BANDED IRON FORMATION DISCOVERY AT WEST OF GABAL KAMEL, AND ITS GOLD POTENTIALITY WESTERN DESERT, EGYPT

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ABSTRACT

Field mapping of the south Western Desert in the last few years, led to the discovrey of a big occurrence of Banded Iron Formation, to the west of Gabal Kamel, bounded by lat.22º 00` - 22º 30`N and long. 25º 30`- 26º 30`E.

The country rocks are Archean para and orthogneisses with subordinate ultramafic. Pan African granitoids are intruded into older Precambrian rocks. Carboniferous and Cretaceous sediments unconformably overlay the Precambrian rocks.

The BIF crops out as highly folded and faulted beds striking generally NNE-SSE, and extending for several kilometers with a thickness up to 300m. On the sufrace, BIF shows fine lamination where iron oxide bands alternate with silica bands (quartz ,microcrystalline quartz).

Systematic geological, mineralogical and geochemical exploration works were conducted on some selected areas of the BIF outcrops in order to outline the characteristic feature of the ore as well as assessing its gold potentials.

Field observation revealed the presence of a huge deposit of BIF, and the mineralogical studies showed that iron ore minerals are goethite, hematite and magnetite which alternate with silica. Sulphides occur in *trace amounts and are represented by pyrite, chalcopyrite, pyrrhotite and galena. Gold was detected by SEM as fine blebs, cubes and skeletal grains.*

Fire Assay analyses proved that all BIF samples are gold bearing and that gold contents range from 0.35 to 15 g/ton. The Au/Ag ratio is always high (more than 10). Chemical analyses showed that iron oxide contents range from 15 to 76%.

The syngenetic origin of both gold and BIF occurrence is suggested.

Based on the results obtained, this discovery is very promising, and more extensive and detailed exploration is essential in order to estimate the gold content in BIF and outlines the mineralized zones within the ore bodies. The Egyptian Geological Survey is currently carrying out a field work program to delineate and assess these zones.

INTRODUCTION

The southwestern corner of Egypt have recieved little attention from authors and authorities especially from the economic mineral deposit point of view. Consequently, no systematic exploration work was previously carried out at this area. Recently, and through the new policy of EGSMA and within the national program of sustainable development of Southern Egypt, some efforts were devoted to explore this virgin area. Among the main results of this exploration was the discovery of huge deposit Banded Iron Formation (BIF) between lat 22^{o}00` - 22$^{o}$30` N and long. 25^{o} 30` - 26$^{o}$ 30`E. (Fig.1).

The occurrence of gold within BIF was reported from many areas in Egypt (Dardir and El Chimy 1992) and the world e.g. South and Central Africa, Canada, Brazil and Zimbabwe (Fripp 1976), so, prospection for gold in this BIF was initiated.

The present paper present some preliminary results of the exploration work which carried out for gold in some selected areas of BIF outcrops. Both field and laboratory work revealed that these areas are promising and detail exploration is suggested.

The area was previously studied by Richter (1986) who differentiated the Precambrian rocks into three rock formations :

- High grade granulite “Granoblastic” Formation overlained by :
- The remobilized “Anatexite Formation”, then
- The youngest, clearly bedded “Metasedimentary Formation”.

The contacts between these formation are not clear being covered beneath extensive sand sheets.

Richter and Schandelmeir (1990) noted an itabiritic sequence of iron quartzite that crops out for several kilometers in the area of ring structure east of Gabal Kissue (Sudan), The same rock was recorded by Hunting (1974) as quartz-magnetite gneiss east of Gabal Arkenu (Libya).

Conco-Corporation (1987) compiled a geological map for the south- - western part of Egypt on scale 1:500,000 They followed the classification used by Richter (1986).

Five years ago, EGSMA and IRC of Libya planned to map and explore the Libyan-Egyptian border sheets (Jabal Arkenu and Jabal Nazar). Most of the present authors participtated in this work and the geological maps on scale 1:250,000 are now in preparation (Said, et al, 1996). Naim et al, (1996) recorded the presence of banded iron Formation in these border areas in the form of small beds and lenses within the Precambrian rocks. Khalid and Diaf (1996) found that gold in this formation attained 7 g/ton in both the Libyan sheet (east of Arkenu) and southeast of Gabal Nazar (Egypt).

GEOLOGICAL SETTING

The area west of Gabal Kamel forms a part of Aluwaynat region, and is covered by the following rock units arranged from oldest to youngest

6- Quaternary deposits including playa, sand sheet and dunes.

5- Tertiary volcanics in the form of basaltic, trachytic and phonolitic plugs and dykes.

4- Phanerozoic sediments of Carboniferous and Cretaceous age.

3- Intrusive calc-alkaline to alkaline granitoids and gabbros.

2- Ultamafic rocks.

1- Old metamorphic rocks of probably Archean age (Sultan et al.1996, Klerkx 1980)

The first group comprises para and orthogneisses of granulite and amphibolite facies. The paragneisses include migmatite, biotite gneiss, quartzite, quartzofeldspathic gneiss, marble with calc-silicate, as well as banded iron formation. The orthogneisses consist mainly of diorite and granite gneiss in addition to porphyroblastic granitoids.

Ultramafic rocks are well exposed and show syntectonic emplacement along NE-SW structural trends and are in most cases, associated the BIF beds.

Intrusive calc-alkaline and alkaline granitoids are very similar to G_2 and G_3 of Hussein et al (1982). In addition, some minor gabbroic mass are recorded.They resemble the younger gabbros of Takla et al (1981). This plutonic association is generally related to the Pan-African Orogeny.

These basement rocks of, Aluwaynat area were subjected to uplifting and doming by the end of the Paleozoic. Erosion exposed the basement rocks in the core of these domes.Later on,and during Tertiary epoch, the area became unstable and this led to extrusion of volcanic rocks in the form of plugs and dykes.

EXPLORATION METHODS AND TECHNIQUES

The exploration work reported upon here comprised the following activities :

1- Detail geological mapping on scale 1:20,000 with special emphasis on tracing and outline the B.I.F outcrops at 12 areas (Figs 2-13).
2- Sampling the mineralized beds along profiles and traverses cutting perpendicular to the strike of ore bodies (each samples was about 10kg weight).
3- Opening trenches across the mineralized zones in order to delineate their boundries and to collect channel samples for gold assaying by Fire Assay and spectral analyses.
4- Mineralogical investigation was carried out on thin and polished sections. The gold was confirmed by scanning electromicroscope (SEM) and XRD.

5- Chemical analyses for some representative samples to elucidate their iron contents.

Mode of Occurrence of BIF

Field observations showed that the B.I.F occurs in highly folded, faulted and sheared beds forming relatively high ridges (average elevation from the ground is about 40 m). These beds strike NNE - SSW and dip, in most cases, to the NW - SE at angles from 40^o to 75^o . Their width ranges from 5 meters to more than 300 m (as in the case of K_7) and extends along strike for about 4.8 km (k_{12}). The beds end abruptly by fault displacements or by passing under thick sand sheets.

The country rocks include paragneisses (quartzite, quartzofeldspathic gneiss), granite gneiss and amphibolite with serpentinite rocks ($K_{2,}$ K_3, K_4, K_6, K_8, K_{11}) or small intrusion of calc-alkaline and alkaline granite (K_2, ...).

The deformation style of the Banded Iron Formation is in great harmony with the regional deformation of the country rocks and evidently the ore bodies have the same structural history as the enclosing stratigraphic sequence of the area.

The selected areas for the present study were numerated from K1 to K15.

The BIF is composed of alternative bands of quartz and iron oxides, and silica (quartz, chert and jasper) bands. The iron content varies greatly from place to another.The ore minerals comprise hematite, magnetite and goethite. The quartz bands, in most cases, contain garnet (K_3, K_6) in appreciable amounts, as well as vugs filled by clay or carbonate. Chert occurs either as parallel unmappable bands (K_6, K_7) or as thin bands alternate with quartz-iron bands. Jasper is present as thin lamellae being oriented parallel to the main banding trends. The dominant BIF facies present is the oxide facies with minor carbonate, silicate and sulphide facies.

In many parts, thick iron and quartz bands were separated probably due to metamorphic segregation. Here, flakes of hematite (specularite) are the main constituents of iron bands. Quartz bands are black and are occassionally sulphide bearing.

In all BIF occurrences, the beds are enclosed within a “quartzite” of chlorite-mica-malachite and deformed quartz. This rock contains sulphide minerals in notable amounts. Fuchsite (Cr-muscovite) also appear as very thin flakes. Garnet bearing layers are present in some places (K_3). This formation could be representing the silicate and sulphide facies of the banded iron formation. (Hussein 1998).

Hydrothermal activity accompanied E-W active faults is well illustrated in the presence of secondary goethite and silica. Goethite occurs as fissure filling or as welding material for BIF fragments, and in this case the primary banding is partially disturbed.

Deformation Phases of B.I.F :

Field observation showed that there are four phases of deformation which affected the B.I.F.

D_1 The present area was subjected to compression stress in the E-W direction as deduced from anticlinal and synclinal folding (F_1) dips due west and plunging in NE accompanied by foliation (S_1) in the same trend of fold axes with the increase of stress, a system of overthrust faulting was formed. This is clearly shown in the disappearance of the eastern limbs whereas the western limbs were overthrusted.

D_2 The stress in E-W was continuous, and a system of dextral strike slip faults taking N 25° E were formed in parallel with the fold axes and foliation trends.

D_3 This phase is clearly observed in sinstral strike-slip faults in N110° perpendicular to the first one and foliation trend. A new type of folding (F_2) was initiated and well-defined in incompetent rocks e.g. the quartzofeldspathic gneiss. In B.I.F,however, the formation of fractures and fault breccia are the main result. Iron solution which deposited the fracture filling (goethite) is observed accompanied to this stage. Secondary foliation (S_2) is observed in this phase.

D_4 As a result of continuous stress in the E-W, a tension zone in N-S was found and a normal fault system with E-W direction is observed causing the disappearance of BIF beds in northern part of the area (K_7, K_6). In the southern parts a graben was formed between K_{11} and K_{12} (Fig.22).

RESULTS OF EXPLORATION

1. Results of Mineralogical Studies :

105 representative thin and polished sections were prepared for microscopic investigations. The study shows that the rock is composed of

quartz and iron oxides oriented in alternative thin and thick lamellae. Quartz crystals are highly sheared, fractured and show wavy extinction and represent about 40 to 53% of the rock.

The opaque minerals are represented by hematite, goethite and magnetite. Sulphides (pyrite, chalcopyrite,galena and covellite) are present in trace amounts. Gold occurs as minute specks,while silver was detected by SEM analyses.

Hematite occurs as coarse to fine tabular subhedral to anhedral crystals. Rarely, it is present as intersecting needle-like crystals. Sometimes, it contains relics of magnetite as an indication of its origin. Occasionally, it displays partial alteration to goethite.

Goethite occurs as fine anhedral crystals and as aggregates intergrown with hematite.

Magnetite occurs as fine to coarse grains oftenly altered to goethite. It is the original iron ore mineral. Rarely, it shows either regular or irregular martitization.

Traces of ilmenite, galena, pyrite and chalcopyrite are present as minute specks disseminated in the rock.

Semi-quantitative XRD analyses revealed the presence of the following minerals in decreasing order of their abundance : Quartz 55% , goethite 23%, hematite 20%, kaolinite 1% and chlorapatite 1%.

Gold is detected by Scanning Electro-Microscopy as fine cubes and skeletal grains of grain size below 25 microns in hematite and quartz (Figs.23-24). The gold bearing samples were analyzed also by EDX (energy dispersion spectrometer) for different spots. The analyses revealed the presence of gold specks in both quartz and iron oxides as fine blebs, cubes and skeletal inclusions. The grain size ranges from 3 μm to 18μm (Figs25,26,27).

2. Chemical Composition :

From the studied areas 30 samples were chemically analyzed to determine the ranges of the iron content of this formation. Results are given in Table (1).

3. Results of Gold Analyses :

The collected samples were analyzed by Fire Assay for gold. The highest values were reanalyzed using large quantity (about 100 gm) and in most cases, the results were practically duplicated. Some selected samples were chosen for quantitative spectral analyses for gold and other elements to determine other elements associated with gold.

Results of Fire Assay analyses are given in Table (2) whereas Figs (2-14) show the gold distribution in the B.I.F. occurrence.

Associated Elements :

From the area (K_{12}) 21 samples were analyzed by quantitative spectral analyses in order to determine the associated elements with gold. The results of analyses are given in Table (3) :

Table 3
Results of the Analyses
K12 (sp.A)

(In ppm)

	K 12/18	25	27	29	30	33	34	35	36	37	average
Au	1.771	13.75	12.25	1.23	10.94	1.44	10.66	9.42	10.5	11.15	8.3
Ag	-	-	-	-	-	4.11	-	-	-	-	
As	172.7	2877.5	2257	2144	1120	50.5	2373	1641	920	1230	1478.6
Be	509	469	160.7	167	164.7	-	187.6	201	518	558.7	297.6
Co	67	84	-	73	76.7	51.5	78	78	80.7	86	67.5
Cu	238	1364	637	638	849	432	1652	1219	1650	1126.9	1102.5
Sm	125.4	198	156.8	154.7	130.5	97.9	146	136	133	97	137.5
Sn	379	301	70.6	58	98	319	94	885	234	292	193
Tb	62.1	-	-	-	17.17	96.15	-	-	-	38.4	21.4
Zn	198	4133	1.332	2569	10.36	140	8104	5033	2926	1928	2739.9
Rock type	Qz	BIF	BIF	BIF	BIF	BIF	BIF	BIF	alt.z.	alt.z.	

The Probable Origin of Gold In B.I.F. :

The origin of BIF received extensive discussions and the comprehensive reviews were given by Gross (1965) and James (1966). The BIF of the Canadian Shield were considered by Goodwin (1973), Goodwin and Shklanka (1967) to be submarine chemical sediments precipitated on the sea floor during the quiescent fumarolic periods between phases of magmatic and volcanic extrusion. Both iron and silica were derived from volcanic sources Goodwin (1964). Fripp (1976) suggested the same source for the vubachikwe, BIF, Rhodesia when he stated that Sulphide and Carbonate rich BIF were derived from a volcanic exhalative source.

The worldwide association of gold mineralization with Archean BIF is well documented (Fripp 1976, Boyle 1979).

Two types of gold deposits associated with BIF are observed .The first type is attributed to quartz veins and sulphide replacement zones in the BIF epigenetic type as in Carshow and Malga, Timmins area, Canada (Fyon and Crocket 1983). The second type is the stratabound gold deposits where gold sulphides and BIF are consanguineous syngenetic origin (Ridler 1970, Sawkins and Rye 1974) as in Zimbabwe (Fripp 1976).

The present authors are more inclined to the syngenetic origin of gold in the studied areas and it is proposed that Au, Ag, As and other associated elements in addition to BIF are consanguineous being formed by thermal brines capable of transporting gold and other elements as soluble complex ions (Fripp1976).

Such complex deposits are submarine chemical precipitate deposits, derived from solutions extruded from subaqueous active fumaroles

(Fig 28).

DISCUSSION AND CONCLUSION

From the foregoing survey, it could be concluded that :

1- The BIF occurs in highly folded and faulted beds similar to the Archean BIF occurrences in other parts of the world. The deposits are characterized by their huge volume, up to 300m width and attains several kilometers in strike length. The sptial association with ultramafic rocks are of great significance.

2- Mineralogical studies revealed that the opaque minerals are goethite, hematite and magnetite with sulphide traces. Goethite could be formed at the expense of sulphides. Gold is recorded and confirmed by SEM and EDX analyses and has grain size less than 25μm.

3- Chemical analyses show that iron oxides range from 10% to 76.9%.

4- All the analyzed samples either by FA and SP.A. are gold bearing. Gold contents range from 0.35 to 15 g/ton with an arithematic mean of 2.5 g/ton.

On the basis of the on hand data, it is strongly recommended to conduct a more detailed exploration program in order to outline the more rich zones within the ore bodies.

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