وزارة الطاقة والثروة المعدنية

النحاس والمنغنيز- وادي عربة-نمري- 1973

THE HASHEMITE KINGDOM OF JORDAN
NATURAL RESOURCES AUTHORITY
Mining Division

THE COPPER AND MANGANESE PROSPECTS OF WADI ARABA

(REPORT ON PHASE—ONE)

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AMMAN . JULY . 1973

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ABBREVIATIONS

MD	- Mining Division
NRA	- Natural Resources Authority
J	- Jordan
GGM	- German Geological Mission

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I. INTRODUCTION

This Report is intended to cover the results and conclusions of the Pilot Exploration Scheme, which has been conducted by the Mining Division of the Natural Resources Authority (MD/NRA), during the years 1966, 67, 72 and 1973, to obtain certain basic informations relating to the copper and manganese prospects of Wadi Dana - Finan - Khirbet el-Nahas area, (Fig. 1).

The Report is presented in such a way so as to give the reader a general idea about the geology of Wadi Araba, with special reference to the copper and manganese occurrences in its vicinity, included are abstracts from the major reports which dealt with the area prior to 1966.

By the time this Report will be circulated, the major area of Wadi Dana - Finan - Khirbet el-Nahas, will be undergoing further examination. It is expected that a considerable amount of data will be forthcoming from this additional work, which will undoubtedly have an important influence on the final interpretation of data already presented in this Report.

Therefore, it is intended to eventually issue a more expanded version of this Report at the end of the second phase of work which has already begun. Completion of this work is expected by the end of 1974.

It would be very much appreciated, if those who are interested in the expanded report, can pass to us their views, suggestions and criticisms relating to this initial Report, so that we may accommodate in our later version, corrections, additions or deletions which they may care to recommend.

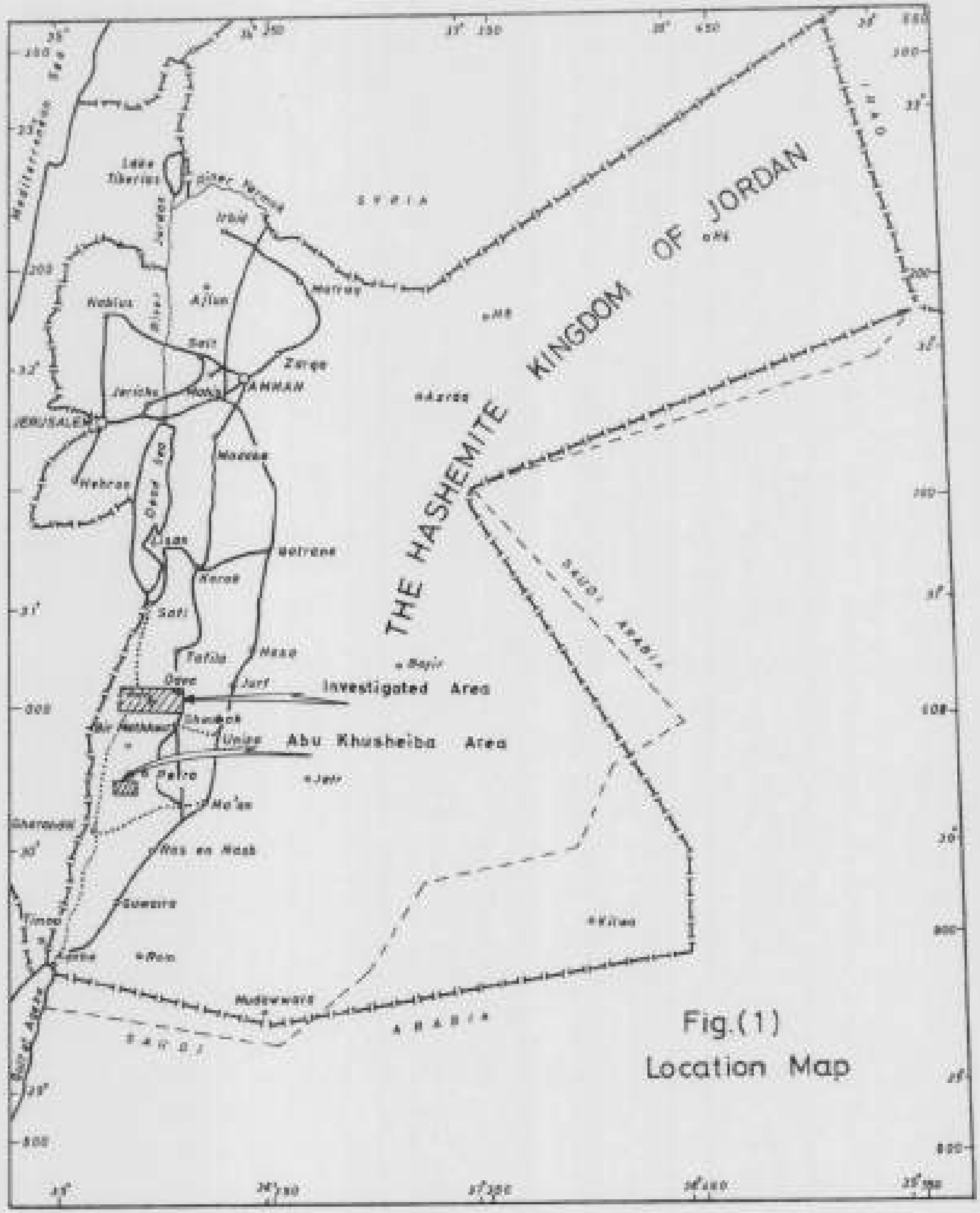


Fig.(1)
Location Map

International Border
New Border
1st. Class Highway
Dirt Track

Scale : 1: 2,500 000

II. ABSTRACTS

The investigated area, is situated in the margin of a large graben zone and forms a portion of the Wadi Araba Rift Valley which extends between the southern end of the Dead Sea and the Gulf of Aqaba.

Secondary copper mineralisation have been reported in two of the major rock units existing in the area, i.e. the Variegated Sandstone Unit (The Upper Copper Horizon) and in the upper member of the Dolomite Limestone Shale Unit (The Lower Copper Horizon). Both units are of Cambrian Age. In the Lower Copper Horizon, some local manganese concentrations are found.

A syngenetic origin has been postulated for both the copper minerals of the Upper Horizon and the local concentrations of manganese ore existing in the Lower Horizon. On the other hand copper minerals of the Lower Horizon have been considered of epigenetic origin resulting from the leaching and reprecipitation of the copper minerals of the Upper Horizon.

As a result of the Pilot Exploration Scheme which was conducted by (MD/NRA) in the area, a total of 35.7 million metric tons of copper in measured/indicated/ inferred classes, has been calculated to have an average grade of 1.36% copper. In addition there are 1.5 million metric tons of manganese ore in the same classes with an average grade of 29% manganese.

In the expected category of reserves there is estimated an additional 50 million tons of copper ore and 3 million tons of manganese ore in the same area.

All of this tonnage is related to the Lower Horizon.

In the Upper Horizon, copper mineralisation is rather patchy and erratic, and something like 3 million tons of Cu-ore of an average grade around 0.65% can be selectively mined from the different outcrops. This area is still undergoing investigations.

III. HISTORY OF MINERAL EXPLORATION IN WADI ARABA

The heaps of copper/manganese slag that are scattered around Finan, Khirbet el-Nahas, Sabra and Aseon Jaber, along with man-made land-marks identified with copper mining and smelting activity at Wadi Khalid Twin-Shaft, Um el-Amad and Abu Khusheibeh, give the observer the impression that, certainly, in ancient times, a substantial and prosperous copper industry existed in the Wadi Araba (cf. Key Map of Wadi Araba, Fig. 2).

The archeological studies which were conducted by N. Glueck (1940), B. Rottenberg (1962) and the Jordan's Department of Antiquities in 1968, revealed that the mining of copper in Wadi Araba existed during the Proto-Urban Age and lasted till the end of the Nabatean period.

During this century, Blake (1930) and Glueck (1940), made some reference to the occurrences of copper, manganese and iron minerals in Wadi Araba.

In 1952, Benson visited Wadi Dana area and reported that good prospects of copper and manganese do occur in this area.

In 1954, the Ministry of National Economy retained Mackay and Schnellmann (A British Consulting Firm) to conduct a technical and economic feasibility study to the manganese occurrences in Wadi Dana. They did some pitting and trenching across the strike of the Mn-deposit. On analysing the samples which were collected, Mackay and Schnellmann terminated the programme, due to the fact that the copper content in the Mn-ore was rather high exceeding 1.5% Cu, which they considered as an undesirable constituent in the Mn-ore, because, in their opinion, it would make metallurgical separation difficult.

In 1958, Mr. Weiss (A Junior German Geologist, who was retained by the late Mr. Amin Kawar), wrote a short report about Wadi Araba (not published) in which he made a reference to the copper minerals occurring in the Nubian sandstones of Abu Khusheibeh. Enclosed in his report, is a map which shows the locality of the Abu Khusheibeh ancient mine.

During the period from 1961 to 1965, the German Geological Mission to Jordan assisted by Jordanian counterpart geologists, conducted a regional geological mapping programme in Wadi Araba. They issued four reports dealing with the copper and manganese occurrences in the area with specific reference to Abu Khusheibeh and Wadi Dana (Bender 1963, Lillich 1964, and Van den Boom 1965).

On the recommendation of the German Geological Mission which stated that "The extent of Abu Khusheibeh copper deposit, its thickness, model content and possible cheap dressing cost, suggest the economic value of the ore", the Jordan Government in 1964 retained Otto-Gold (A German Consultant) to conduct a full-fledged feasibility study for the copper occurrences of Wadi Araba.

Prematurely and without sound justification, Otto-Gold ruled out all the other copper occurrences reported in the area and restricted his physical exploration efforts and major activity to Abu Khusheibeh. He then concluded the following:

"Altogether seven individual areas were found mineralised. They are widely distributed throughout the exploration area.

All seven occurrences are belonging to the same type of deposit, namely to the "arid copper concentration deposits" of H.Schneiderhöhn (Ref. 21) and the "red bed copper deposits" of W. Lindgren (Ref.15), respectively.

The copper is present in the sandstone mainly as the oxides malachite and cuprite, to a smaller extent also chrysocolla and atacamite(?) may participate.

No copper sulphides were recorded in the Cambrian sediments.

The tenor of mineralisation remains generally unchanged throughout the entire explored area.

The more important copper mineralisation is restricted to one and the same favourable sandstone horizon of unit cb_3. Copper showings in other units, such as the basal conglomerate cb_1 and the stratigraphic higher sandstone of unit cb_4, are bearing no significance.

Outside the Cambrian sediments copper was found in the Precambrian basement. There it occurs as copper-staining of malachite in different crystalline rocks at several widely scattered localities, and as lean sulphide dissemination of chalcocite in two separate outcrops of narrow diabase dykes.

"Both modes of occurrences are of no practical significance, however.

In general, copper mineralisation was found to be of very low grade and mostly assayed below 1%.

Values better than 1% Cu are rare and mostly confined to thin layers in patches of very limited lateral extent within the different mineralised areas.

Exception occur in prospecting field II - West where the average copper grade exceeds the overall average and reaches 1.05%. However, the tonnage involved in this field is rather small.

No zones of enrichment are indicated at greater depth from surface by drilling. Favourable hostrocks or contacts below mineralised areas were found completely barren.

Copper content in the main favourable horizon is irregular in the vertical direction as well as laterally. The same was observed to apply for the mineralised thickness.

Mineralised fields are delineated by major faults with considerable amounts of displacement and are further sub-divided by transversal faults which cause tilting and significant horizontal and vertical off-sets. None of these faults were observed to be mineralised. All "faults are younger than the copper mineralisation in Cambrian sediments, some of the major structures may have an early origin, however.

Detailed exploration in the general region of Wadi Abu Khusheibeh has proven in six different fields

8 million metric tons of probable reserves with a grade better than 0.50% Cu.

From this probable reserve, 2 million metric tons have a grade exceeding 0.75% Cu, and 800 000 metric tons have a grade better than 1% Cu.

The total metal content of the proven tonnage amounts to 51 100 tons of copper. The average copper grades of the different mineralised fields are the following:

II - West = 1.05%, V - North = 0.69%,
V - Middle = 0.70%, V - South = 0.56%,
VI - Middle = 0.70%, and VI - South = 0.70%.

In the above estimation of reserves only mineralised material with a grade better than 0.5% Cu over a minimum thickness of 0.5m was taken into account and no deduction for losses of any kind and dilution were considered. Moreover, no distinction was made between ore minable by open-cast methods or by underground methods.

On the basis of studies of phase C we know that copper grade and the available reserves are not sufficient to render the copper occurrences in the area of Wadi Abu Khusheibeh economically minable.

"For greater detail we should like to refer to the above mentioned studies of phase C which concern the feasibility of a mining operation under the local conditions.

Until the end of investigations in phase B we had hoped to find additional ore deposits such as discovered in field II - West with mineralised patches of ore exceeding 1.5% Cu, and more extensive areas of mineralisation like in block V - South which indicates a rather regular copper distribution but an unfortunate low grade of 0.56% Cu.

In the entire exploration area of Wadi Abu Khusheibeh only 800 000 tons of probable ore is available with a grade exceeding 1% Cu. This very small reserve is originating from many individual and widely scattered areas. The largest of these areas is located in prospecting field II - West. The mineralised field II - West measures 55.240 m^2 and its probable ore reserve amounts to about 148.000 tons. The average grade is 1.05% and the total copper content approx. 3000 tons, i.e. the equivalent of a six-months' production of a very small copper mine.

<u>On the basis of our estimation of reserves and the results of certain studies in phase C it must be concluded that the copper occurrences of Wadi Abu Khusheibeh are to be considered</u>

"insufficient in quantity and of a grade too low to be economically minable under the present conditions." (Otto-Gold 1964).

In 1965, the Mining Division of the Natural Resources Authority of Jordan, was established. In 1966 it launched an exploration campaign in the northern parts of Wadi Araba, with special attention being paid to copper and manganese. This campaign was interrupted by the 1967 June War. Later on, in 1972, work was resumed, but this time it was restricted to the Wadi Dana - Finan - Um el-Amad - Khirbet el-Nahas area, which in 1967 was being delineated as having the best known copper and manganese prospects in the northern parts of Wadi Araba.

After considering budget limitations, shortage of field equipment and due to the uncertainty as to the actual relationship of the copper to the manganese, the MD/NRA decided to divide its exploration programme into two phases. The first phase would be a pilot exploration scheme. If this gave a positive result, a wider scheme or second phase was to follow.

The report at hand now, although essentially an interim report, does sum up the results achieved by the above mentioned pilot exploration scheme which ended in May 1973. The pilot exploration scheme established very satisfactory and encouraging results. Therefore, steps to implement the wider scheme of the second phase are already put forward.

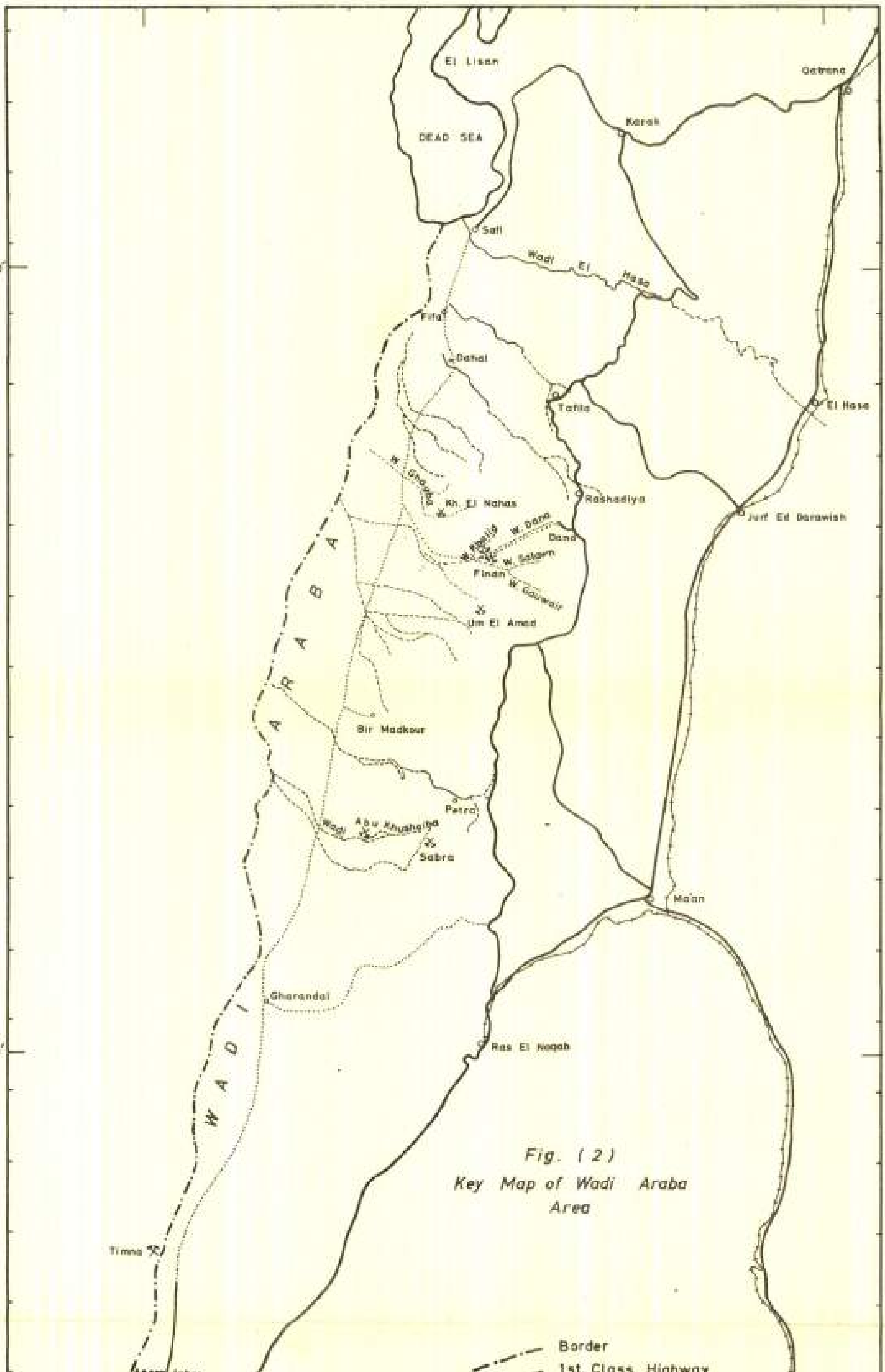


Fig. (2)
Key Map of Wadi Araba Area

IV. GENERAL DESCRIPTION OF THE SUBJECT AREA

The area delineated for its copper prospects (referred to here as the Area), which was partly subjected to the Pilot Exploration Scheme concluded by this Report, is situated at the eastern side of the Wadi Araba Rift Valley, approximately 45kms south-southeast of the southern end of the Dead Sea and 180kms south of the city of Amman (cf. Location Map Fig. 1). It has an areal extent of about 150 square kilometers and conforms the area enclosed between Dana village (east), Um el-Amad (south) and Khirbet el-Nahas - Wadi Ghauba (west-northwest), with Khirbet Finan almost situated at its centre (cf. enclosure No. 1, Geol. Map).

The Area is clearly marked by some major faults, i.e. Wadi Dana fault, Wadi Salawan fault and the Wadi el Hamar - Wadi Ghauba fault complex. These faults with the plateau to the east and Wadi Araba to the west, dissect the Area into four sub-areas, which are known locally as: Khirbet el-Nahas area (north-west), Finan-Ratya area (central), Salawan-Helaisya area (east), and Um el-Amad area (south).

These sub-areas are again sliced by another set of minor faults, branches off the major set. As a result of all these fault systems, the Area is characterised by rugged, high and steep mountains, traversed by deeply incised valleys, with their drainage lines mainly following the fault patterns. In the eastern part, the mountains are higher than 1000 meters above sea level; westwards, toward the Rift Valley, the general altitude decreases gradually to 300 meters at the top of the escarpment immediately overlooking Wadi Araba.

The Area is also marked by three Pre-Cambrian stocks; one stands in the middle of the Area east of Finan, the second towards Khirbet el-Nahas (north-west) and the third towards Um el-Amad (south).

The Area could be reached by a fourwheel drive vehicle from three directions; either from the east via Dana village to Finan, or from the north via Safi-Dahal-Ghuaba to Finan and from the south via Gharandal-Beer Madkour to Finan along Wadi Araba (cf. Fig. 2).

All these routes are not tarmacked, very rough and dusty. However, those that proceed towards Amman and Aqaba eventually connect with first class highways.

It is worth mentioning here that it is foreseen in the Three Years Development Plan of Jordan, both the northern and southern accesses which connect the Area with Safi and Aqaba, will be constructed and tarmacked before the end of 1975.

The Area in general is arid to semi-arid with an annual precipitation (variable according to the relief) between 20mm along the low part of the escarpment and 300mm on the top of the high plateau bordering the eastern side of the Area.

Springs and other water resources in the vicinity are quite adequate, the regular flow of Wadi Ghuwair-Finan stream is around 200 cubic meters per hour. There is also Ain el-Fidan spring, which has a regular yield of about 80 cubic meters per hour. There exist also some other springs towards Hamar-Fidan and Dana.

The weather conditions in the Area are fair and very pleasant during the winter, tending to be somewhat hot during the mid of summer with temperatures reaching about 40°C in July and August.

V. GEOLOGY

A. Regional Geology*

The subject Area is situated in the margin of a large graben zone and forms a portion of the Wadi Araba Rift Valley which extends between the southern end of the Dead Sea and the Gulf of Aqaba.

Along the eastern side of Wadi Araba graben, large stocks of Pre-Cambrian igneous rocks are exposed, which are considered a part of the Nubo-Arabian Shield and consist of intermediate and acid intrusives, such as quartz-diorite, granodiorite and aplite granite, accompanied by numerous dyke rocks which have intruded into the already consolidated abyssal rocks, (G. Van den Boom, et al, 1965).

Quennell (1951) and D.J. Burdon (1959), classified these Pre-Cambrian basement rocks into acid intrusives (the youngest), basic intrusives, red granites and granodiorite.

*For the purpose of this Report, the naming of the different rock units, their nomenclature & dating which were used by GGM/J will be applied here. For further details on the geology of the Area, reference can be made to Burdon(1959),Bender(1963), Lillich (1964) and Van den Boom (1965).

Portions of these Pre-Cambrian igneous basement complex are seen in three places within the vicinity of the subject Area, i.e. north-east of Finan, at Khirbet el-Nahas and west of Um el-Amad (See Geol.Map)

East of Finan, south-east of Wadi Dana, occurs also a unique igneous stock, which is covering an area of (6.5 x 0.5) sq.kms. It is fine grained and of dark grey to black colour, with green coloured spots up to 5 centimeters in diameter. It is very acid with much quartz and encloses some large blocks of pink granite in its body.

Blake (1939), described this stock as a porphyry dyke which is older than the dolerite dykes reported in the same area.

Van den Boom, et al (1965) described it according to its mineral content as porphyrite massive which contains phenocrysts of former mafics, seen as pseudo-morphs surrounded by a fine crystalline ground mass, consisting of tiny feldspar laths, quartz, iron oxides and diorites. He dated it as late Pre-Cambrian.

A net work of thin calcite veins with some barite and abundant manganese oxides, mainly psylomilane, are often seen in this porphyry stock (Nimry 1967). Traces of tin minerals are also recorded in it.

The enclosed geological map, Enclosure 1, gives a general account of the geology of the Area, where the basement complex is seen overlain unconformably by a thick sequence of multicoloured mainly terrestrial sandstones of various ages, which are combined somewhat loosely under the general term "Nubian Sandstone" However, there is a thick wedge of marine sediments near the base of this sandstone in which at least three distinct transgressions of the sea are recorded.

Near the village of Dana (north-east) and east of Um el-Amad area, where the plateau commences, the Nubian sandstone sequence, is overlain by a series of calcareous sediments of the Upper Cretaceous sometimes covered with a Pleistocene basalt flow.

Westwards toward Wadi Araba, terrestrial deposits, talus fans, gravel outwash plains and sand dunes predominate.

In the following pages, a brief description of the Nubian sandstone sequence will be given only due to the fact that most of the Area is covered by this sequence. Table (I) gives a summary of the different rock units, their nomenclature and average thickness.

A. 1. Stratigraphy

A type section of the rock sequence which has been described by Van den Boom (1965) is given in (Fig. 3) to set out the history of the stratigraphy and volcanism in the subject Area.

The terrestrial sandstones and the marine intercalations are tentatively divided into three major rock types. Beginning at the base, these are as follows:

1.(a) The Bedded Arkose Sandstone Unit of Lower-Cambrian Age, pinkish in colour, consisting of coarse to medium grained arkosic sandstone, cross bedded, fluviatile, varying

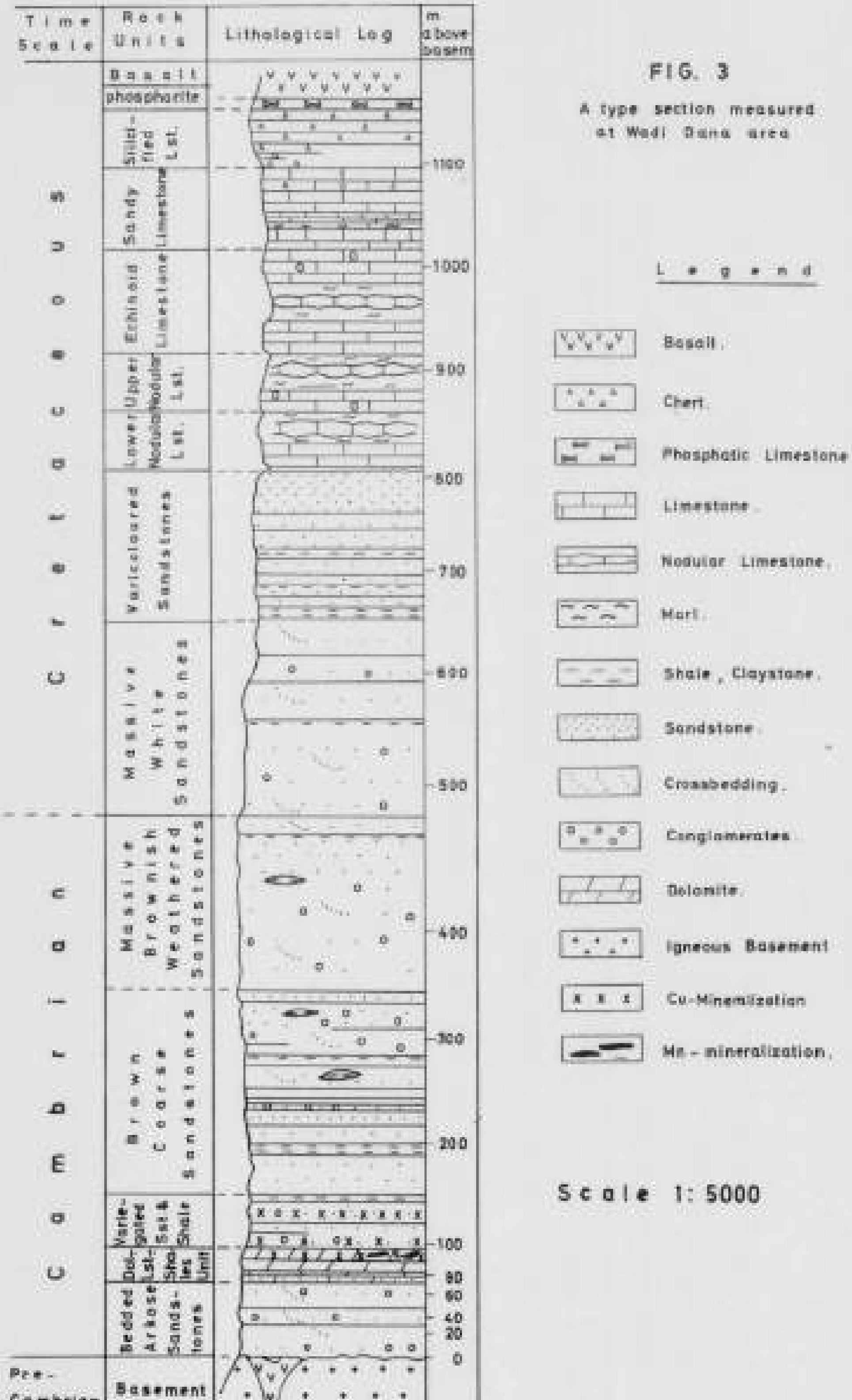


FIG. 3

A type section measured at Wadi Dana area

Scale 1: 5000

from 50-70 meters in thickness. It rests on the basement rock along a very irregular erosional surface, with silty shale intercalations rich in mica, Quartz pebbles are widespread in its body. In some places, it is underlain by basal conglomerates, which overlie the basement rock. However, these conglomerates are not well developed in the Area and the Bedded Arkose directly overlies the Pre-Cambrian basement.

1.(b) <u>The Dolomite-Limestone-Shale Unit</u>

This unit ranges from Lower to Middle Cambrian in Age. It reaches a maximum thickness of about 35 meters in the Area. The unit commences with conglomerates, succeeded by medium grained sandstones, blood-red shales and clay stones of deep brownish to violet colours intercalated with thin layers of micaceous claystone.

The next overlying or mid-section of the unit, is dark brownish to black-greenish, thick bedded sandy dolomites and impure limestone which alternate with thin bedded sandstones and shales.

The uppermost four meters section of the unit, mainly consists of claystone, shale and red siltstone, sometime intercalated with dolomites.

<u>This uppermost section is in fact the major mineral bearing horizon which will be referred to here as the Lower Horizon or sometimes as the Dolomite Horizon.</u> A detailed account of this section will be given later.

What is significant about this unit is that along the eastern side of Wadi Araba it thickens toward the north and wedges out towards the south. Farther to the south of Beer Madkour, which is 22 kms south of Finan, this unit is completely absent and all what can be seen in its place is a reddish to greenish siltstone 10 to 15 centimeters in thickness which overlies the Bedded Arkose and which in turn is directly overlain by what is called the Variegated Sandstone Unit.

This wedging and transition most probably indicates prominent changes in facies from littoral in the south, to fully marine in the north (Otto Gold,1964).

A schematic sketch which illustrates this postulated facies change, is given in (Fig. 4).

Though the unit is not fossiliferous in the subject Area, it was assigned by Blake (1939), on lithological grounds, as of Middle Cambrian Age. Its equivalent at Timna area (Jabal Menich) was similarly designated.

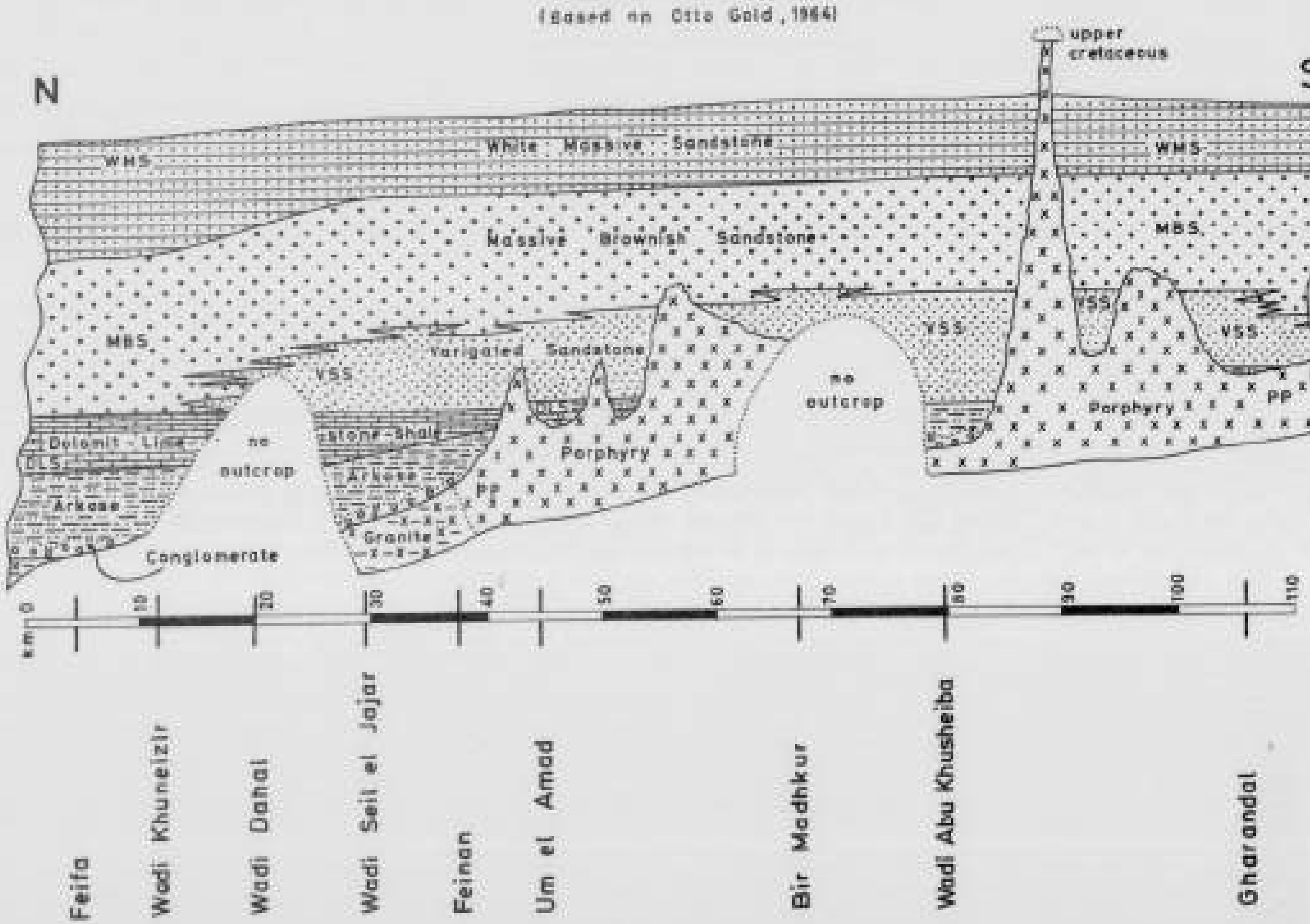
1.(c) <u>The Upper Nubian Sandstone Sequence</u>

The entire marine sequence in the Area is overlain by the main body of the Nubian

Fig -(4)

Distribution of Facies along the Eastern Rim of Wadi Araba

(Based on Otto Gold, 1964)



sandstones, several hundred meters thick. Like the Lower Nubian Sandstone (the Arkose), this is mainly terrestrial in origin and could be sub-divided lithologically into the following units:

i. <u>The Variegated Sandstone Unit</u>

It overlies the Dolomites and Shales mentioned in (1.(b)) and attains in the Area a maximum thickness of about 45 meters. Farther south towards Abu Khusheibeh it reaches a thickness of about 100 meters. It was dated by Lillich (1964) as of Uppermost-Lower to Middle Cambrian Age. According to Van den Boom et al (1965), it has been deposited mainly in a continental environment but has some local marine littoral expressions.

<u>Copper mineralisation usually occurs in the upper portion of this unit, approximately 40 meters above the top of the Dolomite Limestone Shale Unit.</u>

Sometimes mineralisation is also seen in the lower portion of the unit near its lower contact with the Dolomite Horizon.

The copper ore appears mainly difused in a matrix of a coarse to very coarse sandstone. The lower portion of the unit is highly jointed and fractured. Usually the joints and fractures are filled with material from the underlying unit, mainly clay material. Whenever manganese is available in the underlying horizon, the joints and fractures are filled with manganese and clay.

The copper occurrences in this unit, shall be referred to later as the Upper Horizon, which will be dealt with in more detail in the following chapter.

ii. The Massive Brownish Sandstone

For the purposes of the geological map, Enclosure 1, which is accompanied with this Report, the Massive Brownish Sandstones were treated as one mapable unit. Effectively they are two different units and both are of Middle to Upper Cambrian Age.

The lower unit, which is known as the Brown Coarse Sandstone Unit has a maximum thickness of about 180 meters in the Area. Its lower portion consists of light grey and white, fine to medium grained, sandstone, intercalated with fine grained, reddish to violet sand layers. Its upper portion is rather massive, locally cross bedded, brown to light grey in colour and intercalated with shale layers.

The upper unit, which is known as

the Brownish Weathered Sandstone Unit which has a thickness of about 150 meters, is restricted in the Area to the parts west of Dana village, north of Salawan-Helaysia area and east of Um el-Amad area. It consists mainly of dark reddish and brownish sandstones with some local violet and yellowish colouration. These sandstones are partly cemented and friable.

iii. The White Massive Sandstone Unit

Of Upper Jurassic to Lower Cretaceous Age. It attains a thickness of about 180 meters in the Area. It consists of white coarse to medium-grained sandstones which contain gravel layers and lenses as well as quartz pebbles up to several centimeters in size. These sandstones are generally massive, sometimes crossbedded and weathered in typical conical and rounded shapes.

iv. <u>The Varicoloured Sandstone Unit</u>

Of Lower Cretaceous Age with a thickness of about 150 meters. In the upper portion there are alternating coarse and fine grained sandstone layers. The middle section is medium to coarse grained thin bedded sandstone. In the lower part, the sand is fine to medium-grained and thin bedded with shale intercalations. It is varicoloured, sometimes deep brownish or white grey with occasional local expressions that are violet or yellowish. It is somewhat friable and not very well cemented.

Table (I)

A Summary of the Mapable Rock Units in the Subject Area

Rock Type or Unit Name	Symbol	Measured Thickness M.	Dating By GGM/J	Colouring on the 1/25,000 Geol. Map	Remarks
Aplite Granite	Gr		Pre-Cambrian	Deep red	Intrusive
Porphyrite	PP		Pre-Cambrian	Green	Intrusive
Quartz Porphyry	QP		Pre-Cambrian	Light red	Intrusive
Bedded Arkose	BAS	50-70	Lower Cambrian	Brown	Terrestrial
Dolomite-Lime-Stone Shale	DLS	35	Uppermost Lower to Middle Cambrian	Blue	Marine
Variegated Sand-stone	VSS	45	do	Yellow	Terrestrial
Massive Brown Sandstone	MBS	330	Middle to Upper Cambrian	Orange	Terrestrial
Massive White Sandstone	MWS	180	Upper Jurassic	Grey	Terrestrial
Varicoloured Sandstone	VAS	150	Lower Cretaceous	Pink	Terrestrial

A. 2. Structure and Tectonics

The subject Area is situated just east of the Wadi Araba Rift Valley (striking N 10°E) and therefore has been strongly affected by the graben tectonism, which may have commenced as early as the Jurassic (Burdon 1959). It is cut in the middle by the major Wadi Dana fault (E.207, N. 010), which is dissected by other faults striking approximately 90°- 140°. Beside Wadi Dana fault and its associates, the Area is also characterised by Salawan fault (85°) and the Wadi el Hamar-Wadi Ghauba fault complex. Beside these major faults, the Area in general has a large number of faults of lesser magnitude which can be grouped into two sets: one set is striking parallel to Wadi Dana major fault, the second set generally strikes 45° west-northwest. On the whole, these fault systems mark the Area with a series of faulted blocks mainly downstepping towards Wadi Araba with variable dips ranging between 4° and 30° mainly N.N W.

Wadi Dana and Salawan faults are believed to be thrust faults accompanied by a strike slip displacement.

The other faults appear to be tension faults. Both fault systems and the associated structures are Cretaceous to Recent (Quennell 1951).

The folding of strata in the Area is rather negligible.

The copper and the manganese ores in the Area appear not to be genetically related to any fault system. All faults are postmineralisation.

Some minor gashes and tension fractures, filled with copper, or copper-manganese ore are observed in the Lower Horizon. Investigations suggest that they are basically postmineralisation and the ore was introduced to them at a later stage as a result of percolating mineral solutions.

There is some evidence that the processes related to manganese mineralisation were controlled by shallow basin-like structures, which were later affected by a high degree of distortion (Nimry 1967). This also disturbed the lower member of the overlying Variegated

Sandstone Horizon as evidenced by fractures and joints soaked with clays and minerals from the Lower Horizon.

Pre-Cambrian tectonics in the Area were mentioned by Quennell (1951, 1956a). He considered the existence of the granites and the granodiorites of the basement complex, as well as the remnants of metamorphism near Aqaba, as an evidence of Pre-Cambrian folding and orogeny with granite formation and emplacement. However, the internal structures and relationships of these rocks have not yet been studied. The dominant manifestation of Pre-Cambrian tectonics are the dykes and joints found in the rocks of the basement complex.

B. Geology of the Ore Bearing Horizons and Patterns of Mineralisation

Mineralisation in the Area is limited to two rock units i.e. The Variegated Sandstone Unit (the Upper Horizon) and the Uppermost section of the Dolomite Limestone Shale Unit (the Lower Horizon).

In the Upper Horizon, copper minerals are seen mainly in the upper section of the unit and the bottom section which is directly overlying the Lower Horizon. The middle section of the unit is a barren zone, contains nearly no copper; it is friable with colours varying from white to light pink.

The upper section, where mineralisation varies in thickness between 1m and 3m, is made up of medium grained sandstones ranging in colour from light brown and grey to nearly white. Green shades identify copper mineralisation whenever present. It is rather laminated with true bedding and cross bedding alternations. Its upper contact with the overlying rock is marked by red or deep brown layer of siltstone which have a variable thickness ranging between 25cms and 3 meters.

The lower section, where mineralisation varies in thickness between 1/2 meter and 4 meters, is made up of medium to very coarse well cemented sandstones of deep brown and sometime black or grey to white colours. It is highly jointed and fractured. Usually the joints and fractures are filled with material from the underlying horizon. Whenever copper minerals are present, it has a very distinguished green or deep blue colours.

Black specks of manganese oxides are often observed in the unit. Whenever the lower section is underlain by a manganese concentration zone, manganese staining and fillings dominate.

The unit is also characterised by reddish porphyry fragments which serve as markers (Otto-Gold 1964).

Copper mineralisation in this unit is rather patchy and not persistent. It occurs in the form of diffusions, sporadic nodules and veinlets, 1 to 3mm in diameter, and sometimes as flat lenses 5 to 15cms in length, usually their colour is dark green to black with a brownish-red halo and greenish shaded rim with copper constituents mainly malachite and cuprite without any sulphides (Otto-Gold 1964). The brownish-red halo is caused by a relatively high iron content, mainly limonite.

The copper ore lenses frequently assume a seam-like appearance and can be traced intermittently for several meters. Locally, this mode of occurrence is particularly common in the Salawan area. In any case, it has no present known economic significance.

In the horizon of the Dolomite Limestone Shale Unit, i.e. the Lower Horizon, mineralisation is confined to the uppermost four meters section of the unit. This mineralised section consists mainly of blood-red silty clay at the top which is of a thickness ranging between 1/2 meter and 2 meters, underlain by yellowish to grey dolomite of a thickness varying from few centimeters to 60 centimeters; sometimes completely absent. The dolomite section is underlain by a black-brown or green shale, intercalated with thin bands of dolomite and sandy shale. The shaly section, which forms the bottom member of the Horizon, ranges in thickness between 1/2 meter and 3 meters.

The thickness of the dolomite facies in the Horizon is increasing towards the extreme northwesterly part of the Area. In Khirbet el-Nahas area, the dolomite section sometimes reaches a thickness of 1 meter.

In this Lower Horizon, where straight copper ore is present along with local concentrations of copper-manganese ore, the copper mineralisation, as such, is more or less persistant laterally without serious variations.

Across the width of the Horizon, the copper dispersion pattern starts at the top with almost a uniform grade which increases toward the middle section and decreases gradually downwards from there until it becomes very lean near the bottom of the section. It fades gradually beyond that.

The distribution of the manganese minerals in the Horizon is not as persistant as copper. It is mainly confined to the clay section. Sometimes when present it extends down to the underlying dolomite section.

As a general case, there is always a background value of manganese available in the clay and dolomite sections of the Horizon, which ranges between 0.5% and 5%. Manganese ore, which is of economic value, is only present in the form of lenticular ore bodies widely spaced over the area which look like scattered islands of concreationary manganese ore bodies superimposed in an erratic manner on the copper horizon (the same case is reported at Timna). These lagoonal orebodies extend laterally to several hundred meters and attain a central thickness of about 2.5 meters. Near the borders of these orebodies, the manganese concretions get smaller and more sporadic in occurrence till it is completely absent and new facies of manganese varves alternating with red-claystone become dominant. It then gradually disappears and only traces of manganese are evident. It seems that the lateral pattern of the copper content in the Horizon is not affected by the abundancy of manganese, although when manganese orebodies are existing it was noticed that the vertical distribution of copper is directly proportional to the manganese content (Fig. 5). This phenomena was related by Nimry (1967) to the scavenging property of the hydrous colloids of Mn-oxides and their afinity to adsorp foreign cations.

Fig(5-a)

Graphical Representation of the Cu. and Mn. cotents in the samples collected from Bore-hole N°. 2 at Dabbah Area

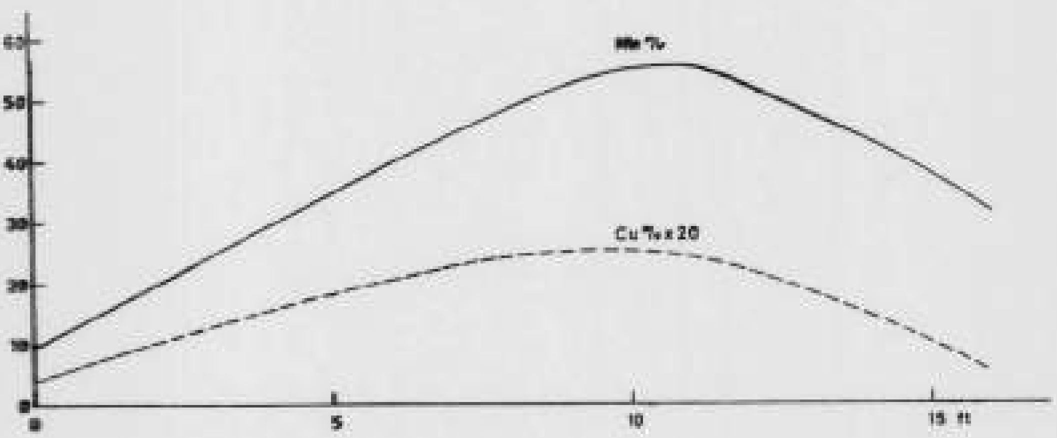
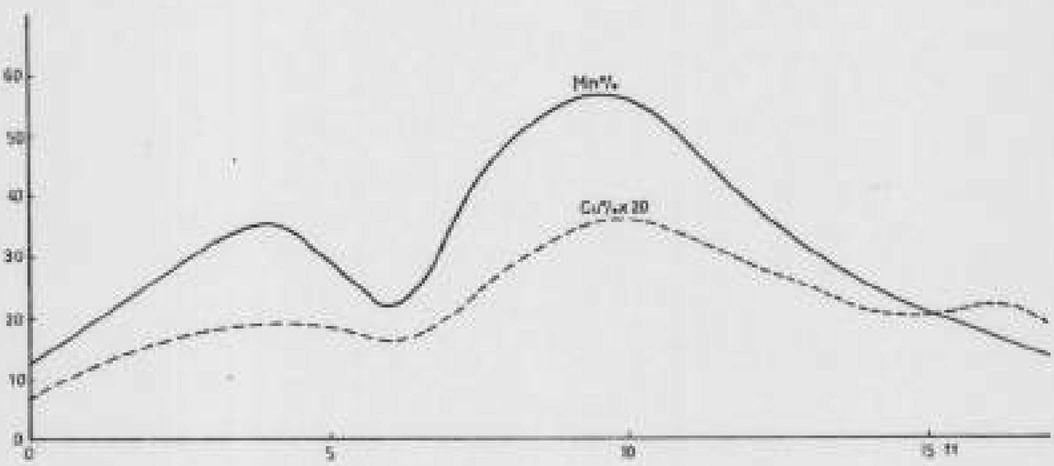


Fig (5-b)

Graphical Representation of the Cu. and Mn. cotents in the samples collected from Bore-hole N°. 3 at Dabbah Area



VI. MINERALOGY & CHEMISTRY OF THE ORE DEPOSITS

In the Upper Horizon the predominant rock-forming mineral is quartz. Minor constituents are microcline, kaolinite, calcite and sericite. Copper oxide in the form of malachite is the most dominant copper mineral. Cuprite is also present.

The malachite is usually found occupying the interstices between quartz grains and fragments of other rock-forming minerals. Frequently it is found filling the fissures and fractures intersecting the rock.

In both cases malachite seems to replace the sandstone ground-mass in as much as it spreads out from interstices and openings in the rock (Otto-Gold 1964).

The cuprite occurs partly in pure form and also as a mixture of cuprite and limonite. Sometimes the cuprite is altered to malachite.

The carbonate required for this alteration process may partly originate from the ground-mass of the rock, or from percolating weak solutions (Otto-Gold 1964).

Often, malachite can be seen in fissures and fractures dissecting cuprite. The alterations of cuprite to malachite indicates that malachite is younger than the cuprite.

Copper minerals also exist in the same Horizon as tiny nodules, specks or small lenses which are mainly of malachite surrounded by bleached halos and occasionally have a core of cuprite or copper sulphides. In most cases the bleached halos have an inner zone of limonite.

Porphyry fragments are quite common in this Horizon and there is a distinct relationship between the copper minerals and these fragments. In many cases the malachite appears associated with the porphyry fragments.

According to Lillich (1963) "investigations as to the minerals representing the mineralisation proved the following copper minerals enumerated according to their decreasing abundance.

Malachite, cuprite, chalcosite, bornite and chalcopyrite. Chalcopyrite, bornite and chalcosite, occur only to a minor degree and are found in the inner part of larger nodules".

A representative groove sample which was collected from one of the mineralised sections of the Variegated Sandstone Unit gave, on analysis, the following results:

Element	Content %	Element	Content ppm
Cu	0.53	Ag	5
Fe	0.03	Au	10
Al_2O_3	3.64	Pb	100
TiO_2	0.06	Zn	-
MnO	0.005		
CaO	0.48		
SiO_2	91.04		

In the Lower Horizon, the predominant rock forming minerals can be grouped into the silicate-aluminium group and the calcite-dolomite group. Quartz, kaolinite, calcite (limestone) and dolomite are dominant. Feldspar, montmorillonite and baryte are present in negligible amounts.

Iron oxides in the form of hematite, geothite and limonite are quite abundant and it may average around 6% by weight of the total rock.

Lithologically, the Lower Horizon can be subdivided into three members, i.e. the claystone-silt member at the top, the dolomitic-limestone member in the middle and the shale-limestone member at the bottom. The dolomite member is not always distinct and sometimes facies of claystone or dolomitic-shale are seen in its place.

Oxides of manganese, which are mainly confined to the claystone member, occur in various forms, such as concretionary, massive, crystalline, granular, botryoidal and sometimes with fibrous and radiate structure in addition to the usual amorphous forms.

An X-Ray test, which was carried out in the laboratories of the Geology Department (Leicester University) on five samples of the Mn-ore representing the disseminated type as well as the concretionary type, showed that pyrolusite is the most dominant mineral. Psilomilane and cryptomilane are also present but not in significant amounts. Wad is also abundant. It occurs massive either earthy or compact. In X-Ray diffraction tests, it gave some peaks indicating the presence of pyrolusite

A composite sample collected from each of the prospecting tunnels numbered D_2, D_3, D_4 and D_5 which penetrate in a Mn-zone, gave, on analysis, the following reqults:

	D_2 %	D_3 %	D_4 %	D_5 %
Moisture	0.63	0.51	0.64	0.61
Loss on Ignition	8.33	9.16	6.54	9.51
SiO_2	21.7	16.7	12.71	18.45
Fe_2O_3	5.6	13.83	11.99	22.11
Al_2O_3	8.25	4.75	4.92	6.91
P_2O_5	0.90	0.29	0.24	0.29
TiO_2	0.29	0.31	0.32	0.39
CaO	3.05	1.80	1.24	2.14
MgO	0.48	0.27	0.54	0.44
MnO	45.79	48.90	56.72	36.13
CuO	2.09	1.78	1.99	1.77
Na_2O	0.33	0.36	0.27	0.31
K_2O	2.29	0.94	1.64	0.82
SO_3	Trace	Trace	Trace	Trace
Total	99.73	99.88	99.76	99.88
MnO_2	56.08	59.93	69.52	44.28

Malachite and chrysocolla are the most abundant copper minerals in the Lower Horizon. Malachite occurs either disseminated or as replacements and fillings in the rock-mass. Whenever manganese ore is present, it is usually soaked or invaded by malachite. The malachite as such is seen either in its soft earthy form with pale green colours or locally hard botryoidal with light green to very dark green colours.

Chrysocolla is mainly found in the amorphous or earthy form or sometimes as incrustations or stains along the fracture plains of the shale member. Due to the fact that up to 8% of the copper minerals in the rock are not soluble in acid, it is believed that they may be associated with diaptase in the ore.

Other suspected copper minerals which mainly occur aggregated with malachite either along fissures and cracks or as pockets, staining, or disseminated, are atacamite, plancheite, shattuckite and bisbecite. In one sample of copper-manganese ore, the presence of copper sulphide was also suspected. In one locality near Fifa, a thin vein of primary copper-lead sulphide was seen dissecting the Dolomite-Limestone Shale Unit. It is believed that such vein came to existence at a later stage as a result of a local hydrothermal activity, and have no relation whatsoever with the secondary copper mineralisation treated in this Report.

Table (II) gives a type analyses of seven samples which have been collected from two different grooves, one across the width of tunnel (D 53) and the second groove across the width of tunnel (D 54). The lithological set-up and mineralisation in these two tunnels were considered representative of most of the conditions prevailing in the Area.

Accordingly, these samples were studied with the view of providing a general idea concerning the major constituents of the rock forming minerals of the Horizon in addition to providing information on the chemical and physical characteristics of the constituents which would be of prime interest to the metallurgist.

Table (II)

A Type Analysis of the Mineral-Bearing Rock

	Sample RG1/53 %	Sample RG2/53 %	Sample RG3/53 %	Sample RG1/54 %	Sample RG2/54 %	Sample RG3/54 %	Sample RG4/54 %
Loss on Ignition	6.47	4.71	13.11	7.95	6.98	4.58	4.13
SiO_2	49.44	60.74	53.81	54.63	58.77	62.48	62.04
Al_2O_3	18.50	19.80	12.54	22.36	22.40	19.42	21.31
Fe_2O_3	12.18	3.45	1.31	12.10	5.95	3.96	5.82
Na_2O	0.21	0.25	0.49	0.52	0.75	0.64	0.58
K_2O	0.14	0.45	0.39	0.10	0.23	0.49	0.62
CaO	0.36	0.75	8.08	0.03	0.07	0.05	0.33
MgO	1.62	2.39	5.48	0.43	1.75	2.36	2.97
CuO	1.65	2.63	2.53	0.36	0.76	2.63	0.93
MnO_2	7.91	3.60	1.58	0.29	0.82	1.86	0.38
PbO	0.58	0.24	0.02	0.27	0.29	0.36	0.05

Table (II) (Cont'd)

	RG1/53 %	RG2/53 %	RG3/53 %	RG1/54 %	RG2/54 %	RG3/54 %	RG4/54 %
P_2O_5	-	0.57	0.08	-	-	0.11	-
BaO	-	0.16	0.18	-	-	0.14	-
Ni	-	0.007	0.01	-	-	0.01	-
CO	-	0.004	0.004	-	-	0.005	-
Sr	-	0.004	0.009	-	-	0.001	-
Zn	-	0.03	0.01	-	-	0.02	-
SO_3	-	0.08	0.40	-	-	0.08	-
Total	99.06	99.87	100.04	99.04	99.07	99.20	99.16
Specific Gravity	2.80	2.60	2.60	2.70	2.60	2.60	2.61

VII. ORIGIN AND GENESIS OF MINERALISATION

In this chapter, the origin and genesis of both copper and manganese will be treated separately starting with manganese.

A. Possible Origin and Genesis of the Manganese Ore

The world's manganese deposits can be generally grouped into five major categories (C.F.Park,Jr.(1956)), as follows:

i. Hydrothermal deposits.

ii. Sedimentary deposits.

iii. Deposits composed mainly of low temperature silicates and hausmannite and associated with submarine flows.

iv. Metamorphic deposits, and

v. Residual accummulations and laterites.

Accordingly, the problem of the origin and genesis of the manganese occurrences under consideration may be divided into the following three component problems:

(a) In which of the above mentioned categories should these occurrences be placed?

(b) What is the source of these occurrences?

(c) What was the mineralisation process?

Several people have raised almost the same type of questions for the origin and genesis of the manganese deposits of both Timna and Wadi Dana. Their conclusions could be summarised as follows:

<u>Timna Ore</u>	
Sturm (1953)	: Syngenetic
Bentor (1956)	: Syngenetic
<u>Wadi Dana Ore</u>	
Blake & Ionides (1939)	: Syngenetic
Benson (1952)	: Epigenetic
Mackay & Schnellman(1954)	: Epigenetic
McKelvey (1959)	: Hydrothermal
Demag (1960)	: Hydrothermal
Boom et al (1965)	: Syngenetic
Nimry (1967)	: Syngenetic

From a negative point of view, the ore could not be hydrothermal because of the following reasons:

(a) There has been no magmatic activity in the vicinity since late Pre-Cambrian, except for some reported occurrences of porphyry which cut the Lower Pre-Cambrian, 60 kilometers to the south of Finan.

(b) If the deposits are hydrothermal and of the replacement type, such replacement would be expected to take place against an impermeable barrier; in other words at the lower part of the Dolomite Lime-Stone Shale Unit, but not at its top, just below its contact with the Variegated Sandstone Unit which is a very permeable rock.

Some people might consider the deposits resulting from a cavity-filling process and not replacement type deposits. However, any cavity of the size of any of the ore lenses seen at Wadi Dana would have been structurally unstable. Also, there are no signs of pre-mineralisation fracturing in the bearing horizon and the ore, as such, is interbedded with highly plastic clays.

(c) The relation between Wadi Dana deposits and those reported at Timna, which are 110 kilometers apart, is very well demonstrated by lithology, mineralogy, chemistry and mode of occurrence. In our opinion, both are of the same origin, and such a great lateral spread would be expected to be beyond the scope of any hydrothermal source.

(d) The complete absence of thermal alterations of any kind in the bearing rock, even on a micro scale, is also evidence against the deposits being of hydrothermal origin.

A metamorphic origin is also excluded, due to the fact that there are no signs of any regional or contact metamorphism present in the Area.

As there is no evidence of any submarine flows or submarine volcanic activity in the Area or the surrounding vicinity during the Cambrian period, mineralisation derived from submarine hot springs would appear most unlikely.

A residual or lateritic origin is also not possible, due to the fact that an oxidation process acting on dolomite to yield a manganese deposit equivalent to the deposits of Wadi Dana, would need as a starter an unrealistic amount of suitable rock. There is no visible evidence to justify such process(es) as having taken place in the Area.

A sedimentary (syngenetic) origin of the manganese occurrences in the Area, is clearly attested by its form and its confinement to one rather narrow stratigraphic horizon.

As already recognised by Sturm (1953), Bentor (1956), Boom et al (1965) and Nimry (1967), the evidence of a syngenetic origin of Wadi Dana and Timna Mn-deposits is based on the following considerations:

(1) The syngenetic origin of the bedded manganese is attested by the original varve-like structure of the rock with its alternating manganese-bearing and manganese-free layers.

(2) Some of the concretions or their broken

and distorted pieces, are seen to be caught in the fractured and brecciated zone of the immediate overlying sandstone beds. On the other hand, some blocks and fragments of the overlying sandstones, occur in the manganese body enclosed in the ore, without being impregnated, although they are much porous than either the claystone or the dolomitic-shale of the horizon.

(3) The proof of a syngenetic origin of the manganese concretions is also afforded by the fact that elliptical concretions embedded in the claystone, have their long axis vertical or nearly so. They show definite gradational arrangements, the larger concretions being seen in the lower part of the mineralised section, with the rock surrounding the concretions showing a fabric of flow structure.

All of these features are best explained through the assumption of gravity settling of the manganese concretions, while the embedding rock was still wet and plastic, before it became indurated (Bentor 1956).

The conclusion is that the manganese occurrences of Wadi Dana are of syngenetic origin. This judgement does not exclude the possibility that a migration and diagenetic process has taken place after the early deposition of the ore.

The veins of manganese which have been recorded in the porphyry dyke of Finan area (Nimry 1967), the veins of manganese accompanied with baryte which are oftenly seen associated with the basaltic dyke rocks existing in Wadi Araba (Bentor 1956 and Bender 1963) and the high background value of manganese recorded in the magnetic basement complex of southern Jordan; all of these together, may explain the original source which fed the Lower Horizon with its manganese ore.

The mineralisation process, most probably followed the weathering and denudation of the manganese-bearing basement rocks and the associated dykes. With the aid of water-flushes, streams and other possible natural means of transportation, the weathered manganese was carried to its present localities which apparently were defined by shallow water basins or lagoons.

B. Possible Origin and Genesis of the Copper Minerals

Starting with the genetical problem of the copper minerals in the Upper Horizon of the Variegated Sandstone Unit, the following modes of occurrences and observations can be noted:

i. Mineralisation is seen either as disseminations of copper bearing nodules associated with porphyry fragments, or

ii. As thin lenses of high grade copper ore, and,

iii. Streaks of comparatively high grade ore combined with fine disseminations or specks of copper ore minerals and nodules of 1-5mm in diameter.

Examination of such occurrences in outcrops, core samples and under the microscope, jointly with chemical testing has shown that the copper bearing nodules and lenses are composed mainly of blackish cuprite ore surrounded with malachite. Sometimes the nodules are entirely composed of malachite.

According to Otto-Gold (1964), "the presence of cuprite may be indicative of the original presence of the primary copper mineral, chalcocite ?".

The density of the nodules seems to have affected the degree of diffused mineralisation. The same thing can also be noted in the case of porphyry fragments. There is an obvious relationship between the density of such fragments and the grade and degree of mineralisation, which in fact points back to the origin of the copper.

"Under the microscope a distinct relationship was noticed between the copper minerals and porphyry fragments. Porphyry fragments occur in all transitions, from finely dispersed detritus to coarse-clastic clusters of fragments. The malachite appears in many cases closely associated with the fragments. It also occurs within the porphyry fragments as fillings of vesicles and vugs (replacement of feldspar ?) and of fissures and cracks.

Another unique occurrence are sphaeroidal malachite rings up to several centimeters in diameter with a sandstone core. Malachite often fills fissures and cracks in sandstone or occurs as coating along joints. Leaching effects and bleaching are usually associated with it. Sometimes, not a trace of copper remains in the leached sandstone.

These observations point to a later migration of copper in the rock which probably is still taking place in our times. Such migration may occur in the micro range as well as on a large scale. It is likely caused by manifold changes in regional elevation and seasonal fluctuation of water tables and/or by effects of the normal seepage or percolation of meteoric waters in a desert environment.

In the field; one gains the impression that a great number of different types of mineralisation exist. However, by examining the drill cores, it soon becomes evident that the variety is rather limited to a few typical modes which show transition" (Otto-Gold 1964).

Macro-Scale observations have shown that mineralisation is displaced by faulting; thin stringers of malachite within the matrix of the rock itself are seen to be displaced. In two places at Wadi Dana, joints which intersect the Variegated Sandstone Unit and extend through the overlying unit and terminating at the upper contact of the underlying unit, were observed to be filled with malachite but only where they occur below the upper contact of the mineralised horizon. This happened most probably as a result of solutions that formerly drained into such joints from the surrounding rock.

Such observations and remarks, with the absence of any sign or relation between mineralisation in the Upper Horizon and a hydrothermal source at depth, lead to the conclusion that the copper minerals in the Variegated Sandstone Unit, originally existed in the Pre-Cambrian basement in the form of sulphides. Later, upon exposure, weathering and fluvial transportation, they were brought to their present horizon concommitantly with the other rock forming minerals which constitutes the Variegated Sandstone Unit. Such transported copper minerals were again subjected in their new locality to a leaching and diagenetic process.

Therefore, it can be concluded that copper mineralisation in the Upper Horizon is of sedimentary syngenetic origin subjected to a diagenetic process.

The remnants of copper sulphides and copper stockworks which can be observed in some parts of the basements at Wadi Dana area, Abu Khusheibeh and near Aqaba, are in fact indicative of the validity of such conclusion.

According to Otto-Gold 1964 "the deposit in Abu Khusheibeh is an arid copper-concentration deposit of the Red Bed Type".

Lillich (1963) says that "the type of mineralisation in the copper bearing white fine sandstones point to a synsedimentary origin as indicated by the following observations:

"(a) Traces of copper ore mineralisation are exposed in a large, elongated area between the region of Gharandal and the south end of the Dead Sea. They are restricted to a certain horizon in sediments of Uppermost Lower to Middle Cambrian Age.

(b) In a limited area around Wadi Abu Khusheibeh, the main mineralisation is even present in the copper bearing white fine sandstones, confined to the lower third of the unit.

(c) The copper bearing white fine sandstones have been deposited in a marine environment and thus differ from the continental sandstone that lies above and below.

(d) Ore nodules in the mineralisation zone are aligned along the crossbedding and bedding planes. Diffuse mineralisation emphasises the bedding and crossbedding by a changing intensity of the green colouring. The copper seams in the copper seam zone are limited to a well defined horizon and can be traced for some 100m.

" The close relation between bedding and mineralisation may indicate that copper was deposited simultaneously with the quartz grains. On the other hand, this fact may be due to a change of the matrix-grain ratio, as a higher percentage of matrix makes possible an enrichment of ore.

(e) The mineralisation in cracks and fissures does not extend laterally into the enclosing rock faces. No influence on the degree of mineralisation in the sandstone beds has been observed.

(f) The copper mineralised horizons are displaced by faults. Thus, the mineralisation could only have taken place before tectonic movement."

According to Bentor (1956), "the copper in the Lower Horizon of the upper-member of the Dolomite Limestone Shale Unit, is of sedimentary origin and it is closely connected with the manganese existing in the same horizon. Both were brought by rivers into the Silurian(?) lagoonal sea and there deposited together with sandstones and shales".

However, Van den Boom, et al (1965), say that "the copper mineralisation in the upper portion of the Dolomites and in the manganese ore, is of epigenetic origin. The copper of the overlying sandstone has been transported by descending solutions to the carbonatic sediments where the metal content was precipitated". He also concluded that, "the highest manganese content occurs in the upper portion of the orebodies, while copper is highest in the lower part".

The possibility that some of the copper existing in the Lower Horizon associated with the manganese was brought by rivers, is not excluded, although there is no clear evidence to prove this except the presence of the copper sulphide traces which have been detected in one polished section belonging to the copper-manganese ore in Wadi Dana.

Inspite of what Van den Boom says, we believe that whenever manganese is present in the horizon, the copper content is directly proportional to the manganese content (Fig. 5). This conclusion is in harmony with the fact that clay minerals, organic material and colloids of hydrous iron and manganese oxides are the material primarily responsible for the adsorption of cations (Hawkes and Webb 1965).

The following observations can also be pointed out:

i. The downward movement of copper solution from the Upper Horizon towards the Lower Horizon is attested by the presence of mineralised joints and fractures reaching from the Upper to the Lower Horizons.

ii. In some place at Wadi Dana, thin lenses of manganese ore 20-30m long, have been recorded in the middle member of the Dolomite Limestone Shale Unit, 15 meters below the major manganese horizon. Such lenses have shown on analysis that either they are free from copper or their copper content is negligible and cannot be matched with the copper content in the major manganese horizon, though it is believed that both are from the same origin and were brought to their horizons in different stages. If the copper of the Lower Horizon was also from the same origin as stated by Bentor, then the manganese of the different levels should be of the same copper content, which is not the case.

iii. In places, where the fluctuations of the old water table levels are demonstrated, we see that copper diffusions marks the level of the water table in the lower member of the Variegated Sandstone Unit and grades down towards the Lower Copper Horizon.

iv. Geochemical observations show that the copper content of the Dolomite Horizon grades from high values at its top part to low values downward.

vi. Analysis of drill cores from the down-faulted blocks of the Variegated Sandstone show that they contain only traces of copper except near their contact with the Dolomite Horizon. Bleaching effect in such cores is quite obvious. On the other hand, whenever copper mineralisation is low in the Variegated Sandstone, it is relatively high in the Dolomite Horizon and vice versa.

These observations with the absence of any direct relation between copper mineralisation and any hydrothermal activity in the Area, point to the conclusion that mineralisation in the Lower Horizon is of epigenetic origin which resulted from the leaching and redeposition of copper which formerly existed in the Upper Horizon. As concluded by Van den Boom, the copper of the Variegated Sandstone Unit has been transported by descending solutions to the Lower Horizon, where it replaced carbonates and other rock forming minerals, or produced inter-growths along fissures, cracks and cavities. Occasionally, where manganese was present in the clay section of the Horizon, the copper cations were adsorbed by manganese .

The prevalence of copper mineralisation in the Lower Horizon independant from the manganese concentrations, is, in fact, against the idea of Bentor, that the copper in this Horizon is sedimentary and of the same origin as the manganese.

The vast lateral spread of copper in Wadi Araba in general and the obvious relationship between the Timna copper deposit and the copper ore in the subject Area, is a proof against any relation which might be postulated between such deposit and mineralisers from depth. Such widespread mineralisation seems to be beyond the capacity of any direct hydrothermal source.

VIII. ACTIVITIES CONCLUDED IN THIS REPORT

A. Field Activities, Procedures & Accomplishments

The subject Area was delineated as a result of the reconnaissance survey which was initiated in 1966 by MD/NRA and interrupted by the 1967 June War. Before this interruption, some physical exploration activities had commenced, using core drilling, prospect tunnelling, pitting and trenching, with special stress made on the manganese occurrences in the top of the Dolomite-Limestone Shale Unit.

The general impression at that stage was that copper occurring in the Dolomite Limestone Shale Unit of the Area, would only be found associated with the manganese ore, thus it was to be regarded as an impurity.

With this impression in mind, ten boreholes were cored to penetrate the manganese horizon and eighteen prospect tunnels were driven to depths ranging between 45 meters and 168 meters, across the strike of the manganese deposit in the general direction of the dip, to penetrate the orebody itself.

Interpretation of the data which resulted from this activity, aided by the knowledge about the regional geology of Wadi Araba and the correlations made with the Timna copper mining area, led to the following conclusion: The manganese concentrations occurring in the top of the Dolomite Limestone Shale Unit are of the syngenetic lagoonal type and exist only as separate lenses of moderate dimension. On the other hand, the copper minerals occurring in the same horizon are of the epigenetic type which were superimposed on that horizon at a later stage as a result of a leaching process which took place in the overlying Nubian Sandstones (Van den Boom, 1965; Nimry 1967).

This new concept then, led to the belief that the copper umbrella is much wider than that of the manganese and more persistant; it could be available anywhere in the Horizon, whether there are appreciable concentrations of manganese, or not, and where conditions in the Area are similar to the conditions reported at Timna.

In fact, this was the case observed in the prospect tunnels which were driven at that time.

But in spite of all the justifications and evidences which became available, there was still some doubt, that the copper minerals observed which were not associated with the manganese concentrations within the vicinity of the manganese deposit at Wadi Dana, might only be solution migrations derived from aqueous leaching of the copper minerals associated with the manganese orebody.

Due to this uncertainty, when the work was resumed in 1972, it was decided that the exploration programme should be implemented in two phases.

In the first phase, a pilot exploration scheme was to be put forward to cover an area of about four square kilometers, using core drilling, prospect tunnelling, pitting and trenching.

In the second phase, which would be dependant on a positive result from the first phase, a more general exploration programme was to follow.

The strike of the Dolomite copper-manganese bearing horizon, outcropping along the northern side of Wadi Dana and the two blocks embracing Wadi Khaled up to Wadi Ratya (cf. Geol. Map, Enclosure 1), were selected to be the subject of this pilot exploration scheme.

Implementation of this scheme became effective in March 1972, and was concluded by the end of May 1973.

Three NRA rotary drill rigs were involved plus two GEOMINCO (Hungarian Contractors) rigs. Eight mining crews were also involved plus some other crews who were busy in preparing accesses to the drilling sites.

In this programme, 40 boreholes were cored, 16 prospect tunnels were driven and 35 trenches dug to cut the strike of the ore horizon (See Table III). In addition, 50 kilometers of inland jeep tracks were also opened up to allow for mobilizing the equipment and staff.

The boreholes were arranged at random spacing. Drilling was either by airflush or mud flush depending on the depth of the lower ore horizon. Generally speaking, all boreholes deeper than 90m were drilled by mud flush. The depth of the boreholes ranged between 40 and 227 meters.

Cores of HX, NX, BX diameter, depending on the size of the rig used, were taken from both the Variegated Sandstone Horizon and the Dolomite Limestone Shale Horizon. Every borehole was terminated at a depth of 4.5 meters below the upper contact of the Dolomite Horizon. On completion, each borehole was plugged with a cement collar specifying the reference number, dates of start and completion of the borehole.

Every borehole was lithologically logged and described relative to depth. The core samples were then sent with their field numbers to the Mineral Laboratory in Amman for determining its copper and manganese content.

The prospect tunnels and the trenches (which were all confined to the Dolomite Horizon) were groove sampled across their widths.

Sampling widths in every case were not to represent more than 0.7 meters of the mineralised section, except in some special cases. The individual sampling width would, over its length, comprise as many separate samples as there were lithological changes.

To aid the metallurgical studies which are foreseen at a later stage, special groove samples have been collected to represent the different types of the mineral bearing rock. These samples were analysed in detail with special stress on the rock component and its metal content (Table II).

Tables (III) and (IV) give summaries of the sampling programme and the related area of influence for each of the computed assay values at the different investigated blocks, of both copper and manganese.

B. Laboratory Procedures

After logging, marking and labeling, all samples were despatched to the Mineral Laboratory in Amman.

The core samples were secured in wooden core boxes; the groove samples were preserved in cloth bags lined with polythene.

On receipt of the samples by the Laboratory, it was first checked and inspected jointly by the Base Staff Geologist and the officer of the preparation room at the Laboratory.

After checking and inspection, the core samples were split along their long axis into two halves, one half going back to the Sample Library of the MD/NRA and the other half going to the Laboratory for treatment. The groove samples were mixed, coned and quartered; one half was retained in the Laboratory, while the other half was sent back to MD/NRA Sample Library.

After the foregoing preparation, both types of samples being retained for treatment, were crushed to 1/4". Then, after mixing, coning and quartering, each sample was split into two halves, one half being put aside for reference and special investigations if needed; the other half crushed to -10 mesh and after repeated mixing, coning, quartering and splitting, it was reduced to 50 grams. This was then ground to -100 mesh and transferred to the chemistry room.

In the chemistry room, a small representative portion of the sample, weighing 4 to 5 grams, was taken for analysis and the remainder of the -100 mesh portion kept for reference and checking purposes.

The 4 to 5 grams, were then digested in 20 millilitres of aqua-regia solution, then heated until nearly dried. The nearly dried portion was then boiled in distilled water and filtered. The precipitate was washed with 250 ml. of distilled water and tested by the AAS for copper and manganese. The results were then reported back to MD/NRA.

Occasionally, some selected samples, would be repeated by MD/NRA for checking the accuracy and promptness of the Laboratory procedures.

Some special samples, like those reported in (Table II) were selected to represent the different types of the ore bearing rock. A study was then made of their physical and chemical differences especially as regards their mineralogical composition and variation in specific gravities for the purposes of this Report and to assist any further investigations including metallurgical which may be made in the future.

Table (III)

A Summary of the Cu-Sampling Programme & Related Areas of Influence

(1) Sampling Location Or Block No.	(2) Average Cu-Assay of Block %	(3) Width of Cu-Ore Section M.	(4) Area of Influence M^2	(5) Volume M^3	(6) Volume X Assay $M^3.X\%$
T-1 Dabbah	1.21	1.8	728	1310.4	1585.584
T-2 "	1.6	2.4	558	1339.2	2142.720
T-3 "	1.58	2.6	308	800.8	1265.264
T-4 "	1.23	2.4	2349	5637.6	6934.248
BH-2	0.94	1.8	2196	3952.8	3715.632
BH-3	1.07	3.66	1556	5694.96	6093.607
BH-4	0.86	1.8	4080	7344	6315.84
BH-7	0.72	1.8	3175	5715	4114.80
BH-10	0.87	1.6	6370	10192	8867.04
BH-11	0.8	1.9	2160	4104	3283.20

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Table (III) (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) $M^3.X\%$
D-14	1.05	2.2	18895	41569	43647.45
D-13	0.84	2.2	27234	59914.8	50328.43
D-12	1.44	1.9	29070	55233	79535.52
D-11	1.23	2.1	26622	55906.2	68764.63
D-X	1.4	2.3	23000	52900	74060
D-10	2.01	2	15615	31230	62772.3
D-7	0.9	1.9	33225	63127.5	56814.75
D-8	1.1	2	27450	54900	60390
D-6	1.01	2.1	16050	33705	34042.1
D-5	1.2	2	22950	45900	55080
D-4	1.71	2.1	11250	23625	40398.7
D-3	1.5	2	09450	18900	28350
D-2	2	1.9	14250	27075	54150
D-1	1.21	1.8	18602	33483.6	40515.2

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Table (III) (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) $M^3.X\%$
D-22	1.13	1.8	42450	76410	86343.3
D-23	1.3	2.1	32550	68355	88861.5
D-24	1.1	2	19200	38400	42240
D-21	1.2	1.8	32353	58235.4	69882.5
D-20	1.3	2	11120	22240	28912
T-21	0.8	1.8	3375	6075	4860
T-20	0.9	2	3750	7500	6750
T-19	1.4	2	4750	9500	13300
T-18	1.65	2	5250	10500	17325
T-23	3.1	2.2	4750	10450	32395
T-17	1.5	2.4	7250	17400	26100
T-16	0.8	2	7300	14600	11680
T-15	1.3	2.1	5500	11550	15015

Table (III) (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) $M^3 . X\%$
T-14	1.2	2.0	5250	10500	12600
T-13	1.0	1.8	4500	8100	8100
T-12	0.9	2.5	6250	15625	14062.5
T-24	0.96	2.1	3625	7612.5	7308
T-11	0.5	2.3	4250	9775	4887.5
T-10	1.6	2.05	4125	8456.3	13530
T-9	0.93	1.9	3000	5700	5301
T-7	1.39	5.35	2875	15381.2	21379.9
T-5	1.17	1.8	4900	8820	10319
T-2	1.3	2.1	3550	7455	9691.5
T-1	1.43	1.6	12750	20400	29172
T-6	0.82	2.7	3850	10395	8523.9
T-8	2.37	2.5	3900	9750	23107.5

Table (III) (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) $M^3.X\%$
P-1	1	2	16775	33550	33550
P-2	1.6	3.1	(cf.D-31 & D-32)	-	-
D-33	1.1	2.6	10950	28470	31317
D-32	1.1	1.8	18370	33066	36372.6
D-31	1.0	2.3	21500	49450	49450
D-30	2.4	2.5	20000	50000	120000
D-42	2.0	2	42486	84972	169944
D-41	1.3	2	35478	70956	92242.8
D-40	1.9	2.1	29400	61740	117306
D-54	1.4	2.3	20425	46977.5	65768
D-53	1.7	2.4	19475	46740	79458
D-52	1.8	2.3	66039	151889.7	273401.4
D-51	1.4	2.5	27160	67900	95060

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<u>Table (III)</u> (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) M^3.X%
BH-13	1.4	2	(cf.BH-113 & BH-1o9)	-	-
BH-16	1.36	2.1	92328	193888.8	263688.8
BH-17	1.3	2	30360	60720	78936
BH-19	1.4	1.8	30728	55310.4	77434.5
BH-83	The Cu-Horizon is weathered				
BH-84	1.36	2	46389	92778	126178.1
BH-89	Not Completed			-	-
BH-90	Not Completed			-	-
BH-91	1.13	3.3	32841	108375.3	122464.1
BH-92	0.87	2.0	31097	62194	54108.7
BH-93	0.8	2.5	39701	99252.5	79402
BH-94	1.09	3.3	56801	187443.3	204313.2
BH-95	Ancient Workings			-	-

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<u>Table (III)</u> (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) $M^3.X\%$
BH-96	1.05	4.5	48915	220117.5	231123.4
BH-97	1.0	3.5	40759	142656.5	142656.5
BH-98	0.96	3.0	47950	143850	138096
BH-99	The Cu-Horizon is weathered				-
BH-100	1.14	2.35	49770	116959.5	133333.8
BH-101	0.79	1.75	105386	184425.5	145696
BH-102	1.0	2.0	150392	300784	300784
BH-103	1.6	2.15	106863	229755.4	367608.7
BH-104	1.4	1.5	99988	149982	209974.8
BH-105	1.2	1.85	113146	209320	251184
BH-106	6.25	1.3	115646	150339.8	939623.7
BH-107	1.02	1.6	72285	115656	117969
BH-108	0.99	1.5	98270	147405	145930.9
BH-109	0.7	2.4	96245	230988	161691.6

Table (III) (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) $M^3.X\%$
BH-110	0.85	1.5	88835	133252.5	113264.6
BH-111	2.3	1.8	110525	198945	457573.5
BH-112	1.4	2	139937	279874	391823.6
BH-113	1.6	3.7	63119	233540.3	373664.5
BH-114	0.87	1.3	70864	92123	80147.2
BH-115	1.65	2.0	99544	199088	328495
BH-116	Not Drilled		-	-	-
BH-117	Not Drilled		-	-	-
BH-118	1.37	2.15	73012	156975.8	215056.8
BH-119	1.5	1.5	64486	96729	145093.5
BH-120	1.2	1.8	66746	120142.8	144171
BH-121	1.2	2	138661	277322	332786.4
BH-122	1.31	2.2	127507	280515.4	367475
BH-123	0.90	2.0	83673	167346	150611.4

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Table (III) (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) $M^3.X\%$
BH-124	1.51	1.93	62668	120949.2	182633.3
BH-125	The Cu-Horizon is weathered			-	-
BH-126	Penetrated through a fault plane			-	-
BH-127	1.24	3	102580	307740	381597.6
BH-128	Not Drilled		-	-	-
BH-129	Not Drilled		-	-	-
BH-130	1.1	1.8	14301	25741.8	28316
Total			3699942	7750943	10553593

Average Assay Value $= \frac{10,553,593}{7,750,943} =$ 1.364% Cu

Average Apparent Width $= \frac{7,750,943}{3,699,942} =$ 2.09 m.

Average Read Width of the Mineralised Section $= 2.09 \times 0.99027 =$ 2.069 m.

Note: Cosine 8^o = 0.99027

8^o = the angle of regional dip of the Cu-Horizon.

Table (IV)

Summary of the Mn-Sampling Programme and Related Areas of Influence

(1) Sampling Location Or Block No.	(2) Average Mn-Assay Value of Block	(3) Width of Mn-Ore Section	(4) Area of Influence	(5) Volume	(6) Volume X Assay
	%	M.	M^2	M^3	M^3.X%
T_1 Dabbah	47.3	1.8	728	1310.4	62618
T_2 "	39.8	2.4	558	1339.2	54560
T_3 "	40.49	2.6	308	800.8	32400
T_4 "	44.9	2.4	2349	5637.6	253665
BH_2 "	44.6	1.8	2196	3952.8	173932
BH_3 "	31.8	3.6	1556	5694.9	176545
BH_7 "	20.3	1.8	3175	5715	120015
BH_{10} "	14.3	1.6	6370	10192	142688
BH_{11} "	25.1	1.9	2160	4104	102600
D 14	36.4	2.2	9447	20284	730260

Table (IV) (Cont'd)

(1) No.	(2) %	(3) M.	(4) M^2	(5) M^3	(6) $M^3.X\%$
13	15.8	2.2	13617	24957	389312
12	16.3	1.9	14535	27616	441856
11	43.0	2.1	13311	27953	1201979
X	48.2	2.3	11500	26450	1269600
6	23.9	2.1	8025	16852	404448
5	34.6	2	11475	27950	978250
4	47.4	2	4725	16812	790164
3	37.7	1.9	7125	9450	349650
2	12.2	1.8	9301	18537	222444
1	10.4	1.8	21225	16742	167420
20	14.5	2	5560	11120	155680
Total			149246	283470	8230086

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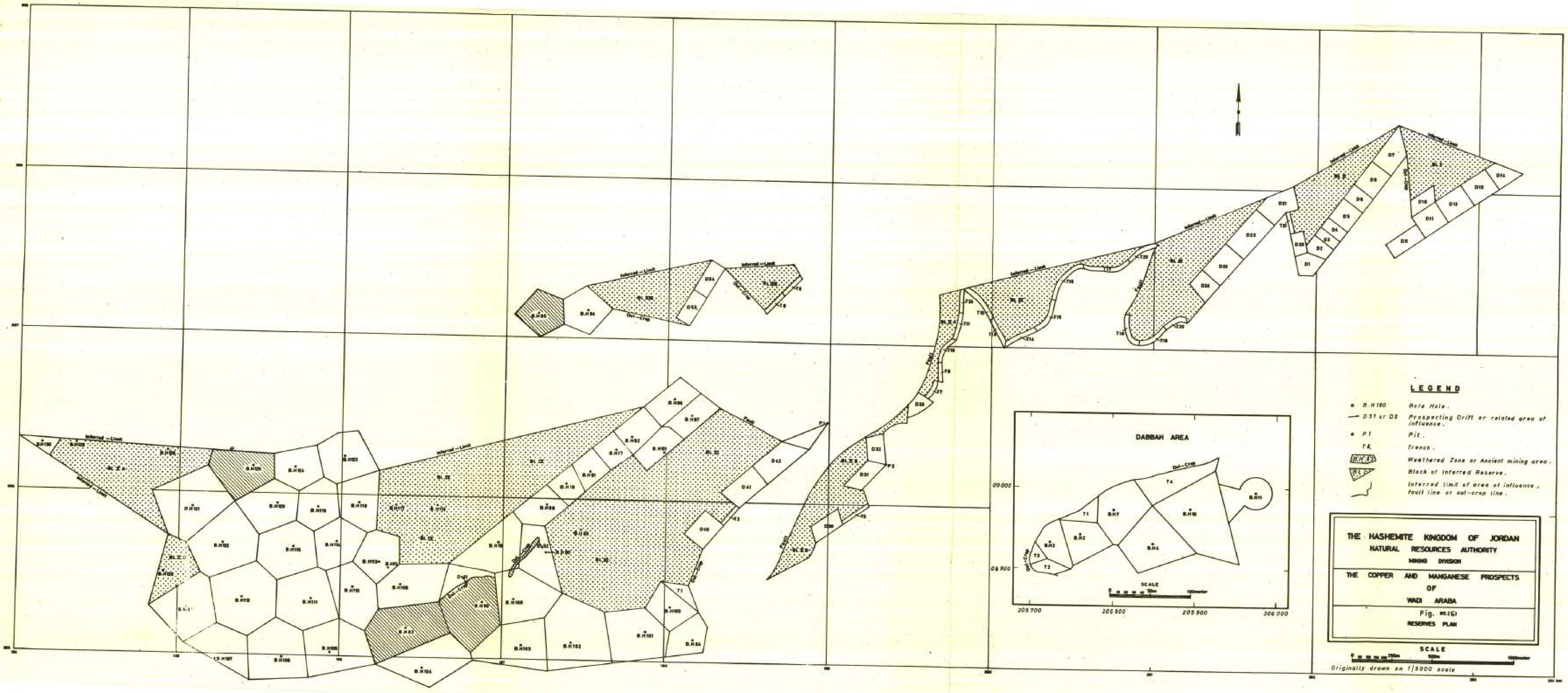
Average Mn-Content	=	29%
Average Width of Mn-Section	=	1.9m
Specific Gravity of Ore	=	4.2
Tonnage, Measured & Indicated	=	1,190,983 MT

Table (V)

Blocks of Inferred Reserve And Their Computed Areas

Block No.		Area of Block M^2
I	. . . .	134330
II	. . . .	141725
III	. . . .	247285
IV	. . . .	160230
V.A.	. . . .	67900
V.B.	. . . .	175200
VI	. . . .	833495
VII	. . . .	69732
VIII	. . . .	162940
IX	. . . .	658042
X.A.	. . . .	258196
X.B.	. . . .	63190
	Total Area	2,972,265


LEGEND
B.H100 Bore Hole.
D31 or DX Prospecting Drift or related area of influence.
P1 Pit.
T4 Trench.
B.H 43 Weathered Zone or Ancient mining area.
BL.I Block of Inferred Reserve.
Inferred limit of area of influence, fault line or out-crop line.
DABBAH AREA
THE HASHEMITE KINGDOM OF JORDAN
NATURAL RESOURCES AUTHORITY
MINING DIVISION
THE COPPER AND MANGANESE PROSPECTS OF WADI ARABA
Fig. (6)
RESERVES PLAN
SCALE
Originally drawn on 1/5000 scale

IX. VALUATION OF ORE RESERVES

1. Copper Ore Reserve

A. Definitions, Parameters and Limitations

The terminology and definitions of the different classes of ore reserves, adopted by the U.S. Geological Survey and the U.S. Bureau of Mines, will be used for the purpose of this chapter.

Accordingly, the ore reserves which have been fully or partly investigated within the scope of the Pilot Exploration Scheme will be reported on the basis of the following definitions:

"1. Measured ore is ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings and from the results of detailed sampling. The sites for inspection, sampling and measurements are so closely spaced, and the geologic character is defined so well, that the size, shape and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits which are stated, and no such limit is judged to differ from the computed tonnage or grade by more than 20 percent.

ii. Indicated ore is ore for which tonnage and grade are computed partly from specific measurements, samples, or production data, and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurements, and sampling are too widely or otherwise inappropriately spaced to outline the ore completely or to establish its grade throughout.

iii. Inferred ore is ore for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The

Such reserve based on measurement by means of drifts and trenches, will also be classed as <u>measured and/or indicated ore</u>.

Under the category of inferred ore, will be computed all reserves that lie within the dotted areas shown on the Reserve Plan - Fig. 6.

specific geologic evidence of their presence. Estimates of inferred ore should include a statement of the special limits within which the inferred ore may lie". (Mckinstry 1948).

iv. Another class of ore will be reported here under the name of expected ore, because it cannot be included under any of the above classes. It was estimated on the basis of the broad knowledge of the geologic character of the Area and the very widely spaced pilot sampling of some of the outcrops.

It is to be noted that in our statement of reserves, both the measured and the indicated reserves will be reported together, due to the fact that at this stage, drawing of a clear demarcation line between these two classes is not recommended, especially since some of the areas containing these reserves, are currently being subjected to further investigations and follow-up drilling.

Under this category of reserve, shall be included all tonnage measured by means of drill holes, drifts, trenches and close outcrop sampling; linked with our knowledge of the geology of the district and more particularly the geology of the deposit and the dispersion pattern of copper mineralisation in the Horizon (cf. Reserve Plan - Fig. 6).

Whenever core drilling was used and as long as the grid spacing did not exceed 500m, the computed ore was classified as <u>measured and/or indicated</u>.

Whenever sampling and measurements were made by means of drifts, the average assay value and ore thickness of the equally spaced groove samples (taken from stations at 5 meter intervals along the walls of every drift) were applied to an area bounded by an inferred

Sections of these various areas will each be given the average assay value and ore thickness of the block(s) of measured and indicated reserves, that lie in immediate proximity. The geological data, structural pattern of outcrops and results of pilot sampling in the various dotted areas will also be considered in their evaluation.

The category of expected ore, shall be purely based on geologic and outcrop evidence, as long as it is believed that such expected ore is not very deep or beyond the reach of the explorer. Although the Lower Cu-Horizon in the subject Area is not less than 150 square kilometers in area (cf. Geologic Map - Enclosure 1), only about one-fifteenth of this area was selected for consideration as a good target for expected ore.

The reported reserve as such under all categories shall be limited to the computed tonnage in the Lower Cu-Horizon, only. No attempt will be made to compute the reserve which was intercepted locally in the Upper Cu-Horizon of the Variegated Sandstone Unit, due to the fact that the Cu-dispersion pattern in this

Horizon is rather erratic and patchy, and cannot be reasonably forecast for distances longer than 20m from any sampling station. Nevertheless, something like three million tons of Cu-ore of an average grade around 0.65% Cu can be selectively gained from the different outcrops of the Upper Horizon.

B. Statement of Reserves

Table (III) gives a summary of the sampling programme and areas of influence related to every average value computed for each block from the individual sub-measurements made at the different sampling stations within that block.

Table (V) gives the plan areas of the different blocks of inferred ore.

For the purpose of the calculations made for this Report arbitrary cut-off grade of 0.4% Cu was established.

This cut-off grade was employed all the way through the calculations of the average Cu-assay values

Accordingly, the following tonnages were obtained:

i. Measured and/or Indicated Reserve

(a) Ore : 19,816,889 metric tons with an average copper content equal 1.364%, and an average thickness equal to 2.06 meters.

(b) Copper : 269,510 metric tons.

ii. Inferred Ore

15,919,450 metric tons, most probably of the same grade and thickness as above.

iii. Expected Ore

50,000,000 metric tons (minimum), possibly of the same grade and thickness as above. This expected ore lies mainly in Wadi Ratya, Khirbet el-Nahas, Wadi el-Hammar and Helaysia-Salwan areas.

2. Manganese Ore Reserves

The same definitions which were used for defining the Copper Ore classes and categories, will be used in the case of calculating Manganese Ore Reserves. The projected limits of the ore-lenses for the inferred and potential ore, depended mainly on evidence from drill holes, drifts, trenches and outcrop sampling. The mode of occurrence of the manganese concentrations in the Area, was carefully taken into account, when the estimation was made for the different categories of ore reserves reported herein.

Such manganese concentrations were intercepted in the following areas and blocks:

At Dabbah area in general (except in block BH-4), and in blocks numbered D 1, 2, 3, 4, 5, 6, 11, 12, 13, 14, 20 and X.

Very rich outcrops of concretionary manganese ore, were also located at Salawan and Wadi el-Hammar areas.

Computations and interpretation of the measurements and observations made at the different localities gave the following results:

i. Measured and/or Indicated Reserve
1.19 million metric tons of ore, with an average content of 29% manganese and 1.4% copper, and having an average thickness of 1.9 meters (Table IV).

ii. Inferred Ore
400,000 metric tons most probably of the same grade and thickness as above.

iii. Expected Ore
3,000,000 metric tons, are expected to exist mainly in the vicinity of Wadi Dana, Salawan and Wadi el-Hammar areas.

In computing the above tonnages, a specific gravity of 4.2 was used.

X. CONCLUSIONS AND RECOMMENDATIONS

From the subject matter and illustrations of the preceeding chapters, we can conclude the following:

1. Approximately, 36 million metric tons of ore reserve with an average grade of 1.36% Cu have already been measured/indicated and inferred in the subject Area. Beside this reserve, a minimum of 50 million metric tons of ore of the same grade is expected to exist in the same area.

2. Manganese ore reserves of 1.6 million metric tons have also been measured/indicated and inferred with an average content of 29% Mn. In addition, there is an expectancy for reserves of another three million tons of Mn ore.

3. The above stated reserves all exist in the Lower Copper Horizon. However, there are another three million tons of copper ore reserve with an average grade of 0.65%, existing in the Upper Copper Horizon of the Variegated Sandstone Unit, which can

be mined from the outcrops of this Unit within the subject Area.

4. The area which was investigated within the scope of the Pilot Exploration Scheme only covered a very limited portion of the subject Area where both copper horizons are known to exist.

5. Mineralisation in the major Copper Horizon (the Lower) is of epigenetic origin which was brought to its present level by descending solutions from the Upper Copper Horizon. The lateral distribution of copper minerals in this major Horizon is rather persistant and uniform. On the other hand, copper mineralisation in the Upper Horizon is patchy and cannot be safely forecast to distances longer than 20 meters from the sampling stations.

6. There is a good chance that the copper deposit under consideration might eventually prove to be a relatively big copper deposit whose development and exploitation could, in the future, play a major role in the economy of Jordan. Even now,

with the amount of reserves which have been already established, there is justification for Jordan to build a copper plant of moderate size.

7. The mineral bearing horizon, which is lithologically designated as dolomite-limestone-shale, has shown, on chemical analysis, that it is mainly composed of silica and alumina. The carbonate content is much less than would be normally expected with the presence of dolomite and limestone facies.

Accordingly, the following recommendations are put forward:

A. The area to be covered by drilling and sampling should be expanded with special emphasis on areas where the major copper horizon is outcropping or expected to be relatively shallow.

B. On the completion of the recommended second phase of work, a sub-surface structural and tectonic map for the Copper Horizon should be constructed to assist mine planning in the future.

C. Steps toward defining the best means of extracting the metal from its ores should be initiated.

D. Future planning for the development of the Area, should take into consideration the possibility of utilizing the manganese as a by-product of the copper plant.

E. The Area should be made easily accessible throughout the year for heavy duty equipments and trucks.

F. Since the water resources and springs existing in the Area, are not yet utilized, a first priority for their use should be reserved for a possible future copper plant.

XI. BIBLIOGRAPHY

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