Detection of High Potential Gold Mineralization Areas Using Landsat 8 Data in Northeastern Sudan

AHMED SALAH OSMAN ALI

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Faculty of Geoinformation and real estate

Universiti Teknologi Malaysia

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This thesis is dedicated to my beloved Mother, Father, Family and friends

Thanks a lot for your kind help and encouragement

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ABSTRACT

This investigation used Landsat 8 data for mapping lithological units and alteration zones to detect high potential areas for gold mineralization in Red Sea Hills in Sudan part of the Arabian-Nubian Shield (ANS). The study area contains three gold mines part of Ariab mining district in Red Sea Hills, Northeastern Sudan. There are three types of gold deposits in the study area (Supergene deposits, polymetallic massive sulphide deposits and The Ganaet deposits) are being mined in Hadal Auatib mine, Hassai mine and Kamoeb mine. The objective of this study was to find new high potential areas for gold mineralization in the area. Color composite, band ratio, principle component analysis, directional filtering, minimum noise fraction (MNF), spectral angle mapper (SAM), matched filtering (MF) and Mixture-Tuned Matched-Filtering (MTMF) were used for geological mapping in this study. The results of this study showed the distribution of the lithological units and the hydrothermal alteration zones along with new high potential areas for gold mineralization which can be used in the future and proved the ability of Landsat data in mapping these feature. The results indicate that Landsat 8 data are capable to identify lithological units and alteration zones at a regional scale. However the identification of specific hydrothermal alteration zone is not feasible. High potential areas have been identified in the study area. Fieldwork verified the image processing results.

ABSTRAK

Penyiasatan ini digunakan Landsat 8 data untuk pemetaan unit lithological dan zon pengubahan untuk mengesan bidang yang berpotensi tinggi untuk mineral emas di Red Sea Hills di Sudan sebahagian daripada Perisai Arab-Nubian (ANS). Kawasan kajian mengandungi tiga lombong emas sebahagian daripada daerah perlombongan Ariab di Red Sea Hills, Timur Laut Sudan. Terdapat tiga jenis deposit emas di kawasan kajian (deposit Supergene, polymetallic deposit sulfida besar-besaran dan Deposit Ganaet) sedang dilombong di Hadal Auatib saya, Hassai lombong dan Kamoeb saya. Objektif kajian ini adalah untuk mencari kawasan yang berpotensi tinggi baru untuk mineral emas di kawasan itu. Komposit warna, nisbah band, analisis komponen dasarnya, penapisan arah, sebahagian kecil bunyi minimum (MNF), sudut mapper spektrum (SAM), penapisan dipadankan (MF) dan Campuran-ditala Dipadankan-Penapisan (MTMF) telah digunakan untuk pemetaan geologi dalam kajian ini . Keputusan kajian ini menunjukkan pengagihan unit lithological dan zon perubahan hidroterma bersama-sama dengan kawasan-kawasan yang berpotensi tinggi baru untuk mineral emas yang boleh digunakan pada masa akan datang dan membuktikan keupayaan data Landsat dalam pemetaan ciri ini. Keputusan menunjukkan bahawa Landsat 8 data mampu untuk mengenal pasti unit lithological dan zon pengubahan pada skala serantau. Walau bagaimanapun pengenalpastian khusus zon perubahan hidroterma tidak boleh dilaksanakan. Kawasan berpotensi telah dikenal pasti dalam kawasan kajian. Kerja lapangan disahkan keputusan pemprosesan imej.

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LIST OF ABBREVIATIONS

ANS	Arabian-Nubian Shield
EME	Electromagnetic energy
NASA	the U.S. National Aeronautics and Space Administration
SAM	Spectral Angle Mapper
MF	Matched Filtering
MTMF	Mixture Tuned Matched Filtering
MNF	Minimum Noise Fraction
GPS	Global positioning system
GIS	Geographical Information System

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Remote sensing technology can be used to derive useful information about the terrain in earth science. Minerals resources are important natural assets and it is a nation's best interest to stimulate a greater understanding of its indigenous wealth. Any industry in the world in one way or another need minerals, so any country in the world need to explore its Stock from minerals for their economy improvement.

The real begging to use remote sensing technology in minerals exploration came after the Second World War, where the aerial photogrammetry was used at that time. After satellite lunching, remote sensing technique was becoming profitable when using in geological applications. This technique includes acquiring, processing, and interpreting images and related data, acquired from aircraft and satellites that measure the interaction between features and electromagnetic energy. (Di Tommaso and Rubinstein, 2007; El Desouky et al., 2008; Gabr et al., 2010; Massironi et al., 2008; Pour and Hashim, 2011).

Nowadays, 73 earth science satellites currently operate under national and regional government auspices or under commercial ownership. In 2005, the U.S. National Aeronautics and Space Administration (NASA) alone were flying 80 instruments on 18 spacecraft. These instruments use remote sensing technologies that include scatterometers, multispectral and hyperspectral imagers, polarimetric and sounding radiometers, radar and laser altimeters, sounding LIDAR and radar, and synthetic aperture radar (NASA 2003). The instruments provide more than 1,800 science data products for study of physical, geophysical, biochemical, and other parameters (Macauley and Vukovich, 2005).

Remote sensing applications are used for mineral exploration in two applications (map geology and the faults and fractures that localize ore deposits, and recognize hydrothermally altered rocks by their spectral signatures). Multispectral satellite images are used to interpret both structure and hydrothermal alteration. The use of digital process TM ratio images can identify two assemblages of hydrothermal alteration minerals (iron oxides and clays minerals). Hyperspectral imaging systems can identify individual species of iron and clay minerals, which can provide details of hydrothermal zoning (Sabins, 1999).

Remote sensing images have been widely and successfully used for mineral exploration for decades. Although gold cannot be detected directly by any remote sensing method, the presence of minerals such as iron oxides and clay minerals, whose diagnostic spectral signatures, (in the visible/shortwave infrared portion of the electromagnetic spectrum) could be used as indicators for identification of hydrothermal alteration zones, which are associated with gold occurrences (GRAS, 1990; Kujjo, 2010).

In term of multispectral satellites, SPOT, Landsat Multi-Spectral Scanner (MSS), Landsat Thematic Mapper (TM) and ASTER are the major satellites that are using for mapping geology for regional scale. Landsat Thematic Mapper /Enhanced Thematic Mapper+ (TM/ETM+) images were used for exploring alteration minerals associated with epithermal gold and copper mineralization. SWIR bands (bands 5 and 7) of TM/ETM+ satellites have been used to identify hydroxyl-bearing minerals of copper/gold exploration (Clark et al., 1991; Cocks et al., 1998; Kruse, 1999; Abdelsalam and Stern, 2000; Perry, 2004; Hallman and Ramsey, 2004). The Advanced Spaceborne Thermal Emission and Reflection Radiometer remote sensor (ASTER) has good resolution in the SWIR bands for mapping hydrothermal alteration mineral zones with porphyry copper and epithermal gold mineralization. On the other hand, the hyperspectral where the image has more than 100 bands has been used in satellites and aircrafts platform. Some of the airborne that has been used in hyperspectral spectroscopy are HyMap and AVIRIS, where in term of satellites there is Hyperion sensor (Kavak, 2005; Pour and Hashim, 2011; Clark et al., 1991; Cocks et al., 1998).

NASA has launched two generations of unmanned Landsat satellites that have acquired valuable remote sensing data for mineral exploration and other applications. Both generations were placed in sun-synchronous orbits that provide repetitive images of the entire earth, except for the extreme Polar Regions. The first generation Landsats (1, 2, and 3) operated from 1972 to 1985 and is essentially replaced by the second generation. The second generation (Landsats 4, 5 and 7) were launched in 1982 and continue to the present. Landsat 6 of the second generation was launched in 1993, but failed to reach orbit. Images are acquired by the thematic mapper TM, which is an optical-mechanical cross-track scanner. An oscillating scan mirror sweeps the field of view of the optical system across the terrain at a right angle to the satellite orbit path. A spectrometer separates solar energy that is reflected from the earth’s surface into narrow wavelength intervals called spectral bands. Each band is recorded as a separate image. The recent one was Landsat 8, which was launched on 11 Feb 2013 (Also known as the Landsat Data Continuity Mission). Landsat(TM/ETM+) images have been used in minerals mapping and detection in many studies (Sabins, 1999; Ramadan and Abdel Fattah, 2010).

Gold exploration in Sudan has begun since Pharaonic ages (3,000 years ago), but the number of the people and dry hot weather caused the mining procedure to be patchy and fugacious in process. The period that can be consider as a regularly and continuous mining period is the British Colonization years from 1900 to 1956. Of course there was some Mining Ahli along the boundaries with Ethiopia, The Democratic Republic of Congo, Uganda, Central African Republic, and based on artisanal mining. Although that mineral exploration began in Sudan before in the surrounding countries, and there is stocks of a various types of minerals (chromite , gold, iron, silver, manganese, copper, iron, mica, and graphite), there still are no fitting evaluations of stores and numerous mineral events remain unexploited because of wrong prospecting systems (GRAS, 1990; Kujjo, 2010).

The best possible utilization of mineral investigation techniques was postponed until the 1970's, throughout which the Sudanese Geological Survey placed more than 50 gold handling destinations. Consequently, joint wanders between Sudan and outside organizations in the 1980's have furnished chances for the provision of up to date innovations to gold investigation. Subsequently, significant revelations of gold stores in the Red Sea Hills empowered the quest for gold in ranges of quartz veins, as well as in rocks connected with gossans.

Gold investigation and abuse in Sudan goes once more to the Farah and Turkish periods. Gold used to be investigated by utilization of customary strategies at Nahral-Neel, Blue Nile and northern Sudan. The antiquated locales uncovered at those regions were something like twelve destinations. Gold is found at al-Mazroub territory where Gossanic proofs holding gold metal and other related mineral have been uncovered. Geophysical studies have been directed over a zone of something like 13.5 square kilometers stretched out at longitude 4.5 kms (north/south) and scope 3 kms (east/west). These studies have demonstrated vicinity of expansions of Gossanic confirmations in profundities that are evaluated at 150 meters inside the ground. Gold mineral and other related minerals have additionally been run across at

Block No. The medium of gold metal in the dirt and waterways stores measure to 300 and 6oo particles in a million separately.

The study area is a part of the Arabian Nubian Shield (ANS), which it exposure of Precambrian crystalline rocks on the flanks of the Red Sea. The Precambrian crystalline rocks are for the most part Neoproterozoic in age. Topographically and from north to south the ANS incorporates the countries of Israel, Jordan, Egypt, Sudan, Eritrea, Ethiopia, Yemen, and Somalia. The ANS in the north is uncovered as a component of the Sahara Desert and Arabian Desert, and in the south in the Ethiopian Highlands, Asir territory of Arabia and Yemen Highlands.

1.2 Statement of problem

The key elements in minerals exploration are to gain understanding of geologic area through lithological mapping and to assist in defining potential target areas. To map bedrock and identify presence and abundance of specific minerals at specific scale, it is possible to use remote sensing techniques. Remote sensing is a useful tool to lithological and alteration zones structure (Sabins, 1999).

Sudan is one of the African nations which appreciate imposing land differing qualities. Its topographical guide contains numerous sorts of rocks going from sedimentary rocks, to basal rocks and molten rocks. Because of the geographical structures which go once more to a large number of years together with the development of tectonic plates and mainland and maritime sliding, immense mineral materials of budgetary quality were shaped in Sudan. These mineral possibilities are conveyed as per their surroundings of starting point where ophiolite rocks are found in the Red Sea, Blue Nile, Qalalnahal and northeast of Nuba Mountains regions, where these zones are rich of minerals of financial esteem, for example, chromite, magnesite aspestos and talc.

The study area had received less attention in terms of geological research in the past. However, some projects have been carried out, most of which aim at the appraisal of surface, groundwater resources and mining area structure. Among the researchers are Andrew and Karkanis (1945), Mansour and Samuel (1957), Gabert et al. (1961), Rodis and Iskander (1963). In addition, suitable image processing techniques are used to extract useful geological information from the Landsat 8 data for arid-semiarid regions.

1.4 Objectives

The objectives of this research are:

1. To conduct a remote sensing investigation for gold exploration purpose in the northeastern Sudan (Hassai mining area, Red Sea Estate).
2. To detect high potential area of gold mineralization using Landsat 8 data.
3. To run adequate image processing techniques to discriminate lithological units and structural elements in the study area.
4. To produce geological map contains high potential gold occurrence locations.

1.5 Scope of the study.

The area is located in northeastern Sudan and bounded by latitudes 18° 40′ 33″, and longitudes 35° 36′ 39″. It includes a part of Red Sea estate, which includes a mining area. This area is approximately 50km from Khartoum.

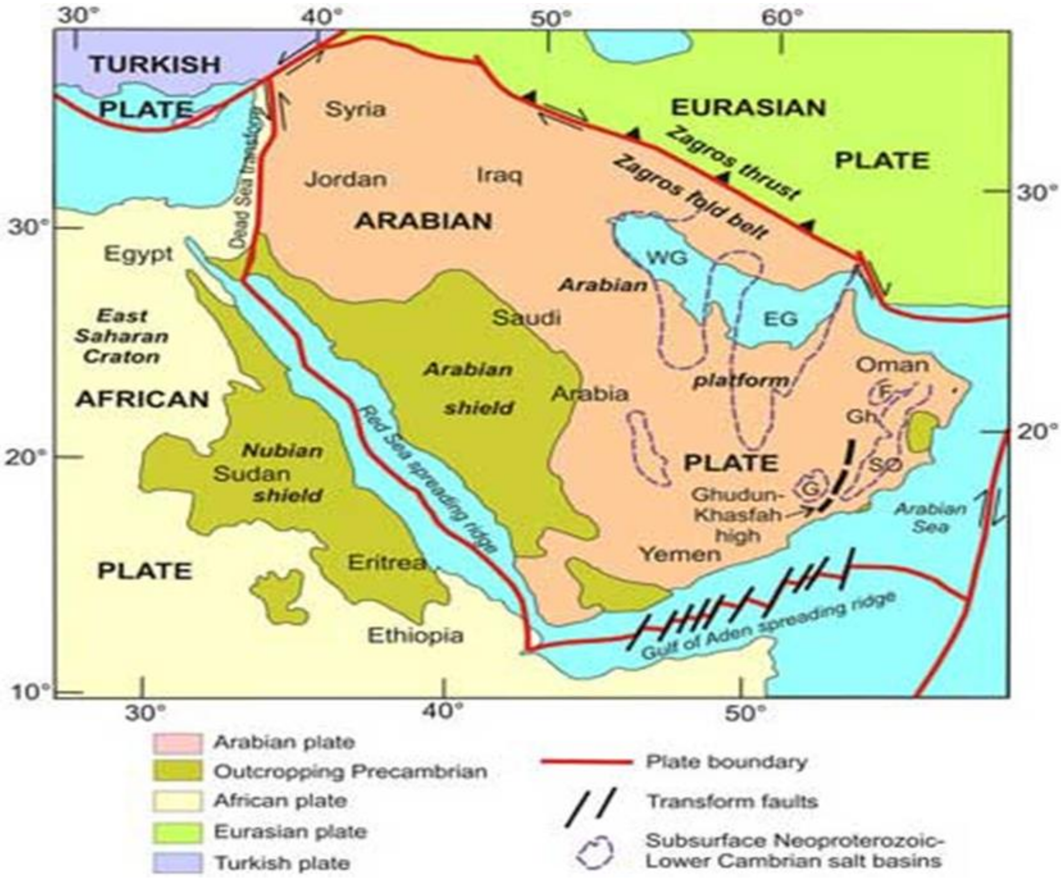

Figure 1.1: The Arabian Nubian Shield (ANS) (Sultan et al. 1993).

The area contains the Sudan's Hassai gold mine and it is a part of the Arabian-Nubian shield (Figure 1.1). The study area is facilitated inside the Proterozoic-aged Ariab greenstone. The area rocks incorporate fundamental and acidic volcanic rocks, tuffs and greywacke's that are meddled by late stones. A few mineralized stores are facilitated inside particular stratigraphic units of the Ariab area. The Ariab arrangement is structurally isolated into five units. Unit A is the basalt unit intruded by diorite and gabbro. Andesitic and deictic magmas on top of pyroclastic rocks are facilitated in Unit B, a thick halfway unit. The third unit designated C is acidic in nature and incorporates sodium-rich rhyolite and rhyodacitic magmas, tuffs and arches. Our study area contains part of Ariab series (Figure 1.2) and other parts to investigate the potential of gold deposit in these areas.

Figure 1.2: Gold mines in the Arabian Nubian Shield (Sultan et al. 1993).

1.6 Significance of the study

This study attempted to identify and analyze the role of remote sensing technology and especially Landsat data in lithological mapping and the identification of hydrothermal alteration zones. The benefit of this study will return to the country of Sudan in the future by using the results to identify the high potential areas for gold mineralization in the study area.

Landsat 8 data was used in this study due to the unavailability of the other remote sensing data that are associated with the identification of the individual species of iron and clay minerals in the study area. The results of this remote sensing study can be useful for the field of mineral exploration in Sudan and for future research in the area to start from the result of this study.

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