MINISTRY OF ENERGY AND MINERAL RESOURCES
Mineral Status and Future Opportunity

COPPER

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CONTENTS

List of Figures

List of Tables

List of Appendices

Copper

1. Introduction

Wadi Araba is part of the Jordan Rift Valley, which extends about 175 km from the southern edge of the Dead Sea in the north to the shore of the Gulf of Aqaba. It was considered in ancient times a bridge between Asia and Africa because it lies at the cross roads between the two continents (Figure1).

The copper deposits in this area are mainly present in the Cambrian rocks and have not been commercially exploited. Copper ore was mined and smelted extensively in ancient times by Nabatians, Egyptians and Romans (Omari, 1978). Archaeological discoveries in Wadi Araba was dated copper production as far back as 3,000 years B.C.There are three large slag heaps in the Finan district within the Wadi Araba area and fragments of partially smelted copper can be found in it. The copper ore was brought to the Finan district from the adjacent localities of Wadi Khalid and Wadi Dana. Many adits were discovered in these areas by the (NRA) which had been driven into the outcrops of the copper bearing horizons. Some of these adits extend more than 30 meters into outcrop. In Um EL Amad, 5 km to the south of Fienan area, the largest old mine found in Wadi Araba is still in a good condition. It is an underground mine within an area of 80 x 80 meters.

2. Main Localities of Copper Ore Deposits

Copper ore deposits are occurred in four main areas within the Wadi Araba (Figures, 2 & 3) these are as follows:

2.1 Wadi Abu Khushayba Area

The area is located in the southern part of Wadi Araba about 100 km north of the Aqaba and about 6 km south east of the Dead Sea-Aqaba Highway. The copper mineralization is present in an area of about 24 km2. The ores are present in white fine-medium grained of sandstone and the thickness is ranging from 1-3 m. It is noticed that the Wadi Abu Khushayba area is occurred out side of the Dana Nature Reserve (Figure 2).

2.2. Feinan Area (Wadi Khalid, Wadi Dana and Wadi Ratyia)

The area is located in the center of Wadi Araba, about 35 km to the north of Wadi Abu Khusheiba and covers an area of about 30 km2. The Feinan Area and its constituents are within the area of Dana Nature Reserve (Figure 3).

2.3. Khirbet EL Nahas /Wadi Jariya Area

It is located in the central part of Wadi Araba Region 20 km north of Feinan Area and about 150 km north of Aqaba with total area of about 60 km2. The Khirbet El Nahas/ Jariya area is within the area of Dana Nature Reserve (Figure 3).

2.4. Um El Amad/ Wadi Malaqa Area

It is located about 2 km to the south of Feinan area with a total area reached to about 20 km2. The area is located out side of the Dana Nature Reserve as illustrated by (Figure 3). Therefore, further exploration studies are highly recommended. More drilling boreholes and trenches must be taken into account to estimate the copper ore reserves in the area.

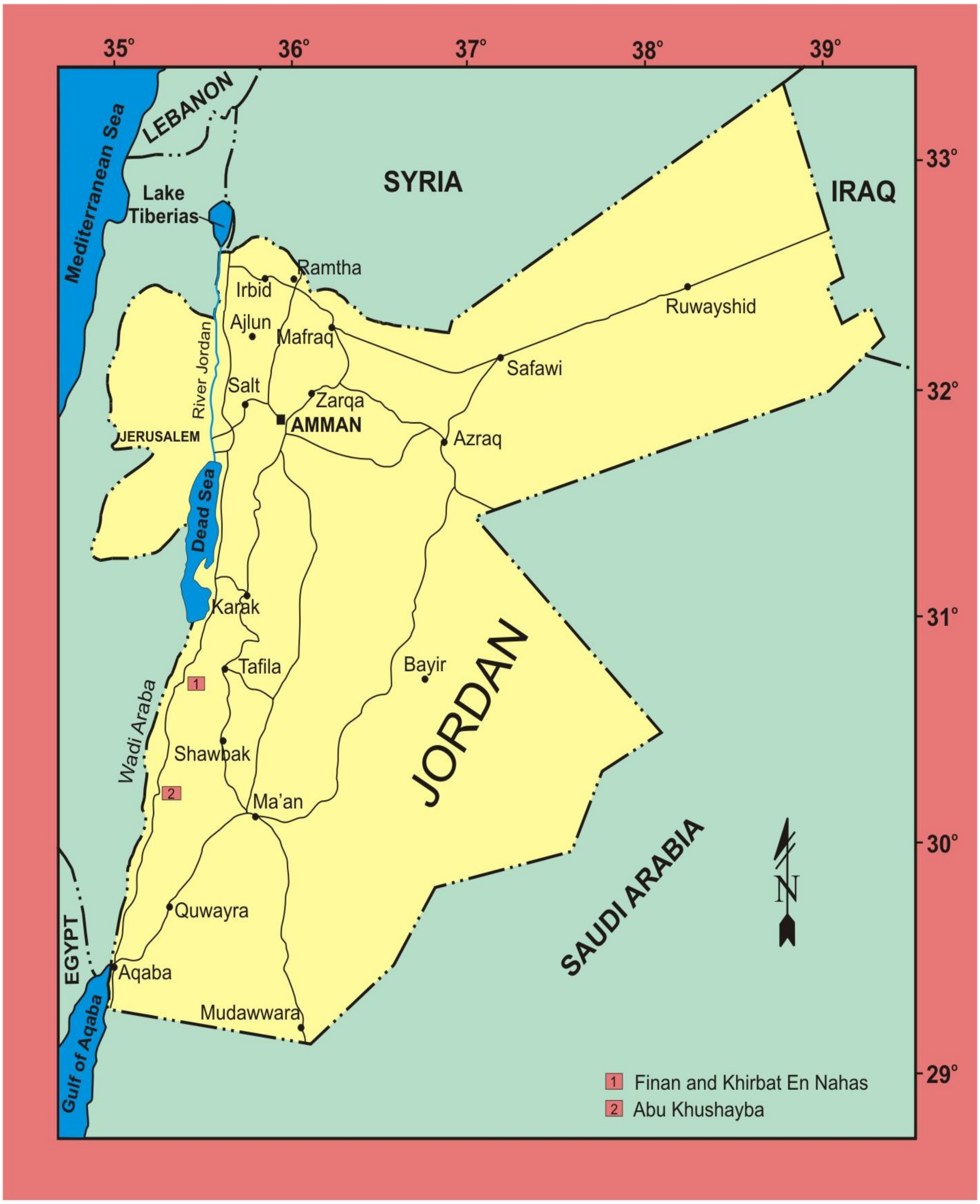

Figure 1: Location map of the study area.

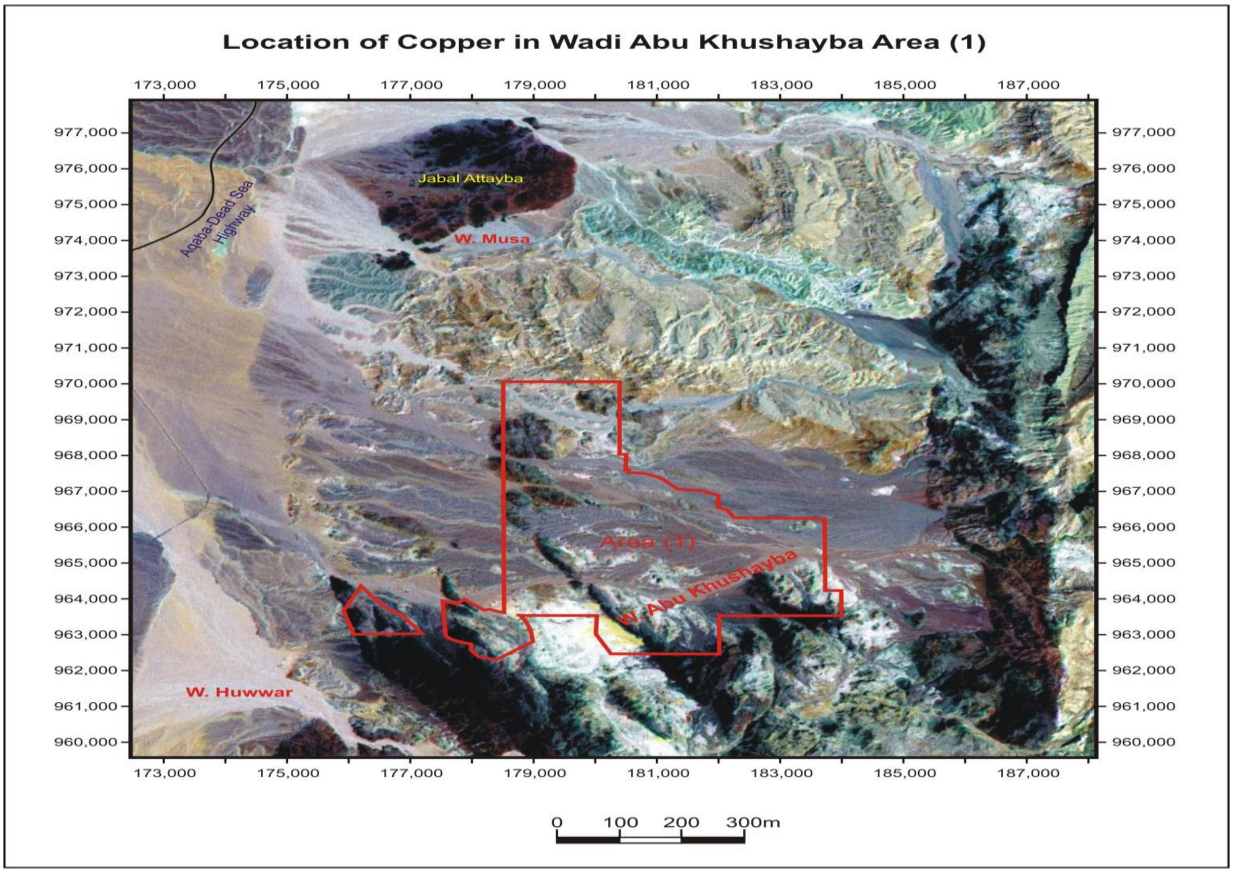

Figure (2): Landsat image of Abu Khusheiba area.

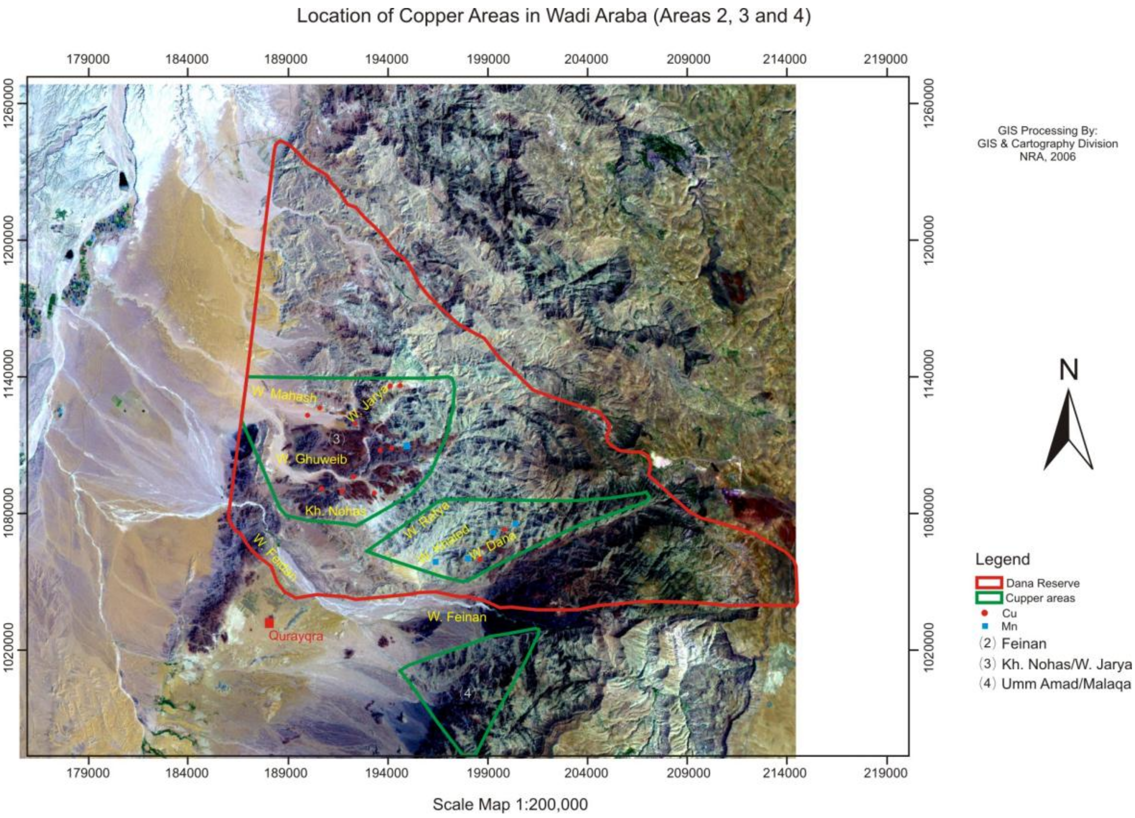

Figure (3): Landsat image of Feinan, Khirbet EL Nahas and Um EL Amad areas.

3. Geology of the Hosted Rocks

The copper mineralization in Wadi Araba is mainly limited to the Burj Dolomite-Shale and Abu Khusheiba Sandstone Formations (Cambrian age). Both formations are typically exposed in the study area. The formations overlay the Salib Arkosic Sandstone Formation and overlain by the Umm Ishrin Sandstone Formation. The later formations are part of the lower part of the Ram Group that uncomformably overlies Precambrian rocks. The copper mineralization in the area thought to be leached from the basement rocks to the Burj Dolomite-Shale and Abu Khusheiba Sandstone Formations due to the hydrothermal solutions.

The main localities that are affected by high mineralization are found in Wadi Dana, Wadi Khalid and Wadi Ratyia in Feinan area as well as in Wadi El Jariya within the Khirbet EL Nahas area.

3.1. Geology of the Burj Dolomite Shale Formation

The Burj Dolomite-Shale Formation has been subdivided into three members these are as follows from bottom to top:

3.1.1 Tayan Siltstone Member

The lithology of the lower part of the Burj Formation (Tayan Siltstone Member) consists mainly of green, brown siltstone, intercalated with thin beds of sandstone, which contained glauconite mineral. The presence of glauconite indicates a shallow marine environment. There are also thin beds of sandy dolomitic limestone occurring as intercalations in this member.

The low grade of copper makes this member of no economic value. The copper is present as a fine dissemination scattered in the siltstone and present along the bedding planes mainly as the mineral malachite. Manganese was widely distributed and rich in this member particularly in the eastern part of the Wadi Ghuwayb area (Rabba, 1994).

3.1.2. Numayri Dolomite Member

The Numayri Dolomite Member is exposed along the eastern flank of Wadi Araba from the southern part of the Dead Sea to Wadi Magatha, which is about 20 km south of Khirbet Finan. It consists mainly of sandy dolomite, dolomitic limestone intercalated with thin and thick beds of sandstone. The mineralization only occurs in the uppermost part of this member as filling the cavities, fractures, pores, and present along the bedding planes.

3.1.3. Hanneh Siltstone Member (HS)

The Hanneh Siltstone Member represents the upper part of the Burj Dolomite-Shale Formation that consists of two different lithological sub-members with a total thickness reached to about 30 m, these are:

Shale Sub-Member

The shale in the study area that forms the lower part of the HS member is 2m thick. It has green to dark brown color and intercalated with a thin bed of sandstone. In addition to the presence of copper and manganese mineralization, apatite mineral is discovered in the Wadi Khalid, Wadi Dana and Wadi EL Jariya. It was associated with copper and manganese minerals within the shale unit. Mineralogical study of several copper rich shale samples showed that a sufficient quantity of apatite mineral reach up to 50 % which allow them to be called phosphatic shale (Rabba, 1993). The copper mineralization occurs as a cavity filling and along bedding planes and veins.

Variegated Sandstone Sub-Member

White to yellowish white sandstone varies in grain sizes, with a total thickness of 28 m. The copper mineralization occurs only in the lower most part of this unit; it is erratic and patchy acting as cementing grains of quartz.

3.2. Geology of the Composite Mineralized Vein of Apatite in Feinan area

Rabba in 2004 discovered a composite mineralized vein that contains apatite, uranium, manganese and traces of gold in Feinan area/Wadi Araba. The mineralization is limited to the Burj Dolomite-Shale Formation (Cambrian), which is typically exposed in the study area.

There are at least three different hydrothermal eruption events that took place along the mineralized vein in the Feinan area (Rabba, 2004). The main and earlier one is the apatite-bearing vein (eruption phase no. 1) invaded by calcite mineral (eruption phase no. 2), followed by the last eruption (phase no. 3), which are consists of manganese (black to dark grey in color).

3.3. Geology of the Abu Khusheiba Formation

The Formation is equivalent to the Burj Dolomite Shale Formation. The copper minerals occur in a white, medium to fine-grained sandstone, which overlay the Salib Arkosic Sandstone Formation. The copper mineralization consisted mainly of secondary copper minerals occurring as fine scattered disseminations in the white sandstone along the bedding planes and the planes of the trough and planar cross-bedding. In addition, there were lithic fragments of 0.5-2.0 cm diameter containing copper minerals, which were randomly scattered in the sandstone. These fragments are black-brown in color and altered to bright green malachite in places.

4. Ore Properties

4.1. Mineralogical Properties of Copper Ore

The mineral identification was carried out on ten hand specimen samples by (Rabba, 1993). The most abundant mineral identified in the Feinan area was chrysocolla followed by malachite. The subordinate minerals are planchite, atacamite, bisbeeite and the last one was the mottramite. The last two minerals were unknown in the Feinan area. Mottramite was discovered by electron probe microanalysis and the other mineral was identified by X-ray diffraction method. The chrysocolla and malachite were the two minerals associated mostly with each other in many places in the Feinan area.

The copper mineralization was found in three different ore types: in the sandstone, the copper mineralization occurred as cement for the quartz and feldspar grains with crack fillings and along the bedding planes. The main gangue minerals are quartz, k-feldspar, apatite and illite. In shale the copper mineralization occurs as cavity fillings and also some layering along the bedding planes, while in dolomite, copper mineralization presents only as cavity fillings along fractures and pores in the rock.

4.2. Physical Properties

The copper ores are present in the form of oxide minerals due to that the mineralogical studies revealed that it would be very difficult to physically liberate copper minerals from the gangue materials. The following are the main physical properties of copper minerals in Wadi Araba:

Table (1): Physical properties of copper ore.

Property	Description
Color	Green to blue
Luster	Adamantine or sub metallic to dull or earthy.
Crystal Habits	Long needle-like crystals or fuzzy crusts and prismatic form
Cleavage	Prismatic cleavage
Fracture	Conchoidal
Hardness	3.5–5
Specific Gravity	Approx. 6 (very heavy for translucent minerals)
Streak	Brick red
Associated Minerals	Chrysocolla, malachite, planchite, bisbeeite, atacamite and mottramite.
Melting Point	900-1100 ºC
Other Characteristics	Forms a surface film with long exposure and filling cavities, fractures and cracks. It also present as granules scattered in sandstone unit.

4.3. Chemical Properties of Copper Ore

The following tables summarized the chemical analysis of copper ore deposits in Wadi Araba, (Nimry, 1979 and Raba'a, 1993).

Table (2): Chemical analysis of the mineral-bearing rock (Nimry, 1979).

Oxides	Sample No. RG1/53	Sample No RG2/53.	Sample No. RG3/53	Sample No. RG1/54	Sample No. RG2/54	Sample No. RG3/54	Sample No. Rg4/54
L.O.I	6.47	4.71	13.11	7.95	6.98	4.58	4.13
SiO2	49.44	60.74	53.81	54.63	58.77	62.48	62.04
Al2O3	18.50	19.80	12.54	22.36	22.40	19.42	21.31
Fe2O3	12.18	3.45	1.31	12.10	5.95	3.96	5.82
Na2O	0.21	0.25	0.49	0.52	0.75	0.64	0.58
K2O	0.14	0.45	0.39	0.1	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
MnO2	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 (3): Electron-probe microanalysis of bluish green chrysocolla (Rabba, 1993).

Area	Cu%	Si%	Ca%	Al%	Ba%
Area 1	37.4	19.3	0.4	0.8	-
Area 2	34.2	15.5	0.5	1.0	1.0
Area 3	32.7	19.5	0.7	1.63	-
Area 4	39.2	19.7	0.7	1.4	-

Table (4): Electron-probe microanalysis of mottramite (Rabba, 1993).

Area	Cu%	Si%	Pb%	Ca%	V%
Area1	21.3	0.9	32.4	4.4	10.4
Area2	17.5	0.06	45.3	1.34	11.0
Area3	16.7	0.03	49.3	0.01	11.0

Table (5) Electron-probe microanalysis of light green malachite (Rabba, 1993).

Area	Cu%	Si%	Ca%	Al%	K%
Area1	53.6	0.09	0.0	0.0	0.02
Area2	52.8	0.12	0.08	0.03	0.04
Area3	53.4	0.15	0.0	0.05	0.0
Area4	53.7	0.069	0.068	0.03	0.0
Area5*	51.2	4.13	0.05	0.13	0.0

* This area contains small inclusions of chrysocolla.

Table (6): Electron-probe microanalysis of planchite (Rabba, 1993).

Area	Cu%	Si%	Ca%	Al%	K%
Area 1	43.2	15.8	0.2	0.4	0.08
Area 2	43.3	15.4	0.2	0.5	0.02
Area 3	39.3	19.7	0.06	0.2	0.05
Area 4	39.4	19.7	0.1	0.2	0.05
Area 5	42.0	21.0	-	-	0.3

5. Copper Reserves

Copper reserves in Wadi Araba area was estimated to be about 52.8 million ton, while the metal reserves of native copper (Cu) were estimated to be 903780 ton. The reserves are distributed in four main localities as listed in tables 7, 8, 9 and 10.

6. Previous Studies

The most important previous systematic investigations that carried out in the Wadi Araba area which were conducted by the following organizations:

6.1. German Geological Mission

The first detailed exploration studies were carried out by Otto Gold during 1961-1964 in the Abu Khusheiba area. They studied the copper mineralization and produced geological maps for the area (Attachments).

6.2. Natural Resources Authority

In 1966, the NRA started an exploration program for copper and manganese in Wadi Araba. In 1972, the NRA concentrated their work in the Feinan area. Between 1972 and 1973 the NRA drilled and cored 40 boreholes, drove 16 tunnels, and dug 35 exploration trenches in the copper ore layers. Rabba, (1993) studied a metallurgical test work on the copper ores of Wadi Khalid in Feinan area. The examined samples were collected from two rock types (shale and sandstone). Two different acids were used for extraction the copper from the copper ore. These were sulphuric and phosphoric acids. The results of NRA works are as follows:

(a) The reserves of copper ore are about 19,816,889 metric tons in Feinan area with an average copper content of 1.36% and an average thickness about 2.06 % meters.

(b). Inferred ore reserves of about 15,919,450 metric tons in Feinan area with most probably of the same grade and thickness as (a).

(c). Expected ore reserves of Feinan area is about 50,000,000 metric tons (minimum) with possibly of the same grade and thickness as in (a).

6.3. Bureau de Recherches Geoloqies er Minieres (BRGM)

During 1974-1975 the French BRGM carried out their own estimates of reserves using the NRA data of drilled boreholes and they drilled another 11 boreholes. The estimate reserves largely confirmed the NRA estimation. In addition, they suggest a mining procedure to extract the copper ore and a scenario of feasibility study for Feinan area as follows:

Long wall extraction with back filling is considered to be the ideal mining method for extracting the copper ores.

They found out that the price of copper (at that time 1975) was low and the proved reserves were insufficient to produce native copper.

6.4. Seltrust (England) 1985

The results of the Seltrust Company summarized as follows:

Studied the copper ore from the technology and economic point of view.

The best process to produce copper is the thin layer leaching followed by solvent extraction and electro winning.

The cost of a unit to extract 3000 tons/year copper is 17.5 million Sterling pounds.

6.5. Hanbo Group (South Korea) 1994

They evaluate the previous studies and found that the copper ore deposits are a promising project and they suggested a full exploratory work in order to sign agreement with NRA to produce native copper.

6.6. Phelps Dodge (South Africa) 1999

They showed interest to make MOU with NRA and put a full exploratory program and budget, but under condition which was carve out the Khirbet El Nahas area from Dana Nature Reserve.

7. Exploration Activities in Wadi Araba

7.1. Wadi Abu Khusheiba Area

Otto Gold studied in details the copper mineralization during 1961-1964, and the following works were achieved:

Detailed geological map scale 1:10,000 including all the exploration activities (boreholes, groove, trenches and drifts), the map is presented in Appendix 1. Landsat image of Abu Khusheiba area is presented in (Figure 2).

Drilled 94 boreholes with total depth reached to 4979 m.

436 trenches with total length reached to 511 m.

304 groove with total length reached to 2528 m.

5 drift along the horizon with total length 150m.

Table (7): Summery of the exploration activity in Wadi Abu Khusheiba area.

Total area	24 km2
Thickness (m)	1-3
Copper reserve (million ton)	8
Cu%	0.65
Metal reserves (tone)	52000
Price of copper (US $) in 24/5/2006	8600
Economic Value (million US $)	447.2

7.2. Feinan Area (Wadi Khalid, Wadi Dana and Wadi Ratyia)

This area was subjected to the following exploration activities these are as follows:

BRGM produced six geological maps scale 1:2,500.called Dana Map Area 1, 2,3,4,5 and 6 (Figures 4, 5,6,7,8 and 9). All the exploration activities (boreholes, trenches and drifts) are located on these maps and available in the NRA. All these maps are compiled in one map called Geological map of Feinan, Dana, Wadi Khaled, Umm El Amad and Khirbat El Nuhas Copper (Appendix 2).

The Natural Resources Authority (NRA) studied the area in full exploratory program during (1971-1973) by Nimry and the following works were achieved:

Drilled 142 boreholes with depth ranging from 40-242 m.; 42 trenches and 42 drifts. The results of the exploration are presented in Table 8.

Table (8): Summery of the Exploration Activity in Feinan Area.

Total area	30 km2
Thickness (m)	2
Copper reserves (million ton)	19.8
Cu%	1.36
Metal reserves (tone)	269280
Price of copper ($) in 24/5/2006	8600
Economic Value (million $)	2315.81

7.3. Khirbet EL Nahas /Wadi Jariya Area

This area was subjected to the following exploration activities these are as follows:

The BRGM produced a geological map scale 1:10,000 during their work in the area (1974-1975).

The NRA studied the area during (1979-1980) which drilled and cored boreholes, drove tunnels and dug trenches, but unfortunately the exploration works and the analysis were not documented.

Reconnaissance and foot prospecting were performed during (1992-1993) by the NRA (Abu Snoubar, 1996). He collected 136 samples for chemical analysis to determine the Cu% in order to estimate the copper reserves. The collected samples were distributed as follows:

24 grab samples from Wadi Ghuwayb/Mahash Area

82 channel samples from (previous trenches and drifts) Wadi EL Jariya and Jabal Marzuka.

30 grab samples from Khirbet El Nahas Area.

Details information about the thickness of copper horizon and copper % are presented in Table (9).

Table (9): Summery of the exploration activity in Khirbet El Nahas Area.

Total Area	60 km2
Thickness (m)	2.5
Copper reserves (million ton)	25
Cu%	2.33
Metal reserves (tone)	582500
Price of copper (U S $) in 24/5/2006	8600
Economic Value (million U S $)	5009.5

7.4. Um El Amad/ Wadi Malaqa Area

The area was subjected to detail exploration program and the following works were achieved:

♦ BRGM produced two geological maps scale 1:10,000; the first map called Um AL Amad Area and the other map is called Dabbah Salawan area scale 1:10,000.The two maps are available in NRA.

♦ The NRA, (1991) studied the area by Abu Snoubar. Two boreholes were drilled in the studied area and the total depth was reached to about 150m. Several samples were collected and analyzed, but unfortunately, the project was terminated. Table 6 shows the conclusion of the exploration activity in the area.

Table (10): Summery of the Exploration Activity in Um El Amad/Malaqa Area.

Total area	20 km2
Thickness of ore (m)	1.9
Copper reserves (million ton)	-
Cu%	0.8
Metal reserves (tone)	-
Price of copper (U S $) in 24/5/2006	8600
Economic Value (million U S $)	-

8. Mining Methods of the Copper Ores

The French Mining Group (Sofre Mines) as sub-contractors to BRGM, (1993), undertook the mining study. The underground mining extraction in Wadi Araba copper ore deposit does not involve any major difficulties. They suggested three methods of underground mining these are as follows:

1) Parallel back-filled room and pillar recovery.

2) Conventional board and pillar.

3) Long wall mining with back filling.

The Long wall mining with back filling was found to be the cheapest method and gave the highest percent of recovery (almost 100%) and the safest method. The overall operating cost anticipated, i.e. 1.2 JD / d.m.t (in 1993) can be favorably compared with any similar mine in the world.

9. Extraction of Wadi Araba Copper

Previous investigations of the Wadi Araba area revealed that the copper mineralization is essentially all oxide minerals based. The mineralization occurs in dolomites, shale and sandstone mainly as infilling of pores, cavities and fractures. Leaching copper oxide minerals with sulphuric acid has been extensively used as the example in the treatment of Nchanga tailings, Zambia. The following is the metallurgical test works on copper ore:

A. The Seltrust Engineering Ltd (1985)

Seltrust Company performed a metallurgical test work on copper ore of Feinan area in the BRGM Laboratories. The sample for the test work was 20 tons of ore collected from the Numayri Dolomite Member, which is rich in manganese and iron oxide, particularly in the Wadi Dana area. According to the results from the metallurgy department in Orleans France, a sulphuric acid leaching in ″ Pachucas″ tanks can be scheduled under the following conditions:

Dilution: 1/1

Sulphuric acid : 60 kg H2SO4 / ton of dry ore if the gangue acid consumption is low to 288.6 kg H2SO4 / ton of dry ore if the gangue acid consumption is high (contains high carbonates).

Retention time: 3 hours

Ambient temperature: 20 to 35ºC

These leaching conditions applied to a mean ore containing 1.3% of copper, would give the following results for one ton of dry ore:

Total copper input:	13.0 kg
Tailing weight:	950.0 kg
Copper remaining in tailing:	3.325 kg
Extraction copper:	9.675 kg
% Copper extraction:	74.42

Processing Plant

Annual input in metallurgy:	1.100,00 ton / year (dry)
Number of working days:	340 days / year
Daily input:	3235 tons / day
Hourly input:	135 tons / hour
Copper input – per year:	14300 ton

A series of alternative techniques were then studied in an attempt to improve the copper extraction. These included leaching with SO2, and leaching with ammonia or sulphuric acid after a reduction roast. The result showed that only leaching with SO2 increased copper extraction significantly.

B. Rabba, (1993)

He performed a metallurgical test work on copper ores of Wadi Khalid/ Feinan area and the extraction procedure was as follows:

Metallurgical Test Work on Feinan Ore Deposits

Several leaching tests were performed on the Finan sandstone and shale copper ore deposits using sulphuric and orthophosphoric acid.

a) Using Sulphuric Acid in Leaching Copper from:

Sandstone Sub-member:

The maximum extraction obtained after 24 hours with the finest ore sample (<1.0 mm) was 92.0% using an acid strength of 5 ml/100 ml solution with an acid consumption ranges between 14.33 to 28.3 kg/ ton of ore. This compared with a value of 88.6% extraction from the coarse fraction (10.0 mm) with an acid consumption ranges between 17.2 to 32.8 kg/ ton of ore. The particle size of the ore did not therefore affect to any great extent the value of copper recovery.

The amount of acid required to dissolve the copper from the ore and comparing it with actual consumption values reveals that in the majority of tests approximately 30% of acid was consumed extracting copper.

Shale Sub-member:

The maximum copper extraction obtained after 24 hours with the finest sample of shale ore (<1.0 mm) was 80% using an acid strength of 5 ml H2SO4/100ml of solvent. The consumption of acid ranges between 85 to 93 kg/ ton of ore compared with a value of 70% extraction from the coarse fraction (10.0 mm) with an acid consumption ranges between 45 to 59.1 kg/ ton of ore utilizing the same leaching conditions.

b) Using Orthophosphoric Acid in Leaching Copper from:

Sandstone Sub-member:

Leaching results indicated that copper is readily released from sandstone using dilute orthophosphoric acid. The copper extraction results obtained rang from 62% using 2 ml of H3PO4/100 ml of solvent to 90% using 12.5 ml of H3PO4/100 ml of solvent after 24 hours leaching at 30ºC. The acid consumption ranged from 12.25 to 78.37 kg of H3PO4/ton of copper ore respectively.

Shale Sub-member:

The maximum copper extraction obtained from shale ore samples after 24 hours leaching at 30ºC with orthophosphoric acid was 94%. This was produced using concentrated acid solution of 50 ml H3PO4/100 ml of solvent. Extraction from this material dropped to 64% when the most dilute orthophosphoric acid solutions were employed. Similarly, P2O5 and CaO extraction from the shale ore was also depends on acid strength:

Dissolution of the calcium phosphate content of the shale Sub-member with orthophosphoric acid was mirrored by a weight loss of the leaching residue. This ranged from 6-85% depending upon the strength of acid used for leaching.

An examination of acid consumption in the tests performed with shale ore, the values obtained were erratic and probably influenced by the presence of a large amount of P2O5 and CaO in the leach solutions.

Increasing solids concentration revealed however that copper could be leached selectively, so that levels of this metal in solution far exceeded those of iron, manganese and zinc.

10. Feasibility Studies

The evaluation and economic potential of the copper ore deposits in Wadi Araba were carried out several times. In 1975 and 1993 BRGM performed an overall economic study of the copper deposits in Wadi Araba. Vannessa Ventures Ltd Company (VVL) in conjunction with AYA Multi-Investments Ltd Company (AYA) in 2004 examined and assessed the economic potential of the Wadi Jariya copper deposit.

10.1. Evaluation of Feinan Copper Deposits By BRGM (1976)

10.1.1. Methods in Treatment and Production

Three options were developed and summarized hereunder:

Option No.1

The object of a complete feasibility study as:
1) 1.1 million tons of dry ore treated yearly, producing copper cement containing 80% Cu.

2) 10,120 tons of copper produced per year

3) Lifetime of the working is 15 years.

Option No.2

Same as option 1, except for a production of cathodes instead of cement. 10,187 tons of copper would be produced yearly with a slight increase in the recovery.

Option No.3

This option dealt with dimension of basic plant, it is the same as option 2, but with a 4 times larger capacity, that is:

1) 4.4 million tons of dry ore treated yearly.

2) Cathodes production is 40,748 tons of copper per year.

3) Lifetime of the working is 15 years.

10.2. Operating Costs and Replacements

The overall of the total operating costs and replacements are summarized in Table 11.

Table (11): Costs of the operating process and replacements of the Feinan copper ore.

Variables	**Yearly Expenses (J.D)**
Mining extraction	1,316,400
Metallurgical treatment & transport	1,797,677
Overhead expenses (local)	181,353
Town site	291,872
Sub-total	3,587,300
Overhead expenses of registered office& management (5%)	179,365
Total operating cost	3,766,665
Replacement (yearly average value) Mine	249,951
Replacement (yearly average value) Others	21,333
Total Replacement	271,284
Total operating costs& replacements	4,037,949

10.3. Evaluation of Wadi Araba Copper Ore By BRGM (1993)

10.3.1. Capital and Operating Costs

Table (12): Summery of Capital & Operating Costs of Wadi Araba Copper Ore.

Items	2.5 Mt/y Capacity		5 Mt/y Capacity		10 Mt/y Capacity	
	Capital Cost 000 JD	Operating Cost 000JD	Capital Cost 000 JD	Operating Cost 000JD	Capital Cost 000 JD	Operating Cost 000JD
Mine Capital & Operating Costs	40350	4748	80700	9496	161400	18992
Processing	34438	12635	54927	24116	89850	46691
Personnel		2807		4171		6184
Infrastructure	14339	506	20869	814	31335	1301
Utilities	1745	4065	2647	7650	3457	14340
Pre-operating Costs	7019		12951		24213	
Grand Total	90872	24761	159144	46247	286042	87509
Operating Cost		9.9		9.2		8.8
Break even cost per milled ton	13.5		12.4		11.6	

10.4. Vannessa Ventures Ltd Conjunction with Aya Multi-Investments Ltd 2004

10.4.1. Financial Model of Khirbet EL Nahas / Jariya Project

Vannessa Ventures Limited prepared a financial model in Khirbet EL Nahas / Wadi EL Jariya which is sensitive to the following parameters:

Price of copper
Mill head grade
Recovery
Lesser extend to the inflation rate
Operation and capital costs

The basic parameters entered to the financial model are the following:

Reserves: 20.0 million ton @ 2.5%Cu
Production Rate: 3,000 **ton /day @ 2.5%** Cu
Dilution 25% @ 0.0% Cu/ton (built-in)
Mill Recovery: 80%
Copper Price: $US 1.20/Lb Cu
Operating Costs: $US 33.03/ton
Capital Costs: $US 130 million
Inflation Rate (Metal Price Appreciation): 1% p.a.
Inflation Rate (Capital & Operating Cost Appreciation): 2.14% (average) p.a.
Exchange Rate CAD/USD: 1.38

11. Domestic Production and Use

U.S. mine production of copper in 2013 increased by 4% to about 1.22 million tons, and was valued at about $9 billion. Arizona, Utah, New Mexico, Nevada, and Montana—in descending order of production—accounted for more than 99% of domestic mine production; copper also was recovered in Idaho and Missouri. Twenty-seven mines recovered copper, 18 of which accounted for about 99% of production. Three primary smelters, 3 electrolytic and 4 fire refineries, and 15 electrowinning facilities operated during 2013. Copper and copper alloys products were used in building construction, 44%; electric and electronic products, 20%; transportation equipment, 17%; consumer and general products, 12%; and industrial machinery and equipment, 7%.1

Events, Trends and Issues

Copper prices have behaved somewhat erratically after last year's record average of US$399 ¢/lb., the highest since 1966 and the second-highest since 1935. Prices averaged US$343.3 ¢/lb. in December 2011, climbed back up to US$383.6 ¢/lb. in March, then slid to US$336.6 ¢/lb. in June, driven by the inauspicious state of the global economy.

Long-term copper prices are determined by the fundamentals of supply and demand. Shortterm, however, they are driven by financial, market, and other variables. These were key in driving prices down in May and August, then back up in September.

World Resources: A 1998 USGS assessment estimated 550 million tons of copper contained in identified and undiscovered resources in the United States.9 Subsequent USGS reports estimated 1.3 billion tons and 196 million tons of copper in the Andes Mountains of South America and in Mexico, respectively, contained in identified, mined, and undiscovered resources.10, 11A preliminary assessment indicates that global land-based resources exceed 3 billion tons. Deep-sea nodules and submarine massive sulfides are unconventional copper resources.
World Mine Production and Reserves: The reserve estimate for Peru was revised downward to reflect official reported numbers.

Table (13): World mine production and reserves of copper (USGS, 2012).

Country	Mine production		*Reserve base
	2012	2013	
United States	1,170	1,220	39,000
Australia	958	990	87,000
Canada	579	630	10,000
Chile	5,430	5,700	190,000
China	1.630	1.650	30,000
Congo (Kinshasa)	600	900	28.000
Indonesia	360	380	7,000
Kazakhstan	424	440	70,000
Mexico	440	480	26,000
Peru	1.300	1,300	60,000
Poland	427	430	48,000
Russia	883	930	30,000
Zambia	690	830	20,000
Other countries	2000	2000	90,000
World total (rounded)	16,900	17,900	690,000

*Reserve Base— that part of an identified resource that meets specified minimum physical and chemical

Criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated). e :estimated.

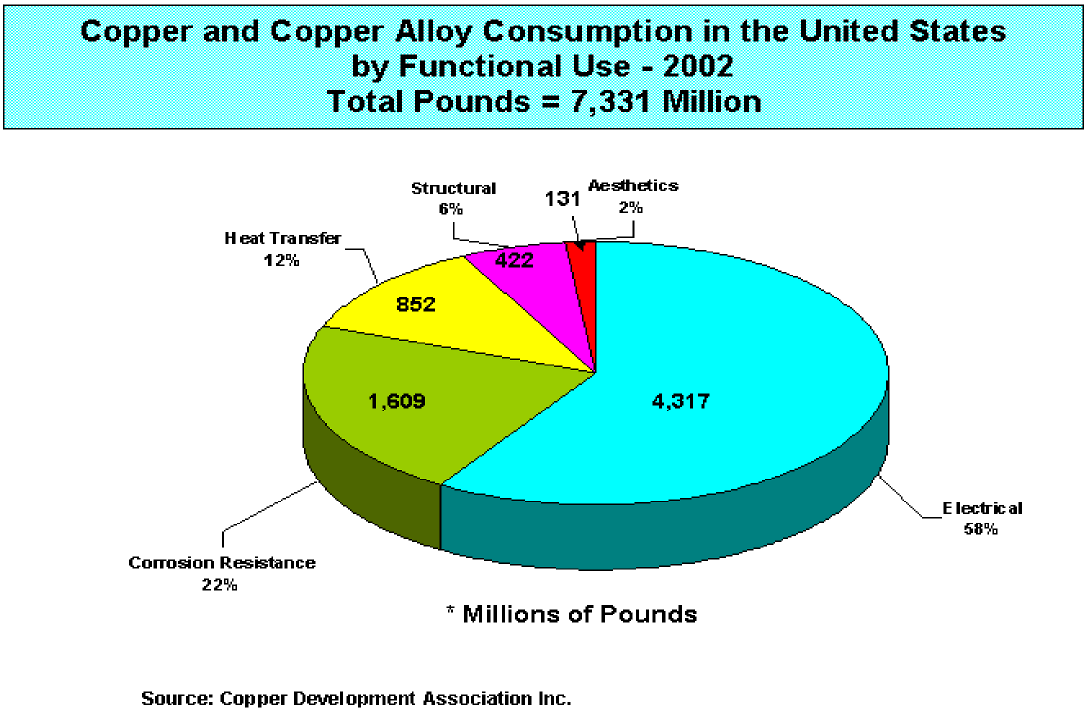

Figure (4): Copper and copper alloy consumption in the United States (USGS, 2005).

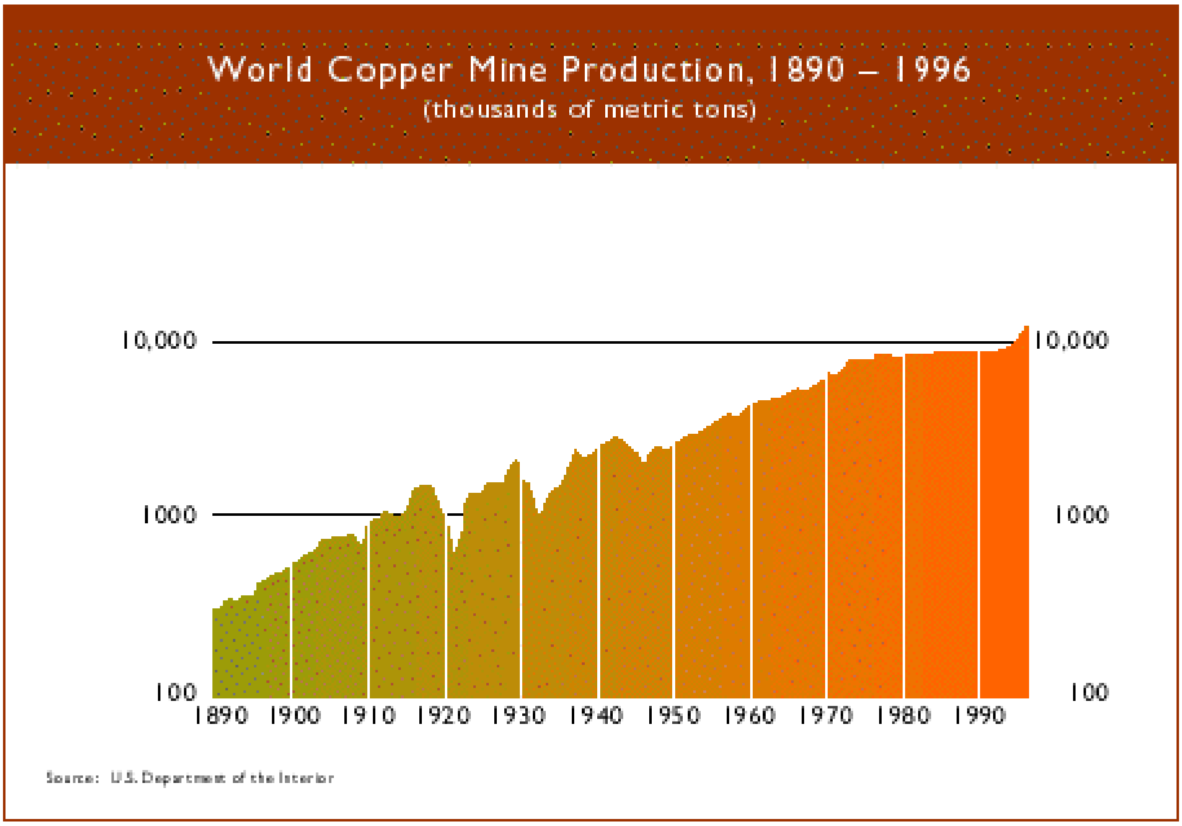

Figure (5): World copper mine production (USGS, 2005).

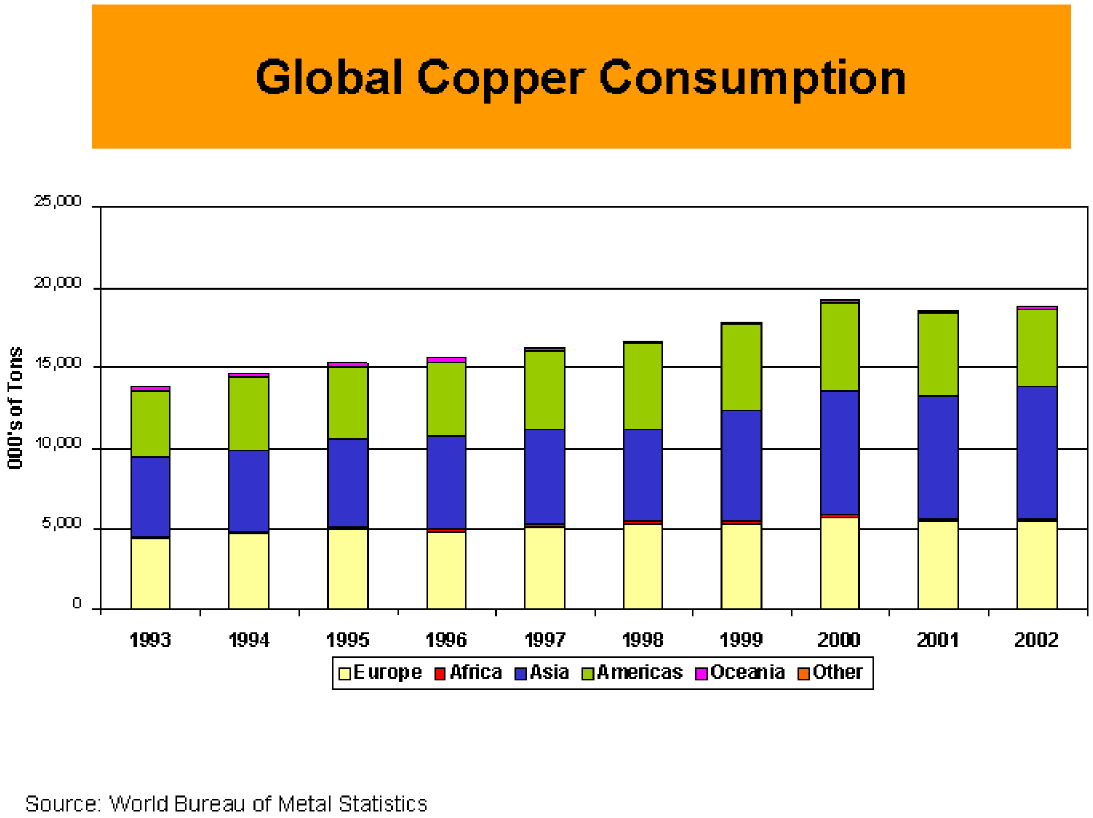

Figure (6): Global copper consumption (USGS, 2005).

Locally Status

No mining activities for copper, because the main localities of copper ore deposits occurred within the Dana Nature Reserve. Jordan import copper from different countries such as china Australia and Canada.

12. Conclusions

The conclusions can be summarized in the following points:

The copper mineralization was found in three different lithologies: in the sandstone sub-member, the copper mineralization occurred as cement for the quartz and feldspar grains. The main gangue minerals are quartz, k-feldspar, apatite and illite. In the shale sub-member, the mineralization occurs as cavity fillings and also some layering along the bedding planes. In the dolomite unit mineralization occurred only as cavity filling along fractures and pores in the rock.

The mineralogical studies revealed that it would be very difficult to physically liberate copper minerals from the gangue materials because of the textures and mineralogy.

The explorations in Khirbet El Nahas area indicated that the Hannah Member (lower horizon) which hosts most of the copper mineralization in the studied area with an average thickness of 2.5 m. The average copper grade is apparently higher than that found in Feinan area. The mineralized horizons were developed over large area and open-ended to the N-NW. Due to the limited outcrops, the sampling density was insufficient to establish large scale distribution trends of the copper ores.

As observed from the results of the metallurgical studies, the orthophosphoric acid is efficient as sulphuric acid in its ability to extract copper from sandstone and shale sub-members. This solvent differs however from sulphuric acid when the shale sub-member samples are considered. Treatment of the shale sub-member with sulphuric acid results in the extraction of copper, formation of gypsum with increase in bulk of the residue and production of mixed sulphuric/phosphoric acid leach solutions. Similar tests performed with orthophosphoric acid and the shale sub-member results in the extraction of copper, decrease in bulk of the residue, but dissolution of calcium phosphate. Orthophosphoric acid leaching would thus appear to be more attractive except that considerable calcium is reported to solution. A number of tests were therefore initiated to investigate calcium removal in the form of calcium sulphate (gypsum) by selective precipitation with sulphuric acid.

Long wall extraction with back filling is considered to be the ideal mine for extracting the copper ore as mentioned by BRGM studies.

The current situation of the main localities of copper ore deposits in Wadi Araba showing that the Abu Khusheiba and Umm El Amad are occurred out side of the Dana Nature Reserve, while Feinan and Khirbet El Nahas areas are occurred within the Dana Nature Reserve.

13. Recommendations

BRGM, 1976 and 1993 suggested extending the copper exploration to the new areas to find additional reserves and they highly recommend Khirbet El Nahas area as a promising area.

Geological continuity of the copper ores could be assessed through a few widely spaced drill boreholes and trenches owing to the fact that drilling on the adjacent area has showed the development of the Hanna member to be relatively consistent over large areas.

Drilled 6-8 boreholes, digging 8-10 pits to depth about 7 meters and 4-6 trenches in Khirbet El Nahas area (Jabal Marzuqa) to follw up the mineralized horizon.

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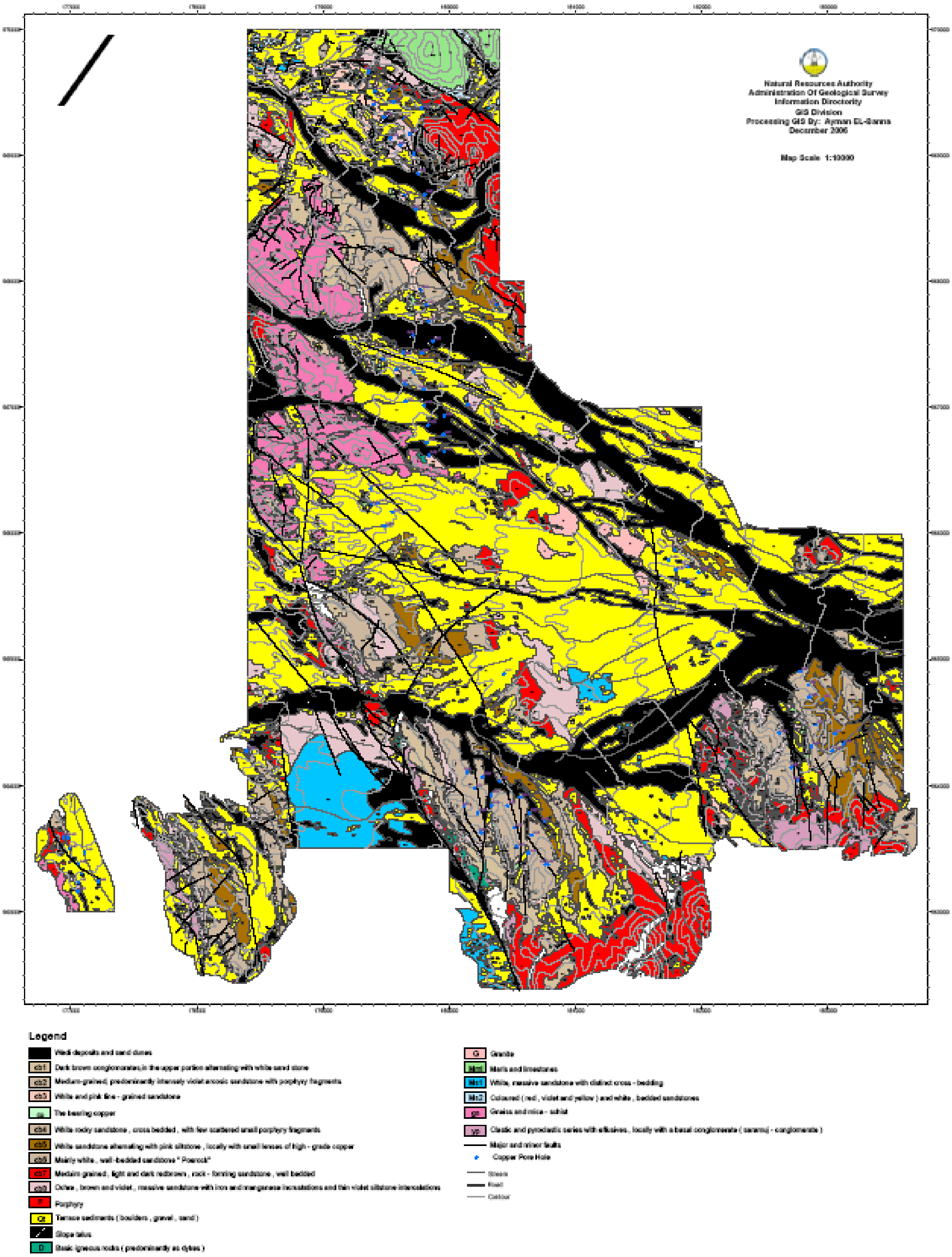
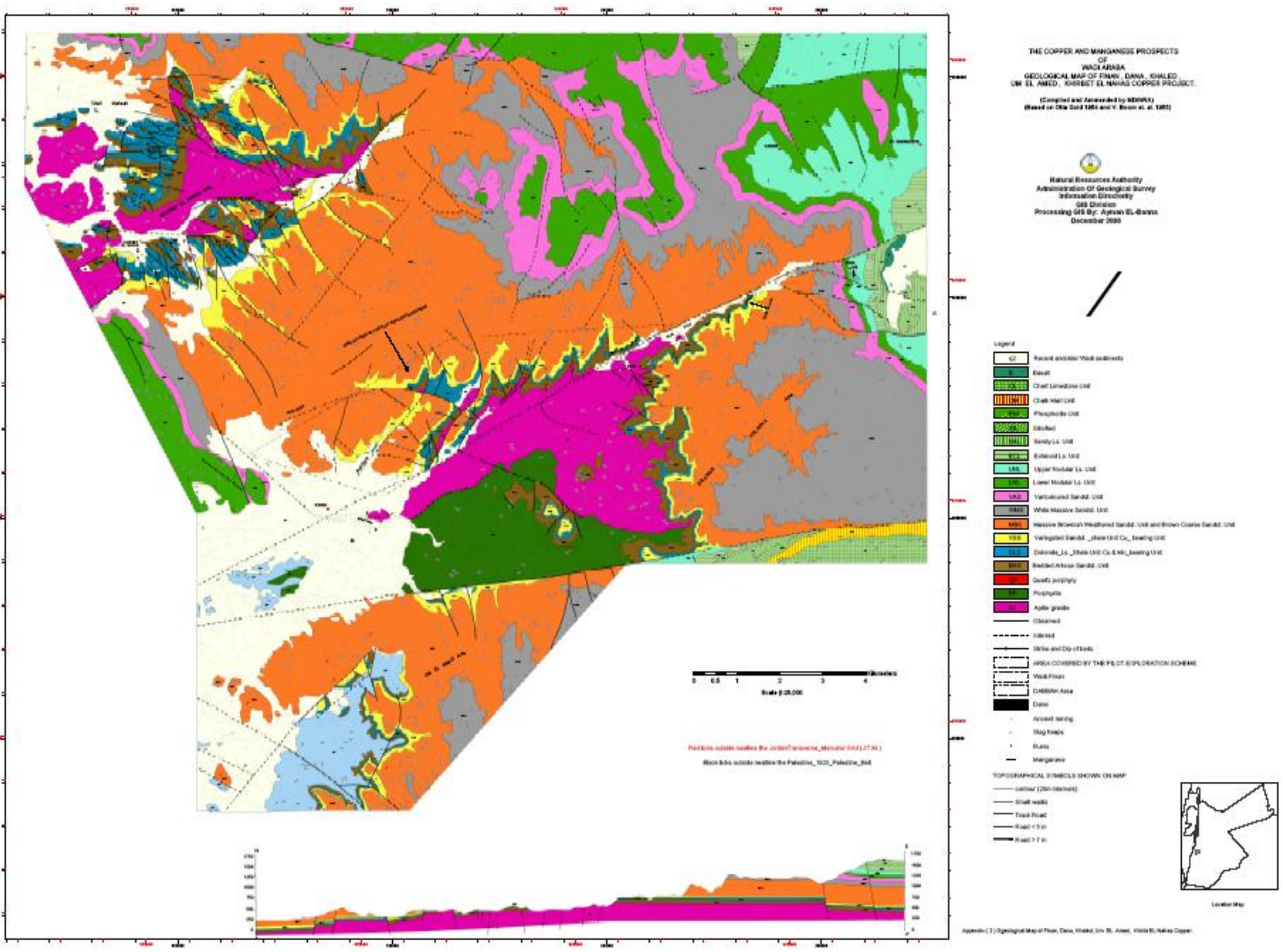
Appendices

Appendix (1): Geological map of Abu Khusheiba area.
Appendix (2): Geological map of Feinan, Dana, Wadi Khalid, Umm El Amad and Khirbat El Nahas Copper.

Appendix (1): Geological Map Of Abu_Khushiba Area




THE COPPER AND MANGANESE PROSPECTS
OF
WADI ARABA
GEOLOGICAL MAP OF FINAN , DANA , KHALED ,
UM EL AMED , KHIRBET EL NAHAS COPPER PROJECT.
Natural Resources Authority
Administration Of Geological Survey
Information Directority
GIS Division
Processing GIS By: Ayman EL-Banna
December 2005
Legend
Basalt
Chert Limestone Unit
Chalk Marl Unit
Phosphorite Unit
Silicified
Sandy Ls. Unit
Upper Nodular Ls. Unit
Lower Nodular Ls. Unit
Varicoloured Sandst. Unit
White Massive Sandst. Unit
Massive Brownish Weathered Sandst. Unit and Brown Coarse Sandst. Unit
Variegated Sandst. _shale Unit Cu_ bearing Unit
Dolomite_Ls._Shale Unit Cu & Mn_bearing Unit
Bedded Arkose Sandst. Unit
Quartz porphyry
Porphyrite
Aplite granite
Observed
Inferred
Strike and Dip of beds
AREA COVERED BY THE PILOT EXPLORATION SCHEME
Wadi Finan
DABBAH Area
Dams
Ancient mining
Slag heaps
Ruins
Manganese
TOPOGRAPHICAL SYMBOLS SHOWN ON MAP
Track Road
Road < 5 m
Road > 7 m
Location Map
Appendix (3) Geological Map of Finan, Dana, Khaled, Um EL Amed, Khirbit EL Nahas Copper