Precambrian Ore Deposits in the Nubian and the Arabian Shields and their Correlation across the Red Sea

By A. Al Shanti, W. Frisch, W. Pohl and M. M. Abdel Tawab*)

Summary

A generalization is attempted of the present knowledge on Precambrian geology and mineralization in the northern Red Sea area:

The northern parts of the Nubian and the Arabian Shields have had a nearly identical Precambrian geological history; thick geosynclinal volcano-sedimentary sequences are intruded by pre-, syn-to post-tectonic magmatic rocks ranging from ultramafics to highly differentiated granites.

The Precambrian ore deposits may be classed into three main groups — 1. Zn-Cu-Pb-Ag-Au-Fe are derived from the early volcanic activities; 2. Cr-Cu-Ni-Co occur within mafic and ultramafic intrusives; while 3. Ta/Nb-Sn-W-Mo-F-Au are connected with late-to post-tectonic granitic intrusions.

Deposits belonging to the three listed metal associations occur on both sides of the Red Sea, and many of them are directly comparable. Because of this the authors consider them as part of one metallogenic province, which may be called "Arabo-Nubian metallogenic province".

The observation, that deposits of the plutonic, acidic affinity (group 3) are more important in the Nubian Shield and the Hijaz, while group 1 deposits predominate in the Najd and Asir areas of the Arabian Shield, leads to the definition of two metallogenic subprovinces. The western "Hijaz-Nubian metallogenic subprovince" is characterized by the Ta/Nb-Sn-W-Mo-F-Au metal association, whereas the eastern "Najd-Asir metallogenic subprovince" comprises more Zn-Cu-Pb-Ag-Au-Fe. Group 2 metals are about equally distributed in the whole area.

Zusammenfassung

Die vorliegende Arbeit stellt den Versuch einer Verallgemeinerung der derzeitigen Kenntnis von Geologie und Erzlagerstätten des Präkambriums im nördlichen Bereich des Roten Meeres dar.

Die nördlichen Teile des Nubischen und Arabischen Schildes hatten eine weitgehend vergleichbare präkambrische geologische Entwicklung: Mächtige geosynklinale vulkano-sedimentäre Folgen wurden durch prä-, syn-bis post-tektonische magmatische Gesteine intrudiert, die von Ultrabasiten bis zu hoch differenzierten Graniten variieren.

Die präkambrischen Erzlagerstätten können in drei Hauptgruppen eingeteilt werden — 1. Zn-Cu-Pb-Ag-Au-Fe wurden durch die frühen vulkanischen Aktivitäten gebracht; 2. Cr-Cu-Ni-Co kommen in basischen und ultrabasischen Intrusiven vor; während 3. Ta/Nb-Sn-W-Mo-F-Au mit spät-bis posttektonischen Graniten verbunden sind.

*) Dr. A. Al Shanti, Institute for Applied Geology, P.O.B. 1744, Jeddah.
Dr. W. Frisch, Geologisches Institut d. Universität Wien, Universitätsstraße 7, A-1010 Wien.
Dr. W. Pohl, Institut f. Geologie u. Lagerstättenlehre, Montanuniversität, A-8700 Leoben.
Dr. M. M. Abdel Tawab, Geological Survey of Egypt, 3, Salah Salem Street, Cairo.

Lagerstätten, die diesen Metallassoziationen zugehören, gibt es sowohl im Osten wie auch im Westen des Roten Meeres; viele davon sind direkt vergleichbar. Aus diesem Grunde halten die Autoren alle diese Lagerstätten für Erscheinungen einer metallogenetischen Provinz, die "Arabo-Nubische Metallogenetische Provinz" genannt wird.

Die Beobachtung, daß Lagerstätten der plutonischen, sauren Verwandtschaft (Gruppe 3) im Nubischen Schild und dem Hijaz-Gebiet wichtiger sind, wogegen Lagerstätten der Gruppe 1 in den Najd-und Asir-Gebieten des Arabischen Schildes vorherrschen, führt zur Definition zweier metallogenetischer Subprovinzen. Die westliche "Hijaz-Nubische Metallogenetische Subprovinz" ist durch die Ta/Nb-Sn-W-Mo-F-Au Metallassoziation charakterisiert, während die östliche "Najd-Asir Metallogenetische Subprovinz" mehr Zn-Cu-Pb-Ag-Au-Fe führt. Metalle der Gruppe 2 sind etwa gleichmäßig im betrachteten Gebiet vorhanden.

The Arabian Shield

To a large extent, the Arabian Shield is composed of magmatic rocks. Extensive metavolcanic series of calc-alkaline affinity, ranging from tholeiitic basalts through great masses of andesites to rhyolites, are intruded by their subvolcanic and plutonic equivalents. The metavolcanics are associated with clastic (and pyroclastic) sedimentary series some of which are highly metamorphic (paragneisses).

With the metavolcanic series, two important groups are distinguished: the Jiddah group is considered to be older (GREENWOOD et al., 1976) and consists mainly of basaltic to andesitic rocks being restricted to the western part of the Shield; the Halaban or Hulayfah (according to nomenclature) group contains a thick andesitic sequence which is overlain by rhyolitic and pyroclastic material. Clastic sediments, cherts, and carbonates are subordinate.

The described series are considered to represent volcanic arcs which have been swept together and cratonized to the end of the Proterozoic (GARSON & SHALABY, 1976; GASS & NEARY, 1976; FRISCH & AL-SHANTI, 1977; see also GREENWOOD et al., 1976). Narrow ophiolite belts and suture zones cut the Arabian Shield dividing it into several segments. These segments are made up of similar rock sequences and don't differ in their ore contents.

Post-orogenic granites of slightly alkalic affinity are of about Cambrian age and are considered to interfere with the northwest trending, left-lateral Najd fault system.

The most important ore deposits in the Precambrian of the Arabian Shield are those of the paragenesis Zn-Cu-Au(-Pb-Ag). These deposits are restricted to the metavolcanics of mostly intermediate to acid chemism of the Jiddah and Halaban (Hulayfah) groups. Both sequences contain the same type of mineralization.

The mineralization is of subvolcanic to synsedimentary origin and occurs disseminated, in stockworks, or as massive sulfide bodies. The side-by-side-occurrence of subvolcanic mineralization and massive submarine-exhalative ore bodies strongly resembles the typical island arc type deposits well known from the circum-pacific region.

The mineralization is associated with the more acid members of the volcanic sequences. We can discern deposits with Zn and Cu (and maybe Pb) and no precious metals, or with Zn-Cu-Au (Pb and Ag may also be important), from deposits in

which Au predominates, with or without accompanying Zn-Cu, Pb, and/or Ag. Pyrite is the most common ore mineral in all the deposits; in those with Zn and Cu, Zn generally predominates. Those with predominating gold generally occur as vein mineralization in the subvolcanic stockwork. The Zn-Cu deposits generally occupy a somewhat higher level, or form massive stratiform sulfide ore bodies. The vein or disseminated mineralization is mostly concentrated along shear zones in the country rocks.

A compilation of the volcanogenic deposits of the paragenesis Zn-Cu-Au in separated belts seems not to be justified: in nearly all parts where certain horizons of the metavolcanics of the Jiddah and Halaban groups are exposed, deposits or occurrences of this type are present. That means that the metavolcanic series let expect the presence of occurrences of this ore paragenesis and type in all places. The disposition of the known occurrences in narrow belts (see Fig. 1) is simulated only by the appearance of the metavolcanics in narrow, mostly north-south trending zones which correspond to the general trend in the Precambrian series.

Together with the volcanic series there are some pyrite deposits without noteworthy amounts of Zn, Cu, or Au.

Together with the post-orogenic granitic intrusions which are scattered all over the Arabian Shield, we find two groups of ore occurrences: on the one hand there are tungsten mineralizations with or without molybdenum but without tin so far known; on the other hand there is a group with U, Th, Nb, and Rare Earth elements. Tungsten occurs in veins and disseminated, the U-Th-Nb-REE mineralization is bound to pegmatitic veins. Both types of mineralization are bound to the vicinity of the intrusive contacts. There are also some fluorspar-quartz veins near the granitic contacts. The granites are alkali feldspar or alkali granites after the nomenclature of STRECKEISEN.

From a post-orogenic intrusion of basic rocks and syenites in the southern part of the Shield, mineralization of titanomagnetite is reported.

Chromite occurrences are known from several ultramafic (mostly ophiolitic) masses in different parts of the Shield.

The Nubian Shield

The geology of the Egyptian part of the Nubian Shield is nearly identical to the nearest portion of the Arabian Shield: Large masses of meta-volcanic calc-alkaline rocks of mostly intermediate composition, but ranging from basic to acid types (basalts, andesites, dacites, rhyolites), together with a thick pile of predominant clastic metasediments (slates, phyllites, gneisses) have been intruded by their subvolcanic and plutonic equivalents (gabbros, diorites, quartz-diorites, granites). Ultramafics have been emplaced into the meta-volcanics and meta-sediments, in part conformably, in part along sutures probably representing deep-reaching faults of variable strike.

The main orogenic deformation was accompanied by wide-spread intrusions of grano-diorites and granites, forming huge batholits with frequently reactive margins, and by metamorphism, which increases generally to the south. To explain this it has been suggested (GINDY 1972), that deeper levels of the same geosynclinal trough are exposed towards the south. The main structural trend of the orogenic deformation is generally assumed to be SE— NW, though other directions of fold-axis are observable.

Post-orogenic granites, although of a more alkalic affinity, are probably consanguinous with the syn- to late-tectonic ones. In fact GINDY (1972) assumed, that the different granites of the Egyptian Eastern Desert represent a virtually continuously evolving granite-series. Faults of NW-strike which probably correspond to the Najd fault system of Saudi Arabia, have only recently been recognized in south-eastern Egypt (KRS, SOLIMAN & AMIN 1973); some of them are intruded by basic dykes, others seem to control the location of post-tectonic "acidic" mineralization (loc. cit.).

Ore deposits in the Egyptian Precambrian include

1. volcano (?)-sedimentary banded iron ores within the meta-sediments (f. ex. Umm Nar — EL RAMLY, AKAAD & RASHY 1963).

2. Fe, Zn, Cu, Pb, (Au, Ag)-sulfide ores which may be lenticular, massive, conformable or disseminated in shear zones; they are always associated with the meta-volcanic series (example: Umm Samiuki — HUME 1937, ABDEL TAWAB 1974).

3. magmatic segregation type ores associated with mafic-ultramafic intrusives: Fe-Ti in gabbro (Abu Ghalaga — AMIN 1954), Cu-Ni-Co in layered gabbro-peridotite (at Gabbro Akarem — BUGROV & SHALABY 1973), and Cr in serpentinites and related rocks (HUME 1937).

4. "acidic" ores of Nb/Ta, Sn, W, Mo, U/Th, Be, F, RE connected with the post-orogenic Gattarian granites; this group includes

— disseminated Nb-Ta-Sn ores in albitized, acidic, last stage granites; huge deposits of this type have been found during the last 10 years (SABET & TSOGOEV 1973, BUGROV, EL GADAEL & SOLIMAN 1973 — at Abu Dabbab, Nuweibi, etc.)

— pegmatitic Sn-Be-Mo-(U-Th) ores of little significance at present

— vein deposits of Sn, W, F, Mo of small scale (f. ex. Mueilha Sn/W — EL RAMLY & AKAAD 1959).

5. Au(-Ag) veins cutting virtually all Precambrian rocks ranging from the early meta-sediments to the youngest Gattarian granites; other ores, though without economic significance, in these veins include: pyrite, galena, arsenopyrite, chalcopyrite, bornite, phyrrhotite, stibnite and sphalerite; gangue minerals are: quartz predominantly, calcite, siderite/ankerite, dolomite; alteration of country rocks includes sericitization, chloritization, hematitization, beresitization, listvenitization.

These veins have exclusively furnished the ancient and modern Egyptian gold production; though not all of them may be of the same origin, HUME (1937) and KOCHIN (1970) considered them to be connected with pre-tectonic epidiorite intrusions, while AMIN (1955) and EL SHAZLY (1957, 59) derived them from the post-tectonic Gattarian granites. To provide a sound basis for a decision on their origin most of these deposits will have to be newly investigated, but some of them are clearly associated with post-orogenic acidic intrusions. Others may be genetically related to group 2), as f. ex. the Hammash Au-Cu occurrences (HUME 1937, MOUSTAFA & HILMY 1958).

In order to allow a quick visual comparison of ore deposits known at present on both sides of the Red Sea, Table 1 summarizes the above outlined data, while a sketch map with the basic features of Precambrian geology and mineralization in the area is presented in Fig. 1.

Nubian Shield (Egypt)	Arabian Shield (Saudi Arabia)	
Au-quartz veins	Au-quartz veins	late-to post-orogenic mineralization
Sn-W-Mo-F-quartz veins	veins with W-Mo and F	
Sn-Be-Mo(-U-Th-) pegmatites	U-Th-Nb-RE-pegmatites	
disseminated Ta-Nb-Sn in granites	?	
Ti-Cr-Cu-Ni-Co in magmatic segregation type deposits	Cr-Ti-V-Ni-Co-Cu in magmatic segregation type concentrations	pre- to late orogenic
Zn-Cu-Pb (Au-Ag) associated with metavolcanics	Zn-Cu-Pb(-Au) in metavolcanics	pre-orogenic
?	Au(-Zn-Cu) (Ag, Pb) in metavolcanics	
banded Fe-ores in metasediments	banded Fe-ores in metasediments	

Table 1: Precambrian ore deposits in the Nubian and the Arabian Shield

Discussion and Conclusions

The Nubian (Egyptian) and the Arabian Shields are part of one orogen; their geological evolution is widely comparable and many stratigraphic or rather lithologic units can be directly correlated across the Red Sea.

In the same way it is possible to correlate the ore deposits, which frequently comprise almost identical mineral and metal associations on both sides. Accordingly it is suggested, that the ore deposits and occurrences of Egypt and Saudi Arabia belong to one metallogenic province (in the sense of PETRASCHECK, 1965), which may be called the "Arabo-Nubian metallogenic province".

This is based on the following:

— all ore deposits have been formed during the orogenic epoch responsible for the cratonization of the Arabo-Nubian Shield, which was concluded by the Pan-African Orogeny (KENNEDY 1964); because of this they are the result of one metallogenic epoch;

— the whole area is part of a zone of orogenically deformed Upper Proterozoic geosynclinal deposits (in the sense of CLIFFORD 1970), thus representing one major tectonic realm;

— the related mineral compositions and metal associations of the deposits;
— the frequent similarity of the form of the deposits, and
— a comparable density of mineralization.

In fact it is the last point, that asks for further enlargement: It was stated above, that large deposits of rare metals (Ta/Nb, Sn) exist in Egypt, equivalents of which have not been localized in Saudi Arabia until now. Similarly, a big number of base metal deposits are known in the Arabian Shield with the exception of the northwestern part (Hijaz area). They have only few counterparts in Egypt.

Though present and future research in both countries may alter this picture of the distribution of ore deposits, it seems to be possible now to define two metallogenic subprovinces in the area: One comprises the Nubian Shield and most of the Hijaz area of Saudi Arabia, containing mainly deposits related to intrusives of late- to post-tectonic age; the other covers the Najd and Asir areas of the Arabian Shield, and is characterized by deposits genetically related to pre- or early-tectonic volcanic activity.

The first may be called the "Hijaz-Nubian metallogenic subprovince", the second "Najd-Asir metallogenic subprovince" (Fig. 1).

It is tempting to relate the difference between the two metallogenic subprovinces to the existence of a more continental base of the orogen in the west, whereas the eastern subprovince may reflect a more oceanic base with stronger emphasis on volcanic arc mineralization.

If this is correct, then some of the metals occuring predominantly in the western subprovince may be inherited from older continental crust. Several radiometric age determinations in the 1000 m. y. range have been made known from both Egypt (Meneisy 1972) and the southwestern Arabian Shield (Greenwood et. al. 1976), which point to the existence of Kibaran rocks in the area. Metals of the Sn-W-Mo association may be remobilized from an older cycle.

Considering practical application of the interpretation presented, it is obvious that important recent finds like Abu Dabbab in Egypt will rise considerable interest in the corresponding areas of the Arabian Shield. In view of the immense areas which would have to be prospected, the authors think that exercises like this one, leading ultimately to a delimitation of metallogenic units at all scales, will contribute essentially to a rational choice of prospective target areas.

Here it may be concluded, that deposits of the post-tectonic acidic affiliation will preferably be prospected for in the Hijaz-area of Saudi Arabia, while only scattered deposits of the volcanic association, so frequent in Najd and Asir, may be expected to exist in the Hijaz and in Egypt.

References

Abdel Tawab, M. M.: Zinc-lead deposits in the Eastern Desert. Geol. Surv. Egypt Paper **61**, 47—54, 1974.

Amin, M. S.: Geological Features of some Mineral Deposits in Egypt. Bull. Inst. Desert d'Egypte **5**, 209—240, 1955.

Brown, G. F.: Tectonic map of the Arabian Peninsula, 1 :4,000,000. — Arabian Peninsula Series, Map AP-2, Dir. Gen. Min. Res., Kingdom of Saudi Arabia. Jiddah, 1972.

BUGROV, V. A. & I. M. SHALABY: First discovery of Ni-Cu sulfide mineralization in gabbro-peridotitic rocks in Eastern Desert of Egypt. Ann. Geol. Surv. Egypt **3**, 177—183, 1973.

BUGROV, V. A., A. A. EL GADAEL & M. M. SOLIMAN: Rare-metallic albitites as a new type of ore-mineralization in Egypt. Ann. Geol. Surv. Egypt **3**, 185—205, 1973.

CLIFFORD, T. N.: The structural framework of Africa. 1—26 in: African Magmatism and Tectonics. Oliver & Boyd, Edinburgh 1970

EL RAMLY, M. F., M. K. AKAAD & D. M. AL-FAR: Cassiterite-wolframite mineralization near Gebel El-Mueilha (Eastern Desert of Egypt). Geol. Surv. Egypt paper **6**, 18pp, 1959.

EL RAMLY, M. F., M. K. AKAAD & A. H. RASMY: Geology and structure of the Umm Nar iron ore deposit (Eastern Desert of Egypt). Geol. Surv. Egypt paper **28**, 29pp, 1965.

EL RAMLY, M. F.: Geological Map of the Basement Rocks in the Eastern Desert of Egypt. 1 : 1,000,000 — Geol. Survey of Egypt and Mining Authority, Cairo 1972.

EL SHAZLY, E. M.: Classification of Egyptian Mineral Deposits. Egypt. Journ. Geol. **1**, 1—20, 1957.

EL SHAZLY, Notes on the Mining Map of Egypt. Rpts., 20th Int. Geol. Congr. Mexico 1956; Ass. Afr. Geol. Surv., 423—437, 1959.

FRISCH, W. & AL-SHANTI, A.: Ophiolite belts and the collision of island arcs in the Arabian Shield. — Tectonophysics **43**, 293—306, 1977.

GARSON, M. S. & M. KRS: Geophysical and geological evidence of the relationship of Red Sea transverse tectonics to ancient fractures. Geol. Soc. America Bull. **87**, 169—181, 1976.

GARSON, M. S. & SHALABY, I. M.: Precambrian-lower Paleozoic plate tectonics and metallogenesis in the Red Sea region. — D. F. STRONG (ed.): Metallogeny and Plate Tectonics: Geol. Ass. Canada Spec. Paper Nr. **14**, 573—596, 1976.

GASS, I. G. & NEARY, C. R.: Granitic association of northeastern Sudan. — Geol. Soc. Amer. Bull. **87**, 1501—1512, 1976.

GINDY, A. R.: Toward a kinematic classification of the Egyptian Basement. Ann. Geol. Surv. Egypt **2**, 47—77, 1972.

GREENWOOD, W. R., HADLEY, D. G. & SCHMIDT, D. L.: Generalized geologic map of the Arabian Shield, Kingdom of Saudi Arabia, 1 : 4,000,000. — Dir. Gen. Min. Res., Jiddah, 1974

GREENWOOD, W. R., HADLEY, D. G., ANDERSON, R. E., FLECK, R. J. & SCHMIDT, D. L.: Late Proterozoic cratonization in southwestern Saudi Arabia. — Phil. Trans. Roy. Soc. London, **A 280**, 517—527, London 1976.

HUME, W. F.: The Minerals of Economic Value. Vol. II, part III of Geology of Egypt, Cairo 1937.

KENNEDY, W. Q.: The structural differentiation of Africa in the Pan-African (± 500 m. y.) tectonic episode. 8th Ann. Rep. Res. Inst. African Geol. Leeds, 48pp, 1964.

KOCHIN, G. G.: The occurence of gold in the Eastern Desert of Egypt. 53—54 in: Studies on some Mineral Deposits of Egypt. Geol. Surv. Egypt 1970.

KRS, M., A. A. H. SOLIMAN & A. H. AMIN: Geophysical phenomena over deep-seated tectonic zones in southern part of Eastern Desert of Egypt. Ann. Geol. Surv. Egypt **3**, 125–137, 1973.

MENEISY, M. Y.: On the Isotopic Dating of the Egyptian Basement Rocks. Ann. Geol. Surv. Egypt **2**, 103—109, 1972.

MOUSTAFA, G. A. & M. E. HILMY: Contribution to the geology and mineralogy of the Hammash copper deposits (South Eastern Desert of Egypt). Geol. Surv. Egypt paper 5, 14pp, 1958.
PETRASCHECK, W. E.: Typical features of metallogenic provinces. Economic Geol. 60, 1620—1634, 1965.
SABET, A. H. & V. TSOGOEV: Problems of geological and economic evaluation of Tantalum deposits in Apogranites during stages of prospection and exploration. Ann. Geol. Surv. Egypt. 3, 87—107, 1973.
SAID, R.: The Geology of Egypt. Elsevier Publ. Co., New York 1962.
SHALABY, I. M.: Zinc-Lead deposits in the Eastern Desert. Geol. Surv. Egypt paper 61, 47—54, 1974.
VAN DAALHOFF, H.: Mineral locality map of the Arabian Shield, Kingdom of Saudi Arabia, 1 : 2,000,000. — Geol. Map GM-15, Dir. Gen. Min.Res., Jiddah, 1974.

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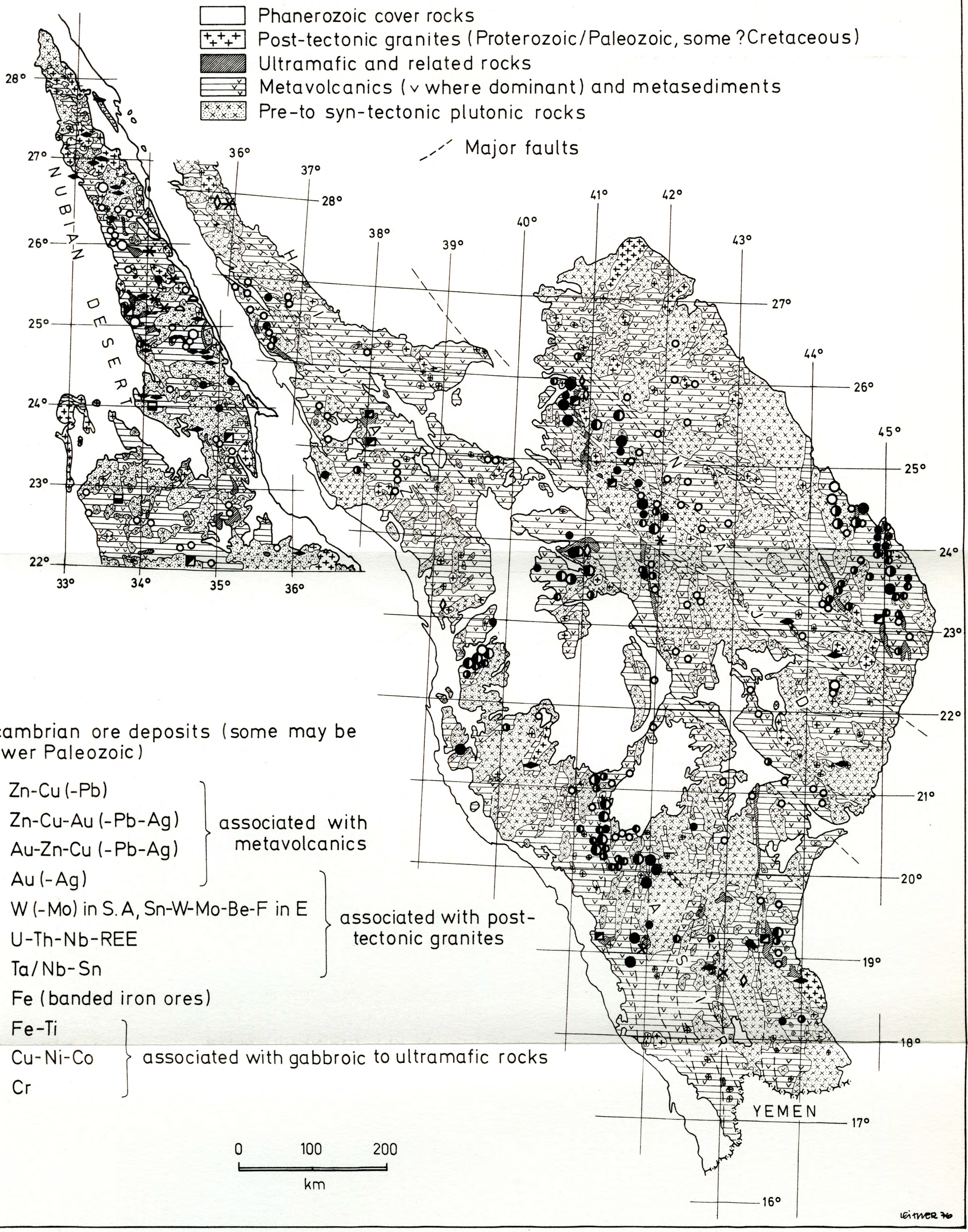

Fig. 1 : Metallogenic sketch map of the Nubian (Egypt) and the Arabian Shields. Geology after EL RAMLY (1972) (Egypt) and BROWN (1972) and GREENWOOD et al. (1974) (Saudi Arabia). Ore deposits after SAID (1962), completed (Egypt), and VAN DAALHOFF (1974) (Arabian Shield). Pre-rift position after GARSON & KRS (1976).