Remote Sensing & GIS Techniques for Gold Exploration

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Abstract-- Natural mineral resources are the backbone of the development of industry and economic growth of the country. Which gives exploration and mining of mineral ores, manufacture and marketing of these raw materials added value to the country's national income. Knowing the importance of mineral ores and the importance of using new technologies in the exploration, such as remote sensing and geographic information systems (GIS). Eastern Al Uwaynat area in southeast of Libya has been selected to be the study area where the oldest rocks (Precambrian) unfold. Now a today's, it focuses of attention of many foreign companies, where these companies has done geological and geochemical studies in the area for Industrial Research Center (IRC) Libya.

This paper presents the usage of remote sensing and geographic information systems (GIS) techniques to produce probability maps of the existence of gold based on geological criteria for the presence of gold derived from several references and remote sensing data and available maps for the region and field data.

Keywords— mineral resources, remote sensing, geographic information systems (GIS)

I. Introduction

THE important of gold and its high value made the government gives attention to this material. Different opinions on the existence of gold in Eastern Al Uwaynat were raised, this study trying to shed some lights on this subject. Jabal Arkenu in Eastern Al Uwaynat was chosen as the study area as it is the most probable area bearing gold.

This selection adopted after reviewing previous studies made by three companies (mentioned below), and comparing the results with studies made by the Industrial Research Center, Tripoli, Libya [1].

- Compagnie General de Geophysiqe (C.G.G) Massy, [2].
- Hunting Geology and Geophysics Ltd: Herts U.K. (H.G.G), [3].
- Centro Ricerche Geologche (C.R.G.S.P.A), Firenze [4].

Several geological criteria for gold mineralization was compiled from different references[5] [6] [7] [8] [9] [10] [11], that appears to be suitable for this area such as: Banded Iron Formation (BIF)**,** Quartz veins**,** Major Faults, Dykes, Infracambrian sediments, Triassic rocks, Cambrian rocks. These were added in to the data base as layers along with the results of the geochemical studies.

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A database was created and named "Gold" in which all the layers were populated and linked together by specific relations. Other information was also input to the database such as; sample analysis results, and Libyan international boundaries map. The color and size of the symbols used in the database were the same as the ones used in the geological maps produced by the IRC**.**

II. Area Of Study

Arkenu area as shown in figure (1) is made up of undifferentiated Precambrian rocks (PE) overlain by Paleozoic and Mesozoic sediments which intruded by granites (PEgc, PEgg, PEgr), gabbros (PEgr) ring complexes, and Tertiary volcanic (Tb, Tt &Tp). Quaternary sediments (Qg, Qp, Qw, Qs & Qd), cover all the area [12].

Fig. 1 Geological map of Study Area [12].

Jabal Arkenu area is situated between: Latitudes 22° 00' 00" & 23° 00' 00" N and Longitudes 24° 00' 00"& 25° 30' 00" E, and covers about 25,000 sq. km. The investigated area lies at the southeastern part of Libya and the southwestern part of Arab Republic of Egypt. The most prominent geological and topographic features of Jabal Arkenu, area are the ring complexes which comprise Jabal Babein, Jabal Bahari, Jabal Arkenu, and NE of Jabal Al Uwaynat. Numerous basaltic, trachytic and phonolitic plugs occupied the eastern and western sides of the area. High granitic mountains forming a belt extending in NE direction are observed in the eastern side of Jabal Arkenu area. Undifferentiated Precambrian rocks occupy the central and eastern part of the area and include amphibolites, migmatitic gneisses, quartzite, quartzofeldspathic gneisses, biotite gneisses, diorite greisses, granitic gneisses, quartz-magnetite-gneisses (Fe) and porphyroblastic granitoids as shown in figure (2) and figure (3). These rocks are highly metamorphosed and have been subjected to faulting and folding [12]. Paleozoic and Mesozoic sediments flanked unconformably the undifferentiated Precambrian rocks on the northern, western, eastern and southern parts of the investigated area. A remnant of Infracambrian sediments, from a belt trending NE, at the southern of Jabal Arkenu.

Paleozoic rocks (Cambrian, Ordovician, Silurian, Devonian and Carboniferous) occur mainly in the northwestern and southeastern side of the mapped area. Quaternary deposits are distributed all over the area.

Fig. 2 Quartz- Magnetite-Gneiss, East Jabal Arkenu [12].

Fig. 3 Conglomerate Bed at the Base of Arkenu Formation [12].

III. Data Acquisition

Several kinds of data have been used in this study. The data was collected from different sources and different organizations.

3.1. Remotely sensed data

Satellite imagery is very helpful in these kind of researches. Multispectral LandSAT 7 images were used in this study to produce thematic maps. Further the Radar images and airborne geophysical survey for eventuated Aero magnetic data were used. At present, there are several remote sensing satellites providing imagery for research and operational applications.

3.2. Existing Maps

Existing maps are considered as the best and widely available source of data. In this study many maps were used as shown in figure (4). Maps with different scales and types, such as; geological maps scale 1:250,000. As well as geological observation maps and maps showing scintillometer readings.

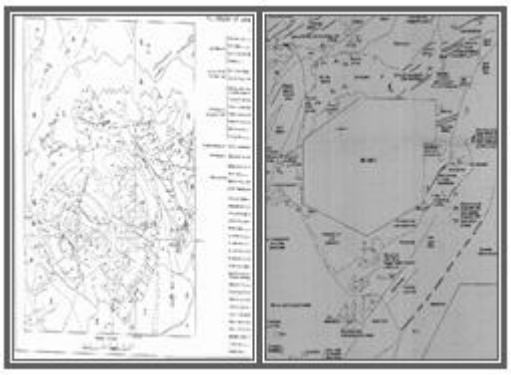

Fig. 4 Existing Maps [4].

3.3. Field Observations Data

In this research the results of field work done by Industrial Research Centre (IRC) were used. Recent samples were taken by (IRC) for the study area and figure (5) shows the location of these samples.

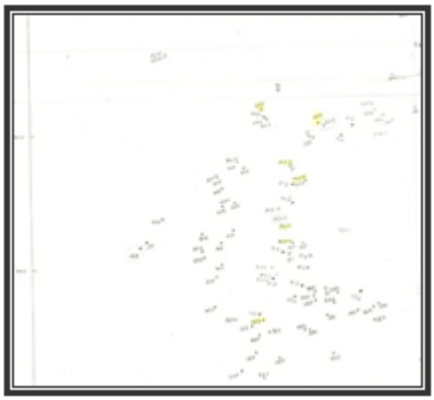

Fig. 5 Samples Location Map[1].

IV. Geologycal Criteria

A comprehensive study of the geological and geochemical criteria for gold mineralization was done from different sources and references [5] [6] [7] [8] [9] [10] [11]. A list of the criteria suitable for the area was chosen and compiled as follows;

A. Banded Iron Formation (BIF) [6]

These exist as layers ranging in thickness from few meters up to hundreds meters as shown in figure (6) and it outcrops on the surface for nearly 9 Km in some areas bearing faults, mafic and felsic dykes. The chemical analysis results of some 35 samples collected showed [7];

- Average of gold (Au) content up to 1.2g/ ton
- Average of silver (Ag) content up to 1.89g/ ton
- Average of copper (Cu) content up to 47.17g / ton
- Average of zinc (Zn) content up to 46.6g/ ton
- Average of lead (pb) content up to 4.1g / ton

BIF rock has a high percentage of fe_2o_3 (34-65%) the rate of Gold in this rock (0.3-11.84 g/ton).

Fig. 6 Quartz- Magnetite-Gneiss (B.I.F) [8].

B. Quartz veins

Quartz veins [8] [9] [10] are widely distributed in the study area figure (7, 8). It runs to large distances up to 11 km with thickness ranging from 30 to 100 meters. The results of 23 samples showed that it has an average of gold content of about 0.6 g/ton, 0.7 g/ton of silver, 86.9 g/ton of copper, 26 g/ton of zinc and 12.5 g/ton of lead.

Fig. 7 Quartz veins of Arkenu area [11].

Fig. 8 Dissected Quartz Vines Covered by Sand Sheet inside Jabal Arkenu Ring Complex [12].

C. Major Faults

Faults layer is the results of integration of geological, remote sensing and geophysical maps. This layer include the three types of faults outcrop in the area, defined fault, inferred fault, and concealed fault figure (9).

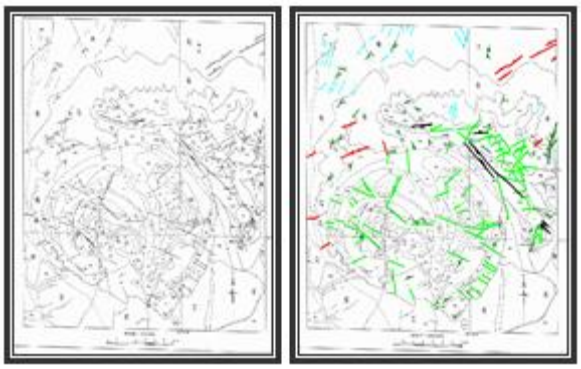

Fig. 9 Faults Layer Map [8]

D. Dykes

This layer includes the four types of dykes outcrop in the area, mafic dykes, felsic dykes, intermediate dykes and dolerite dykes as shown in figure (10).

Fig 10 Geological Notes Map [2].

E. Infracambrian sediments

This layer includes Infracambrian sediments (iEA, iEM, iEQ) present in the area figure (1).

F. Precambrian rocks

This layer includes Precambrian rocks (PE) overlain by Paleozoic and Mesozoic sediments which intruded by granites (PEgc, PEgg, PEgr), gabbros (PEgr) ring complexes.

G. Triassic rocks

This layer includes Tertiary volcanics (Tb, Tt &Tp) present in the area which according to study by IRC is an indication of the presence of gold [13].

H. Cambrian rocks

This layer includes the Paleozoic rocks (Cambrian) occurred mainly in the northwestern and southeastern side of the mapped area.

V. Procedures And Results

The following steps were made to achieve the objectives:

1- The existing maps were scanned and rectified using ER MAPER image processing software. These maps were geological maps, mineralized occurrences maps, airborne geophysical survey maps and ground follow-up maps for radioactive base metal and iron ore mineralization.

2- All the maps were overlaid together and an area was chosen as the most probable area bearing gold because it has the most criteria present and this area was ½ degree by ½ degree in Jabal Arkenu.

3- The list of criteria chosen was then put into layers in ArcGIS software. These layers include;

I. Geology layer which includes geological map of study area Figure (11) and Quaternary sediments (Qg, Qp, Qw, Qs & Qd), which cover all the area.

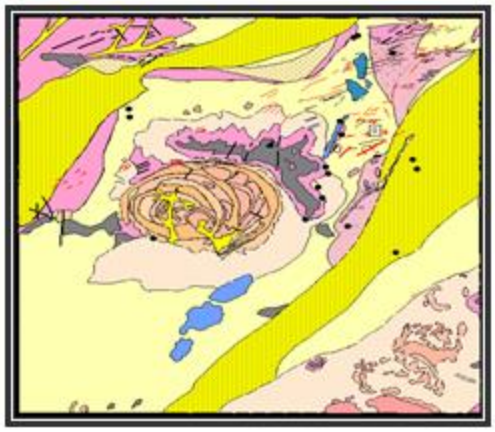

Fig. 11 Geological Binary maps of Faults and Geological Units in Study area.

II. Aeromagnetic layer includes total intensity aeromagnetic map present in the area figure (12).

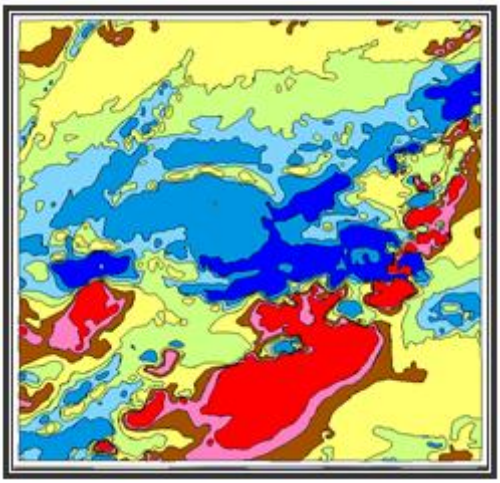

Fig. 12 Total intensity aeromagnetic map of the Jabal Archenu.

III. Remote sensing layers: includes faults map, alteration zones map and rock units map figure (13).

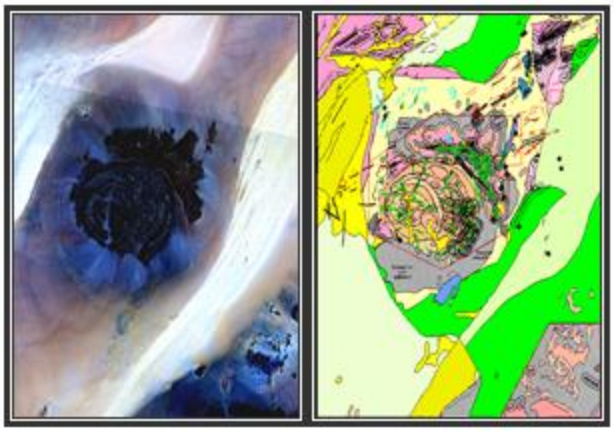

Fig. 13 Landsat TM image in study area

IV. Alteration layers: the alterations data which was identified in the field by geologist figure (14).

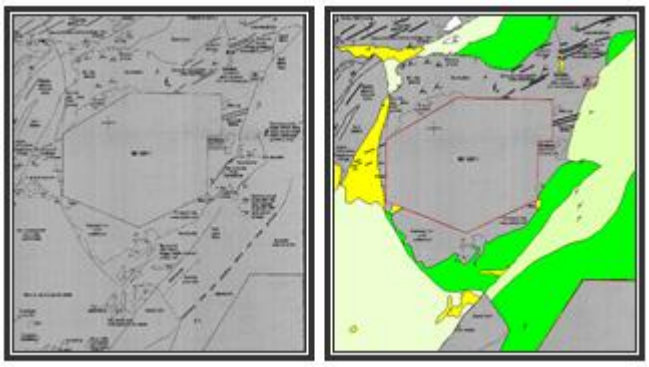

Fig. 14 Geological Observation Maps [2].

4- A database was created and named "Gold" in which all the layers were populated and the layers were linked together by specific relations figure (15). Other information was also put into the database such as; analysis sample results, and the map of Libyan international boundaries. The color and size of the symbols used in the database were the same as the ones used in the geological maps produced by the IRC.

Fig.15 The base map of Gold Criteria in study area.

5- A grid was created covering the whole area with a spacing one minute by one minute (1'x1')

6- Creating a layer representing points in the center of each cell contains value number for every type of the criteria. The number of all seven factors shown in figure (16 a,16 b). A new field was created containing the total number of factors in each cell. Thus obtaining a new layer representing the number of factors figure (17)

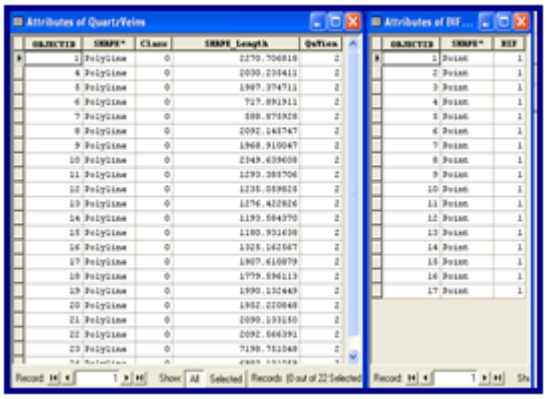

Fig 16 a: Attributes of Quartz veins.

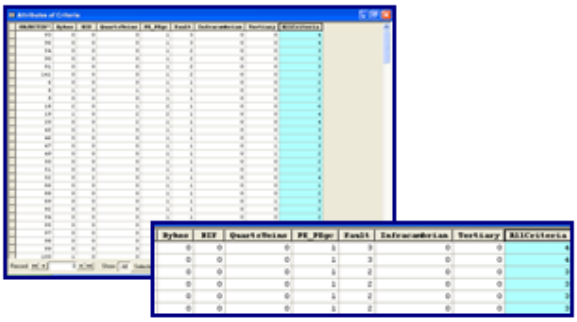

Fig. 16b: The criteria table is classified in different weights .

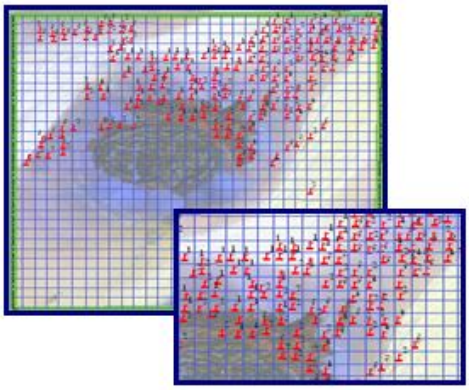

Fig. 17 The criteria layer is classified in different weights maps.

7- A spatial analysis was done on this new layer using the density tools choosing the field that contains all criteria. The result was a factor density map for the area shown in figure (18).

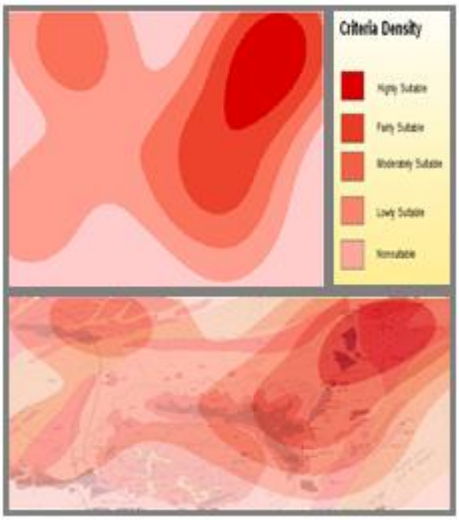

Fig. 18 A density map was produced from all the criteria.

8- To get a clear picture of the situation based on the type of criteria rather than the number of criteria present in each cell, a field was added to all layers representing the factors and this field was given the name of the layer. A weight was given to the factor depending on the importance of the factor from 1 to 9 one being the most important factor shown in figure (19).

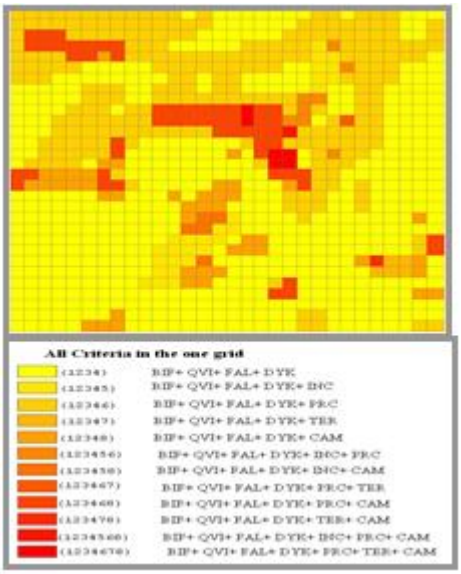

Fig. 19: The grid layer, was joined with the criteria layers.

9- Then each layer joined with the grid layer using the attributes. Thus joining data from another layer based on spatial location. The result was a number of maps showing the relation of each layer with the grid layer. These maps were overlaid together and the result is a map showing the relation of all factors with the grid, thus obtaining probability map based on the type of the factor. The map was converted to vector data shown in figure (20).

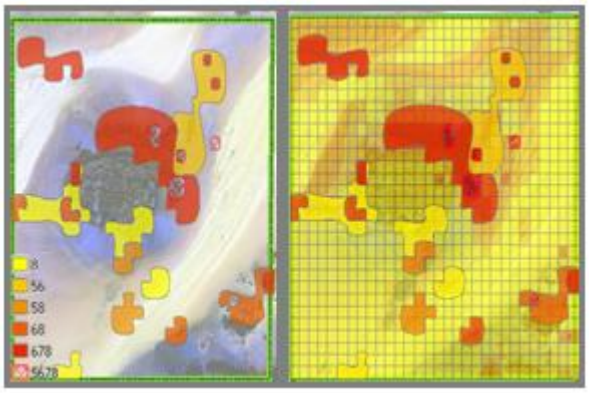

Fig. 20: The final map grades the region into five subclasses in terms of suitability.

10- To confirm the results of these two probability maps, the one base on number of factors and the other base on type of factors, the results were compared with the results of chemical analysis for the samples obtained for this area. Figure (21) shows that the results match with the two maps obtained by the authors.

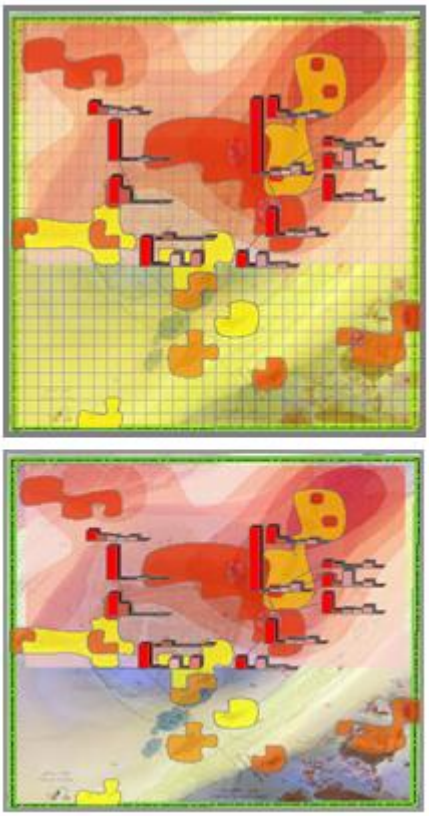

Fig 21: The final map and the density map in order to confirm the results obtained.

11- The area was then classified based on existing probability ranges from high to non.

VI. Conclusion

Gathering and analyzing all the criteria in the study area and studying the probability maps which the authors had produced, It is clear that gold and silver are present in outcrops bearing iron and quartize veins, alteration zones, dykes, and faults in area located north and east of Arkenu, figure (22). The presence of Gold mineralization in this area, maybe because of its concentration during regional

transformation in quartize or its movement to the nearby veins and alteration zones[14]. The presence of rear elements in this area relates to alkaline rocks, and calc-alkaline rocks forming ring complexes.

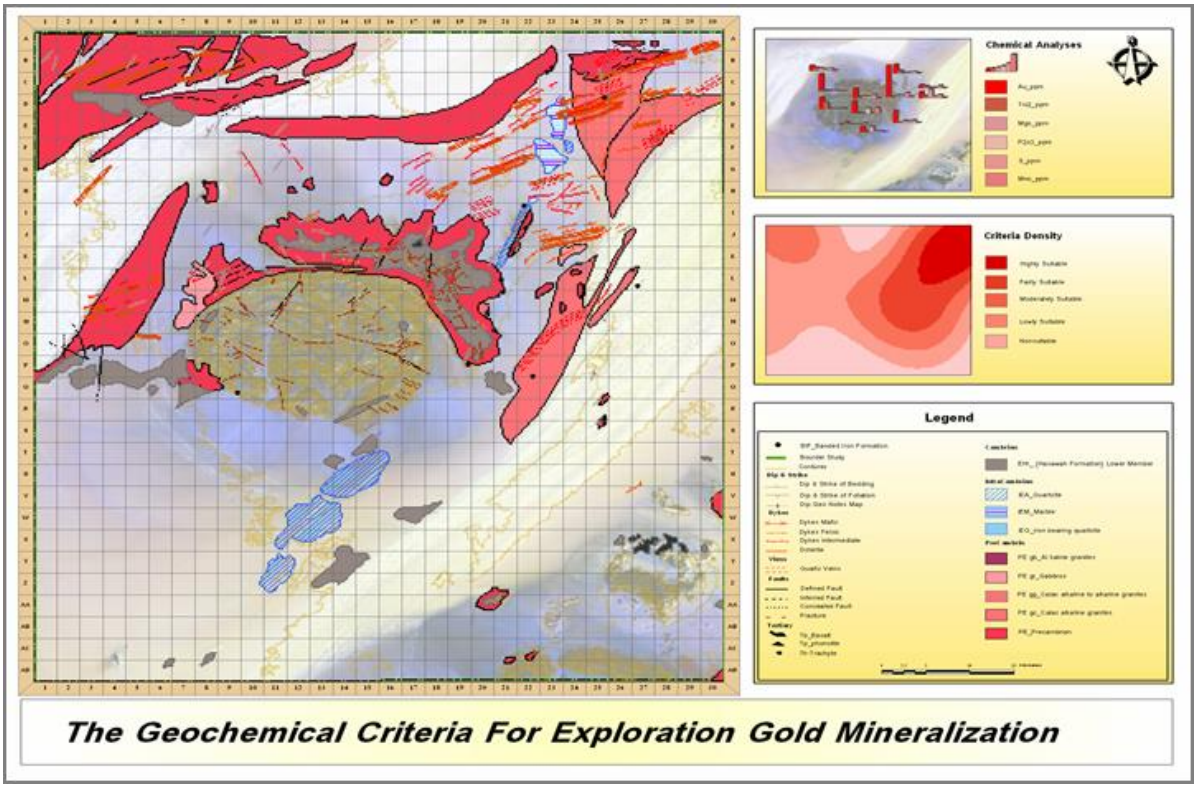

Fig. 22 The combined map

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