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MINERALOGY, WALLROCK ALTERATION AND ORIGIN OF THE KHASHM EL- FAKH Fe-Cu- MINERALIZATION, KID AREA, SOUTHEAST SINAI, EGYPT.

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ABSTRACT

The Wadi Khashm El-Fakh Fe-Cu mineralization, SE-Sinai, occurs in the Tarr complex which comprises the southern member of the Kid Group. The mineralization is hosted in a submarine, highly deformed Late-Proterozoic volcano-sedimentary Pile. This Pile has been affected by low grade metamorphism of epidote-amphibolite facies.

The results of field work and laboratory inspections are eventuated simple mineralogy of two distinct assemblages. The first includes: magnetite, specularite, hematite and martite forming together integral bands of variable thickness and connected to disconnected nature. These bands are hosted in metagraywacke-metapyroclastic association and deformed with prominent cataclasis whereas, their enveloping rocks are highly epidotized. The second is formed of malachite, chrysocolla, azurite, cuprite and chalcanthite in addition to relics of chalcocite, covellite and digenite collectively hosted along fractures of partly sericitized rocks and in quartz veins. Genetically, the iron-bearing minerals are mostly of syngenetic exhalative origin while the Cu ones are late and epigenetic.

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INTRODUCTION

The Kid area lies in the southeastern part of Sinai Penisula, Egypt, Fig.1, comprizing a fault-bounded sector of Late-Proterozoic rocks. These include a wide variety of volcano-sedimentary associations (the Kid Group, Shimron, 1984) and small part of relatively older gneissic rocks, occupying together a domal structure of about 600 km^2. The volcano-sedimentary associations occupy the large part of the Kid terrain and are represented by: (1) volcanic products, alkali rhyolite, high K-dacite, pyroclastic, andesite and basalt, possibly related to active continental margin (Furnes etal., 1985); and (2) shallow marine sediments, mainly; conglomerate, graywacke, siltstone and siliceous mudstones interbedding the volcanic ones. These have been deformed, influenced by low grade metamorphism and intruded due south by late-to post-orogenic granite and due north by gabbro-diorite complex (El Gaby et al., 1988 and Hassanen, 1992).

The southern most portion of the Kid Group, the Tarr complex, Shimron (1975), is characterized by local development of several occurrence of fracture filling Cu mineralization. The anomalous and more accessible ones are those reported in the vicinity of the Wadies; Tar, Khashm El-Fakh, Hatermiya and Samra (Fig. 1) Through our recent inspection of the Cu-bearing rocks of Wadi Khashm El-Fakh, far as 3 km from the Wadi enterence on the Gulf of Aqaba, we were able to figure-out for the first time a co-existine Fe-rich mineralization. It is encountered as integral bands of variable thickness intimately associating

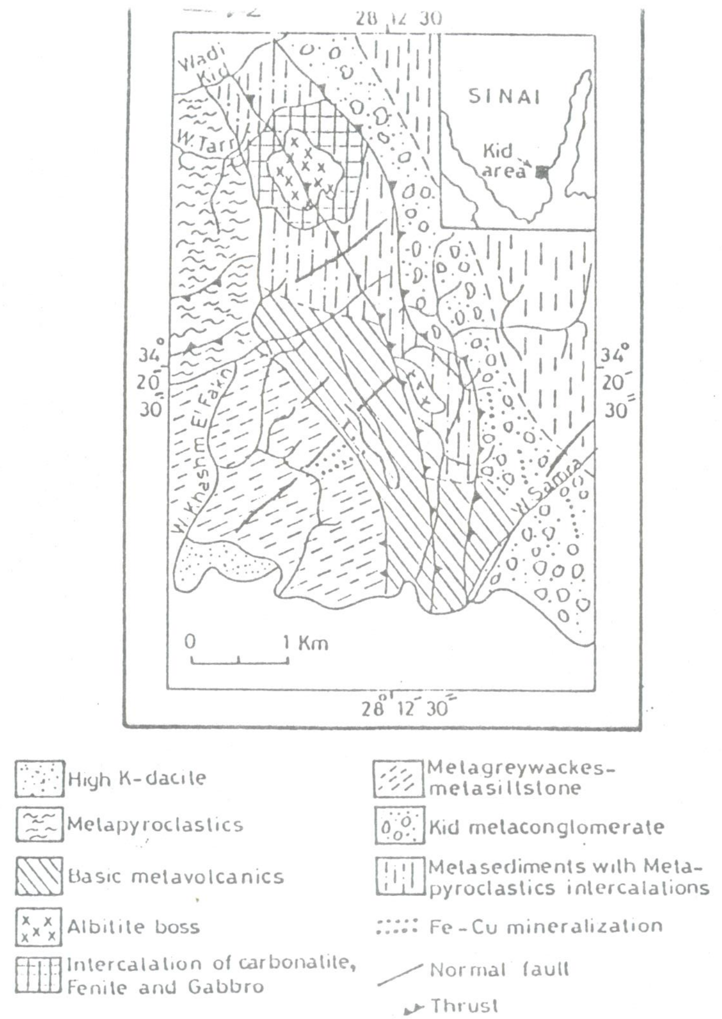

Fig. 1: Simplified geologic map of Wadi Khashm El-Fakh-Wadi Tarr, southeast Sinai Peninsula (modified after Shimron, 1984).

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metagraywacke-metapyroclastic rocks hosting the Cu one. This has attracted our attention to look for any possible relations, between the Fe-and Cu-bearing constituents in this particular zone So , mineralogy and textural features of these constituents are visualized in relation to their enclosing rocks. It aims to unravel the possible origin and evolution of the Fe-Cu-mineralization since the occurrence of Fe-ores in the other localities can not the excluded.

Geologic Setting

The different occurrences of the Cu-mineralization in the Tarr complex are confined in general to the metagraywacke-metapyroclastic associations lying between Wadi Samra (NE) and Wadi Tarr (SW). They are accompanied by local development of some albite-carbonatite masses (Cretaceous age, Shimron, 1975), fenite aureole, explosion-breccia, olivine dolerite and basalt of Tertiary age (Hassanen and Harraz, 1991). The assemblage, as a whole has been emplaced into host rocks comprising: metagraywacke, metaconglomerate, metapyroclastics and andesites. The metamorphic grade of these hosting rocks belongs to greenschist up to mid-amphibolite facies.

Structurally, three major and numerous minor faults cut across the complex assuming generally a NW trends being a conspicuous lineament that can be traced across the Sinai Peninsula to the Gulf of Suez on the west side and the Straits of Tiran on the east. Other faults are mostly represented by minor ones trending NE directions. The intersection of these two faults directions is reflected in smaller scale faulting, jointing and conspicuous fracturing that may be regarded as possible sites of localizing the Cu mineralization.

The pattern of the Cu-mineralization is dominated by structural factors rather than lithological or stratigraphical ones (Fig.2). It is trapped selectively along fractures of the hosting metagraywacke-metapyroclastics, acquisitive of late epigenetic formation. Rather, the Fe-rich assemblage occurs as banded intercalations in the same country rocks, suggestive of their possible syngenesis with these rocks. They are characterized by variable thickness (10-40 cm) with connected to disconnected (one to several meters) nature and generally assuming a horizontal to subhorizontal position with respect to the datum plane. The different bands are highly deformed with prominent cataclasis and obvious schistosity. The cross sections (Figs. 2A and B) show the main rock units between Wadies Tarr and Hatami and the field relationship of the Fe-Cu-mineralization to the deformed zone.

Host Rocks

The whole rock association that hosted the Fe-Cu-mineralization comprises metagraywacke, arkosic-metagraywacke, epiclastic siltstone, pebbly mudstone with intercalations from crystal lithic and coarse ash tuffs. The Fe-bands are intimately associated with the metapyroclastic materials but may extend through the metagraywacke rocks. According to Hassanen and El Shazly (1989), the metapyroclastic materials are composed of: (a) metadacite crystal lithic tuff and (b) metadacite crystal-lithic-lapilli tuff.

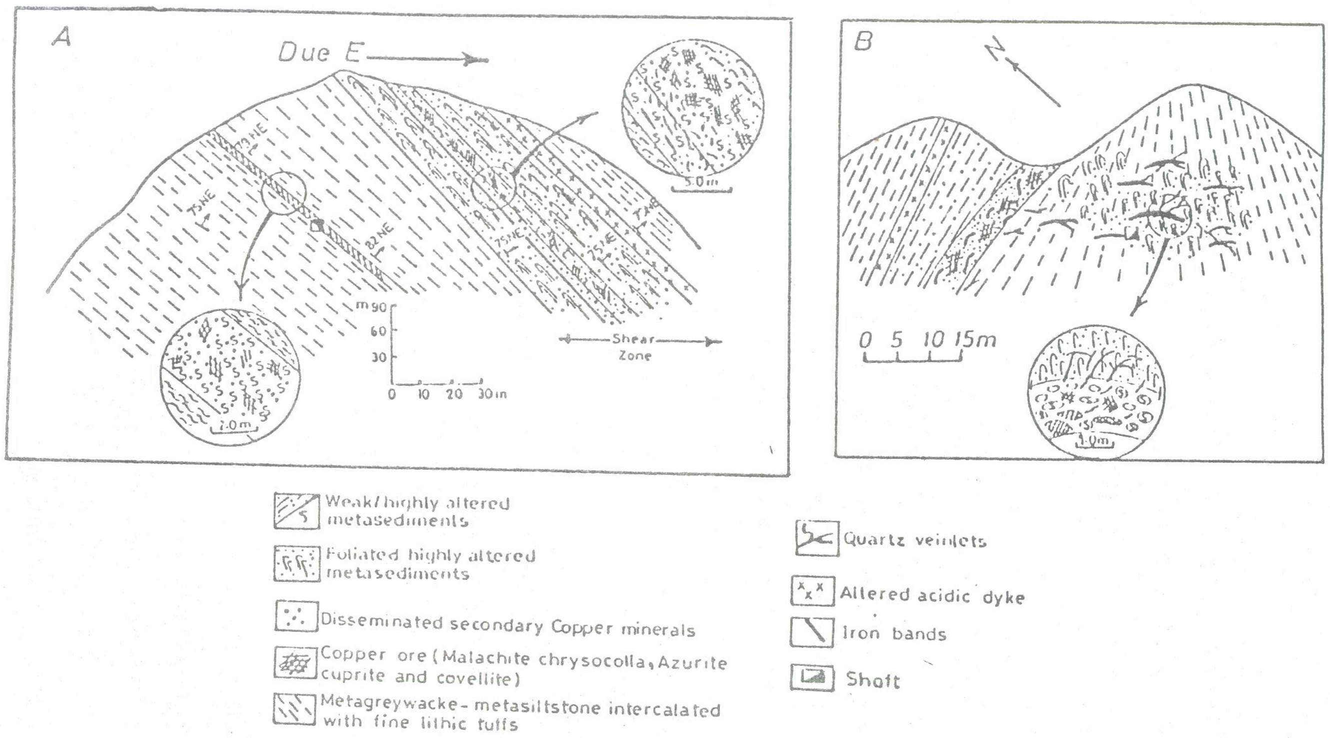

Fig. 2: Geological longitudional cross-section showing the mineralized: (A) the Fe-bands, and (B) Cu-mineralization in relation to the quartz veins.

The metadacited crystal lithic tuffs are generally fine grained composed of angular to subangular crystal fragments of plagioclase together with dacitic lithic fragments. They are set in a microcrystalline matrix which exhibits intergranular or pilotaxitic texture. The metadacite crystal-lithic lapilli tuffs are coarse grained and consist of ill-sorted angular lithic fragments (5 mm across) and crystal ashes embedded in fine graine ashy matrix. The lithic grains consist of dacitic, quartz porphr and less common chert fragments.

The metagraywackes are fine to medium grained and of greenish grey colour. Close to the Fe-bands, they are partially to completely epidotized. Quartz, plagioclase, actinolite, chlorite and minor potash feldspar comprise the whole make up of the less altered parts. These are set in a matrix of microcrystalline nature and of the same mineralogy. Felsic and volcanic glass fragments are also recorded. The plagioclase and quartz constituents are angular to subangular, oftenly streched and deformed with development of undulatory extinction.

Mineralogy

Based on microscopic inspections supplemented by X-ray analyses, three anomalous types of Fe-Cu mineral assemblages are recognized.

The first type is characterized by abundant Fe-bearing oxide minerals predominantly: magnetite, hematite and specularite in addition to secondary formed martite and relatively farless goethite and lepidocrocite. These oxide minerals are, as microscopically observed, so far of variable abundance throughout

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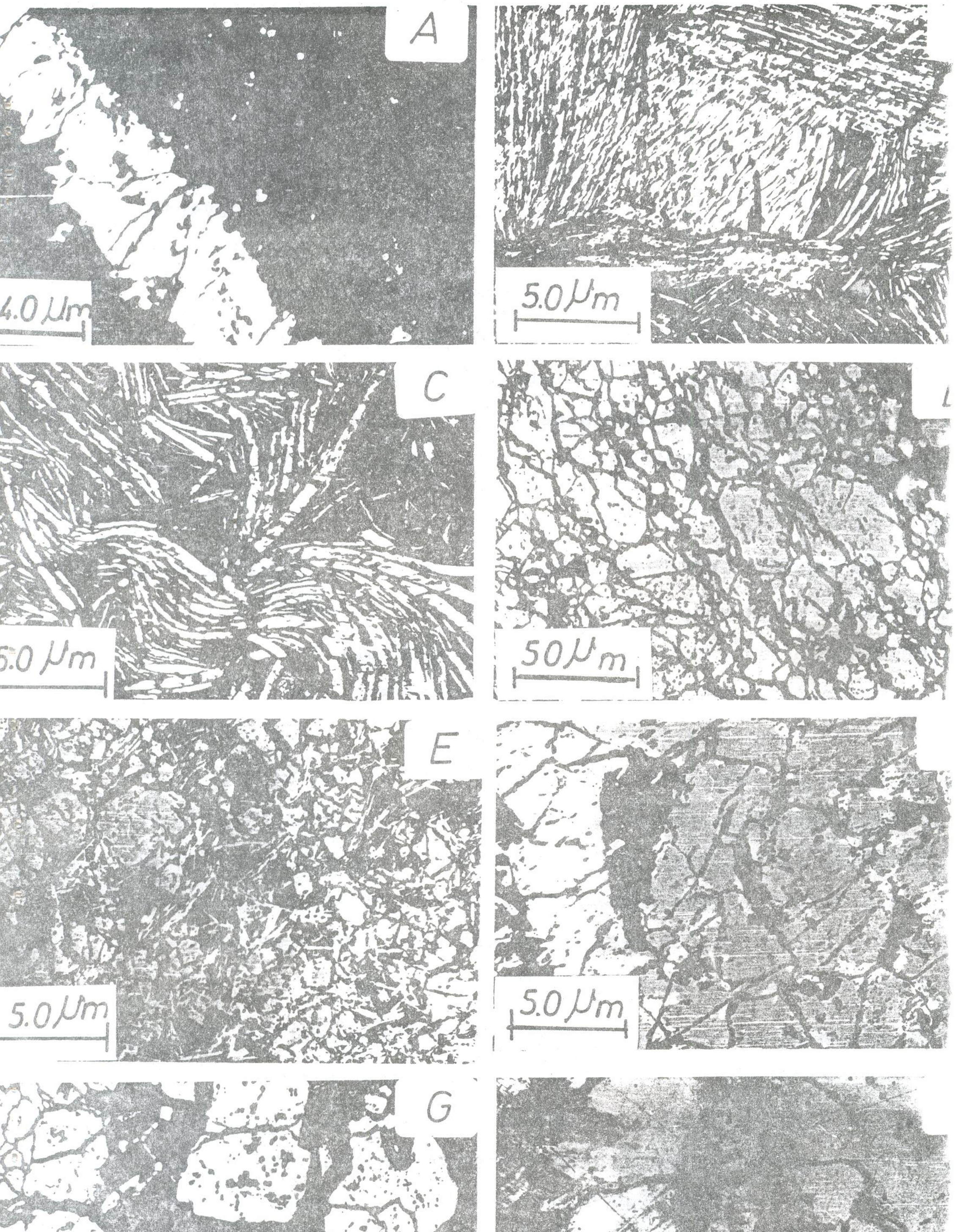
Fig. 3: (A) Magnetite crystals stuffed along a frscture in the host rocks, (B) Fibrous style of hematite or specularite crystals, (C) Acicular to lath-like crystals of the specularite, (D) Magnetite crystal highly deformed with cataclastic texture, (E) Hematite-magnetite association notice, recrystalization of the former, (F) Massive magnetite crystals with fracturing and alteration to hematite, (G) Magnetite crystals showing granulose-like texture and partial to complete martitizations (left of photo) and (H) Covellite lamallea enclosed in chalcocite in intergrowth relation.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the bands but commonly associating micro-to-crypto-crystalline silica and epidote. Minor amounts of calcite, chlorite and tuffaceous material are not uncommon. These together would account for the bulk composition of the different Fe-rich bands. However, lately formed veinlets filled by Fe-oxides (Fig. 3A) or fine grained quartz-stained by malachite or Fe-oxides cutting across the host rocks are also detected. It is generally noticed that:

1- The magnetite-hematite admixture are in excess of 80% bulk composition of their enclosing bands or veinlets. Texturally, their crystals manifest a myriad variety of forms, indicative of tectonism and recrystallization. These include banded style of fibrous (fig. 3B) lath-like or acicular forms (Fig. 3C) and about prismatic to granular sometimes intented to idiobalstic with prominent fracturing and cataclasis (Figs. 3D and E). Selectively, the hematite crystal are commonly stuffed in such a manner that would portary clear schistosity, while the magnetite ones are to a great extent of massive nature (Fig. 3F) sometimes with granulite-like texture (Fig. 3G).

2- The martite is directly related to the magnetite, being localized almost as lamellae on octahedral planes or crackes and as patches at margins and around holes in magnetite crystals, as the martite formation has proceeded in most cases toward partial to complete pseudomorphism of the parent or crystals, would suggest oxidation enhanced by temperature elevation through metamorphism of the hosting rocks.

3- The goethite-lepidocrocite admixtures are relatively farless abundant and occur as alteration product of the parent magnetite and/or hematite. The lepidocrocite is scarce and the goethite is the frequent, commonly forming colloform texture.

The second type is made up essentally of Cu-minerals, principally: malachite, crysocolla, azurite, cuprite and chalcanthite in addition to relics of a pre-existing chalcocite, digenite and covellite. These are commonly encountered as admixtures of two or more minerals along fracture of the hosting rocks and in quartz veins. However, the relative abundance of these constituents and their housing fractures would point to a low grade Cu-mineralization.

The chalcocite relics enclose sometimes lamellæ of covellite (Fig. 3H) and in other portary intergrowth relation with the digenite where the latter assumes a small, of needle-like forms (0.05 mm). If this is a true intergrowth, it will account for unmixing of solid solution formed above 93°C (Craig, 1974).

The third type includes admixtures of both Cu- and Fe-bearing minerals. Commonly, the Cu-minerals are dispersed within the fractures filling Fe-oxided and scarcely traped along fractures in the Fe-oxide bands.

From the table (1), the following are relevant:

Mn

The Mn-contents range between 204 and 638 ppm. The average value is 33 ppm close to that for exhalative-volcanic Fe-ore at Semna, central Eastern Desert, Egypt (300 ppm, Bishara

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Table 1: Chemical analysis of some selected samples of the Khasha El-Fakh Fe-Cu mineralization.*

Sample no.	Cu	Fe	Mn	Cr	Co	Ni	Co/Ni
F.6	2480	21.00	280	400	90	124	0.73
2.A	4640	20.00	232	510	122	159	0.77
Bo	4400	19.70	328	400	186	171	1.09
F-1	1101	20.02	446	400	80	129	0.62
d-5	4674	10.80	638	393	55	125	0.44
4-A	4803	17.45	206	397	99	140	0.71
Cu-5	4700	15.40	488	400	44	111	0.40
7A	1220	21.50	298	510	110	142	0.77
B2	48[illegible]4	15.78	204	399	72	85	0.85
3A	2820	20.80	244	510	120	167	0.72
Average	3132	18.45	336	432	98	135	0.73

** All analyses in ppm except Fe in weight percent.*

and Habib, 1973) and Fe-ore of magmatic origin (Gasparrini and Noldrett, 1972) . However, it is comparable to a large extent with that given by Bajwah et al. (1984) for volcanogenic exhalative deposits.

<u>Co/Ni</u>

The Ni-contents, 85-171 ppm (average 135 ppm) are relatively higher than that of the Co, 44-186 ppm (average 98 ppm), in the study samples. The Co/Ni vary over a narrow range 0.40 to 1.09 with an average of 0.73. These have been compared with other types of mineralization. Both the Co and Ni contents in the study samples are to a great extent comparable with other volcanogenic exhalative deposits, e.g. Kiruna, (Parak, 1975 a,b), little Cardia (Mason, 1981), Northern Sweden (Landberg and Smellie, 1979) and Big Cadia (Bajwah et al., 1984).

Cr

The Cr-contents range between 393-510 ppm (average 432 ppm). These are much high relative to that given by Bishara and Habib (1973) to the Semna Fe-deposits, central Eastern Desert, Egypt (45 ppm).

Cu

The Cu-contents range between 1101 and 4814 ppm with average value of 3132 ppm. This may owe its existence to finely dispresed Cu minerals as contaminants in the Fe-rich bands.

Wallrock Alteration

The wallrock alteration of the metavolcanic-metasediments in the study zone is not only related to the mineralogic composition of these rocks but also affected by the presence and distribution of the Fe-bands and Cu-mineralization. The mineralization resulted in a large diffuse and rather irregular zones of prevasive alteration. Propylitic and sericitic alteration zones are the most distinct ones recognized around the mineralization. The strong propylitic assemblage is well developed near the shear zones. The different alteration zones assume a rather subellptical form trending NW-SE and corresponding to the strike of the iron bands and the shear zones. They are co-axially arranged outward from sericitic core with a local thin argillic zone through propylitic one (Fig, 4). However, the chlorite-calcite-biotite-assemblage developed in the country rocks due to the low-grade metamorphism (greenschist facies) may locally obliterate a clear distinction and subsequent delineation of the limits of the wallrock alteration zones. The Cu-mineralization is commonly confined to sericitic zone while the Fe-mineralization is enveloped by strong propylitic zone (Fig. 4). The following observations are relevant.

Sericitic alteration

Sericitization is widespread as prevasive type in all rock units in the area. It is more conspicuous around the Cu zones where shear zones are prominent. In the northern part of the studied area, it constitutes the inner most alteration zone (Fig.4). The mineral assemblage in this zone includes white mica (sericite), quartz, variable amount of clay minerals, sphene and secondary Cu-sulfide and carbonate minerals; which conform the term as defined by many workers (Hemley and Jones, 1964 and Mayer and Hemley, 1967). This assemblage is most likely formed on the expense of plagioclase and potash feldspars and less common on biotite. However, the potash feldspar of the outer limit of the sericitic zone (argillic zone) is slightly to intensively altered to clay minerals. This may be attributed well to dropping in the (a_k+/a_H+) of the ore bearing fluids (c.f. Helgeson, 1969).

The presence of minor amounts of sericitic assemblage in the northeastern part of the study zone suggest that sericitic alteration is paragenetically superimposed on the earlier alteration stages (propylitic).

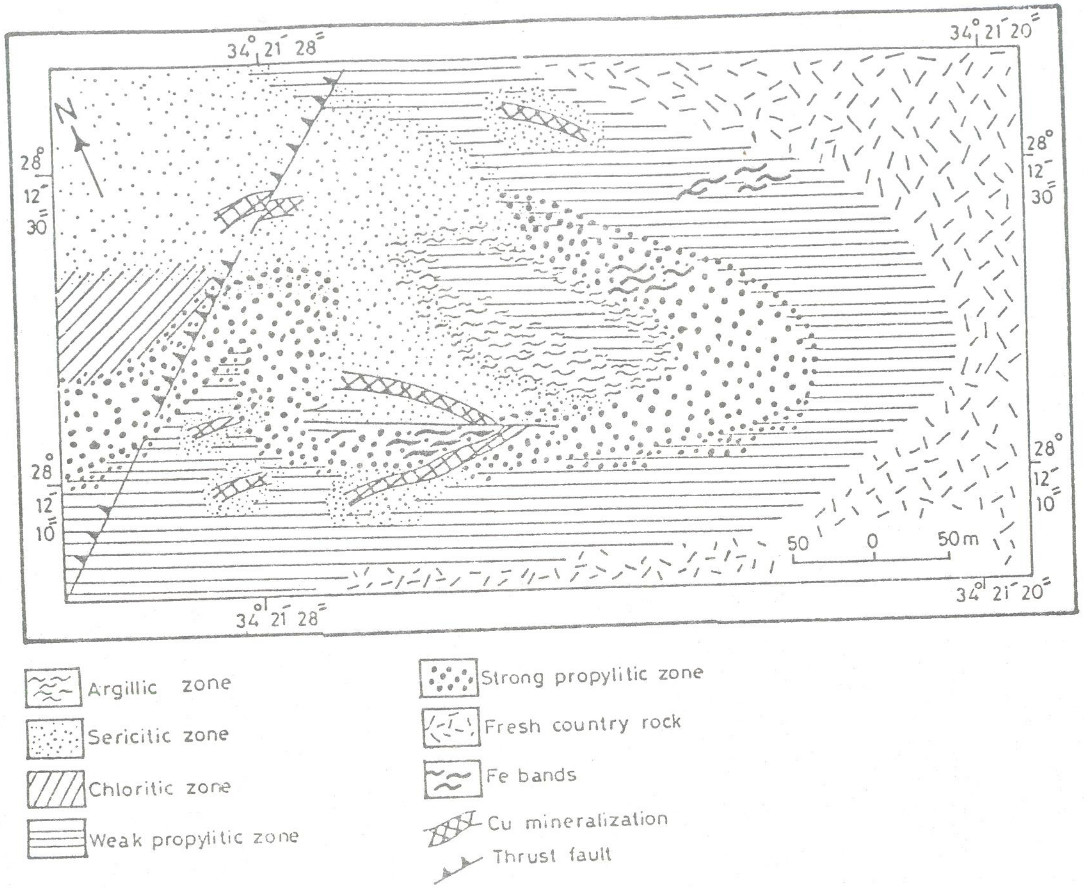

Fig. 4: Alteration map of the Fe-Cu mineralization at the Wadi Tarr, southeast Sinai.

In the southern part of the study area where Cu-Fe mineralization is detected in a thrusted zone, the assemblage is mostly a mixture of propylitic and sericitic materials. In this alteration mixture, small amounts of albite are recognized which may indicate the role of high oxygen fugacity during depositions of Fe-minerals (Helgeson, 1969).

Propylitic alteration

This type occupies mostly the outer most alteration zones around the mineralization and fadesout gradually to the fresh rocks. It is characterised by the mineral assemblage; chlorite, epidote, actinolite, calcite, sericite, sphene, quartz, Na-feldspar and iron oxide minerals.

Unlike the sericitic alteration, the propylitic type is clearly associated with Fe-rich bands. The paragenetic position of the propylitic alteration might be considered as the last interacting event of the ore-bearing fluid on the country rocks possibly suggesting alteration under low pressure and temperature conditions (Gurilbent and Park, 1986).

A zone of soft, bright green coloured constituents is formed close to the sericitic alteration zone. It consists almost entirely of epidote and chlorite. This alteration zone might represent the advanced stage of propylitization where the latter locally overlapped with the chloritic zone. Most of the iron ore bands in the southern part are characterized by this alteration zone. The excellent development of this zone may owe its extistence to the metamorphic effect that superimposed on the Fe-band and their hosting rocks.

DISCUSSION

The basement sector at the Kid area has been the topic of several research works . However, little current is being devoted to the Cu-mineralization that hosted locally in the volcano-sedimentary Pile. The area is interpreted as a fault-bounded domal structure comprizing three distinct tectono-stratigraphic units, namely; old infra-crustal gneiss, large volcano-sedimentary pile and late intruding boides of variable compositions (Shimron, 1984).

The volcano-sedimentary pile occupies the large part and has been deformed and influenced by low grade metamorphism. Furnes et al. (1985) and Atalla (1989) assigned this pile as a part of active continental margin. Hassanen (1992) agreed with this assumption and has presented geochemical evidences in agreement with a subduction related volcanic arc setting to the metavolcanics of the Tarr complex. On comparative basis, Shimron (1984) regarded the Cu-mineralization occuring in the Tarr complex as a prophyry type coincidently formed with the albite-carbonatite bodies. However, the local occurrence of some Cu-minerals filling fractures in the albitites and also association of Tertiary volcancity (Hassanen and Harraz, 1991) would add weight to a late chronological formation sequence. Obviously, the different occurrences of the Cu-mineralization in the area are, as so far observed, similar in mineralogy and mode of occurrence and have been evaluated as a lean Cu ore.

Despite the spatial occurrence of the Cu-mineralization at Wadi Khashm El-Fakh with Fe-bands, yet the previous studies faild to report any information on these bands.

In view of the present work, the orgin and evolution of Wadi Khashm El-Fakh Fe-Cu-mineralization may be interpreted well as follows. Because of its intimate association with the volcano-sedimentary pile, the volcanic activity is the feasible source of materials. However, the impartial occurrence and assembly of the Fe oxides as banded intercalations and the Cu-bearing assemblage in a fracture filling style in quartz vein would suggest that: (1) they are not coenheritance of a same parent material, and (2) their formation was largely controlled by stratigraphical and structural factors. These together with the submarine nature of the volcano-sedimentary pile, the large abundance of the pyroclastic material and the wallrock alteration around the Fe-and Cu-bearing assemblages impart to the validity of the following proposal. The extrusion of the Late-Proterozoic volanic products, pyroclastics, rhyolites and high K-dacite, was most likely followed by syn-volcanic faults. The latter affected these products and enhanced the development of convective hydrothermal systems. Ascending of at least subqueous Fe-rich volcanic emanations along such syn-volcanic faults promated the formation of the Fe-rich bands (Oftedahl, 1958; Krauskopf, 1967) that has taken place under shallow marine conditions. The volcanic activity was followed by sedimentation and occassionally interrupted by extrusion of other volcanics. Finally, the volcano-sedimentary pile and the Fe-rich bands were subjected to deformation, low grade metamorphism and intruded in part by granitoid. The granoblastic intergranular textures and deformation fabrics emphasize on recrystallization. Metamorphic and deformation fabrics emphasize on recrystallization. Metamorphic remobilization created secondary delicate vein-like occurrences of the Fe-oxides.

The coincidence in space of the Tertiary basalt and the Cu-mineralization indicates well rejuvination and propagation of the fractures to depth. Along these fractures a hypo, ascending Cu-rich but sulfur defficient solutions probably leached from hidden source gave rise to the Cu-mineralization.

CONCLUSIONS

The Fe-Cu mineralization at Wadi Khashm El-Fakh comprises two distinct associations of the metallic constituents, including: Fe-oxides and Cu-bearing assemblage. The geologic setting would emphasize on the volcanic activity as a feasible source of material. The occurrence and essembly of the Fe-oxides indicate well that their formation was coincident in space and time with the enclosing metapyroclastic-metagraywacke association, i.e. stratigraphically controlled formation. On the other hand, the Cu-bearing assemblage occurs as fracture filling style suggestive of late epigenetic formation. The Cu-mineralization and the alteration style could simply be used as guide to look for iron ones in the other localities.

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التمعدن والتغير واصل تكوين خام الحديد والنحاس بوادى خشم الفخ بمنطقة الكيد جنوب شرق سيناء مصـــر

محمد عبد الروف الدحار   محمد عبد السميع حسنين
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حســن زكــريا حــراز
كليــة العلوم ـ جامعة طنطـــا

يتضمن البحــث دراسة خامات الحديد والنحاس والتغيرات المصاحبة لهــم صخــور المكان الحاوية بمنطـــقة خشم الفخ ـ جنوب شـرق سيناء٠ فقد اظـهـرت الدراســة الحلقية تواجد الخام فى صخـــور بركانية ـ رسوبية مهشــمة تنتمــى الى العصــر البرتيروزوى٠ وهذه الصـــخور قد تعرضـت لدرجة تحول منخفضـة ممثلة لشـــحنة الابيدوت ـــ امفيبوليت٠

وقد اظهرت نتائج الدراسة العملية وجود مجموعتين من التمعدنات ذو تركيـب معدنى مختلف وتشمل:

المجموعة الاولى : معادن الماجنيتيت والاسبيكيولا ريت والهيماتيت والمارتيت والتى تكون فيما بينها رواسب شريطية مختلفة السمك وذات طبيعة متصلة او غير متصلــة٠ ومعادن هذه المجموعة ايضا مكتنفه داخل صخور الميتا جريواك والفتات البركانيـــة التى تعرضت لعمليات تغير مختلفة ابرزها تكوين ابيدوت٠

المجمـــوعة الثانية: فتشمل معادن الملاكيت والكريزوكولا وازوريت والكوبريت والكالسيت بالاضافة الى بقايا معادن الكالكوسيت والكوفيليت والديجينيت٠ وهذه المعادن مكتنفه خلالا الشقوق وعروق المــرو٠

وبالنسبة لاصل هذه الخامات فان المعادن الحاملة للحديد ذو اصل بركانى معاصـر Exhalation Syngenetic بينما خامات معادن النحاسس ذات اصل تكوينى لاحق Epigenetic وصاحبها تكوين الميكـا البيضـاء Sericite بكميات ملموســة٠