World Journal of Applied Research
worldappliedjournal.com
Online ISSN: 3107-8885
Received: 27-01-2026, Accepted: 26-02-2026, Published: 13-03-2026
Volume 2, Issue 1, 2026, Page No. 1-7

Utilization of remote sensing in prospecting for mineralization zones in blue - Nile region, South-western Kurmuk, Sudan

Hassabelrasoul Elsidig Elhadi Ahmed[1], Sadam Hassan Mohmed Ahmed Eltayib[2*]
[1] Department of Hydrology, Faculty of Minerals and Petroleum, International University of Africa, Sudan
[2] Department of Geology, Faculty of Sciences and Technology, Omdurman Islamic University, Sudan
Corresponding Author: Sadam Hassan Mohmed Ahmed Eltayib

Abstract
This study explores the application of multiple remote sensing techniques for gold prospecting in the challenging, rugged, remote, and marshy terrain of the Blue Nile Region, South-west Kurmuk. The methodology involved the acquisition, processing, and interpretation of Landsat 8 (OLI) images and high-resolution Google Satellite Data. Advanced image processing techniques such as False Color Composites (FCC), Band Ratios (specifically iron and clay indices), and Feature Oriented Principal Component Selection (FPCS) were utilized to delineate geological indicators associated with gold deposits, including various hydrothermal alteration zones. Digital Elevation Model (DEM) data also contributed to geomorphological and hydrological analysis. The results demonstrate the reliability and applicability of these methods, with clay mineral analysis strongly indicating hydrothermal alteration, a favorable environment for economic mineralization. While other spectral analyses (Abrams, Sabins, Crosta ratios) showed negative results for gossan and iron oxides, suggesting a different type of mineralization. The study highlights the effectiveness of Earth Observation satellite images for geological mapping in difficult - to - access areas and recommends subsequent reconnaissance field surveys for promising zones identified through strong clay signatures and structural trends.

Keywords: Remote Sensing, Prospecting, Landsat8, Alteration, Band Ratios

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) [3]. Besides, a considerable number of ore occurrences contain sulphide minerals particularly pyrite (FeS_2) 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) [3]. This suite of alteration features proved to be extremely useful in delineating a variety of hydrothermal ore deposits (Drury, 1993) [3]. 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) [5]. 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) [9]. 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. Multiple Remote Sensing Techniques have been utilized in prospecting for gold in the rugged, remote and marshy study area, Blue Nile Region, South-west Kurmuk. The utilized procedure involved the acquisition, processing and interpretation of Landsat 8 (OLI) images, coupled with the processing and interpretation of high resolution Google Satellite Data. The results of the two methods were then compared, their reliability assessed for further development. These methods proved their reliability and applicability; recommended this work be progressed further into the reconnaissance field surveys. In conclusion they encouraged the researchers to conclude that Earth Observation (EO) satellite images are of vital importantance as sources used in the field of remote sensing. This is particularly true in geological mapping, especially in rugged and remote areas that are difficult to access terrestrially. The Landsat 8 OLI images provide multi-band spectral data that allow for the detection of mineralization indicators, such as oxide minerals (like iron oxides) and clay minerals associated with hydrothermal alterations, which are often indirect indicators of gold presence. On the other hand the Google Satellite data consists of panchromatic full color base map captured 2018 with spatial resolution of approximately two meters.

Among the most prominent satellites used in this field are:

- **Landsat:** Provides images with a spatial resolution of up to 30 meters in the visible and near-infrared spectral bands, enabling the application of techniques like Band Ratios and Principal Component Analysis (PCA). (Sabins, 1999) [12].

- **ASTER:** This satellite provides additional thermal spectral band data effectively used to detect spectral changes in minerals, particularly in monitoring hydrothermal alteration zones.(Pour & Hashim, 2011) [11]. The use of this data contributes to improving the accuracy of geological map interpretation and identifying promising areas for mineral exploration, making remote sensing an effective technical tool to support geological surveying and preliminary exploration operations. (Sabins, 1999) [12]. Geographic Information Systems (GIS) are also essential tools in the early stages of mineral exploration, as they enable the integration and analysis of various types of geological, structural, and spectral data within a unified spatial environment. By inputting data layers such as geological maps, fault and fold structures, and spectral alteration indicators extracted from satellite images, spatial databases can be built to contribute to the creation of predictive models for areas with high mineral potential. Spatial analysis tools within GIS are used to produce prospectivity maps that allow for focusing on the most probable areas of mineralization. (Gupta, 2018) [7].

Google Satellite Data

Google Satellite data consists of panchromatic full color base map captured 2018 with spatial resolution of approximately two meters As a result of their high resolution these images could be uses in either of the following two ways:-The first Method - they could be utilized as enhancement additive to the OLI Images as resolution merge. In the second method second they could be acquired, separately, processed by use of strong photo-editing software and interpreted. The results thus acquired are to be compared with those attained by other procedures. This integration with remote sensing techniques enables geologists to identify the most promising exploration targets before conducting field visits, which helps reduce time and cost, and increase the effectiveness of selecting sites likely to contain mineral accumulations.

Geological Setting

In the Sudan - Ethiopia borderland - Blue Nile state and Kurmuk region. The study area is a remote wooded and rugged hazardous terrains in the extreme south of Blue Nile State. Geologically the area is located along the western wedge of low-grade volcano-sedimentary-ophiolitic sequence in the East in juxtaposition with the high-grade supracrustal rocks in the West. The volcano-sedimentary sequences were found sandwiched between the high-grade orthogenesis, which occur as wedges, and blocks bounding the low grades to the East and West. Granitoids, slices of basalt-andesite’s, clastic metasediments, and volcanogenic clastic rocks were encountered thrusted on the high-grade rocks of the area. Rocks such as Quartz-chlorite schist, Phyllites, graphitic schist, Marble were found differentially effected by shearing, mylonitization, which were thought to mark major thrust and fault zone, related to the opening and closing of small oceans during Pan African tectonic events, [1100-550] ma. Most rock forming mineral have a little or no response to spectra only a few number of these minerals control the reflectance signatures detected in TM imagery. However, these wave bands cover absorption features present in Iron bearing minerals, hydroxides and hydroxylated silicates such as clays chlorites and serpentine minerals. Whereas variation in opaque mineral with low flat spectra controls the albedo over soil dominated surfaces. Digital image processing started with the idea to manipulate and interpret. (Birrle, 2010; Badr al-Din Khalil Muhammad, 2016) [1, 2].

Objectives

This study aims to employing multiple remote sensing techniques to detect and delineate geological indicators and minerals associated with gold deposits in the study area. This will be achieved through the application of analyses on selected spectral indices (such as iron and clay indices) with the goal of identifying various hydrothermal alteration zones (e.g., argillic, phyllic, and propylitic) that indicate the presence of gold mineralization.

Study Area

The study area is situated 35 kilometers east of Meneg Township, Benishangul - Gumuz Region, western Ethiopia.

The area has rugged hillocky relief and because of its vicinity to the equator it receives intense precipitation. Therefore the area is mostly marshy or it has a dense plant cover a situation significantly dilutes remote sensing methods of discrimination and identification of geological phenomena.

Data and Software Used:

1. Types of Data Used:

The basic Data utilized for the project is the Landsat 8 OLI images with spatial resolution of 30 meters. The second source of data is the Google satellite full color base map captured 2018 with spatial resolution of approximately two meters. ENVI v. 5.6 Software were in processing the Landsat 8 image while My Paint Photo Editing software was used in processing The Google satellite image.

1. Landsat 8 (OLI) Data

Landsat 8 OLI satellite imagery data was downloaded from the U.S. Geological Survey (USGS) website (https://earthexplorer.usgs.gov/), with Path number 174 and Row number 046. It contains 7 multispectral bands with a spatial resolution of 30 meters, in addition to one panchromatic band with a resolution of 15 meters. The image acquisition date was 24/02/2014, and it was cloud-free.

2. DEM Data

Digital Elevation Model (DEM) data for the high-resolution ALOS PALSAR satellite was downloaded from the Alaska Satellite Facility (ASF) Search website (https://search.asf.alaska.edu/#/), with a spatial resolution of 12.5 meters.

2. Software Used

- ENVI (v. 5.6) software for satellite image analysis.
- My Paint Photo Editing software for processing*Google satellite* image.
- ArcGIS Pro (v. 3.1) software for geospatial analysis, data integration, and map production.

Methodology

The methodology involved the digital processing of Landsat Eight 8 OLI satellite data through a series of essential steps, beginning with radiometric and atmospheric correction to enhance the quality of the spectral data and ensure its accurate reflection of the actual land surface. Following this, techniques for improving spatial and spectral resolution were applied by fusing the seven reflective spectral bands (Bands 1–7) with the panchromatic band (Band 8). This contributed to increasing the spatial contrast of the resulting image to produce False Color Composites (FCC), which help in distinguishing surface features with higher accuracy. In the spectral enhancement processing, Band Ratios associated with hydrothermal alterations and gold indicator minerals were calculated, and then separate images representing these indicators were produced. Additionally, the Feature Oriented Principal Component Selection (FPCS) technique was applied to transform the image into new components that highlight the spectral signatures of mineralization areas, and a map for this was produced areas.

Results and Discussion

1. Remote Sensing Techniques

1.1. Creation of False Color Composite (FCC) Image

This method (FCC) aims to enhance the spectral response of minerals associated with hydrothermal alterations, particularly iron oxides and hydroxyl-bearing minerals. In this technique, images of spectral ratios sensitive to mineral alterations are assigned to the primary color channels (Red, Green, and Blue) to produce a composite image that clearly highlights alteration. (Sabins, 1999) [12]. A False Color Composite (FCC) image was generated to visually inspect the study area and determine its effectiveness in defining the mineralization extent, using Band 7 (SWIR2), Band 5 (NIR), and Band 2 (Blue) in R, G, B respectively (Figure3).

1.2. Band Ratios Analysis:

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) [6]. 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) [10]. 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) [9]. 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. Band Ratios analysis is used to enhance spectral contrast by calculating the ratio of Digital Number (DN) values between two or more spectral bands. This method reduces the effects of illumination and topography and highlights the subtle spectral characteristics of minerals and rocks. It is beneficial for identifying various mineral assemblages such as iron oxides and hydroxyl- and carbonate-bearing minerals. (Gupta, 2018) [7] This technique was utilized to produce several analytical maps, as follows:

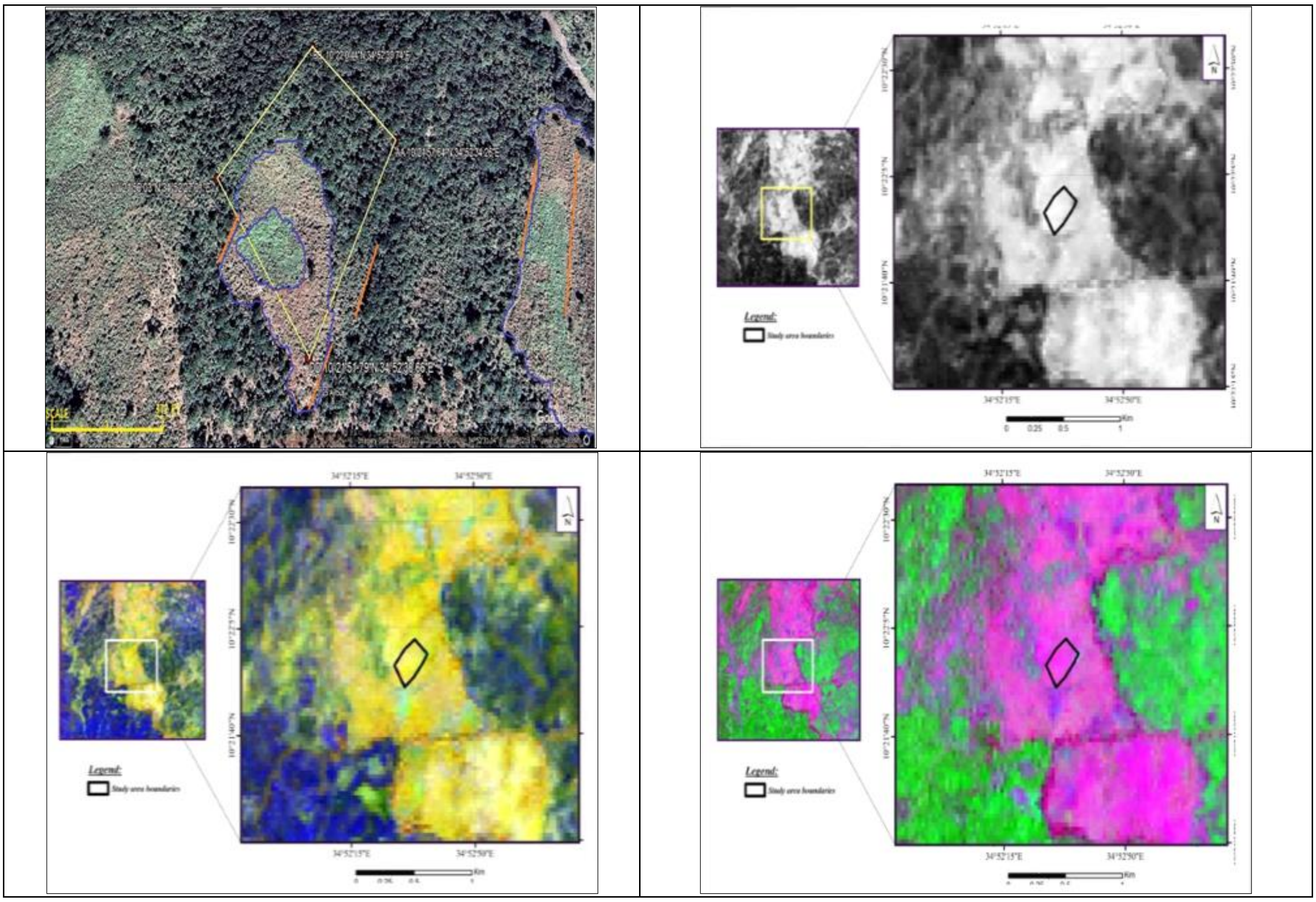

Fig 1: Processed Google Satellite images showing distinct contrast between diverse geologic and alteration units (in pinkish grey color), Study area within yellow polygon.

1.3. Principal Component Analysis (Feature Oriented Principal Component Selection "FPCS"

Feature Oriented Principal Component Selection (FPCS) is a method to select some bands of the image not all to run a principal component transformation. The selected bands are believed to exhibit spectral information over an intended target (Crosta and Mc. Moore, 1989). This method developed by Loughlin (1991) to map alteration zones and it is well known by Crosta image. Theoretically, it is known that the iron oxides minerals and hydroxyl- bearing minerals displayabsorption bands in range of bands 1 and 7 in the ETM+7 data, respectively. Hence, two sets of four selected bands are transformed by unadjusted principal component analysis. The eigenvector loadings are carefully examined to define which Principal Components (PCs) contain information related to the target objects. (El Khidir & Babikir, 2013) [4]. This technique was applied to Landsat images, and the results were as follows:

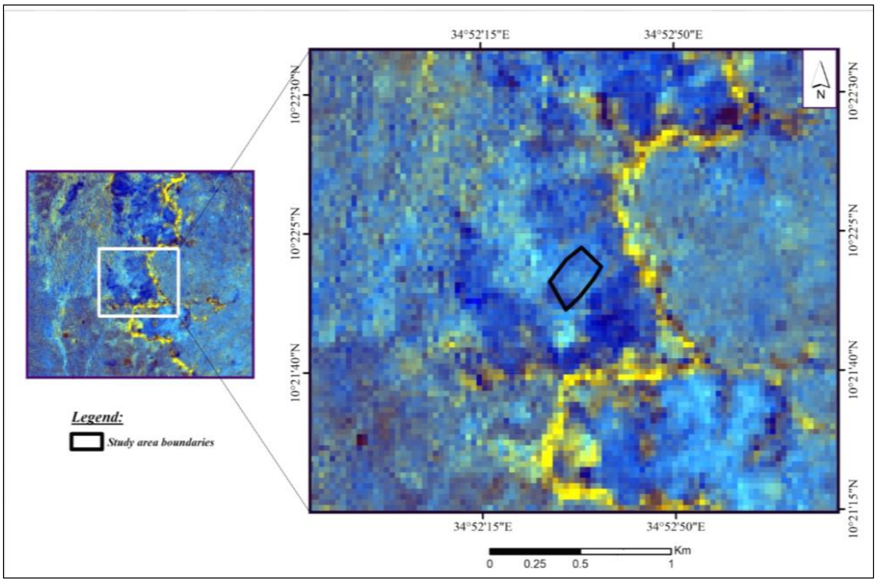

Fig 2: FCC Crosta band ratio image produced from the FPCS products. FCC image produced by selection of (H, H + F, F) in the R, G and B, respectively

2. Digital Elevation Data

The Digital Elevation Model (DEM) is a three-dimensional digital representation of the Earth's surface, and it was used in this study to analyze the geomorphological and hydrological features in the study area. A map of the drainage pattern was extracted and produced, in addition to an elevation map (Figure 3). The resulting map revealed that the predominant drainage pattern in the area is structurally controlled.

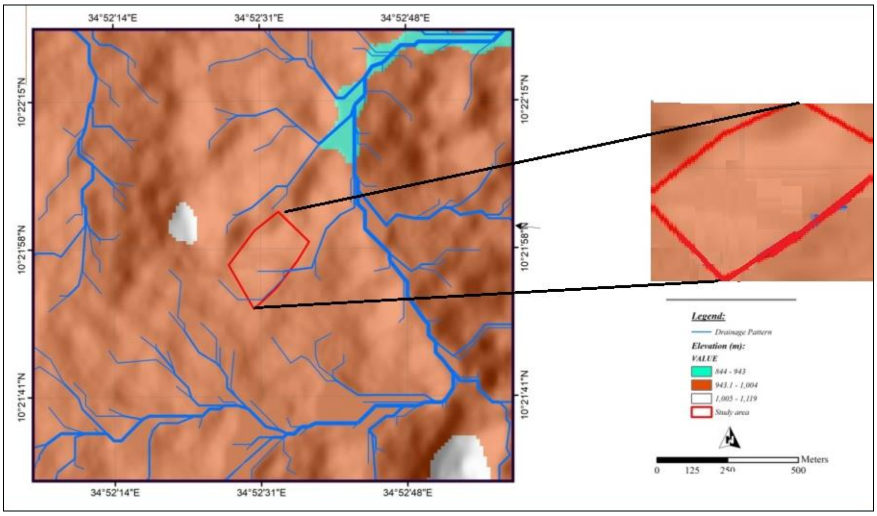

Fig 3: Map showing drainage patterns and elevation in the study area

3. Additional Discoveries

For better results and as an enhancement to the satellite data ETM resolution merge is the most commonly employed to the images. The parameter used for this process is Band 8, however owing to some technical obstacles high resolution Google Earth image has been used instead,-This procedure gave results in strong support to the earlier results. These judgements can be summarized in the following point.

The images revealed good discrimination between the following phenomena

1. The general area is largely physio graphically flat to smoothly hillocky with the Metavolcanics forming the highest topography.
2. Metavolcanics rock masses form extensive exposures east western and at the center of the general area.
3. The Metavolcanics rocks are easily distinguished by their yellowish grey color as well by their strong alignment towards N and NNE direction.

Google Satellite image (Figure 4) of the concession showing this greyish alteration mineralization and the N and NNE structural trend. This trend is the structural control of most of the gold mineralization in Sudan**.**

1. Within the Metavolcanics areas there are relatively marshy site as a result of their topographic disposition.
2. Most of the other art are covered with thick forest cover which masks any fruitful findings

Second within the concession area the Metavolcanics occupy the southwestern part of the area.

They are characterized by their light colors and the zone of mineralization extends further southwards.

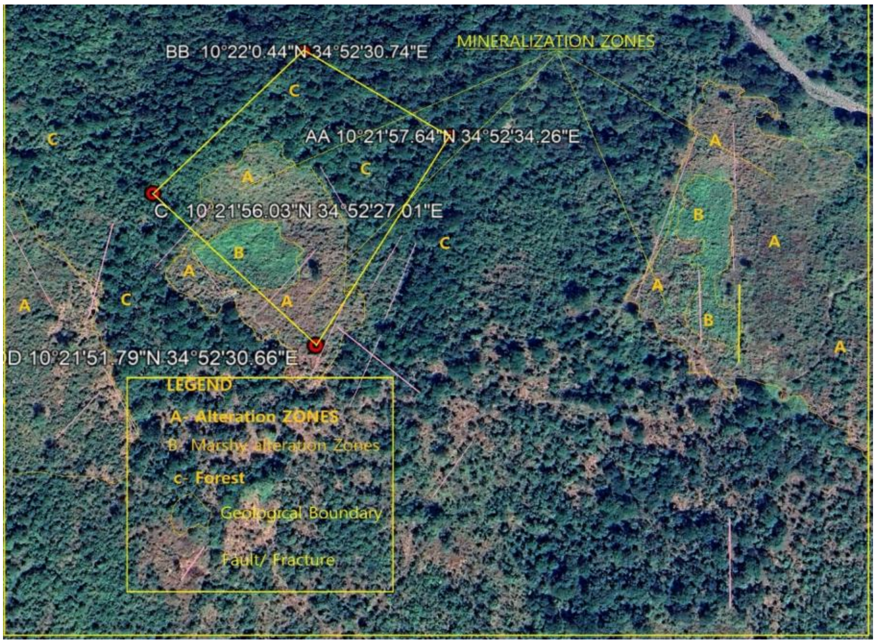

Fig 4: Google Satellite image showing the concession in the center, the western mineral mineralization and extensive eastern mineralization

4. Mineralization:

Mineralization at the general area and within the concession is indicated by the following phenomena (Figure 5).

1. Poor vegetation cover as a result of the acids expelled during the alteration of ore.
2. The relatively light color of the exposed geology as a result of disintegration of the acid Metavolcanics and the clay minerals products of alteration.
3. The Clearly obvious structures consisting of the following trends:
   a. Northwest trending structures especially at the western part of the area this trend may represent a host for orogenic gold.
   b. The second trend is the North an NNE trends which is mostly representing the general metamorphic lineament, however this trend represents the host of almost ninety present of the discovered epigenetic gold deposits in Sudan.

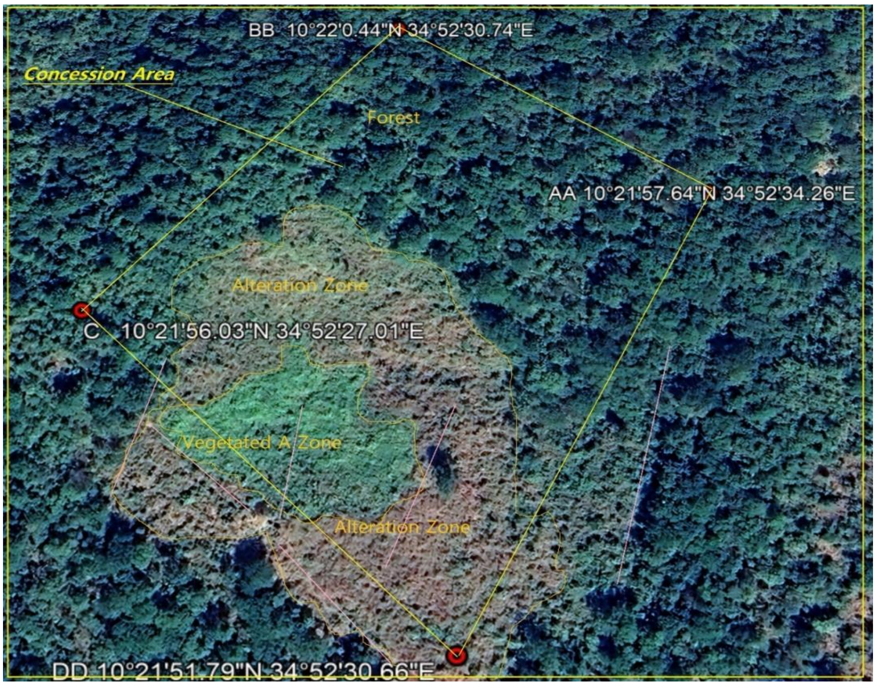

Fig 5: Geological Interpretation of high resolution Google satellite images showing alteration zones and the controlling structure

Conclusion

Based on the results of the spectral ratio analyses conducted on the Landsat 8 image of the study area, these findings can be interpreted as follows:

1. The good result from the clay ratio analysis (indicates the presence of clay minerals in the targeted area.
2. Clay minerals (such as kaolinite, montmorillonite, and illite) are strong indicators of hydrothermal alteration (Argillic Alteration).
3. The presence of clay minerals suggests that the area has undergone hydrothermal alteration processes, which is a favorable environment for the formation of many economic mineralizations' (e.g., gold, copper, silver).
4. The results of the Abrams ratio analysis, Sabin's ratio, and Crosta technique for the study area show negative results.
5. This indicates that the potential mineralization present in the area might not be associated with the formation of gossan and iron oxides, but rather with another type of mineralization.

Further supportive results are demonstrated to be achievable by applying spatial enhancement using high resolution images or by the separate processing and interpretation.

Recommendations

- It is recommended to conduct reconnaissance field execution to perform Ground Trothing for the locations that showed strong clay signatures. Several selected areas have been identified as shown in Figure (5) accompanying. Samples should be collected and the necessary analyses performed.
- The Supplementary investigation by use of Google satellite data have exposed an area which is apparently very prospective lying to the east
- This area seams promising in terms of its surface area, alteration extent as well him strength of the structural signature.

References

1. Badr al-Din Khalil Muhammad. Challenges of border trade between Blue Nile State and Benishangul Region. In: Ahmad AM, editor. Border, peace and development issues in Blue Nile and South Kordofan states. Bergen: Chr. Michelsen Institute (CMI), 2016, 23–40. [in Arabic].
2. Birrle TA. Marketing margin of artisanal gold miners of Menge wereda, Benishangul Gumuz Region, Ethiopia [Master's thesis]. Mekelle University, 2010.
3. Drury SA. Image Interpretation in Geology. 2nd ed. London: Chapman and Hall, 1993, 271.
4. El Khidir SO, Babikir IAA. Digital image processing and geospatial analysis of Landsat 7 ETM+ for mineral exploration, Abidiya area, North Sudan. International Journal of Geomatics and Geosciences,2013:3(3):645–658.

5. Gupta RP. Remote Springer- verlag Geology. Berlin-Heidelberg: Springer, 1991, 356.
6. Elsayed Zeinelabdein KA. Ratio image processing techniques: A prospecting tool for mineral deposits, Red Sea Hills, NE Sudan. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B8. Beijing, China, 2008.
7. Gupta RP. Remote Sensing Geology. 3rd ed. Springer, 2018, 183, 332, 352–354.
8. Kenea NH. Digital Enhancement of Landsat Data, Spectral Analysis and GIS Data Integration for Geological Studies of the Derudeb Area, southern Red Sea Hills, NE Sudan. Berliner Geowiss. Abh., D 14. Berlin, 1997, 116.
9. Segal DB. Use of Landsat Multispectral Scanner Data for Definition of Limonitic Exposures in Heavily Vegetated Areas. Econ. Geol.,1983:78:711-722.
10. Jensen RJ. Introductory Digital Image Processing A Remote Sensing Perspective. 2nd ed. Upper Saddle River: Prentice Hall, 1996.
11. Pour AB, Hashim M. Identification of hydrothermal alteration minerals for exploring of porphyry copper deposit using ASTER data, SE Iran. Journal of Asian Earth Sciences,2011:42(6):1309–1323. https://doi.org/10.1016/J.JSEAES.2011.07.017
12. Sabins FF. Remote sensing for mineral exploration. Ore Geology Reviews,1999:14(3-4):157–183. https://doi.org/10.1016/S0169-1368(99)00007-4