RATIO IMAGE PROCESSING TECHNIQUES: A PROSPECTING TOOL FOR MINERAL DEPOSITS, RED SEA HILLS, NE SUDAN

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ABSTRACT:

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. 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.

1. Introduction:

Gold has been mined in the harsh and rugged Red Sea Hills Region since ancient times and was a major source of wealth for the Pharaohs of ancient Egypt. During the past few hundred years, these ancient workings have been periodically rediscovered. The most recent phase occurred between 1905 and 1940 when the British companies explored the area and developed mines at Gebeit, Um Nabardi, Aberkateib, Oyo, Micraff and Grabein (see fig. 1).

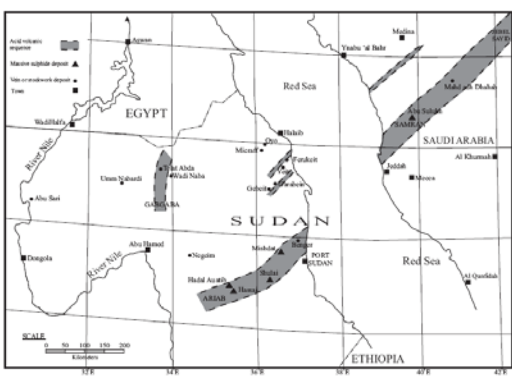

Fig. (1): Mineralized areas in the Nubian-Arabian Shield, modified from RRI (1985)

During the seventies of the last century the Geological Research Authority of Sudan (GRAS) embarked on a series of joint projects in the Red Sea Hills. Geological mapping was carried-out with the Soviet assistance and exploration of the mineral potentialities of the whole region with the French government (RRI – undated). The projects produced informative geological maps and discovered some mineral occurrences in the area; specifically tungsten mineralization (J. Ayoub), chroimte in Hamassaya locality and pyrite in a number of localities around Wadi Ariab.

Commercial gold production commenced in 1990 after the establishment of the Sudano – French Ariab Gold Mining Company. As knowledge of the geology and mineralization of the Red Sea Hills improved, it became increasingly apparent that many of the important mineral occurrences are located along linear structures that appear to be related to deep crustal fractures which have been periodically reactivated. These lineations trend mainly NE-SW and in some cases are associated with the development of localized acid volcanicity, as in Ariab and Gabgaba belts (RRI, undated).

Moreover, most of the known gold and sulphide mineralization occur within rocks of the Nafirdeib Series which appear to form a strongly differentiated sequence ranging from ultramafic, through basaltic, andesitic, and dacitic to rhyolitic volcanics (RRI, undated).

Extensive hydrothermal alteration zones and weathering of the sulphide mineralization within the acid volcanics represent a significant mineral province. In addition to the above the old workings, although of considerable interest in themselves, may in fact be of great significance as geochemical indicators for oxidized sulphide mineralization.

To this end satellite images provide a superb synoptic view where the location of old workings, manifestations of hydrothermal wall rock alterations and gross structural features can be discerned. Such a line of thought is conformable with the findings of (Houston, 1971; Hoppin et al., 1971; Jensen & Bateman, 1981; Sabins 1987; Drury 1993).

2. Data type:

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

Sensor	path	row	date
TM	171	46	13-06-1984
ETM	171	46	04-06-2001

Table (1): Data types used in this study

3. Image Processing:

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 (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). 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 0.35 µm, 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).

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 (see plate 4).

Plate (2): Ratio image obtained using 3/1 band ratio.

Plate (3): Ration image obtained using band ratio 5/7 to map clay minerals

Plate (4): Ratio image obtained using band ratio 5/4.

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 5). 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 6). 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 (E1 Tom, pers. comm.).

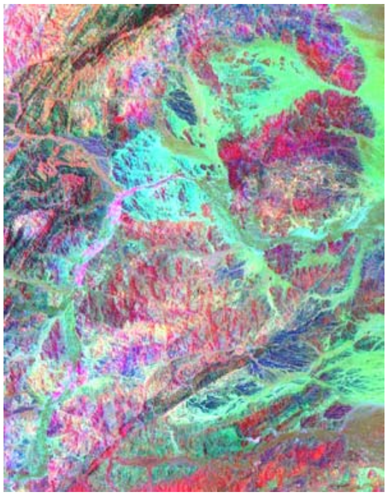

Plate (5): Ratio image obtained using the following band combination: (band 5/ band 7), (band 5/ band 4) and (band 3/ band 1) assigned to red, green and blue filters, respectively.

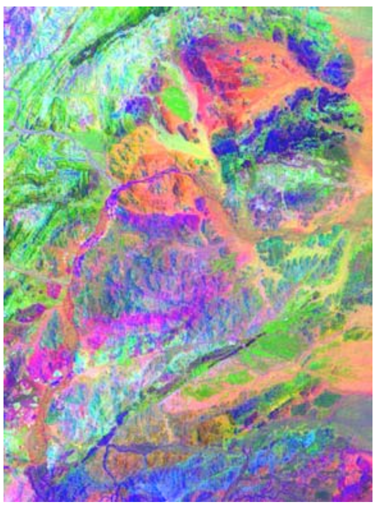

Plate (6): Ratio image obtained the following band combination: (band 5/ band 7), (band 3/ band 1) and (band 4/ band 3) assigned to red, green and blue filters, respectively.

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.

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