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Applications of Remote Sensing and GIS in mineral exploration- A resource-saving technology

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Mineral exploration is a task that we need to approach with maximum information. Missing out on rare metals and minerals can easily occur, and the process of searching for them is a costly risk. That is one of the reasons for remote sensing in mineral exploration being so important. Remote sensing can be used to measure, variations in acoustic wave distributions, force distributions and also electromagnetic energy distributions. The latest progress in the field of remote sensing and origin of new computer software such as Geographical Information System (GIS), ENVIS (Environmental Information Software) have transformed the world and made life much easier for mineral explorers.

1.0 Introduction

"Remote Sensing is a technique in which data are acquired without any direct contact to derive information about objects or materials (targets) located on the earth surface or its atmosphere" (Lillisand, T. M and Keifer, R. W., 1979).

"Remote sensing is the art and science of acquiring information about the Earth's surface without actually being in contact with it. Reflected or emitted energy is sensed, recorded, processed, analyzed and applied to gather that information" (CCRS/CCT).

In general, remote sensing involves seven steps (figure 1):

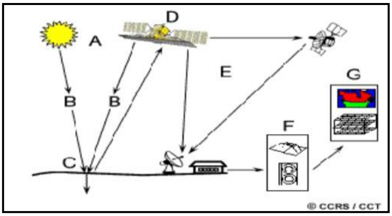

Figure 1: Steps in Remote Sensing (After CCRS/CCT)

1. Energy Source or Illumination (A)
2. Radiation and the Atmosphere (B)
3. Interaction with the Target (C)
4. Recording of Energy by the Sensor (D)
5. Transmission, Reception, and Processing (E)
6. Interpretation and Analysis (F)
7. Application (G)

Remote sensing is done using sensors primarily used to detect the reflected or emitted electromagnetic radiation (EMR). These sensors are installed on vehicles, called platforms and operate with the help of cameras and scanners.

Ranges in EMR are of the primary importance like visible region in the range of 0.4 - 0.7 μm (Blue: 0.4 – 0.5 μm, Green: 0.5-0.6 μm, Red: 0.6-0.7 μm.). Other bands include Ultraviolet (UV) region (adjoins the blue end), Infrared (IR) region (adjoins the red end), Microwave region (longer wavelength intervals ranges from 0.1 to 100 cm, etc.).

The images generated in remote sensing are broadly utilized for mineral exploration in mapping the geological features and lineaments and identifying rocks by their spectral signature. Images are gathered either through synthetic aperture sensors or optical sensors. Synthetic aperture sensors can sense electromagnetic data by transmitting microwaves and receiving the reflected back waves from the Earth's surface while optical sensors measure the spectral data of sunlight reflected from the surface of the Earth.

Reconnaissance lithologic mapping is usually the initial step of mineral resource mapping. Aforementioned is complimented with structural mapping, as mineral deposits often occur along or adjacent to geologic structures, and mapping variation, as mineral deposits are usually linked with hydrothermal changes of the surrounding rocks. In addition to these, knowing the use of multi and hyperspectral remote sensing is crucial as multi and hyperspectral data can help distinguish and thematically map regions of exploration interest by using the discrete absorption features of most minerals. Eventually coming to the mineral exploration stage, GIS stands a useful tool in assimilating and analyzing various georeferenced available data in picking the best sites of mineral deposits.

The exploration of mineral has a very high-cost component and involve intensive labor work, except if they are highly automated. Nowadays, in developed nations, high-end machines perform services in all stages of detections and productions. In underdeveloped countries like Nigeria where technology is deficient, the work is unendurable and clumsy, and hence little exploitations are made. Various studies of mineral deposits showed that much of these countries natural resources are unexploited. Mineral resource mapping can change the entire situation using an integrated application of three geospatial technologies (Remote Sensing, GPS and GIS).

The study area is captured and digitally analyzed using any GIS software like ArcGIS and QGIS. GPS receiver is used to categorize ground sections for the collected data. Geometric corrections, supervised or unsupervised classification and setting quantitative relationships between spectral signatures and ground features that are indicators of appearance or absence of mineral deposits can also be done effectively using these tool.

The applications of aerial photo presentations on a variety of areas, viz, land cover mapping, soil and geologic mapping, zones of mineralisation, wetland mapping, wildlife ecology, archaeology, agriculture, forestry range, land management, water resources, urban and regional planning, environmental assessment, landform identification and evaluation is the real-time programme of various agencies.

With the help of remote sensing, faults, geological contacts and fractures are brought out clearly which help in prospecting mineralized areas. It has proven to be a valuable tool in exploring the mineral resources and separating the favorable areas from unfavorable areas. Remote sensing data provide the lithological, geomorphological and structural guides essential for understanding various parameters responsible for the localization of most of the ore deposits. (Rawashdeh, S.A 2007).

2.0 History and Development

It has been over seven decades that remote sensing technology has been in use but for mineral exploration it has gathered a rapid pace with the advent of firstly taking aerial photographs and doing compare-and-contrast, matching the photos with the findings of gold on the surface and looking for similar features to find gold, and then satellite imagery in the recent years after it became commercially feasible and available, the same compare-and-contrast method was used with satellite images also. Since 1972, satellite remote sensing, combined with other exploration techniques, has proved operational exploration and engineering cost saving and reduced exploration risks through better geological mapping. Land and ocean remote sensing satellite systems have significantly increased our ability to explore, prove, and manage energy and mineral properties globally. The use of remote sensing has been there since over a decade but more recently with the introduction and upgradation of GIS structural and lithological mapping have developed to a very high level, in all the mineralized areas. It has also been observed that new age sensors can map efficiently lithologic and stratigraphic units and identify alteration in rocks, soils, and vegetation cover indicative of undiscovered subsurface minerals. Mapping and monitoring of resource development can also be done using the same sensors. The use of satellite remote sensing data along improved geographic information systems (GIS) has grown substantially through evolving integration with other geophysical, geochemical, and geological data.

3.0 Exploration process using Remote Sensing and GIS

Remote Sensing, GPS and GIS serve as a tool for mineral resource monitoring, and mapping. Remote Sensing has some major advantages at gathering the information, that makes it a competent tool in mineral deposits exploration and extraction, then using GIS to develop geological maps of mines. Collecting and handling data in the field is just the initial step in coming up with an output used in exploration. The next step is to modify the data into information that is presentable and understandable through various image visualization techniques that include, Visual interpretation, Digital processing, Preprocessing, Image Enhancement, Transformations, Classification and Integration.

Remote sensing systems make use of spectral signatures of the features. Every material behaves differently to EMR depending upon their chemical and structural properties, the amount of EMR it reflects absorbs, transmits, emits and varies with wavelength. The amount of radiation from a material is plotted over a specific range of wavelengths. These points are connected and create a curve named as the material's *'spectral signature'.*, It depends on the different properties like the material targeted, the incident energy (angle, intensity and wavelength) and this uniqueness of the reflected or emitted EMR used to detect and discriminate the objects or surface features.

Every object has a unique spectral signature, and similar objects share a similar spectral signature. Hence, one can identify the feature and its characteristics to a great extent with their spectral signatures. An object's spectral signature can be learned using remote sensing sensors data which is need to be analyzed manipulated and processed. Most of this is accomplished by altering spectral color bands of the image.

Spectral signatures form a Spectral Reflectance Curve is a graphical representation of the spectral response over different wavelengths of the electromagnetic spectrum. It provides an in-depth knowledge of spectral characteristics of different rocks or material and also useful to select a specific wavelength band for remote sensing data acquisition, as shown in figure 2. These curves are crucial to interpret and analyze an image obtained in single or numerous wavelengths. Spectral rationing can be carried out on selected bands to improve the spectral resolution of an image using sensors like Landsat 4-5 Thematic Mapper (TM) on the EM spectrum. The quotient images are then aligned and converted into formats like RGB, which is a color composites format. Single TM bands can also be chosen for color composites to increase the classes of the surface materials spectrally as logged by the digital number (DN) values.

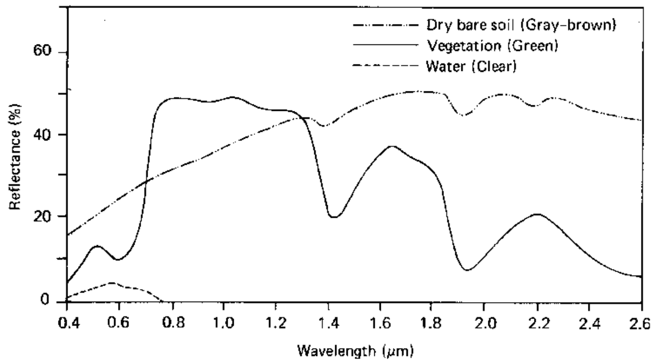

Figure 2: Typical spectral reflectance curves for vegetation, soil and water (After Lillesand et al., 2004)

4.0 Processes involved in mineral exploration

Mineral targeting consists of the utilization of geological traits that control their emplacement. Finding these geological controls is usually viewed within the framework of the parameters that are linked with the depositional and post-depositional processes that have influenced them. Exploration methods are typically designed to take care of the peculiarities of all observable surface geological evidence that can be used to recognize areas of likely mineralization. The use of remote sensing is intended at digitally analyzing and manipulating the information in the imagery, which can be directly associated with the surface processes like weathering and alterations that are connected with mineral deposits. All the geologically associated information generated from the imagery from the database for a GIS-based extraction of the most encouraging areas. Specific attributes that are deemed useful for exploration of the Geology and Mineral Potential is the rock outcrops and lineaments concentration. Aforementioned is a direct outcome of the likely mineralized area as well as vegetation cover designating healthy plant growth as a cause of soil fertility as a result of soil enrichment with minerals. In a situation where the exposures are reduced, mapping usually involves indirect methods such as; Structural evidence, Geochemical evidence, Inference from geological mapping and Geophysical evidence.

4.1 Location of the Study Area

A piece of detailed information regarding the Land Cover area and Latitudes-Longitudes of the area under study. Longitudes and Latitudes are taken and recorded. Remote sensing ensures the availability and rapid access to real-time geospatial data.

4.2 Digital Image Processing (DIP)

The images are firstly pre-processed before the input of the images used. The supplied/input images used can be arranged via various agencies collecting the remote sensing data of that particular area. In countries, government organisations can provide the required data for many cases.
The next step involves the preparation of the dataset related to the area. Satellite orbit information can be used to improve the imagery Ground Control Points (GCPs), if the Digital Elevation Model (DEM) for the area is not present. Imagery rectification can be done to present already geocoded SPOT Multispectral data or Landsat MSS(image -to-image geocoding) using the Universal Transverse Mercator(UTM) coordinate system, Clarke 1880 spheroid, or as required in a region depending upon the location and properties. After developing the images of data needed (training sites), supervised classification (or unsupervised classification) can be carried out to recognize the arrangement of the distribution of the various spectral classes in the images.

Lineaments play critical roles in controlling mineralization. The study of lineaments and their interpretation is necessary for the geological presumptions that have relevance and links to mineral exploration targets (Odeyemi, 1999). Thus, the images are sensibly studied for such features and subsequently subjected to Lineament Density Analysis (LDA) using a pixel size of our requirements. The lineament density is used to aggregate and calculate the total lengths per square kilometer using the appropriate Algorithm. This involves digitization of linear and curvilinear features as segments from properly filtered ETM bands, e.g. considering LanSat7 Bands 5 and 4 are best suited for picking linear features. Enhancement involves not only edge enhancement but also directional filtering. The procedures made the structural features adequately visible for digitization. As these features are digitized, they are saved as layers. These layers go through the overlay process with other segments such as geological structures maps, roads, rivers and other layers for lineaments identification that is then interpreted as geologically related (Short 2001). Any Remote Sensing and GIS software can be used for the lineament density analysis. Utilizing a pixel size of a specific area, the lineaments per square kilometer is automatically calculated whereas the attribute of each segment such as length and orientation and serial number are automatically created and stored in the vector attribute cells. Using the excel functions like histogram, the lineaments can also be automatically aggregated to be displayed in a rose plot.

Lineament density analysis is a typical job in most geological applications of structural controls to mineralization. Zones of intersections and trends are usually sorted after in explorations because it is premised on the fact that mineralization is structurally controlled.

Digital Image Processing is divided into two parts. Digital Image Enhancement where Color Composites, Contrast Stretching, Filtering and Edge Enhancement, Density Slicing, Thresholding, IHS, Time Composite and Synergic Images are done and Digital Image Processing and extraction where Supervised Classification, Unsupervised Classification, Fuzzy Classification, Image Transformation, Principal Component Analysis, etc. are carried out. Some of the image processing software like ERDAS Imagine, ILWIS, ENVI, ArcGIS, MATLAB, etc. are very useful for Digital Image Processing.

5.0 Conclusion

The applicability of geospatial technology helps in mineral exploration by presenting extensive land cover information about mineral a mapping. The spectral properties of soil cover can be known and also the tectonic information delivered about by the distribution of the lineaments features which complement the selection of the promising areas for comprehensive mapping. The benefits of geospatial technology, especially remote sensing, have introduced new extents into the study and understanding of earth's processes and even vegetation cover, which has direct relationships with the deposits. A necessary pre-requisite to joining in these opportunities is the building of various indigenous capacities and competencies for the development and utilization of science and technology (ARCSSTE-E 2007).

The main advancement in mineral exploration is the ability to integrate various forms of data with the help of computers. Noted drill results can be easily integrated with topographic maps, structural maps, air photos, and many other details like ore grade data. Data synthesis can considerably improve the precision and effectiveness of a mineral exploration process. Remote sensing is a mainstay in mineral exploration and for a good reason. Advancements in data processing and remote sensing technology will proceed to allow explorers to take more calculated gambles and assess their mining progress and mineral exploration with a sense of certainty.

It can be inferred that the various computer hardware and software are along with the latest technologies of remote sensing and information technology, are highly valuable and essential for the understanding and assessment of the present or current status of the existing geological resources in any part of the world. Use of computer models have also been useful in the interpretation of the past and present data as well as predicting the future status of these resources in any region which help in implementing the scientific methods for the management and conservation of and accurate exploration of these mineral resources.

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