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Gold prospecting using Remote Sensing 'A case study of Sudan'

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Abstract:- Gold has been extracted from northeast Africa for more than 5000 years, and this may be the first place where the metal was extracted. The Arabian-Nubian Shield (ANS) is an exposure of Precambrian crystalline rocks on the flanks of the Red Sea. The crystalline rocks are mostly Neoproterozoic in age. ANS includes the nations of Israel, Jordan. Egypt, Saudi Arabia, Sudan, Eritrea, Ethiopia, Yemen, and Somalia.
Arabian Nubian Shield Consists of juvenile continental crest that formed between 900 550 Ma, when intra oceanic arc welded together along ophiolite decorated arc. Primary Au mineralization probably developed in association with the growth of intra oceanic arc and evolution of back arc. Multiple episodes of deformation have obscured the primary metallogenic setting, but at least some of the deposits preserve evidence that they originate as sea floor massive sulphide deposits.

The Red Sea Hills Region is a vast span of rugged, harsh and inhospitable sector of the Earth with inimical moon-like terrain, nevertheless since ancient times it is famed to be an abode of gold and was a major source of wealth for the Pharaohs of ancient Egypt. The Pharaohs old workings have been periodically rediscovered through time. Recent endeavours by the Geological Research Authority of Sudan led to the discovery of a score of occurrences with gold and massive sulphide mineralizations. In the nineties of the previous century the Geological Research Authority of Sudan (GRAS) in cooperation with BRGM utilized satellite data of Landsat TM using spectral ratio technique to map possible mineralized zones in the Red Sea Hills of Sudan. The outcome of the study mapped a gossan type gold mineralization. Band ratio technique was applied to Arbaat area and a signature of alteration zone was detected. The alteration zones are commonly associated with mineralization. The alteration zones are commonly associated with mineralization. A filed check confirmed the existence of stock work of gold bearing quartz in the alteration zone. Another type of gold mineralization that was discovered using remote sensing is the gold associated with metachert in the Atmur Desert.

As knowledge of geology and mineralization of the Red Sea Hills improved, it became increasingly apparent that mineral deposits are located along linear structures trending NE-SW and are associated with acid volcanicity. Hydrothermal alterations and weathering processes of the sulphide mineralization produce spectral anomalies that extend beyond the ore body itself. To this end satellite images provide a superb synoptic view of the structural features and the spectral anomalies. Special interest was focused on ratio image processing techniques, whereby false colour composite images were produced using combination of bands in Red, Green and Blue, that rendered maps of alteration zones. Ground-truthing of the outlined areas disclosed the existence of stockworks that contain gold and sulphide mineralization.

I. INTRODUCTION

In the recent years remote sensing was used extensively in many applications such as geological mapping, agriculture mapping, hydrogeological investigation and prospecting for mineral deposits The increasing living standard of the underdeveloped countries entails the search for more resources to meet the demands of minerals.

Therefore, new exploration techniques must be utilized to discover previously unknown reserves. Remote Sensing can map and analyze rocks over hundreds of square miles in a single imagery. This geological mapping may indicate particular areas of interest that can then be investigated in detail on the ground. Improved geological understanding leads to looking for new resources in previously overlooked areas. The main elements of geology in Sudan include high-grade gneisses; low-grade green schist island-arc assemblage of metasediments, metavolcanics and ophiolitic tectonic mélanges. The layered sequences intruded by syn-orogenic and post-orogenic granites; and are separated by structural contacts. The basement rocks are overlain by Nubian Super Group sedimentary cover followed by Tertiary volcanics and blanketed by Quaternary to Recent deposits. Gold exploration and exploitation in Sudan dates back to the Farah and Turkish eras. Gold used to be explored by use of traditional methods at Nahral-Neel, Blue Nile and northern Sudan. The ancient sites discovered at those areas were about twelve sites.

The most common type of alteration is the breakdown of feldspars and ferromagnesian minerals to a variety of clays and other hydroxyl bearing minerals. Such minerals can be detected by remote sensing

techniques since the short wave infrared (SWIR) range of their spectra exhibit absorption (Drury 1993). Besides, a considerable number of ore occurrences contain sulphide minerals particularly pyrite (FeS2) which undergo breakdown to sulphuric acid and a number of ferric hydroxides and complex sulphates which are both strongly coloured and possess crystal field absorption in the visible and near infrared range (VNIR) (Drury, 1993; Lillesand & Kiefer, 1994; Sabins, 1978). This suite of alteration features proved to be extremely useful in delineating a variety of hydrothermal ore deposits (Drury, 1993). It has been well established that ferric iron exhibits pronounced absorption features at around 0.82 μm and 0.35μm, whereas ferrous iron has absorption at 1.0, 4.8-2.0 and 0.55-0.45. Hydroxyl – bearing minerals like clays have a major absorption feature around 1.9, 2.35 and 2.5 (Gupta, 1991). Detection of the above mentioned minerals has been used as prospecting guide for ore deposits. Ratio images are known for enhancement of spectral contrasts among the bands considered in the rationing and have successfully been used in mapping alteration zones (Segal, 1983; Kenea, 1994).

Gold is found at al-Mazroub area where Gossanic evidences containing gold ore and other related mineral have been discovered. These studies have proved presence of extensions of Gossanic evidences in depths that are estimated at 150 meters inside the ground. Gold ore and other related minerals have also been discovered in northeastern Sudan between latitudes (20-00, 21-00 degrees) and longitudes (15-35, 30-34 degrees) east. Geological studies and researches have also proved existence of gold at many places in the country including the Red Sea Mountains, south of Blue Nile, north Sudan (from Halfa northwards until Atbara on east and west of the Nile), North and South Kordufan State, South Darfur State and others.

The overall objective of the present work is to discuss Sudan experiments in using remote sensing to prospect for different types of mineralization and to demonstrate the viability of this technique in such studies.

II. STUDY AREA

The present area that was adapted for studying the mineral deposits using Geo-informatics in Sudan The Bayuda city of Sudan lies in between 18 19 47.62 N 32 40 56.92 E. The total area of study area is 1,535.828296 Square Kilometers. (ETM) image of Landsat 7 satellite are used throughout the analysis. The area of interest is included within the image 174/47. The Bayuda volcanic field is located in the Bayuda Desert of NE Sudan, south of the major Abu Hamed bend of the Nile River about 300 km north of capital city of Khartoum. More than 90 eruptive centers along a WNW-ESE line were constructed over Precambrian and Paleozoic granitic rocks near the center of the Bayuda Desert. Most vents of the Bayuda field are cinder cones that produced lava flows which breached the cones. About 10% of vents in the field are explosion craters, the largest of which, named Hosh ed Dalam, is 1.3 km wide and up to 500 m deep. The youngest basalts of the Bayuda volcanic field appear to post-date the last period of moist climate in Sudan, which ended as recently as about 5000 years ago. One of the least eroded lava flows at Bayuda was dated at about 1100 years ago.

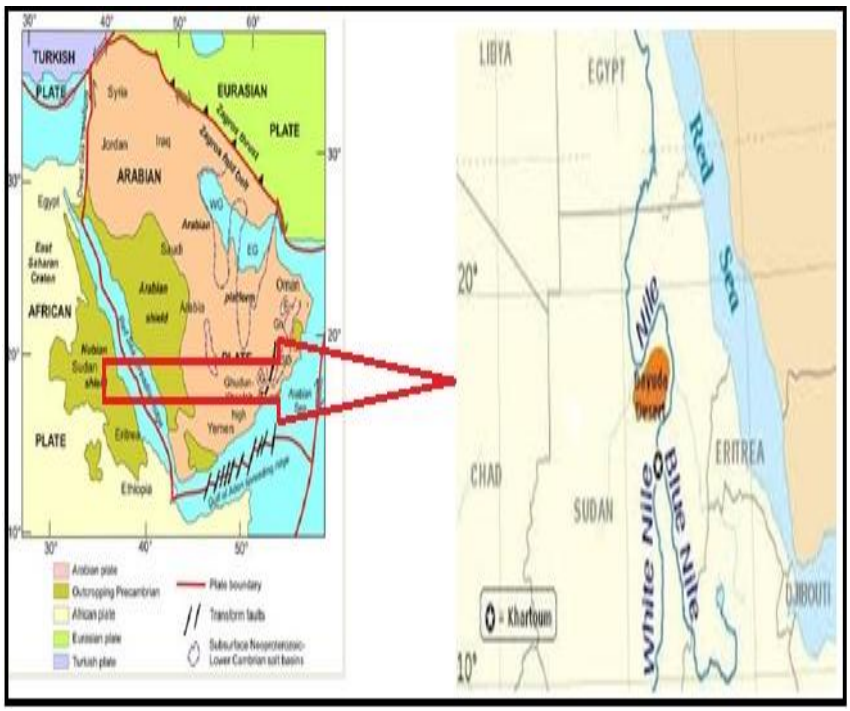


Figure 1. Shows the Location map of Study area

III. MATERIALS AND METHOD

Dataset Used

2. Data type:

Remotely sensed data used in this study are shown in the following table:

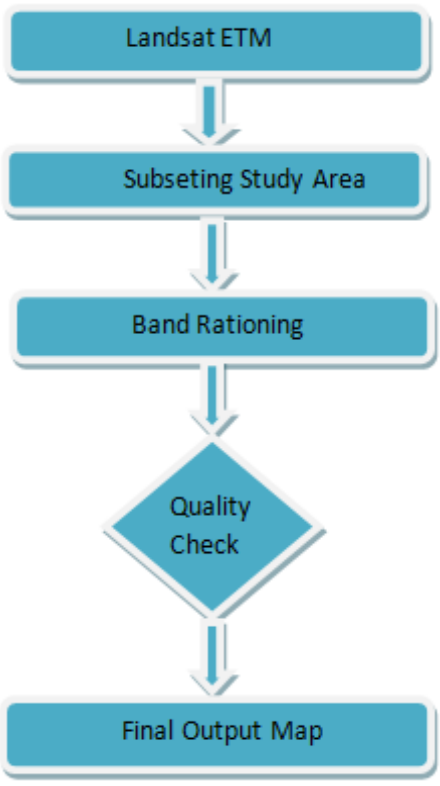
Sensor	path	Row	Date
ETM	174	47	17-04-2005

Table (1): Data types used in this study

During the analysis a simple to complex step-wise path is followed. Each analysis result is compared with the previous one. Conventional methods like color composites, several band rationing techniques, are applied to the original unregistered raw data.The resulting images are considered to be the potential alteration maps. If the results display any convergence with the data acquired from previous works then the final (combination) map of all techniques is registered and processed and prepared for the ground truth. The geology of the area is gathered from the published maps and mostly forms the basis of the ground truth data

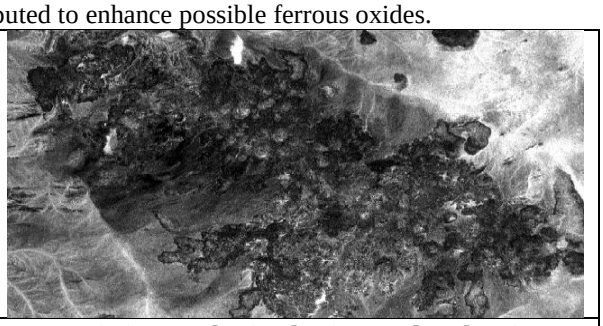
2.1.2 Band Rationing: The band ratio is a technique that has been used for many years in remote sensing to display spectral variations effectively (Elsayed Zeinelabdein, K.A. (2008).

It is based on highlighting the spectral differences that are unique to the materials being mapped. Identical surface materials can give different brightness values because of the topographic slope and aspect, shadows, or seasonal changes in sunlight illumination angle and intensity. These variances affect the viewer's interpretations and may lead to misguided results. Therefore, the band ratio operation could be able to transform the data without reducing the effects of such environmental condition. In addition, ratio operation may also provide unique information that is not available in any single band which is very useful for disintegrating the surface materials (Jensen 1996). The band ratio images are known for enhancement of spectral contrasts among the bands considered in the ratio operation and have successfully been used in mapping of alteration zones (Segal 1983). From the theoretical knowledge of mineral's spectral properties, it is well recognized that the Landsat TM bands ratios of 3/1, 5/7, 5/4 are analyzed for iron oxides, hydroxyl bearing minerals, ferrous oxides, respectively.

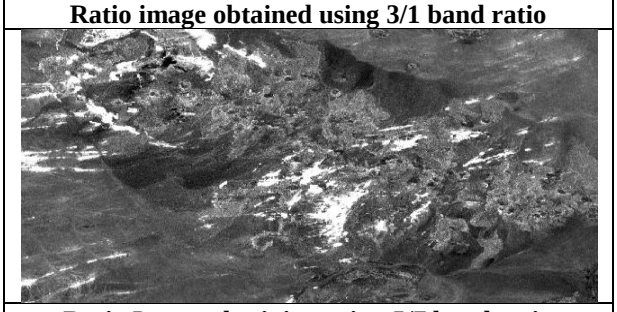


IV. RESULT AND DISCUSSION

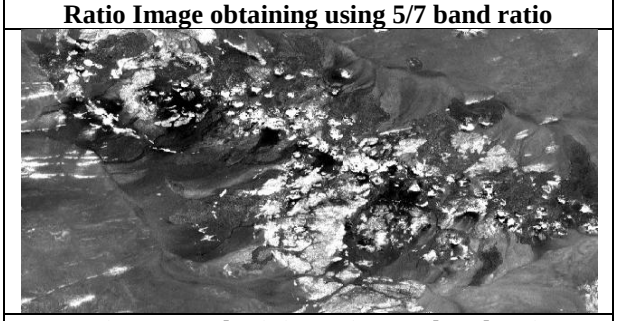
Using the theoretical knowledge about the spectral properties of most rocks and minerals, TM bands 3/1 and 5/7 were selected for iron oxides and hydroxyl bearing mineral respectively (see plate 2 and 3). Whereas band ratio 5/4 has been computed to enhance possible ferrous oxides.



Ratio image obtained using 3/1 band ratio



Ratio Image obtaining using 5/7 band ratio



Ratio Image obtaining using 5/4 band ratio

Based on the above considerations the spectral features of ferric and hydroxyl – bearing mineral, in which hydrothermally altered rocks are often rich, are used to produce a false colour composite image using combinations of bands 5/7, 5/4 and 3/1 in R,G and B respectively (see plate 1). The obtained image has mapped the alteration zone in reddish yellow. This alteration can easily be observed in the lower right corner and right central part of the image.

Another composite ratio image was produced using bands 5/7, 3/1 and 4/3 in R,G and B respectively (see plate 2). Although this combination of ratio image appears to be fairly different from the previous one, the final result remains the same thus lending support to the previous conclusion.

Groundtruthing of the outlined areas of wall rock alterations has disclosed the existence of a quartz stockwork that contains gold and base metal sulphide mineralization.

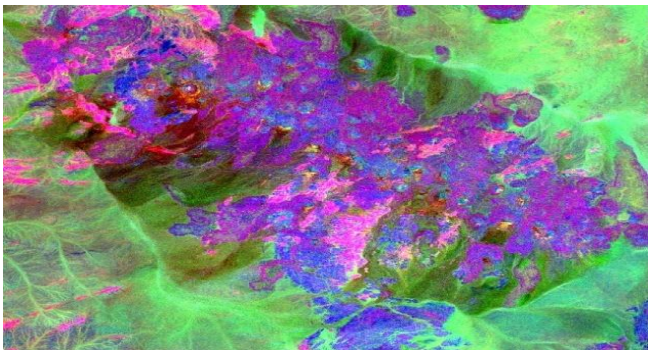


Plate (2) Hydrothermal Composite Image 5/7,3/1,4/3

Ratio image obtained the following band combination: (band 5/ band 7), (band 3/ band 1) and (band 4/ band 3) assigned to red, green and blue filters, respectively.

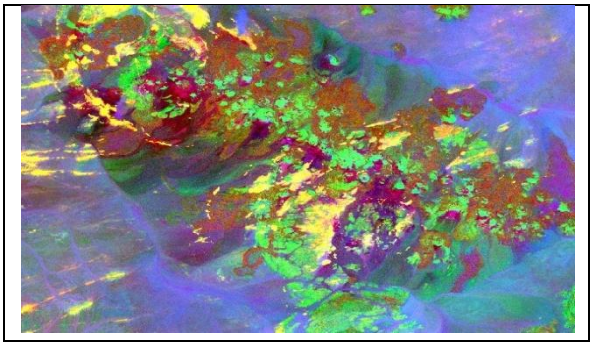


Plate (1):Mineral Composite Image 5/7,5/4,3/1

Ratio image obtained using the following band combination: (band 5/ band 7), (band 5/ band 4) and (band 3/ band 1) assigned to red, green and blue filters, respectively

However, the performed study should be considered a preliminary step to narrow the search area and paves the way for more detailed prospecting in the predefined potential sites.

V. CONCLUSION RECOMMENDATION

The gossan type of gold mineralization was successfully mapped in the Red Sea Hills of Sudan making use of Satellite imagery. The study has demonstrated the application of Remote Sensing as a valuable tool for assessing the alteration zones. The main aim was to prospect alteration zones and compare the results with the field records in order to see as to how accurately remote sensing can be used to make alteration assessments in such a short span of time. This can help as technical alternative which can prospect the alteration zones in very less time and with moderately good accuracy. Emote Sensing technology gives a fairly good result of prospecting the minerals with small amount of field survey and has tremendous advantages in terms of comparatively saving time in prospecting the minerals. The study will go in long way to redress the future mineral challenges that Sudan will face and will help planners to come out with certain concrete measures and policies to address the issues.

Band ratio technique was applied and a signature of alteration zone in Yellowish color was detected. A field check was confirmed the existence of stock work of gold bearing quartz in the alteration zone. Al Ridaa Mining company now is exploiting gold from such mineralization. The increasing demand for cement in the current years leads to the construction of several cement factories. These factories used emote sensingin finding new occurrence for marble.Black sand of magnetite mineralisaton in streams located in northern sudanwas detected using Quick bird high resolution imagery. This type of mineralization appears as brown hues in images. Another type of iron ore was found in magnetite rich microgranite, which appears in blue turquoise color in Landsat images.

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