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DETECTION OF IRON ORE AT WADI EL-MUWEIH AREA DUE WEST OF QUSEIR, EGYPT USING DIGITAL PROCESSING OF LANDSAT DATA

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ABSTRACT

A succession of late Cretaceous Nubia Sandstone overlies unconformably late Precambrian basement rocks at Wadi El-Muweih area due west of Quseir, Egypt. Digital processing of Landsat MSS data of this area has led to significant results. Ratios of the MSS bands and color enhancement were the main techniques used in this study. Three band ratios were employed comprising AT(7/6 x 4/5), AT(7/5) x 2 and AT(4/7)x 0.5. The ratio AT(7/6 x 4/5) was found to be the most appropriate one in detecting bright signatures on the Nubia Sandstone. The signatures appear in the ratio images as series of points ordinated in discontinuous lines along the eastern bank of Wadi El-Muweih. Ground truth investigations revealed that the bright signatures indicate the presence of iron ore bed composing the topmost part of the Nubia Sandstone. It is about 1.5 m thick, covers about 10 km^2, and formed mainly of iron oxide (hematite and goethite)concretions. Preliminary estimations show that the iron ore reaches economic proportions at some places.

Regarding genesis the ore appears to be of hydrothermal origin. Fractures in the basement seem to have controlled the ascent of the ore-bearing fluids which found their way along the stratification planes of the Nubia Sandstone particularly the present horizon. Hematite and subordinate pyrite were first formed but later variably weathered into goethite.

I. INTRODUCTION

The main objective of the present study is to use digital processing of Landsat MSS data in recognizing mineralized zones at Wadi El-Muweih area due west of Quseir, Egypt (Figure 1). From the geologic and tectonic viewpoints this area

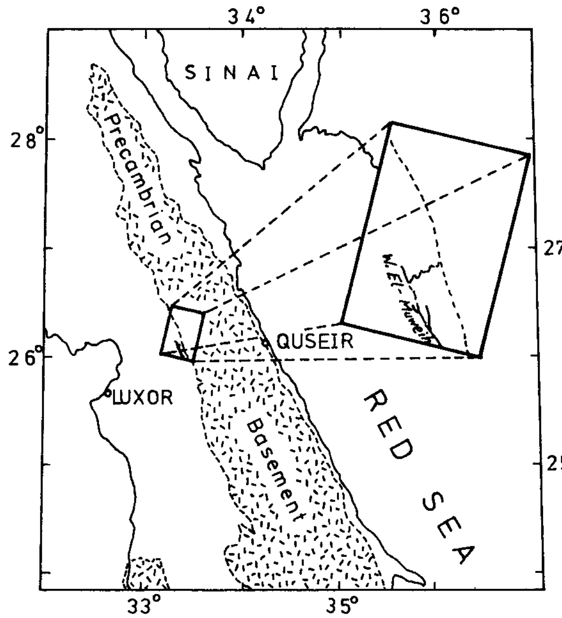

Figure 1. Index Map Showing Study Area

was found promising for mineral exploration. It is occupied by an excellent exposure of late Precambrian basement rocks overlain unconformably, from the west, by a succession of Nubia Sandstone composing the basal part of the Cretaceous-Eocene sedimentary platform. The basement rocks in particular can be considered as possible sources of a variety of mineral deposits, e.g. polymetallic sulfides and (or) hydrothermal mineralizations such as Au, Cu, Sn, W and Mo. The Nubia Sandstone in this vicinity may also represent a host rock for uranium mineralization.

II. GEOLOGY OF THE STUDY AREA

Wadi El-Muweih area (1200 Km^2) is located on the western flank of the Egyptian Precambrian which is unconformably overlain by the late Cretaceous Nubia Sandstone (Figure 2).

The basement rocks comprise the following rock units beginning with the oldest: weakly regionally metamorphosed ophiolitic rocks (i.e., ultramafics, mainly serpentinites, and mafic metavolcanics), syntectonic granitoids, incipiently metamorphosed molass-type sediments, felsites and allied rocks, grabbros and postkinematic granites, together with a series of dykes and quartz veins.

Serpentinites are represented only by a minor lentoidal outcrop in the central part of the study area. This outcrop is enveloped by the metavolcanics and their mutual relation is a matter of current discussion.

The mafic metavolcanics cover extensive ground penetrated and embayed by the other invading masses. They are formed of submarine tholeiitic metadiabases and metabasalts, together with subordinate metandesites. These are intercalated (in places) with lenses of metadacite tuffs. The metavolcanics due east of Gabal El-Eredia are dissected by mineralized quartz veins, carrying hematite and traces of malachite. Such mineralization could have possibly derived from sulfide deposits in depth (Habib, 1982)[7].

The syntectonic granitoids, mainly granodiorite and tonalite, were intruded into the metavolcanics in the northern part of the study area. Their contacts with the invaded rocks are irregular and reactive where assimilation had taken place leading to the development of hybrid diorites.

The molasse-type sediments form NW elongate folded belt stretching between the central and southeastern parts of the study area (Noweir, 1968)[9]. The western (and basal) part of the belt is represented by the Igla Formation (Akaad, 1957)[1] which is formed of a succession of purple and greyish green beds of hematitic siltstones, subgreywackes, quartz volcanic arenites and fine polymictic conglomerates. The major (and younger) part of the belt consists of a greyish green to dark grey interbedded sequence of coarse polymictic conglomerates, greywackes and siltstones of the Shihimiya Formation (Akaad and Noweir, 1969)[2].

The felsites and allied rocks (i.e., rhyolitic flows and tuffs) compose a NW elongate belt in the central eastern part of the study area. They were found to belong to the island-arc volcanics (Dokhan type) both of which are characteristically rich in iron oxides (Essawy and Abu Zeid, 1972)[6]. The rhyolites were erupted prior to the deposition of the molasse-type sediments, whereas the felsites were emplaced after their deposition. The felsites were intruded by the postkinematic granites.

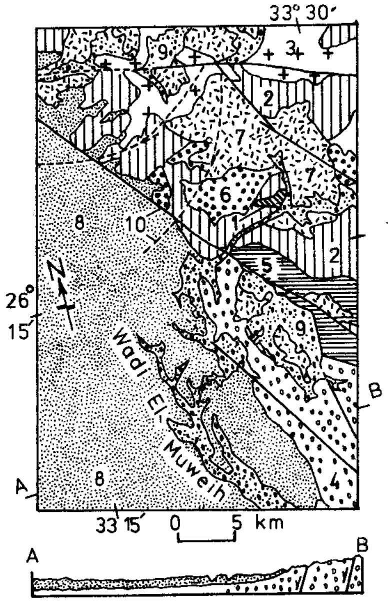

Figure 2. Geological Map Of Study Area (Modified After El-Ramly, 1972)[3]. 1. Serpentinite, 2. Metavolcanics, 3. Syntectonic Granitoids, 4. Molasse-type sediments, 5. Felsites and Allied Rocks, 6. Gabbros, 7. Postkinematic Granites, 8. Nubia Sandstone, 9. Wadi Alluvium, 10. Faults.

The gabbroid rocks are thought to represent post-tectonic intrusions (El-Ramly, 1972)[3] of irregular outlines and limited areal extent. They were intruded into the metavolcanics in the central part of the study area but were themselves invaded and embayed by the postkinematic granites.

The postkinematic granites build up NW mountain ranges forming stocklike bodies and thick sheets. They were discordantly intruded into the above described rocks, and caused in most of them low to medium grade thermal metamorphism. Composition of these granites ranges between adamellite and alkali granite, and their textures vary from coarse granitic to porphyritic. Such granites were genetically associated with the late Precambrian hydrothermal mineralizations, i.e. Au, Sn, W and Mo (El-Shazly, 1957)[5].

A series of silicic, intermediate and mafic dykes as well as quartz veins, all of which belong to the post-granite dykes (El-Ramly and Akaad, 1960)[4] were found to cut across the older rocks. Some of the quartz veins are mineralized, carrying gold, wolframite and molybdenite (Hume, 1937)[8].

The Nubia Sandstone forms a succession of nearly horizontal beds of pale yellow quartz arenite interbedded, in the middle part, with variegated beds of calys and shales. The succession overlies unconformably the molasse-type sediments and the metavolcanics, locally the postkinematic granites. The unconformity surface is nearly flat. The underlying rocks were intensively weathered within a zone of about 10 m thick prior to the deposition of the Nubia Sandstone.

The study area was dissected by a series of faults running NNW,NW and E; curvilinear faults were also recorded(El-Ramly, 1972)[3]. The NW faults in particular are step faults dipping steeply SW. They were responsible for the down faulting, and hence protection from erosion, of the Nubia Sandstone against the adjoining basement.

III. METHODOLOGY

Digital processing of Landsat MSS data of Wadi El-Muweih area was carried out through the Comtal Image Processing System (CIPS) at the University of Missouri-Rolla (UMR). Ratios of the MSS bands and color enhancement were the main techniques employed using the RR program. Due to the band ratio process the influence of topographic irregularities and overall albedo was minimized in an attempt to recognize lithological or mineralogical variations. Three ratios were applied, each of which was subject to color enhancement technique in order to clarify any subtle tonal contrast. The ratios comprised AT(7/6 x 4/5), AT(7/5) x 2 and AT(4/7) x 0.5. The first one proved to be the best ratio whereby numerous bright signatures could be recognized on the Nubia Sandstone surface exposed along the eastern bank of Wadi El-Muweih. The bright signatures appear in the ratio images as series of points ordinated in discontinuous lines running parallel to the basement-Nubia contact (Figure 3). The enhanced ratio images were directly photographed from the Comtal Image Display (CID) by a suitable 35-mm camera using High Speed Kodacolor (ASA 400) films. The color prints were helpful during the field check.

IV. GROUND TRUTH INVESTIGATIONS

Ground truth investigations have shown that the bright signatures reflect the presence of a concretionary iron ore bed, 1.5 m thick, composing the topmost part of the Nubia Sandstone. This bed can be easily distinguished from the unmineralized sandstone by its dark grey color. It extends for about 24 km, along the eastern bank of Wadi El-Muweih, and reaches up to 400 m wide. The concretions are epigenetic, range from ovoidal objects (5x3 cm) up to elliptical and tube-like bodies (30x8 cm), and vary in abundance from one place into another. They are composed of concentric shells, the central parts of which are commonly occupied by ferruginous sandstone. The concretions lie with their broadest surfaces parallel to the stratification planes which can be traced through the former.

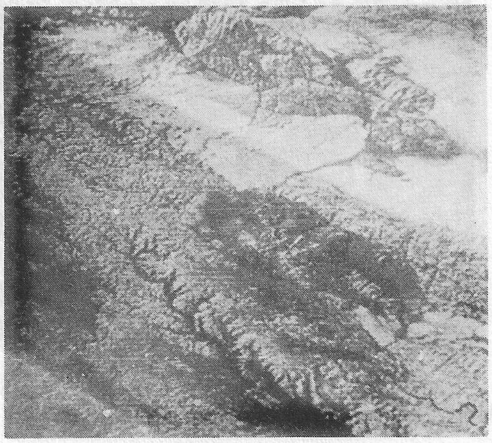

Figure 3. Ratio Image AT(7/6 x 4/5).

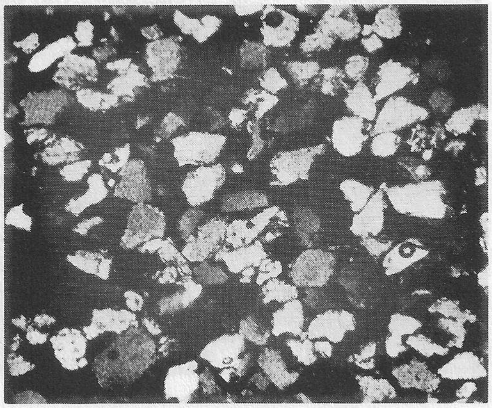

Figure 4. Photomicrograph of Unmineralized Nubia Sandstone. C.N. x 40.

The iron ore also occurs as seams running parallel or, less commonly, crossing meanderly the stratification. The seams in places are so abundant that they gave rise to thick bands up to 60 cm in thickness.In such cases the iron ore possesses gradational boundaries against the sandstone host.

V. MINERALOGY

A. GENERAL ASPECT

The unmineralized Nubia Sandstone is a calcareous quartz arenite composed essentially of quartz and minor accessories of feldspars, magnetite, rutile, epidote and muscovite, all of which are cemented by calcite (Figure 4). The rock is fairly sorted and the grains are rounded, yet they are superficially attacked by the

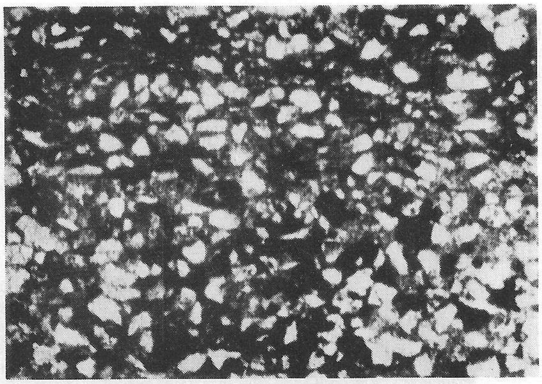

Figure 5. Photomicrograph Of Slightly Mineralized Nubia Sandstone. P.L. x 40.

Figure 8. Intensively Mineralized Nubia Sandstone Showing Subhedral Crystals (H) and Crystal Aggregates (CA) of Hematite. P.L. x 200

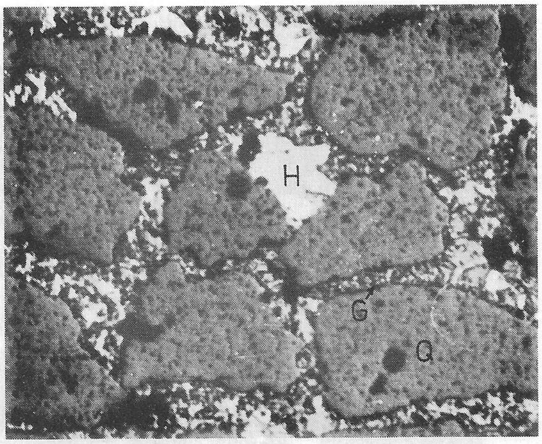

Figure 6. Advanced Stage In Mineralization. Quartz grains (Q) are superficially attacked by the ore. H=Hematite, G= Goethite. P.L. x 80.

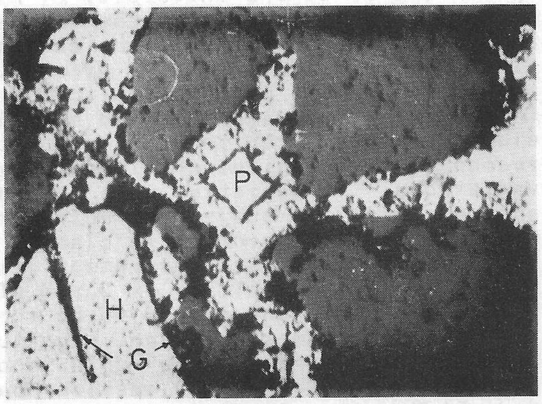

Figure 9. Goethite (G) Replacing Pyrite (P) And Hematite (H). P.L. x 200.

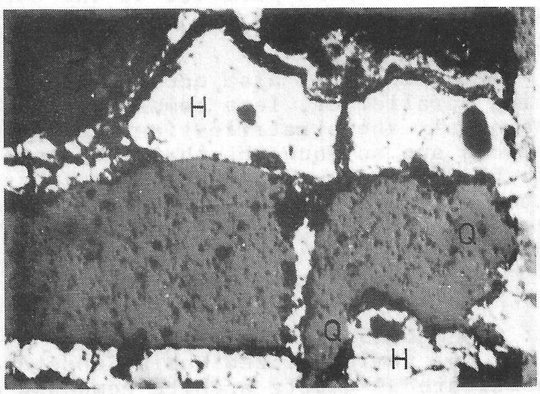

Figure 7. Intensively Mineralized Nubia Sandstone. Quartz grains (Q) are actively attacked and embayed by hematite (H). P.L. x 200.

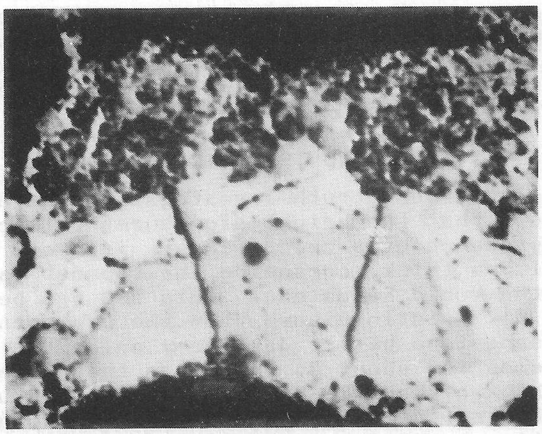

Figure 10. Cryptocrystalline Goethite Formed After Hematite. P.L. x 500.

calcite cement that varies in abundance from 10% to 30% of the rock by volume. In the first stages of mineralization the ore proceeds along the bedding planes at the expense of the calcite cement (Figure 5), and in relatively more advanced stages, the latter is totally replaced by the ore (Figure 6). In the intensively mineralized zones the ore actively replaces quartz grains and is not merely an interstitial filling around grain borders (Figure 7). In such cases the ore reaches up to 70% of the rock by volume.

B. MINERALOGY OF THE ORE

Petrographic and X-ray data have shown that the iron ore is represented mainly by hematite and goethite; pyrite is a minor accessory. Hematite occurs as randomly oriented anhedral to subhedral crystals, 0.3 mm long, and (or) fine crystal aggregates coating and replacing the sand grains (Figure 8). The aggregates are relatively much thicker along the bedding planes and develop a filigree form on the surface (Figure 5). Goethite is represented by cryptocrystalline spheroidal aggregates formed after hematite and pyrite (Figures 9,10). It develops a colloform texture with incipient rhythmic growth.

VI. CONCLUSION

Digital processing of Landsat MSS data including development of ratio images coupled with color enhancement technique proved to be powerful tool in detecting an iron ore deposit at Wadi El-Muweih area due west of Quseir, Egypt. The ratio AT(7/6 x 4/5) provided the maximum discrimination between mineralized and unmineralized Nubia Sandstone. Mineralization occurs mainly in the form of epigenetic concretions formed of hematite, goethite and minor pyrite. Field and laboratory investigations point out that the iron ore reaches economic proportions at some places. Regarding genesis the ore is believed to be of hydrothermal origin. Hematite and pyrite were introduced by hydrothermal solutions coming from the subterranean basement. Such solutions found their way along the stratification planes of the Nubia Sandstone. Structures in the basement seem to have played a significant role in controlling the deposition of the iron ore along the present horizon. Later on, both hematite and pyrite were variably weathered into goethite.

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