray scale Image

Gray scale is an image which consists without any color combination. It has only two shades of color one is black and another is white. Gray scale image middle shade is representing by the same and equal pixel value. Three visible light has been use to transmit light. In gray scale image black represents pixel value 0 and white represents pixel value 1. The rang of pixel value is 0 – 255. In computer image red green and blue color components has been use and each color represents 0 to 255 decibel value and this value then convert into binary value 00000 to 11111. In the gray scale image black portion of shade represent as $R=G=B=0$ and white portion of shade represent $R=G=B=1$.

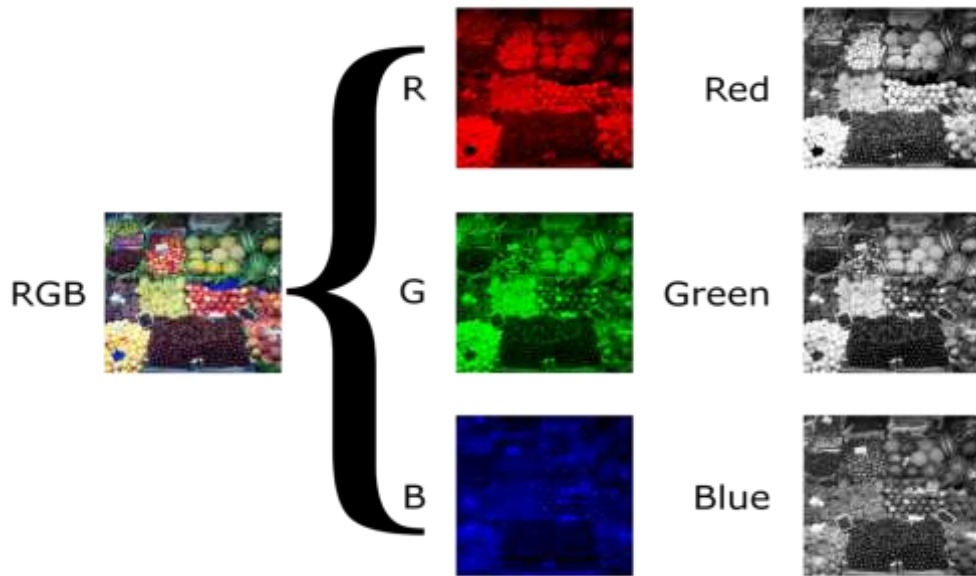


Figure 3.10: Gray scale image.[38]

Chapter 4

Mineral Detection procedure

4.1 Electromagnetic Spectrum

Remote sensing is totally depending on the measurement of Electromagnetic Energy. One of the great and important Electromagnetic source is sun light and that is provide all wavelength energy. Most important wavelength is visible light but some of the wavelength are very harmful for human like X-ray, Ultraviolet wavelength. Satellite are use many sensors to understand and detect Electromagnetic energy wavelength. Remote sensing operates in different territory of the electromagnetic spectrum. Reflection and Refraction are used for electromagnetic radiation. Visible region of electromagnetic spectrum is related to color concept of red, green and blue .Visible light has a shortest wavelength that is use for remote sensing mineral exploration because some of the earth surface material and rock emit visible light .Ultraviolet light has a shortest wavelength which also use satellite remote sensing .Microwave, Infrared and thermal infrared is a longer wavelength electromagnetic spectrum .Thermal wavelength and Microwave also use in remote sensing satellite because thermal infrared provide information about surface temperature and microwave length give information of surface properties .

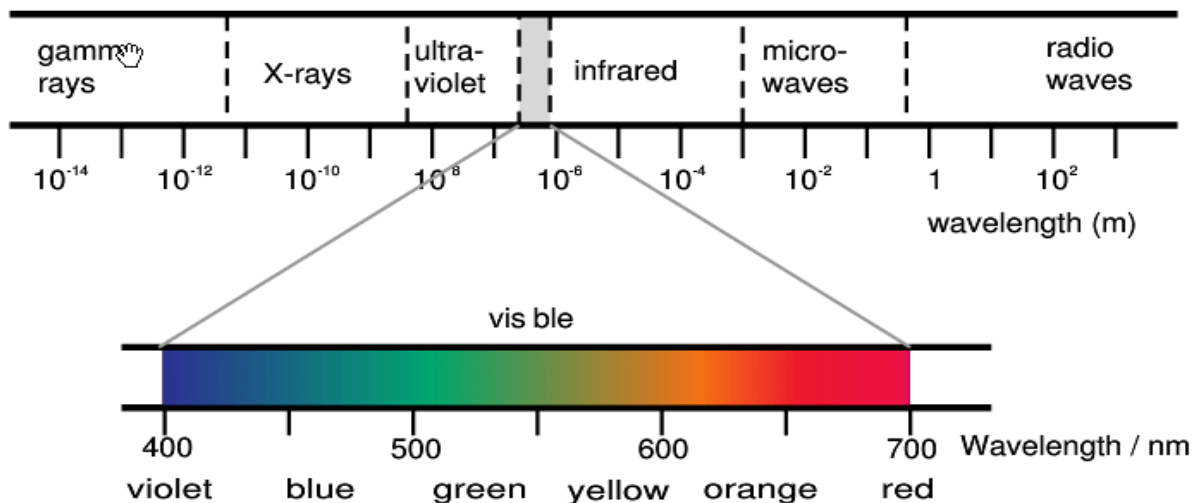


Figure 4.1 : Electromagnetic Spectrum. [39]

4.2 Resolution of Remote Sensing

The major resolution characteristics of remote sensing are classified as,

- a. Spectral resolution
- b. Spatial resolution
- c. Radiometric resolution
- d. Temporal resolution

Spatial resolution: Spatial resolution describe about the pixel size of the satellite image. It is use in remote sensing for close line image resolving. It is a calculation of graphical image which is express as a pixel line, dot per pixel dots per inch. Surface small area can be representing by spatial point. Spatial resolution indicates number of independent value of length. Spatial resolution can be measure by using this formula,

$$A=HB$$

A=The ground dimension of the detector elements

H=The flying height of the platform in meters

B= The instantaneous field of view in milliradians

High spatial resolution range is 0.41-4 m and low spatial resolution range is 30 – 1000 m.

Spectral resolution

Spectral resolution indicates electromagnetic energy radiation wavelength in the satellite remote sensing. It also relates the caliber of sensor. Spectral resolution is existing in remote sensing sensor. The sensor can collect reflected radiance. Spectral resolution identifies the number of spectral bands. This band can help to surface material, mineral detection. Satellite high spectral resolution is 210 band Medium spectral resolution range 4-20 band and low spectral resolution range is 3 band. High spectral resolution of imaging systems generate the opportunity to identify some mineral by their absorption band eminent.

Radiometric resolution

Radiometric information of an image describes the real information of an image. It is used for digital image and photography. Radiometric resolution is used to maintain and resolve the grey scale image. Radiometric resolution has the ability to distinguish the grey scale image

value while collecting image. Radiometric resolution of an image relates its ability. Radiometric resolution of a sensor detects emitted and reflected energy. Radiometric imagery data are present by digital numbers. Brightness levels depend on the number of bits of an energy recorder. If any sensor used 8 bits for recording data, there would be 256 digital values. If use 4 bits there will be digital values available in 0-15 bits. In 8-bit radiometric resolution data a digital number represents as a black and 255 represents as a white.

Temporal resolution

Temporal resolution is defined as the quantity of time needed to revisit and attain information for the same location. Temporal resolution indicates the frequency of data gathering. The quantity of time depends on orbit characteristics and sensor characteristics. Earth surface area can't hold the same geographic image it is changing continuously. Remote sensing satellites have the ability to detect the change in environment. In remote sensing, satellites take the image from the same location at different times; it is very effective to understand the change of earth surface. Change in earth surface area detection can be possible by temporal resolution. Collecting data should be matched to the frequency of change. Temporal resolution will be high if revisiting delay will be low. For taking several images at the same location after a few minutes, temporal resolution should be high and time distance should be short. Temporal resolution generally counts as a day. Satellites can have 14, 15 or 16-day intermediate temporal resolution.

4.3 Pixel and Mixed Pixel

Remote sensing image consists of a matrix of picture elements. Generally, pixels indicate a small number of ground areas. In the remote sensing system, sensors use spatial resolution which refers to pixels. Pixels refer to the images gathered by the satellite sensor. Pixel size may change on the earth surface but resolution can't change. Suppose if a sensor has a spatial resolution of 5 m, it will show full resolution of area 5x5 on 10x10 m. Mixed pixel is a remote sensing procedure where a pixel has a digital number and that indicates emission and reflection energy from the several earth surface and those areas represent as a pixel. A pixel has a predominant value and geographic location address and it is a two-dimensional image. Pixel is nothing but a digital number. For lack of storage, pixel digital number (DN) represents as a bit.

4.4 Remote Sensing system

The electromagnetic energy source provides a high level of energy over all wavelengths. The energy passes through the atmosphere where there is no loss of energy and the energy source falls on the target. Energy fall also depends on the target material. After falling on the target it will interact with the target and generate unique reflected and refracted energy and this energy has different wavelengths. Electromagnetic Band is useful for detecting different kinds of

target because band is different for every earth surface material. Earth surface object show different band characteristics. The sensor is used to capture the reflected and emitted energy from th target. The sensor can collect spatial resolution, spectral information of target. The super sensor like TM,ETM, OLI etc record the information and then transmit to the real time data handling system on the ground.

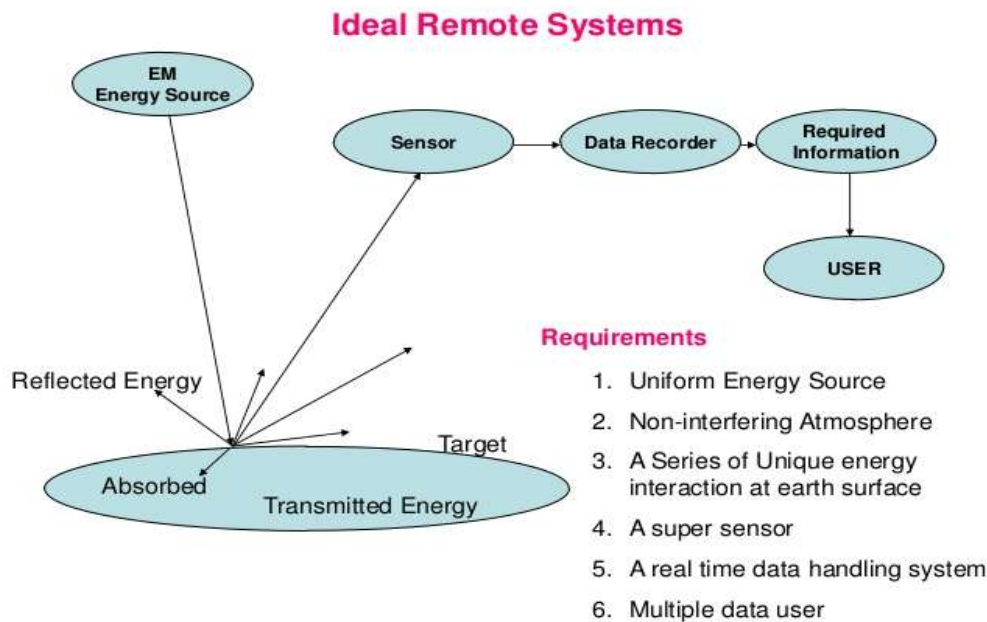
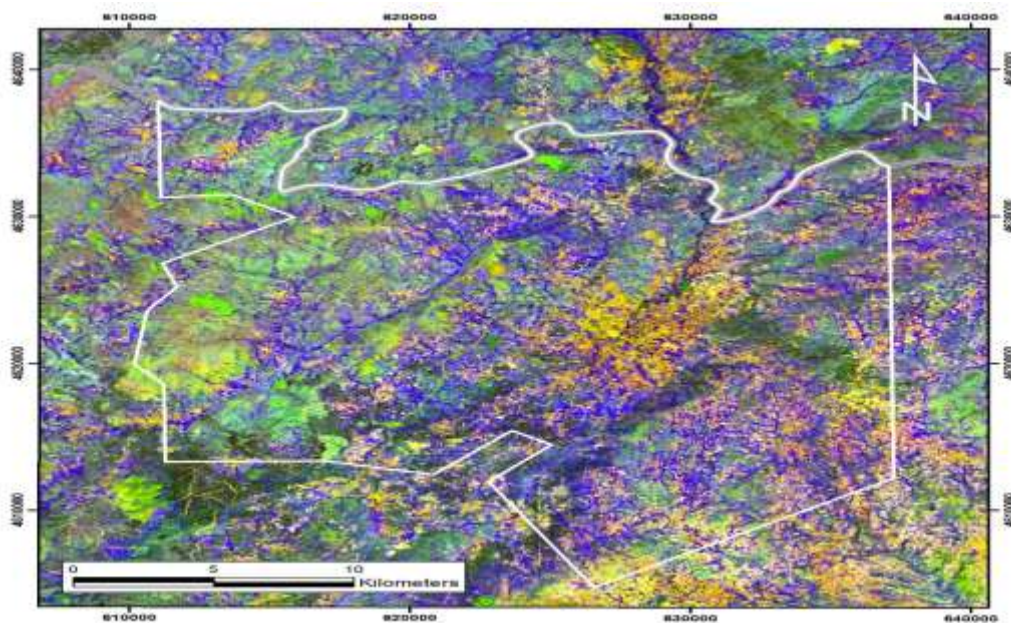


Figure 4.2 : Satellite Remote Sensing.[40]

In remote sensing image and photography are the most important term. Image is a resolution of target are object that has been record by the optical lens camera called multispectral camera. Image is a representation of any surface object that is basically record by the sensor and a remote sensing scannersystem. The satellite scanner generally operates by the specific type of electromagnetic spectrum. The spectrum helps the sensor to capture the Digital Number of surface object. This Digital Number refer as pixel of some specific area. This DN number is very important to understand the characteristics of object. This data is record in data recorder and then transfer real time data handling system to extract the original information about the target. If the sensor can detect the several spectral band from object during sensing it will generate several spectral current and this current can produce Digital Number values.

4.5 Band Ratio Technique

In band ratio technique one band digital number are divided by the another band digital number. This process helps to enhance the picture and improve quality. Every mineral has different band ratio and it depends on the spectral reflectance and absorption characteristics of minerals. In earth surface every mineral and rock has different characteristics. Each Mineral has different band characteristics. So the Band ratio technique will be different for every mineral and rock. When color composition use this band are taken according to spectral reflectance and absorption feature of mineral. Band ratio 4/2 has been use for iron oxidemapping and band ratio 6/7 has been use clay mineral like kaolinite, montmorillonitemapping. Ferric mineral has been map by using band ratio 6/5. The hydroxyl rock band ration is 6/7.



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Figure 4.3 : Minerals Mapping Area.[41]

In this picture show the different earth material has different color. RGB band ratio composition has been use to map this specific area. Here outcrops have been map by the light brown, altered rocks has been mapped by red color and vegetation has been mapped by light blue and their band ratio respectively 4/2, 6/5,5. Hydroxyl rock show red color and dark green color indicate sediment.

4.6 Spectral Reflectance of earth surface material and Mineral

Vegetation

The spectral reflectance of green vegetation is very peculiar and wavelength are also different. In the red and blue region of spread spectrum vegetation has low reflectance but the green region it has high reflectance. Green leaf of the vegetation absorbs most of the energy. The absorption band are around 0.46 micrometer. If the plant or tree leaf can't contain more chlorophyll it will not show the spectral band green, the reflectance will be high in redregion. In the absence of chlorophyll some tree produce anthocyanin and seam to read. Visible spectral pattern are different but Middle Infrared and Near Infrared spectral pattern has no significant difference. Near infrared portion of spectrum starts from 0.7 micrometer. In this region reflectance pass from visible to infrared. In this region green vegetation show high reflectance and transmission and low absorption. The reflection rate is around 50% to 55% and th absorption rate is around 5%. The middle infrared region show reflectance because of water absorption band is 1.4 ,1.9 and 2.7 and reflection occurs in middle infrared because of 1.6 micro meter and 2.2 micrometer.

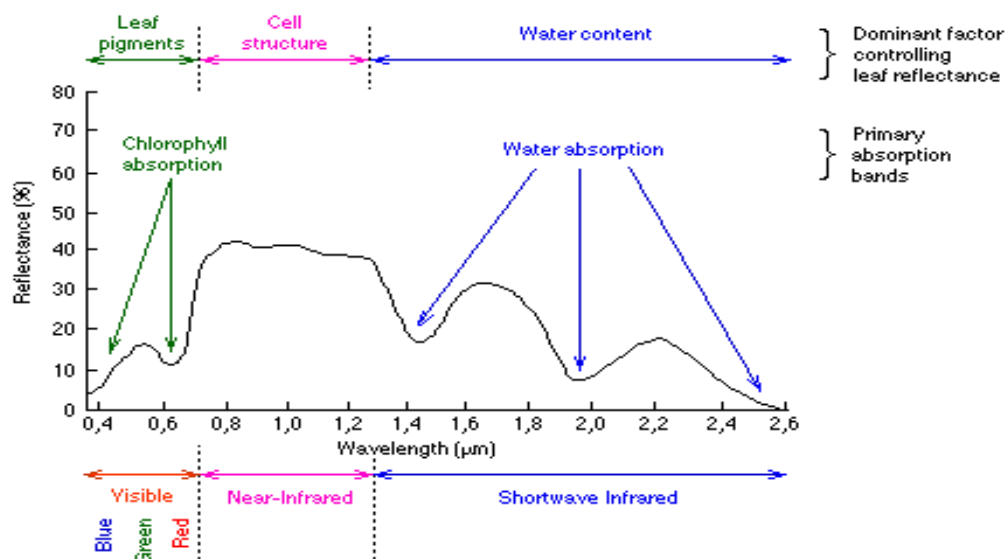


Figure 4.4: Spectral Reflectance of Vegetation. [42]

Water

Water reflectance is very low than vegetation and soil. Vegetation reflect up to 49% and soil up to 35% - 40% but water can reflect only 10% of the incoming electromagnetic radiation. Water electromagnetic energy reflection is visible to near infrared range. Under 1.15 micrometer all energy is absorb the curve indicate the absorption region of water. we already know that water has low reflectance but clear water has a large reflectance in the blue portion of spectral band. In near infrared region water has no reflection but high absorption. Grubby water has high reflectance in the visible region.

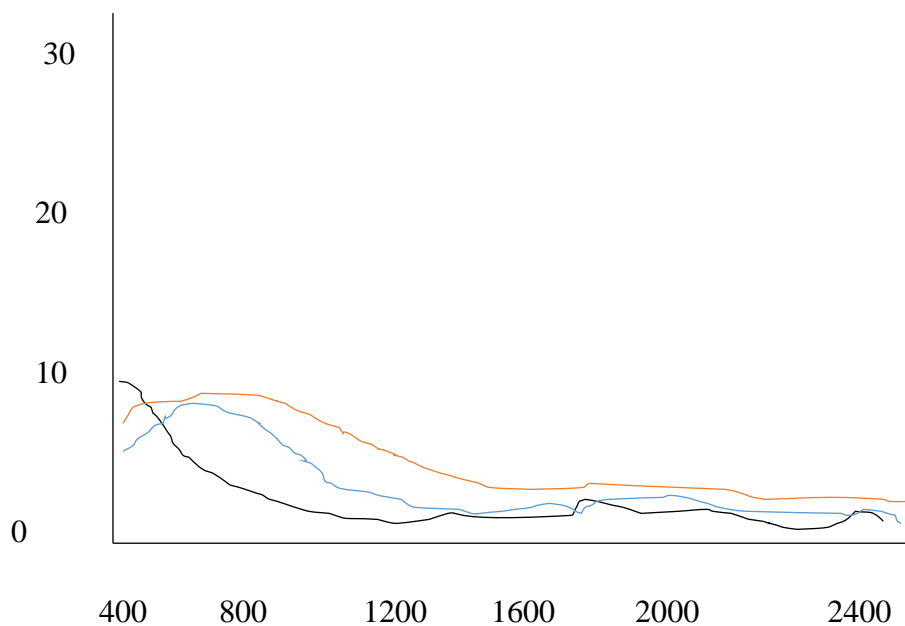


Figure 4.5: Spectral Reflectance Curve of Water

There is some mineral which contain different spectral characteristics and alteration are also different. Mineral spectral reflection and absorption band are different. Here we explain some different kinds of mineral and their spectral signature.

Quartz

The quartz formation can occur by hydrothermal siliceous and this is a hydrothermal alteration system. The Quartz can't form by the spectral feature of VNIR and SWIR region. The spectral range 0.4 μ m-2.5 μ m is not possible to form quartz. Thermal Infrared region is very effective to detect this mineral and wavelength is 8 μ m -12 μ m. The Aster remote sensing TIR is useful to detect this type of mineral.

Clays

Three common types of clay mineral are existing in all over the world like Elite, Kaolinite, Montmorillonite. This mineral has some peculiar absorption and reflection feature. This clay mineral absorption wavelength is 2.06 μm - 2.4 μm and the higher reflectance range is 1.54 μm - 1.76 μm .

Hydroxyl

Hydroxide and water can make spectral absorption range 1.40 μm and 1.90 μm . Metal ion in the hydroxide can be identify by the absorption spectrum 2.20 μm and 2.40 μm . Hydroxyl containing mineral form the alteration of different rock. Fe.MG-oh absorption wavelength 2.34 μm have been produce by chlorite.

Carbonate

Carbonate spectral reflectance in the VNIR region and the absorption wavelength in Short wave infrared region is 1.92.35 μm , 2.342.35 μm and 2.502. 35 μm .carbonate also has an absorption wavelength in TIR 7.0 μm .

Iron oxide

Iron oxide has a spectral fature in Visible NIR region. In ultraviolet red wavelength region 0.64 μm -0.69 μm indicate the strong reflectance feature and ultraviolet blue wavelength region 0.45 μm 0.53 μm indicate absorption characteristics. Hematite, Jarosite, Anomalies and Goethite are some mineral of Iron oxide group. Hematite electromagnetic spectral absorption wavelength is 0.55 μm . Goethite electromagnetic spectral absorption is respectively 0.55 μm and 0.9 μm in Fe³⁺ and F²⁺. Jarosit electromagnetic spectral absorption is 0.90 μm .

The infrared has a wide range of mineral detection capability because of well mineral identification wavelength. The infrared range are extended from Short wave infrared, Near-infrared, Visible band, Long wave infrared and Mid infrared band. Every infrared band has different capabilities and contain different wavelength characteristics for some specific mineral identification. Visible NIR, SWIR and LWIR is more effective for remote sensing sensor for mineral exploration.

Visible Near Infrared has narrow mineral detection ability but it provides many precious information of undetected minerals. The Visible Near Infrared band especially is very effective for iron oxide mapping. Short Wave Infrared band is another important band which helps to identify and distinguishing mineral like chlorites, micas, clay mineral, carbonate, and hydroxyl. The mineral which has a high alteration and alteration region has been map by this SWIR. Lower Wave Infrared is very effective to identify tectosilicates. The SWIR and LWIR combination is very powerful and has a high possibility to detect mineral. The Mid Wave Infrared is very supportive to mark the mineral exciting area. The Mid Wave Infrared wavelength has much potentiality to identify hydrocarbons and bitumen's. Mid wave infrared has oil and gas detection probability. VLWIR have been used to explore mineral it has high potentiality to mapping oxide and Hydrogen Supplied. Detection capabilities of the VNIR, LWIR and SWIR have ben explain in the table of mineral classification. These are the Electromagnetic spectral band where the most mineral detection capabilities are achieving.

Several Mineral Spectral Band Characteristics :

Mineral Group	Example	VNIR Response	SWIR Response	LWIR Response
Amphibole	Actinolite	Non-Diagnostic	Good	Moderate
Pvroxene	Diopside	Good	Moderate	Good
Tourmaline	Elbaite	Non-Diagnostic	Good	Moderate
Garnet	Grossular	Moderate	Non-Diagnostic	Good
Olivine	Forsterite	Good	Non-Diagnostic	Good
Epldote	Epldote	Non-Diagnostic	Good	Moderate
Mica	Muscovite	Non-Diagnostic	Good	Moderate
Chlorite	Clinochlore	Non-Diagnostic	Good	Moderate
Clay Minerals	IlliTe	Non-Diagnostic	Good	Moderate
Clay Minerals	Kaolinite	Non-Diagnostic	Good	Moderate
Feldspar	Orthoclase	Non-Diagnostic	Non-Diagnostic	Good
Feldspar	Albite	Non-Diagnostic	Non-Diagnostic	Good
Silica	Quartz	Non-Diagnostic	Non-Diagnostic	Good
Calcite	Calcite	Non-Diagnostic	Moderate	Good
Dolomite	Dolomite	Non-Diagnostic	Moderate	Good
	Gibbsite	Non-Diagnostic	Good	Moderate
Alunite	Alunite	Moderate	Good	Moderate
	GVpsum	Non-Diagnostic	Good	Good
	Borax	Non-Diagnostic	Moderate	Uncertain
Chlorides	Halite	Non-Diagnostic	Uncertain	Uncertain
Apatite	Apatite	Moderate	Non-Diagnostic	Good
	Bitumen	Uncertain	Moderate	Uncertain
Hematite	Hematite	Good	Non-Diagnostic	Non-Diagnostic
Spinel	Chromite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic
	Pvrite	Non-Diagnostic	Non-Diagnostic	Non-Diagnostic

4.7 Iron Oxide Detection

Iron oxide is one of the vital element and detection is very crucial. The Serra Norte, Brazil is an area where iron oxide is deposited. From this area how to explore iron oxide and what procedure and technology usages we explain in details. Iron oxide is a one of the vital mineral of the surface, It is very difficult to find iron oxide in surface. For mapping iron oxide and clay minerals generally usages Landsat-8 Operational Land Imager and Earth Observing Hyperion imagery and the airborne geophysical data. The Landsat-8/ OLI spectral bands are the visible bands (1, 2, 3, and 4) have higher minimum values than the data in the near- and shortwave infrared bands (5, 6, and 7). In this area contain world class iron ore and the presentences of 67%. Another types of minerals are Silica, aluminum, Magnesium, phosphate. The chief ore minerals are hematite with magnetite. Other minerals are including quartz, kaolinite, gibbsite, smectite, talc, carbonate, and chlorite. Iron ore consists of hematite, friable, granular. Mineral mapping in open rock areas and the area which is covered by vegetation is not only important but also observing mine waste deposits, in order to estimate the level of chemicals and to understand how much risk in this area. One of the best methods for mineral mapping is remote-sensing data. Remote-sensing data have been widely used to gain information about Earth surface properties. Multispectral image data have been successfully used for mineral exploration to map iron oxides. In dry area and wet area iron oxide zones enough to be detected successfully from space borne multispectral data Iron oxides mainly consists of hematite and goethite which arise in the deforested open-pit N4 and N5 mines.

In the VNIR band $0.38\ \mu\text{m}$ to $1.00\ \mu\text{m}$ is the electromagnetic absorption spectrum of iron oxides. It also has large absorptions crystal field and charge transfer absorptions. Crystal field absorption occur because of unfilled electron shells of transition elements. So charge transfer occurs where the absorption of a photon causes an electron to move between ions or between ions and ligands. Hematite and Goethite also have specific crystal field absorptions in $0.64\ \mu\text{m}$ to $0.71\ \mu\text{m}$ and $0.84\ \mu\text{m}$ – $1.00\ \mu\text{m}$ separately, and an absorption feature produced by charge transfers between 0.48 and $0.55\ \mu\text{m}$. Iron oxides and vegetation have pretty similar reflectance spectra in the wavelength regions bands 1 and 2, and a minor variance in band 3. Band 3 is Vegetation peak of reflectance and goethite also has a peak of reflectance is band 3. Hematite has lower reflectance than goethite and vegetation in this band 3. So, these three bands 1, band 2, and 3 are not very suitable in distinguishing iron oxides in vegetated area.

The Landsat 8 spectral region covered by band 4 is more effective to mapping, iron oxides (hematite and goethite) and clay minerals due to their high reflectance in this spectral band. In other hand, the green vegetation absorbs powerfully radiation at the red wavelengths band 4. Generally green vegetation displays absorption in band 7. Iron oxides exhibit absorption features in Landsat 8 OLI band 5. Landsat-8/OLI bands 4 and 5 has been used to distinguish iron oxides from vegetation areas. Clay minerals have reflectance in spectral region bands 1, 2, 3, 4, 5, and 6, than those Clay minerals have absorption characteristics in the

spectralband 7 . iron oxides have not any spectral feature in the Short Wave Infrared (SWIR) region .

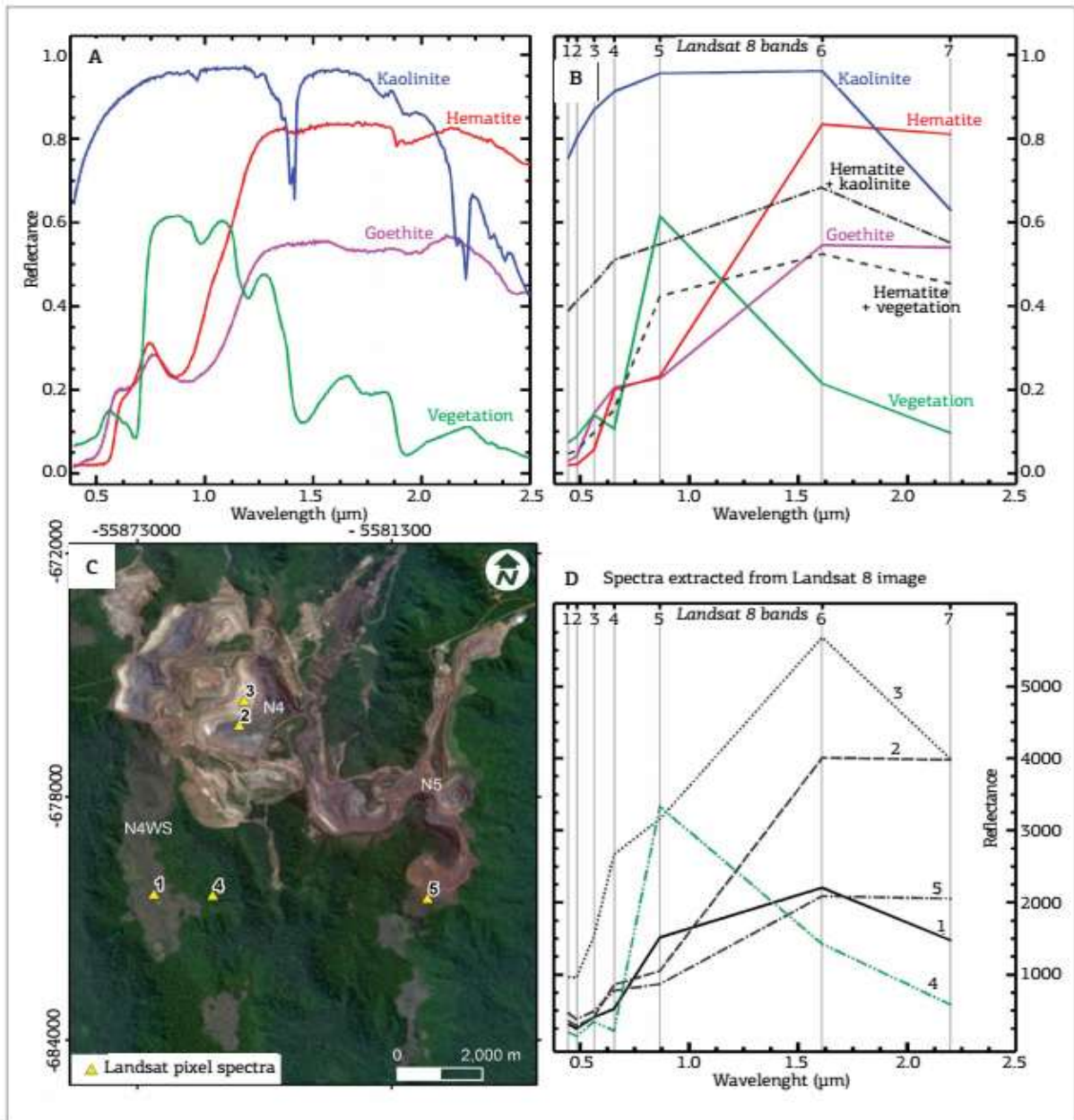


Figure4.6 : Spectral characteristics of Iron oxide and some other rock.[42]

In this figure A show the spectral reflectance of Kaolinite, Hematite, Goethite. In Figure B spectrum 2 located in the high grade iron ore, is similar to that of hematite show the spectral reflectance between spectral band 6 and 5 and also absorption band is 5. Spectrum 3 also display a high reflectance difference between bands 6 and 7. This spectrum also shows a combination with iron oxide, but with fewer percentage of iron oxide than in spectrum 2. Spectrum 5 is alike to hematite or goethite, but also with fewer iron oxide abundance than previous ones. Figure D shows some reflectance spectra extracted from N4, N5, N4WS, and forest areas of the Landsat 8 OLI reflectance data. After collecting Landsat 8 OLI data it is necessary to original information about image data. Band ration technique has been usages for distinguish iron oxide from vegetation area. Band ration is an image processing technique which will help to enhance the iron oxide mapping.

Spectral band ratios have been applied through Landsat8 OLI. This spectralband detect groups of minerals with robust absorption bands at similar wavelengths. Iron oxide minerals which have absorptions in the bands 2 and 5, and high reflectance in bands 4 and 6 Two Landsat-8 OLI band ratios have been applied to highlight iron oxide zones by using this and ratio $4/2$ & band ratio $((4+6)/5)$. Band ratio $4/2$ are useful to perceive the charge transfer absorption of ferric iron oxides in the blue region. The ratio is sensitive to ferric iron. High values of this band ratio indicate iron oxides related to mafic regolith. Extreme values of band ratio $(4+6)/5$ are valuable to sense the crystal field absorption of ferric iron oxide in the band 5. Band ratio $6/7$ is normally used for map clay minerals mapping. Clay minerals contain iron. Vegetation spectra also have a high reflectance on band 6 and low reflectance in band 7. In other hands a simple band ratio $6/7$ usages for clays and vegetation. Band ratio $5/4$ indicate green vegetation region. band ratio $6/7$ divided by the ratio $5/4$ to generate the clay index.

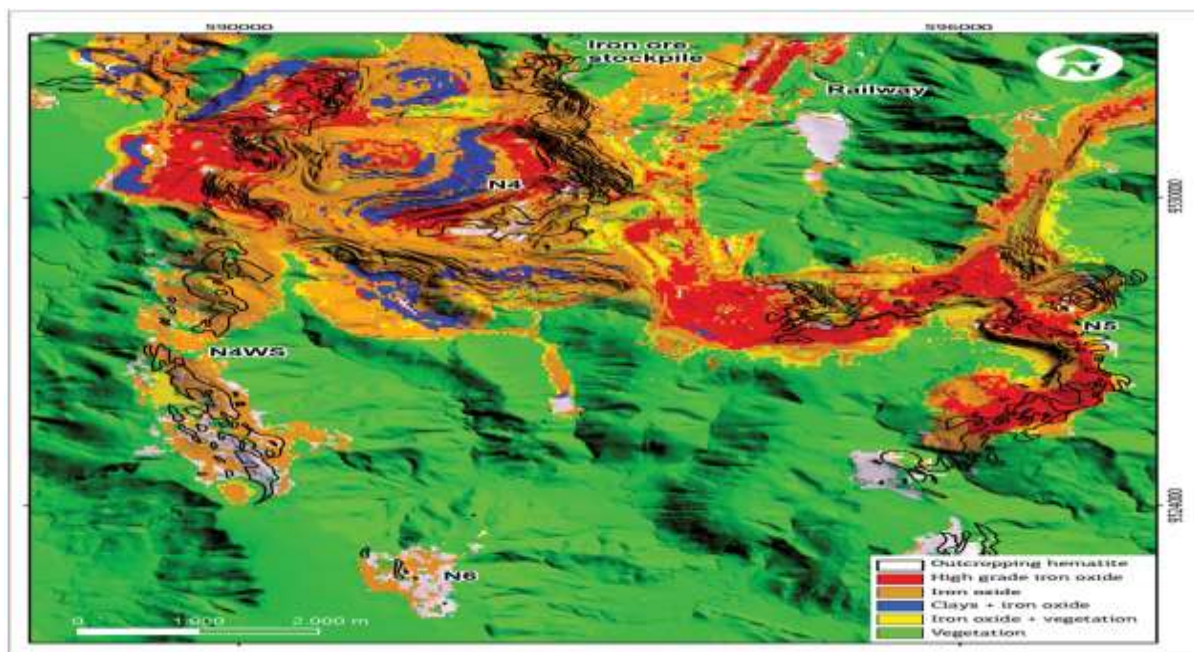


Figure 4.7 :Iron oxide alteration area. [43]

used. Band 6 high reflectance and band 7 low reflectance indicate vegetation area. This ratio can enhance vegetation and clay mineral. Band ratio 6/7 and Band ratio 5/4 are divided to generate clay mineral. This clay is related to form a high grade iron oxide.: Clays + iron oxide Superposing vegetation and iron oxide ratio 4/2 is registered in the class Iron oxide + vegetation.

4.8 Thermal Imaging

The multispectral systems understand radiation in the thermal infrared and the visible and reflected infrared portions of the spectrum. Though remote sensing of energy emitted from the Earth's surface in the thermal infrared is unique than the reflected energy. Thermal sensors usage photo detectors sensitive to sensing photons on earth surface, to detect emitted thermal radiation. Thermal sensors basically quantify the earth surface temperature and thermal characteristics of target minerals.

Thermal imaging refers long wave infrared (LWIR). It is different from VNIR and SWIR. The earth surface mineral or material which has low reflectance but high emission this type of object can be detect by thermal imaging LWIR spectrum. The long wave infrared system is involving the identify of emitted radiation instead of reflected radiation. The wavelength of light absorbed by atmosphere. Thermal radiation of mineral temperature can help to detect minerals by using LWIR imagery. Thermal radiation of earth surface temperature occurs at 8 μm - 12 μm wavelength.

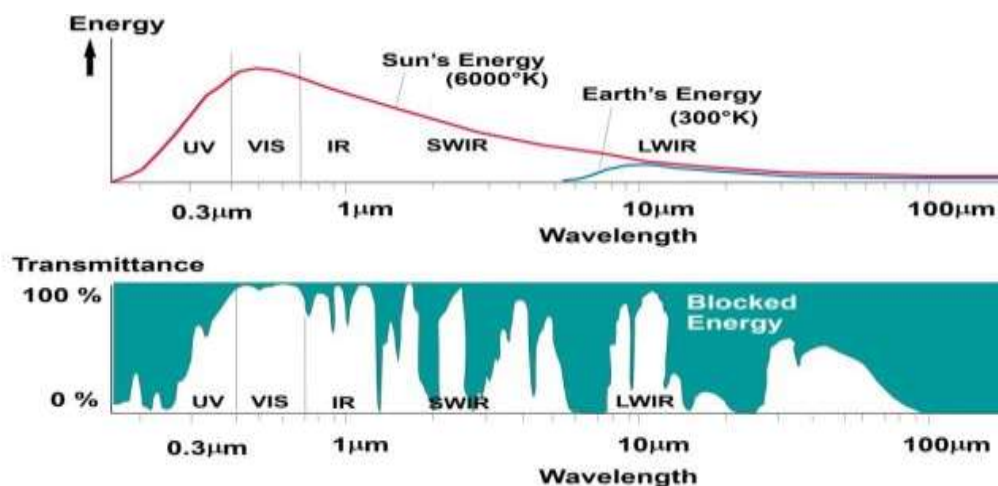


Figure 4.8: Sun energy emission vs earth energy emission. [44]

This above image indicate that sun emitted energy is 6000°K but the earth surface emits 300°K. This are the difference between earth surface and Sun emission. The energy transmission problem can be reducing if detector is closer to the object. This light energy is reserved and this absorption is related to LWIR.

Long wave infrared imagery can identify many minerals spectral characteristics like quartz, silicate, feldspars, garnet, pyroxenes, carbonate, and sulfates. This type of mineral is very difficult to distinguish and identify by the SWIR and VNIR imaging procedure. LWIR imagery can also be capable to identify iron oxide and clay minerals. The capability of the LWIR is to detect quartz and feldspars and map not only alteration but the mineralization. LWIR systems like TIMS Thermal Imaging Multispectral Scanner have been used to map rock compositions including leucogranite, granodiorite, diorite, quartz monzonite, and anorthosite .

Thermal inertia is a another method which has been used for earth surface geological mapping. For determination of Thermal inertia need two different time on is midday another is after midnight. Thermal inertia technique is very complex but it is more effective to identify the image perfectly. Relationship of low thermal inertia zones with mineral was good, however the ore suitably arisen in country rock with a regularly higher thermal inertia. Thermal inertia alterations are not abundant between rock types as they are between combined and separate rock. This thermal infrared procedure has the ability to map rock. Thermal inertia recording is very convenient for mineral exploration in lateritic environments and shallow pediment.

Middle Infrared thermal spectrum is another potential region which wavelength is 3 μm to 7 μm . This wavelength rgion is shorter than main Long wave infrared region which range is 8 μm to 12 μm . The Middle Infrared has been used by stargazers to look at global surface. It also has been used in many petroleum industries. The mineral like Carbonate, Sulfate, Hydrous has a Middle Infrared characteristic for mapping.

Thermal imaging can play an important role in future minerals exploration due to its aptitude to detect many silicate minerals. shorter wavelengths do not have any distinguishable spectra for detecting silicate. In previous low signal to noise ratios and the high cost of cooled detector arrays had been used. At present better technology have been made, as a result better thermal systems are suitable for satellite, airborne systems, hand held instruments, and drill core scanning applications

Thermal properties of Minerals :

Minerals	Specific Heat J/kg-°C	Conductivity W/m-C	Density Kg/m ³
Pure Aluminum	897	220.0	2.707
Pure Beryllium	1885	175.0	1.86
Copper Alloy 11000	385	388	8.934
Pure copper	380	386	8.954
Pure Gold	130	318	18.9
Cast Iron	457	55	7.92
Pure Iron	452	71	7.897
Pure Magnesium	1013	171	1.746
Molybdenum	251	130	10.22
Pure Nickel	445	99	8.906
Pure Sillver	230	418	10.51
Stell Carbon 0.5%	465	54	7.833
Stell Carbon 1.0%	473	42	7.801
Stell Carbon 1.5%	486	36	7.753
Pure zinc	384	112	7.144
Pure Lead	130	35	11.373

4.9 Satellite Image processing

Image processing is the most part of remote sensing and mineral exploration. The raw data which are collect from the earth surface by multispectral camera which has many noise or lacking of original data. Satellite image processing is very crucial for understanding the surface object original shape and color. By using satellite image mineral exploration is possible but the total procedure is very complex. An image refers twodimensional object. Remote sensing images are referring a parts of the earth surface from space. A digital image is a two-dimensional array of pixels. Every pixel has an intensity value called Digital Number. A digital image consists of two or Three dimensional layout of individual picture elements called pixels. Each pixel represents an area on the Earth surface. A pixel has an acuity value and a location address in the two or three dimensional image. The acuity of a pixel is referred as a digital number. Due to the short storage capacity this digital number is present with finite number of bits. The number of bits hold the radiometric resolution of the image data. Eight bit DN represent 0 to 255 where 0 represent black and 255 represent white. When any satellite capture the image it is generally a gray-scale image which has a range of 0 to 255. This is not visible for human as a result digital image processing is necessary for better understanding. In this gray scale image first convert into analog image then it is converted to digital image.

Satellite image processing has many techniques but three processing procedure is essential to extract the original image. Image processing function are Image restroring and Image enhancement.

Procedure of Image Restoration:

1. Restoring Periodic line strip.
2. Restore periodic line dropouts.
3. Random noise filter.
4. Correction of atmosphere scattering.

Restore periodic line dropouts:Satellite camera has a detector to detect the image. Landsat MSS,TM, ETM has also detector.sometimes this detector can't sense proper image because of recording problem. In CCT each scan line is a string zero that represent as a black line on the image. These are called periodic line dropout. The first step in restoration process is to measure the average Digital Number value per scan line for the entire scene. Then the average Digital Number value compared with this scene average. After this process Threshold value is identify as a defective. Then it should be replacing the defective line. every pixel of defective line, an average Digital Number is calculated using DNs for the corresponding pixel. Scan line originally consist of artificial data.

Restore Periodic line strip: Satellite camera has a detector to detect the image. Landsat MSS, TM, ETM has also detector. sometimes this detector can't sense proper image because of recording problem. Landsat MSS spectral band has six detector and Landsat TM spectral band has 16 detectors. Landsat detector is carefully calibrating before launching. Sometimes the detector response can cataract to higher and lower level. This type of incident should not happen. It may hamper total process. If it happens the scan line which is detected by the detector can show the dark or bright than other line. When any individual detectors look like lighter or darker than their neighbor we can call striping. Maximum Landsat 7 satellite do not show real striping. If the striping is visible only show bright, snow, cloud and it is called saturation striping.

Random noise Filtering: Periodic line strip and line dropout is not a random noise so it is very simple to restore. Random noise is very complex to restore properly. Random noise requires more accurate and sophisticated technique. For image specific individual pixel random noise occur with Digital Number. This pixel is much higher and lower than other pixel. Random noise each pixel has to filter for restore the original image. Each pixel of the image yield dark or bright spots image. Random noise pixel is remove by filter and produce an accurate image pixel for better imaging. This filter can help to clear the defect of random noise image. The dark and bright spots can be remove by filter and filter process is given in below.

The spot can be eliminating by filtering in the following procedure:

First kernel has to design which is two dimensional array pixel. This two dimension represents x and y axis with odd number pixel. Then measure the average nine pixel in the kernel. If the central pixel deviates more than threshold value than have to replace pixel by average value. kernel have to move to the right by one column. Average value will be 42. New central pixel value will be new average and it is unchanged. The central pixel Digital Number 90 is replaced by 54. If the right margin of kernel reaches to right margin than kernel return to the left side.

Atmospheric Scatter Correction: Satellite multispectral camera can collect image from ground surface. Earth surface object always radiate ray. When any multispectral camera collect data from surface this radiation can reflect or scatter in atmosphere. As a result, data information loss. Multispectral camera can't extract proper information. IT will produce hazy image and show low image contrast. This type of scattered image can restore by band 7. The shadow area is first mark and spectral Band 7 is draw against Digital Number spectral band 4. Least Square Technique (LST) is used to plot the system. If hazy part were not detected by band 4 the line will go to the origin. Band 4 hazy effect can be correct if interception value is deducting from digital number of band 4-pixelvalue.

Procedure of Image Enhancement:

1. Contrast Enhancement.
2. Density Slicing.
3. Spatial Filtering.
4. Edge Enhancement.

Image enhancement is the process of improving the defect image to original image. It will help to improve the image quality. Different kinds of software use to produce better image quality. Many filter technology and algorithm use for image enhancement. Here we describe some part of image enhancement.

Contrast enhancement:Remote sensing has many problems to collect data from ground surface by sensor. Reflected value which is extract by the sensor sometimes can't match with color display monitor. Material or object of earth surface always reflect are emit energy. Satellite sensor collect this energy information. Image enhancement technique is use to better analysis of image. Brightness value refer as a contrast image. Contrast enhancement is a method this make the image clearer and observable. Image range basically start with between 45 to 95. If the range increase to 0 to 255 to contrast image. Sensor sensitivity is more important when collect low contrast image. Satellite sensor are designed totake unsaturation image. When radiometric image is saturating it is very difficult to capture image. Brightness utilization is the important technique to increase the image contrast.

Spatial Filtering:Filtering is a method to modify an image. Spatial filtering is an image processing method which will allow to change the image pixel predominance to the relative pixel predominance. In this spatial filtering given some pixel value and output can be get after some operation which is done by algorithm. In this spatial filtering technique use two dimensional matrices. Spatial filter is used to remove the unwanted energy which crate hazy of the image. Spatial filter denies the additional noise of raw input. Filtering is a process in which the literal variation of image in frequency of pixel values are enhance. Filter method is basically number of matrix that is done by arithmetic operation. It will format new image from old image by spatial filtering.

Density Slicing:Density slicing is digital image data explanation process that is mainly used in remote sensing image processing for improve the image quality. Density slicing basically change gray scale image to a density interval. Each line has a unique color printer symbol. Image digital slice are exhibit as different color. Density slicing is performed by distributing the range of brightness in a single band into every so often, then assigning each every so often to a color. For example, white and Black thermal image and temperature value of image may be divide into band. As a result, image temperature information can be understanding easily because black color and white color are smaller than other color.

Edge Enhancement: Edge enhancement is a method to describe the structure of satellite image. Edge enhancement is an image making filter which improve the edge contrast of an image or video. For Satellite image processing image edge enhancement in an important part. It is very effective to produce clear, noise free original image. Filter identify the sharp border boundary in the image. Border area image contrast has to be increase. Edge enhancement can be analog image process or digital image or video process. Edge enhancement technique is used to clean video making. Edge enhancement use to reduce noise, remove image defect and better edge sharpening. Edge enhancement can be done by Mat lab, python code, PHP etc. In edge enhancement of multispectral satellite image set as a vector with different dimensions and this is same like number of band image. In this process a pixel is assumed as a vector consists by a number of element. Vector operator use in vector field. prolong the definition of the gradient. Multispectral image is then creating.

Procedure of Image Information Extraction:

1. Principle Component Analysis
2. Band ratio Technique

Band Ratio: In Bandratio technique the DN value of one band is divided by the DN value of another band. Band ration technique help to improve image quality and enhance the image properly. Every material spectrum reflectance is different so band ratio is also different. In band ratio technique the reflected DN value or pixel value has been used. Band combination can be produce by two or more than two color band. This band combination helps to distinguish the invisible remote sensing image and their characteristics. In remote sensing generally 9 bands have been used but every material or mineral has some spectral feature according to those characteristics band ration has been creating. The common band ratio is 4/2, 6/5, 4/5, 6/7 are used for iron oxide, clay mineral vegetation area mapping and enhancement. GIS software are very effective for producing the band ratio for different minerals identification.

Principle Component Analysis: Principle component analysis is generally used in multispectral satellite image. Principle component analysis is a mathematical method and this technique has been used to reduce the remote sensing data dimensionality. The remote sensing satellite data which are taken from earth surface is a numeric pixel value. After reducing the dimension, the image data seen more clear. The picture quality will be improving. For mineral exploration multiple band use in remote sensing, some of this band are correlated. PCA analysis can help to reduce highly correlated band. This reduction can help to analysis less data from more remote sensing image data. Principle component Analysis use statistical data to analyses the remote sensing data. It is basically use to reduce the unnecessary data of remote sensing

Chapter 5

Satellite image processing software

Satellite extract raw image data from earth surface by remote sensing sensor. The sensor information collection can have some problem. The sensor can't collect original image because of atmospheric issue and many other problems. The Satellite raw image can have some missing and inappropriate information as a result the original image can't exhibit. This image quality can be improved by Satellite GIS software. This GIS software help to enhance the picture and make invisible image visible. Satellite image processing software like SAGA, QGIS, OPTICKS, OSSIM, GIMP, INTERIMAGE are popular. Here we discuss about the QGIS and GIMP software image enhancement technique. Both of this software are useful for mineral exploration image enhancement and visualize image.

5.1 Enhancing the color and contrast

Satellite images practically always need improving for different reasons. The brightness series of the scene is not sufficient to scoop the full range of sensor values, when it shows dark and muddy except enhancement of picture. Next thing is 16-bit satellite images essential to be triangular for suitable to the 8 bit range in our monitor. We can accomplish results by *spread* the image values. The red, green and blue brightness levels available on our monitor. Exhibit although continuing inside the range maintained by monitor.

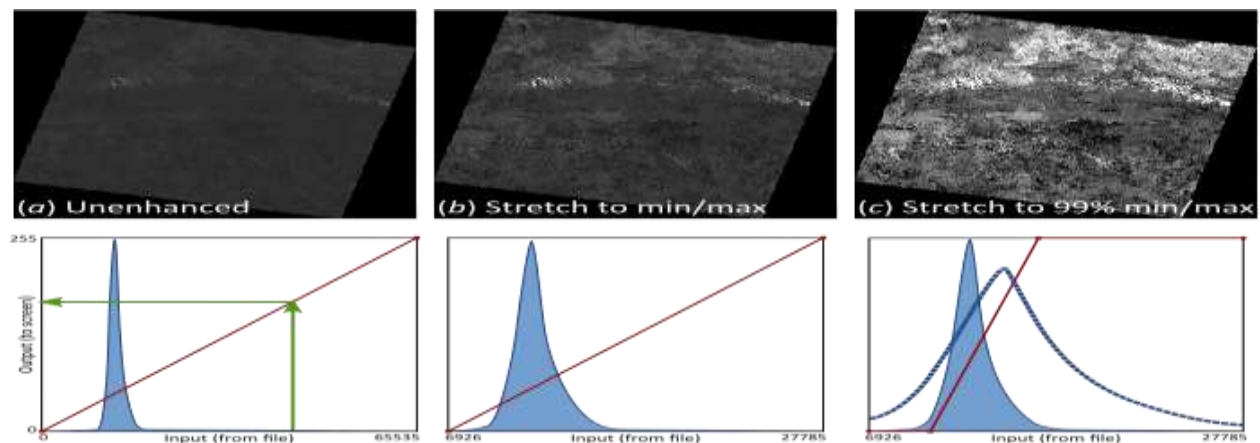


Figure 5.1 : Contrast stretching [45]

In this figure show three different habits to expand the picture values of a single 16-bit band. On the X alliance represents input image data value and the Y alliance represents output values of the image. The picture thumbnails display the effects and the histograms exhibit

characteristics of stretches. The blue histograms display the spreading of the input values, and the red shapes display the lookup.

Generally, contrast enhancements are used to in three band color image generation and producing of enhanced color.

5.2 QGIS Workflow

By using QGIS Landsat 8 raw image data can be enhanced and color will be faultless for showing the image. QGIS is a commercial software where much of the work is already done and some steps should be applying. Here we discuss about 4 steps of QGIS work procedure for Landsat 8 data enhancement.

1. Collect the detached bands into one multi-band image
2. Select a band combination and then enhance the color and contrast
3. Re development the image against working synchronize system
4. Save the enhanced image.

Collect the bands

Formerly generating the file, we have to select the applicable bands in the right order. For producing a specific color composite choice, the three bands in downward order. Then generate a basic multispectral image, select all of the relevant bands in rising order.

we can use QGIS's Raster Merge function to associate the bands into a single image. For QGIS Raster merge function we have to select Raster than Miscellaneous and merge. Then select input file box button. Next step is select individual band in right order by CTRL+click. Then choose output file button and enter a file name. It should be necessary to enable No data value, Place each input file into a separate band, and ensure Load into canvas is enabled.

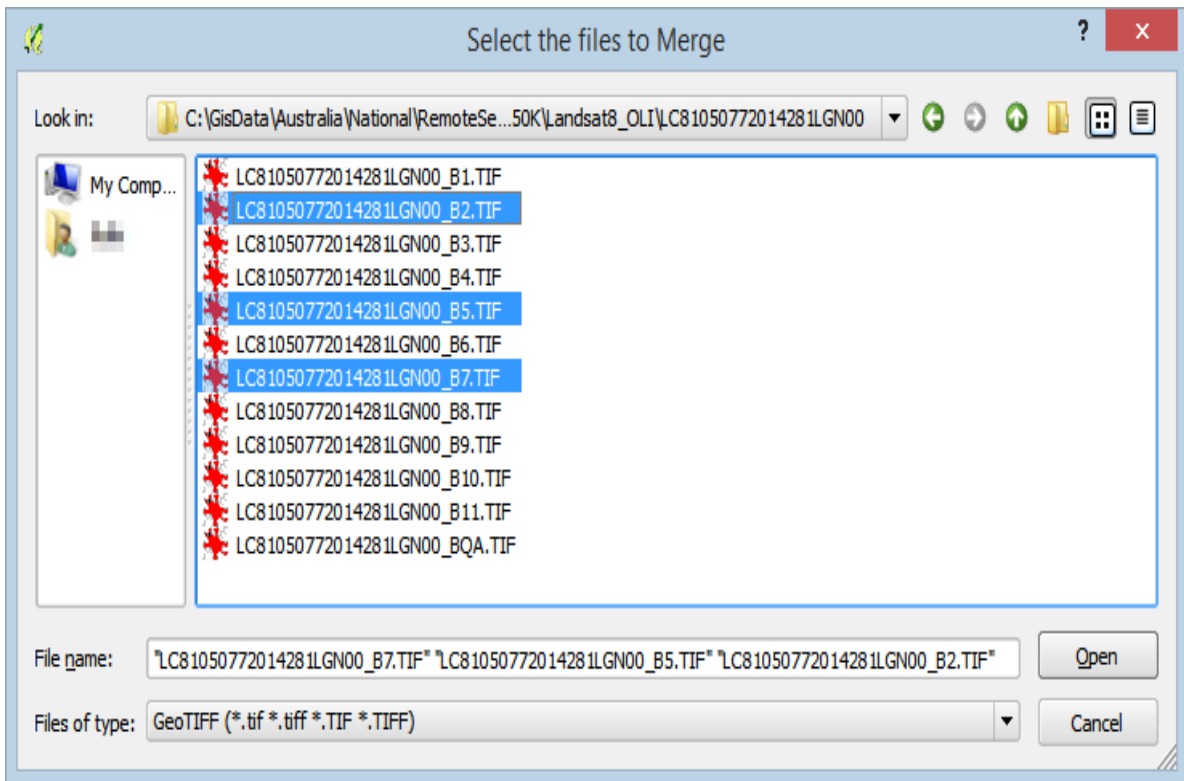


Figure 5.2: Bands 7, 5 and 2 selected in that order to produce a three-band composite.[46]

If three-band composite is already created, we should see that QGIS has formed enhanced version image with no input from monitor. if we created a multispectral image the colors it will be wrong.

Enhance the color and contrast of the entire image

QGIS software comprises two different methods to enhance the color and contrast of an image those are band rendering & color rendering. Band rendering use in each band. color rendering is more vivid to show photograph.

Band rendering procedure in QGIS:

1. click image in the layer panel to display the layer properties.
2. Fixed the contrast enhancement to stretch the Min, Max and accuracy to estimate
3. Select load button to measure the min/max values and click ok to show result.

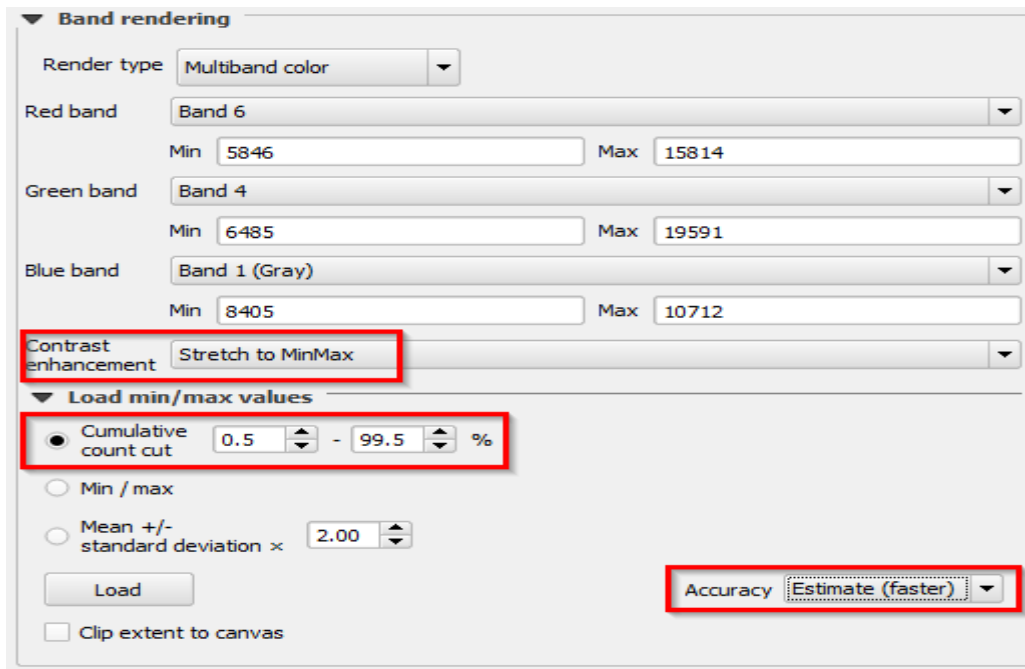


Figure 5.3: QGIS Band Rendering with parameters for a 99% contrast stretch. [47]

[<https://www.micromine.com/satellite-imagery-in-mineral-exploration-part-2-preparing-an-image-with-free-gis-software/>]



Figure 5.4: Unenhanced (left) and enhanced colour composite using a 99% stretch.[48]

Locally enhance the color and contrast

In this above technique has a problem. The satellite can capture only area of interest and the outside of the area show darker after enhancing the image. Enhancing process stretch the outside of image as a result cloud show very bright and water show dark. To avoid this problem, use local area contrast enhancement. In this process zoom the area and apply contrast sketch for visualize the picture. It will make better enhancement for area of interest.

For doing a local area enhancement the scene just includes. We have to take a different zoom levels before makean attractive result.

To do this in QGIS:

1. Confirm the Raster toolbar is visible
2. Zoom and position the view so that it displays area of interest enclosed by a margin
3. Select the Local cumulative cut stretch button on the Raster toolbar
4. Uncertainty the enhancement is wrong, change the zoom level and reapply.

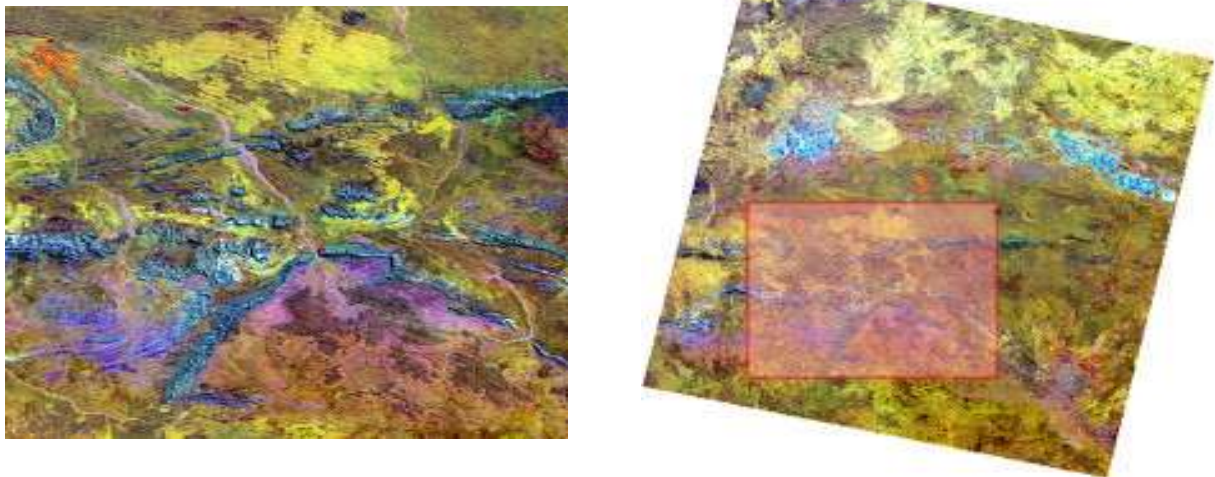


Figure 5.5Local area contrast enhancement. [49]

Redevelopment and save the image

In QGIS software there are different ways to re project an image and we are going to attention on the more visual ones. The better visual method is to fixed the QGIS for our working system.

The QGIS re project image procedure are:

1. select Project and then Project Properties from the main menu.
2. Allow the fly CRS transformation.
3. Locate working coordinate system
4. If it is already used CRS we can select it from the upper window otherwise select it from the lower window.
5. Click OK to display the change.

Now save the image to a file:

1. We have to right click the image in the layer's panel and choose Save As from the pop up menu.
2. Fixed the Output mode to executed image, click the Browse button and then enter a Save as filename.
3. Click the arrow at right of the CRS box and change the CRS from Layer to Project.
4. 4.Click OK to save the file

5.3 Enhancing a satellite image with GIMP

GIMP is an image manipulation program that is widely used for image editing, image enhancement and image visualize quality improvement. GIMP Photoshop has a limitation; it is not perfect arrange 16-bit channel image it only works with satellite 8-bit image data. But this is not a big problem because satellite loss many information when it collects data. GIMP only intention is to visualize and better image quality.

The GIMP workflow includes four steps:

1. Collect the bands
2. Enhance the image
3. Distribute the file
4. Reapply the geo referencing

Collect the bands

The following procedure should be obeying to collect band

1. In GIMP software have to select file Open as layers.
2. After selecting file Browse folder and then click Ctrl+click for pick the band images.

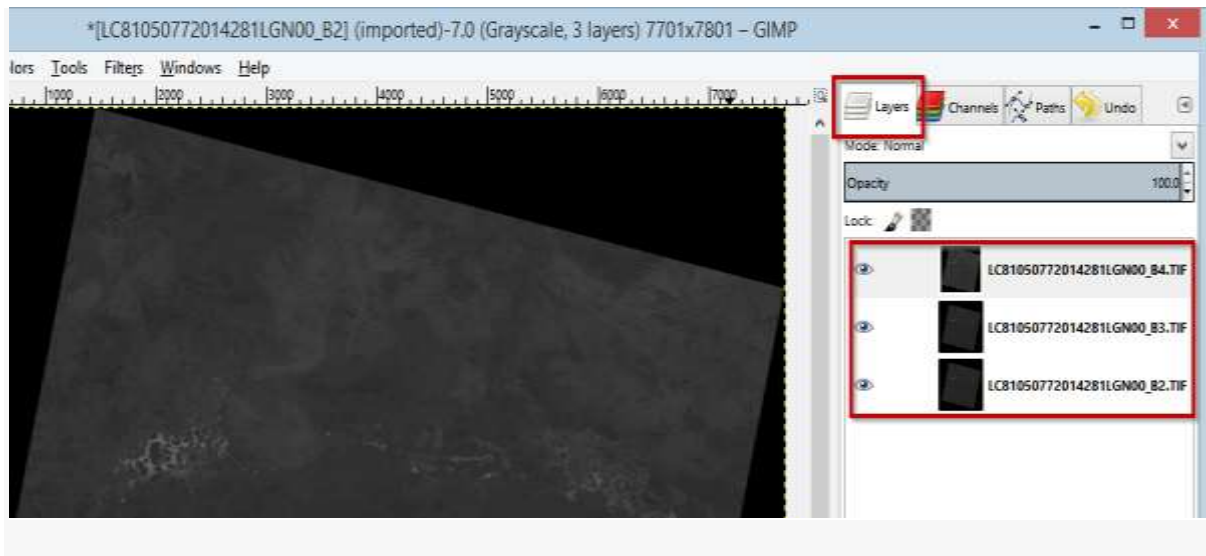


Figure 5.6 : The Layers panel showing the three bands as separate layers.[50]

3. Then Take Colors, select components and Compose and confirm the color model is RGB.
4. After selecting RGB model have to map the Red, Green and Blue channels and then apply change. It will work for natural color image the mapping is correspondingly Red = B4, Green = B3, Blue = B2.

The GIMP display 2 images. One is layered black & white version and another composited color version. The composited color looks like dark.

5. Reject the B & W version.

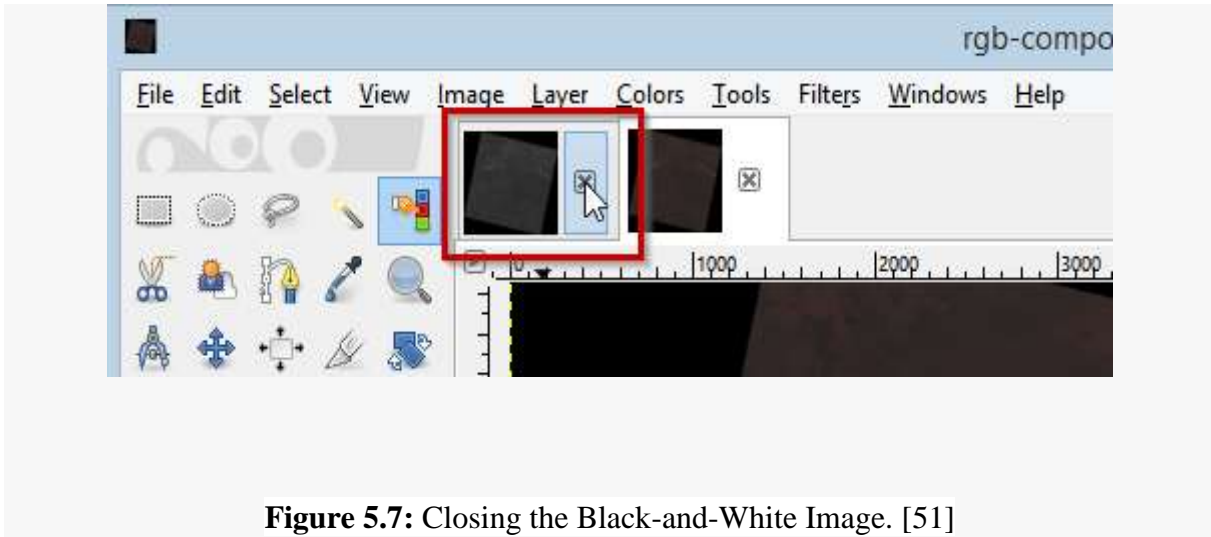


Figure 5.7: Closing the Black-and-White Image. [51]

6. Take Select option by Color and then click somewhere in the black area. The selected black region will be highlighted.

7. Choose Select and now the marching ants only enclose the scene



Figure 5.8 : Marching Ants. [52]

Enhance the image

Basically image enhancement depends on two important tools such as level adjustment and curve adjustments. This level and curve adjustment apply on satellite image raw data image.

Apply a levels adjustment:

1. Confirm the marching ants are visible. If marching ants are not visible, then re-apply the selection.
2. Choose the colors, levels and then click the Auto button of the dialog.
3. change between the red, green, and blue Channels on the levels dialog, and click OK and examine the the input levels.
4. Adjust the black or white points of an individual channel

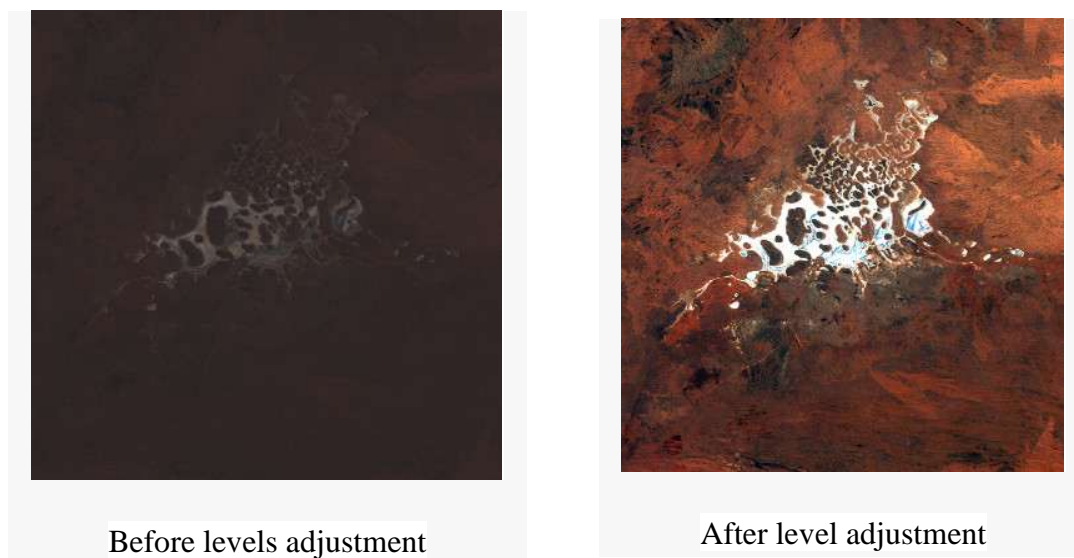


Figure 5.9: Before and after adjusting levels. [53]

5. Click OK to apply the change.

Adjusting curves: GIMP curve adjustment will modify the lookup tables. The the adjust brightness color will vary from 0 to 255. Apply curve adjustment by the following GIMP method.

1. Confirm the marching ants are visible. If marching ants are not visible, then re-apply the selection
2. After marchingant's selection select colors and curves.
3. It will display a curve with line.
4. Repeat the adjustment anywhere on the line.
5. Select OK to apply the change.

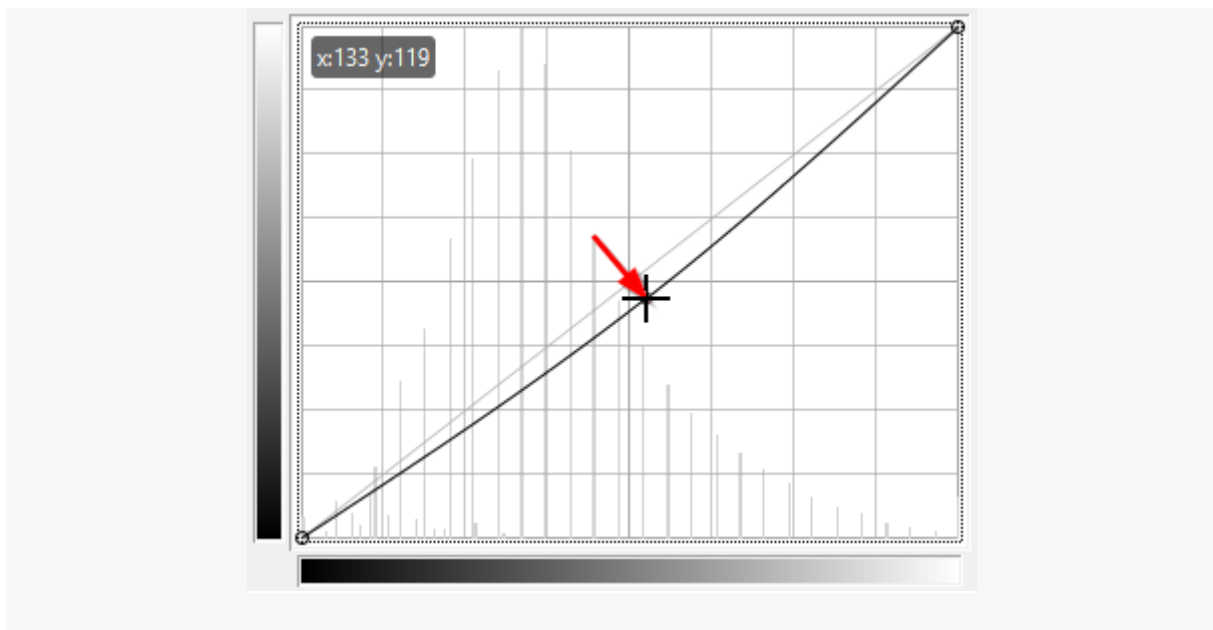


Figure 5.10:Applying a curves adjustment. [54]



Figure 5.11: Before and after adjusting curves. [55]

Export the file:

GIMP Photoshop software saves to it on his own XCF format, so that we must export image to save it any other file type. We have to select the file and export and enter filename. We should also enter the file extension so that GIMP can identify file type because GIMP can't work with 16-bit image data it only work with 8-bitdata.

Reapply the geo referencing: The last step is to apply dereferencing. It will provide real time meta data. For remote sensing image processing it very important to use dereferencing.Dereferencing software help to know the raster data and other important information.

Georeferencing steps:

1. Open georeferencer and add control points to the corners of the image.
2. After exposing Copy and paste the corner coordinates from the metadata file into each control point.
3. If it displays the scene is situated south of the equator, add 10 000 000 meters to the Y values before pasting them into the control.
4. Tag the image with the appropriate UTM coordinate system.
4. Apply the dereferencing and save the result.

Chapter 6

Conclusion

In this thesis we attempt to study the mineral exploration techniques using satellite imagery. Mineral exploration is probably the most important issue because of its unavailability. This thesis is totally study based. Remote sensing is a technique which help to extract information about mineral and their spectral characteristics by using the electromagnetic spectrum. In Remote sensing technique satellite's advanced quality sensors and multispectral camera usually being used. In mineral exploration, at present, the used satellites are Landsat, Aster, Terra X etc. These mineral exploration satellites have multispectral cameras and different kinds of advanced sensors to detect the mineral or monitor earth surface objects. Minerals are usually located beneath the Earth surface, so remain undetected by bare eyes. Some Minerals always emit detected radiations and every rock and minerals have different wavelengths and spectral bands. Satellite multispectral camera sensors can identify this spectral band characteristic and distinguishing specific mineral is possible. Different kinds of earth surface elements like vegetation area, vast water body, mountain and dense forest area exhibit different kinds of spectral reflectance. Similarly, several minerals have unique spectral features, which can be identified by satellite sensors. The Band ratio technique and principle component analysis are among satellite image processing techniques those are generally used after satellite data collection. Band ratio technique is very effective to find out the spectral difference of different mineral – because, every mineral contains diverse spectral band and its band ratio is different and distinguishable. In this thesis we tried to describe how to explore the iron oxide mineral by using its spectral reflectance characteristics. The band ratio $4/2$ has been used to distinguish iron oxide from other earth surface elements.

Thermal imaging is another technique for mineral exploration. We also described, here, how this method works for mineral exploration. In earth surface all of the minerals can't reflect electromagnetic spectrum and this type of minerals can't be found by using Visible Near Infrared (VINR) or Short-wave Infrared (SWIR). Satellite thermographic cameras can be used to identify those. This type of mineral can be distinguished from others by Long Wave Infrared (LWIR) band. LWIR only uses thermal imaging technique. This thermal imaging technique can find out the earth surface minerals and other objects temperature. Volcanic eruption, fire can also be distinguished by thermal imaging process. Satellite image processing is most important part for the mineral identification. In this thesis we also tried to discuss how satellite raw image data is extracted and then modified for better understanding. Image enhancement can help to improve the picture quality. For Satellite image processing several software are presently used like QGIS, SAGA, GIMP, OASIS. We only incorporated how satellite imagery can be enhanced by QGIS and GIMP.

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