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Geological and Geochemical Investigation of Host Rocks of Ni-Cu in Suwar Area North Western Yemen

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ABSTRACT

The Suwar Ni-Cu sulfide host rocks are located at the northwest of Yemen, about 18 km of Hajjah city. The host rocks at Suwar are associated with the ultramafic component of differentiated gabbroid intrusive.

The results of chemical analysis of the major elements present in host rocks of Ni-Cu in Suwar area shows that, the magnesium oxide ranges from 20 to 30% , the silica oxide has an average 40% and iron oxids is also variegate between 14.4 and 18%.

Based on the comparison between the results of the studied Ni-Cu sulfides in Suwar area with that obtained from famous international host rock, it is clear that there is a possible large collection of sulfides and Suwar host rocks which belong to the group which contains magnesium oxide (MgO) ranged between 15 and 33%, associated with high percentage of nickel and low percentage of copper. It also indicates similarity to Jinchuan and Kambalda magmatic bodies in China and Australia respectively. In addition, it shows that the nickel increases in ore with the increase of MgO contents in hosted rocks. Thus, there is a possibility of increasing percentage of nickel concentration in Suwar ore while the study is in progress.

Keywords: Suwar, North Western Yemen, Geochemical analysis, Nickel, Cupper Magnesium oxide and Host rock.

INTRODUCTION

Nickel and copper ores play an important role in the industry because of their multi-usage in different types of alloys. The Suwar Ni-Cu sulfide ores are hosted in ultramafic body located at the southeast of Hajjah city as shown in Fig. (1). The Suwar gabbroid body and its mineralized ultramafic zone are exposed over a length of about 6 km and a maximum width of 2,5 km (Shybani, 2003). Suwar mineralization is exposed on the surface with the chain of gossans shape, which formed in extent that expands about 3 km in the northeast side parallel to the main fault direction.

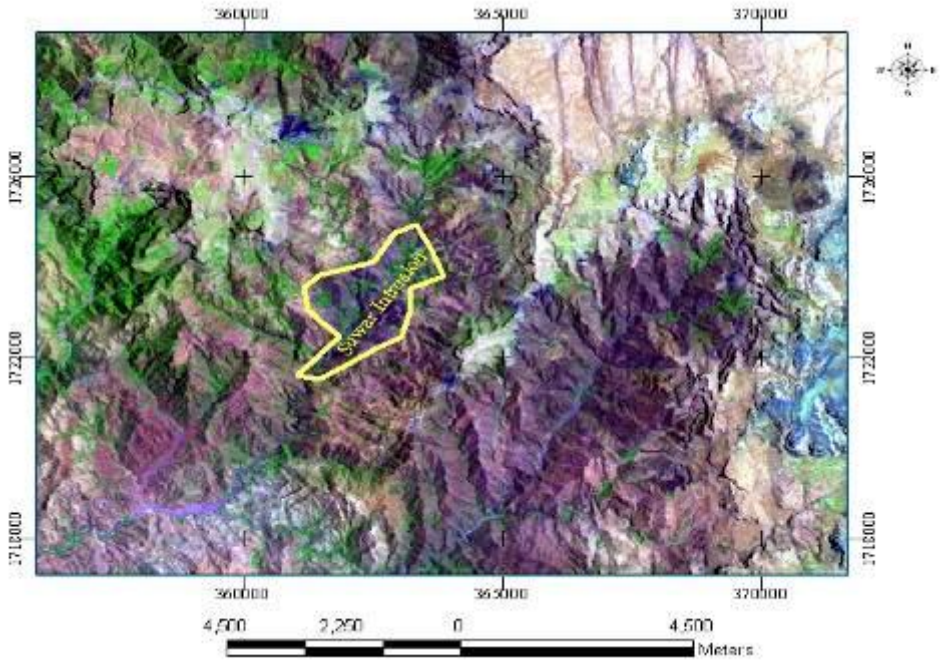


Figure (1): Location map (Landsat-7) of Suwar area

The Ni-Cu showings are located is a lower proterozoic package of mafic rocks intruding a foliated to gneissic dioritic meta-igneous complex. The showings were discovered within an ultramafic complex consisting of peridotite, pyroxenite, gabbro, diorite and minor anorthosite (Ogryzlo, 1997). The showings are easily identified by malachite staining in the mafic and ultramafic rocks. Gossan zone is prominent and is used as a guide for mineralization.

The geology and Ni-Cu sulfide mineralization of Suwar ore body have been documented and this magmatic is considered to be ultramafic related, based on the mineralogic characteristics of the host rocks.

A correlation is carried out between Suwar magmatic body in the study area and the similar Ni and Cu host rocks of famous areas all over the world for defining the geological and geochemical properties of host rock in the study area.

The host rocks of the Ni and Cu ores are subdivided into three groups according to their thickness, areal extent and the concentration of MgO and nickel-copper. Consequently, it was concluded that, the larger one of the differentiated magmatic body was, the more were the possibilities of sulfides of nickel and copper concentration.

Magmatic size bodies fit with the power quality of these bodies as Smirnov (1981) pointed out that energy sources are essential issues in ore formation theory. Magmatic formations associated with sulfides nickel and copper are changing in content from gabbro-dolerite, as Noril'sk deposits in Russia (Borodabeavskaya 1987) to gabbro-troctalite, as

Duluth deposits in United States (Ripley 1981) and to pyroxenite – peridotite –dunite, as Kambalda deposits in Australia (Naldrett, et al, 1977), Jinchuan deposits in China (Chai, et al, 1992) and Suwar deposits in Yemen (Ogryzol,1998). This change is identical to MgO content which takes the percentage from 8-15% in the former areas to 15-33% in the later areas, as mentioned above. Thus, it's observed that there is a clear relationship between mafic coefficient in magmatic rocks and elements percentage of Ni/Cu in ores.

METHODOLOGY

The methods of study include:

1- The field work was carried out and collecting four representative samples of host rocks of nickel and copper in Suwar magmatic body .
2- The laboratory work was carried out for the chemical analysis of the four samples to determine the major oxides contents as SiO2, MgO, total iron oxids etc. The chemical analysis was carried out using Perkin Elmer atomic absorption instrument. It was carried by preparing a solution from the rock powder after burning it at temperature up to 1000°C and then the burned samples were digested with nitric acid and filtrated through filter paper to produce the soultion.

Geological setting

The Suwar Ni-Cu ore occur in the area covering a part of the Proterozoic basement rocks exposed by the headwater of the local Wadi system.

The Precambrian basement of the northwestern part of Yemen is an extension of the Arabian shield to the north and is petrogenetically similar to accreted oceanic arc terrains constituting the Nabitah orogenic mobile belt (Shybani et al, 1997, Canadian, 2000). The Nabitah suture zone may extend to Hajjah in northwest Yemen, as indicated by the presence of deformed ophiolites (Canadian, 2000). The Precambrian basement rocks of northern Yemen are Late Proterozoic in age and they consist the north to northwest trending belts and composed of metavolcanic and metasedimentary rocks, intruded by granitic and granodioritic plutons

The Proterozoic rocks in this area are mostly medium to coarse grained, granitic gneisses, which are extensively faulted and intruded by diabase dykes characterized by steeply dipping northeasterly trending foliation predominates. The gabbroic body intrudes into granitic gneiss and magmatic country rocks (Fig.2 and 3). The Precambrian rocks of study area are overlapped uncomfortably by relatively thin sequences of continental to epicontinental sediments. The flat lying Paleozoic and Jurassic sediments, which cover much of the northern part of the area, including the Permian Akbara shale, which consists mainly shale and siltstone. The Jurassic sediments composed of the Kohlan sandstone and the Amran limestone.

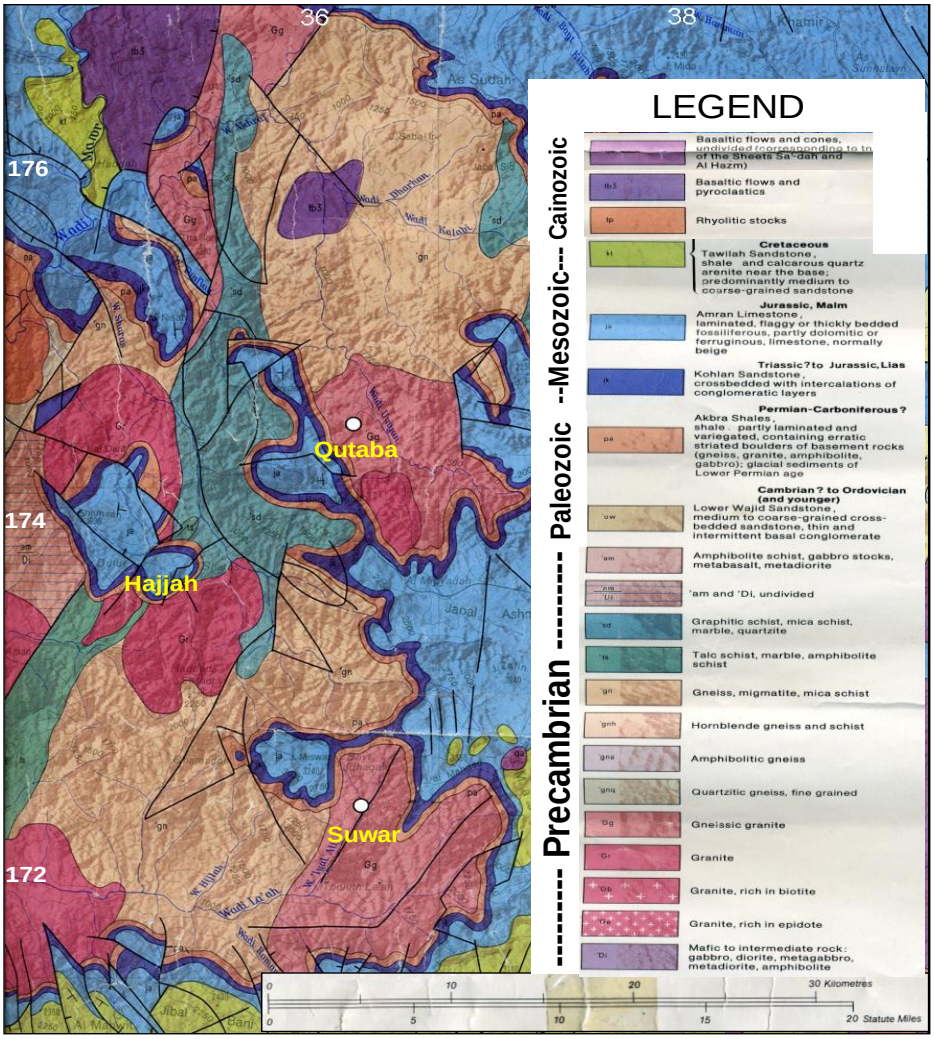


Figure (2): Geological map of the Hajjah region, showing the studied locality of Suwar, southeast of Hajjah City. The map is adapted from the geological map of Al-Hudaydah sheet, prepared by Kruck (1984).

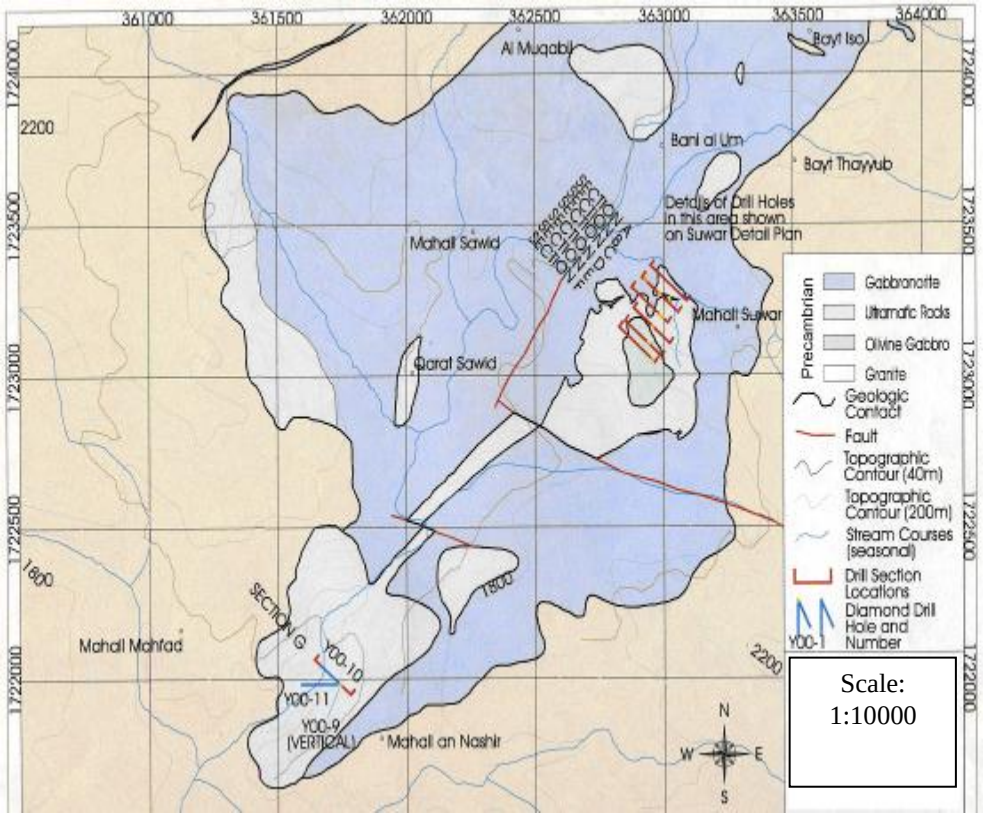


Figure (3): Preliminary geology, Suwar area showing all drill hole locations. Prepared by Canadian Mountain Minerals Yemen LTD.

Geological and Geochemical Characteristics of the Suwar Ore

Sulfide deposits of nickel and copper form a particular group for metallic ore magma. There are lots of huge host rocks in some parts of the world; so these elements in particular play an important role in the economical life. The most important areas are old shields such as Canadian shield (Naldrett, 1986), Australian shield (Ross et al, 1981) and the active platforms, which share the appearance of the magmatic trap in some districts as Noril'sk in Russia (Genkin et al, 1973) and Ensizwa in South Africa (Stump et al, 1982).

Group of magmatic rocks, which hosted nickel and copper ore deposits of variegated ages occurred in different parts of the world are characterized by some identical features like mineralogy and chemical constituent of the hosted rocks and ores. This indicates the existence of one particular type system in the formation and generation of magmatic-hosted nickel. The noticed difference may be as a result of erosion level and the variegated percentage of coming, also nickel concentrations and the productive of ore magmatic bodies. As supported by Smirnov, 1982 who pointed out the magmatic processes and their relation in formation of nickel and copper are similar in all metalugentic epoch from Archaean to Cainozoic.

Nickel and copper Sulfides originated from magma chamber where they are concentrated are mainly related to the fractionation and the gradual melting of the sulfide-bearing magma, which approach in its constituent from chondrite and pyrolite. When the mantle substance melts, it results in the different magmatic material and ore-bearing magma (Lekachev, 1973). The percentage of sulfides in the primitive mantle derived magma substance is not much and approaches less than 1%; so the sulfides concentrate in the parts which have been already influenced by primary melting and getting out the magmatic products which are free of sulfides or sulfides-poor magma (Godlevski, 1968). This means the movement of sulfides-bearing magma are preceded by getting out high of magmatic materials free or poor percentage of sulfides.

The geochemical characteristics of nickel and copper are not identical and the largest nickel percentage is present in the ultrabasic and is 35 times more than in the general percentage in clarke (Salobeb, 1990). For the copper, its largest percentage is present in the basic and intermediate rocks; so it is noticed that the nickel percentage is larger than the copper in the basic rocks (Salobeb, 1990).

For comparing and getting more geological and geochemical characteristics in the mineralization of nickel and copper in Suwar district with the similar and famous mineralization in the world, the researcher has gathered and interpreted some information about many host rocks in the world and this information included standardizations like: thickness and extent of the hosted rocks mineralization, mineralogic composition, the change in MgO concentrations in the hosted rocks and its relation to the concentration of nickel and copper. Accordingly, based on the previous parameters nickel and copper host rocks have been divided into three groups

Group I

This group is characterized by huge intrusive bodies of 1000m thickness and extends to more than 10000m. They are composed of intermediate and basic rocks, and characterized also, by very high degree of secondary changes and recomposition, and may not be involved in the process of auto-metamorphism. The present ore bodies have different forms like veins, layering, and lens. The essential minerals include variegated quantity pyrhotite, pentlandite and chalcopyrite (Makarov, 1989).

Group II

Group II host rock is smaller than the former one and has dimensions ranged from 150 to 700 m thick and length extension ranges between 500 and 8000 m. This group is characterized by complicated differentiation for the magmatic bodies which are basic and ultrabasic. The intrusive ore bodies of this group exposed to the secondary changes more than group I. Parts of this group's bodies are exposed to auto-metamorphism, such serpentinization (Makarov, 1989). Moreover, the ore body is found in different forms such as layering and lens. Mineralogically they are composed of chalcopyrite, pentlandite and pyrhotite, the relation between these minerals is that they are swaged in a large scope.

Group III

The size of the magmatic bodies of this group is less than 100m, it includes metamorphism and the differentiated magamtic bodies which composed of basic and ultrabasic rocks. Nevertheless, the rule of differentiation process in this group is not important because of the

small size of the differentiated bodies. Also the magamtic bodies in this group in particular have large product of ore. The ore body morphology is different, even in the same area, and has different shapes as layering, lens and veins. Ore mineral composition is similar to group I and II, the basic minerals show greater variation in their distribution. In some ores, Pyrite is found as a main mineral, which gets a percentage of 16% (Abdo, 1992).

In the study area Suwar gabbroid and its contained mineralized, ultramafic zone is exposed over a length about 6 Km and width of 2000 m (Shybani, 2003), (Fig.1). The ultramafic rock, exhibits extensive metasomatism, but little metamorphism, being consistent with intrusion at a late or post tectonic stage. The complex body has been subjected to at least one generation of flattening and diabase intrusion. The geological setting of the study area is confirmed as a broadly differentiated basic to ultrabasic intrusive host, this compares favorably in size and character to the several mines and host rocks which are commonly identified as "gabbroid type" as described by Ogryzlo, 1997. The immediate host lithology is usually ultramafic zones associated with a large noritic gabbroid body. Nickel deposits associated with this geological environment constitutes the major, high-grade source of world's nickel (Ross and Travis, 1981).

Accordingly, Suwar host rock belongs to the Group I in extension and thickness. And we notice also that there is a huge approximation in the size of these magmatic bodies that hosted Ni-Cu in Jinchuan intrusions in China where it is 8 km long and about 1000 m in wide (Jia,1986) and Suwar intrusions which are 6 km long and 2000 m wide (Shybani, 2003).

The geochemical characteristics of nickel and copper host rocks are highly variegated as in the following.

The highest nickel content is present in the ultrabasic rocks and is 35 times more than that in the general percentage in Clarke (Salobeb, 1990). For the copper, its highest concentration occurred in the basic and intermediate rocks; so it is noticed that the nickel concentration is higher than the copper in the basic rocks (Salobeb, 1990).

According to the concentration of MgO and its relation ln Ni/Cu. Magmatic rocks, which hosted nickel and copper, are divided into three groups (Abdo, 1992).

These groups are:

I- Mafic rocks with less than 8% MgO and associated with iron and titanium ores

II- Mesomafic rocks. (komatiite) contain MgO ranging from 8 to 33% with nickelefereous magma that characterized by continental magmatic rocks (Borodabeavskaya, 1987).

Mesomafic rocks can be divided into three classes according to the concentration of magnesium and percentage of both nickel and copper:

Class 1: Rocks have Low percentage of magnesium (MgO 8-10%), contain high grade of copper comparing to nickel (Ni: Cu=1:2-4) (Abdo,1992) like Duluth host rock in United States and Kurissk deposit in Cibirc platform (Ripley, 1981 and Borodabeavskaya, 1987).

Class 2: In which MgO content is ranged from 10 to 15% and middle grade of nickel to copper (Ni: Cu=1:1-2) like Naril'sk deposit in Russia (Genkin et. al, 1973).

Class 3: Magnesium concentration variegated between 15 and 33% which is Characterized by high grade of nickel and low grade copper (Ni: Cu=1-10:1) like Kambalda deposit in Australia, Sudbury and Mont Calm deposits in Canada, and Jinchuan deposit in China (Naldrett et al, 1977, Ross et al, 1981, Naldrett, 1989, and Chai, et al,1992).

III- Ultramafic rocks. In which MgO content rich to more than 33% and have high content of silicate, chromites and platinum (Campbell et al, 1984).

The primary sulfide mineralization at Suwar area is composed essentially of pyrhotite, pentlandite and chalcopyrite. Both magnetic (hexagonal) and non-magnetic (orthorhombic) pyrhotite appear to be present in the study area (Canadian, 2000).

The major and trace elements distribution of four rocks samples studied from Suwar host rocks are shown in Table (1)

Table (1): Major and trace elements distribution of the studied samples from Suwar area.

Sample No.	Ca O%	MgO%	SiO_2%	Fe_2O_3%	Al_2O_3%	P_2O_3%	TIO_2	MnO%	Na_2O%	K_2O	LOI	Ni %	Cu %	Ni/Cu ratio	Co%	Ag gm \ton
SR-1	5.19	20.54	45.69	14.40	9.66	0.04	0.53	0.21	1.75	0.25	1.83	0.93	0.367	31	0.044	0.49
SR-2	1.74	30.63	35.39	17.93	3.71	0.04	0.42	0.22	0.76	0.10	9.40	2.03	0.350	6.71	0.095	0.88
SR-3	3.36	24.79	38.55	14.81	7.67	0.05	0.57	0.18	1.29	0.12	8.76	1.36	0.730	21	0.384	2.17
SR-4	3.80	22.50	40.30	14.61	8.21	0.05	0.53	0.21	1.70	0.20	7.9	1.08	0.470	2.31	0.190	3.16
average	3.5	24.6	40	15.4	7.3	0.05	0.51	0.21	1.38	0.17	6.97	1.35	0.479		0.18	1.68

The results of chemical analyses of host rocks of Ni-Cu in the Suwar area indicated that concentration of MgO is variegated from 20.5 to 30.63 % with an average of 24.6 %, while the average of silica oxide concentration is 40% associated with total iron oxide ranges from 14.4 to 17.93 % with an average of 15.4% as shown in Table (1). These results indicate that Suwar host rocks belong to mesomafic rocks. So host rocks of Ni-Cu in Suwar area belong to the group which contains percentage of MgO of 15-33% and they have a high grade of Ni which is ranged between 0.93 and 2.03 % with an average of 1.35 % and low grade of Cu its concentration is variegated from 0.35 % to 0.73 % with an average value o.479% such as host rocks of Kambalda in Australia and that of Jinchuan in China (Naldrett et al, 1977, Jia, 1986).

The relationship between Ln (Ni/Cu) and percentage MgO is shown in figure (4). The huge change of values of certain relations Ni/Cu and the possibilities of changing the

statistic of distribution from the natural value. Therefore, values of natural logarithms are used in analyzing concentration of elements Ni/Cu. So the process of analyzing for relations isn't simple because the available information in the literature give us contents of elements which are often considered to be changing values such as deposit of Sudbury. It is shown in figure (4) that the values have a linear relationship with the formula: LnNi/Cu=o.143 MgO- 1.722. Using the formula, we can predict the relation of Ni/Cu from concentration of MgO in rocks. As shown in figure (4) and formula refers to increasing of nickel in ore with the increasing of percentage of MgO in rocks. The calculated Ni content of the ore shows excellent linear relation with MgO%. These are typical features of magmatic Ni deposits (Naldrett, 1989). The position of values in the figure generally confirms with linear relation for Ln Ni/Cu- MgO. The measured values of Ni content as shown in Table (1) and figure (4) show that the Suwar host rocks is identical to host rocks of Kambalda, Petchenge and Jinchuan.

The AFM ternary diagram (fig.5) of the selected samples shows that the host rocks of Ni-Cu are mesomafic to ultramafic. The total alkali-silica classification diagram (fig.6) shows that the studied host rocks of Ni-Cu of Suwar area are basaltoid.

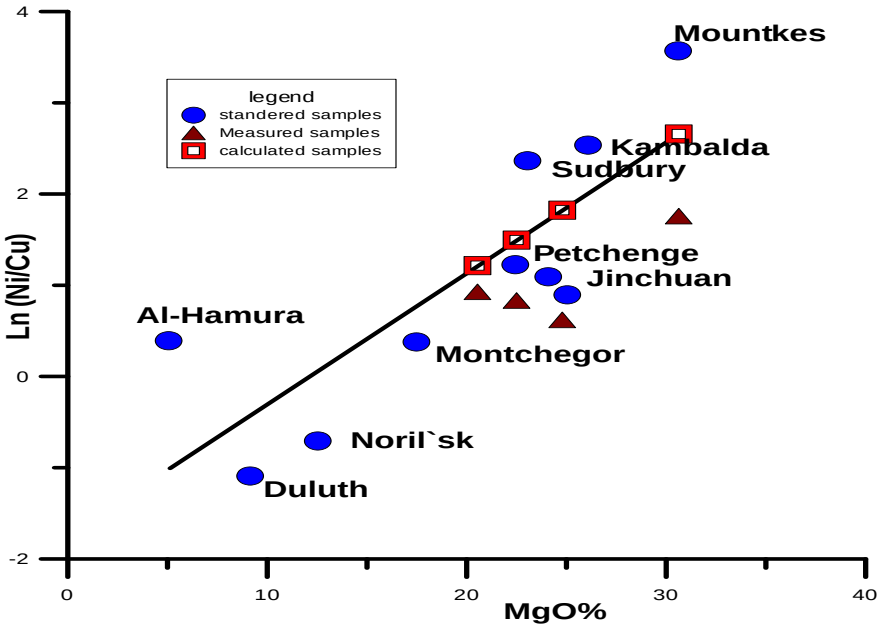


Figure (4): Relationship between MgO % and lin (Ni/Cu)

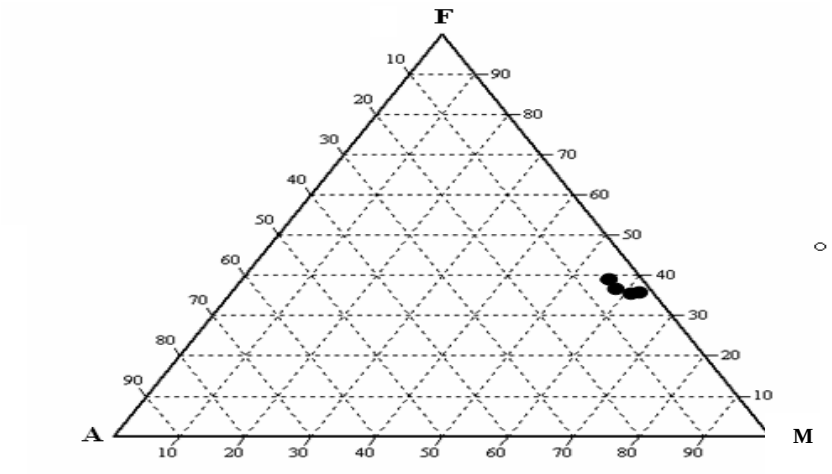
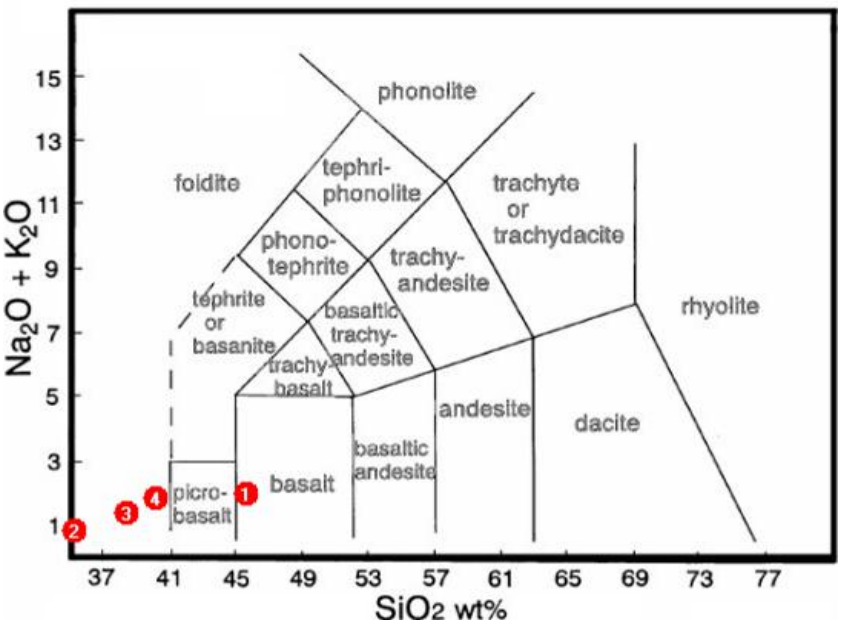


Figure (5): AFM Ternary diagram showing the composition of the host rocks of Ni-Cu from the Suwar area. A=Na_2O+K_2o F=Fe O+Fe_2O_3 and M=M gO IUGS (Le Bas et al, 1986)



Figure(6): Total alkali-silica classification diagram after IUGS (Le Bas et al.1986) showing the basaltoid composition of the host rocks of Ni-Cu.

DISCUSSION

There is a possibility of ores concentration in huge intrusive bodies in crystallization area due to the huge size of these bodies in which a temperature dramatically decreases and variegated. Thus, result in possibility of gathering and concentrating of sulfides.

Geochemical study of major and trace elements of the Suwar intrusion as previously mentioned indicates that the primary magma for the Suwar intrusion which have high MgO content variegated from 20 to 30% is a basaltic magma and that the Ni : Cu ratios in Suwar mineralization is variegated also between 1.86: 1 and 5.8 :1 which is comparable to the magma of Jinchuan complex (Chai, et al, 1992) and the magma of Kambalda complex in Western Australia (Naldrett, et. al, 1977).

The percentage of nickel content in Suwar ore, increase with the increasing of MgO percentage in hosted rocks.

The chemical analysis of hosted rocks of Ni-Cu in Suwar area show that the percent of silica variegated from 35% to 45% with an average 40% and refers to the ultramafic rocks .The percentages of magnesium, iron and calcium oxides refer to the presence of olivine and pyroxene minerals.

Platinum group elements mineralization is always associated with sulfide ores (Naldrett et al, 1989). Naldrett (1981) has indicated that sulfides associated with ultramafic komatiites, which have been crystallized from magmas containing more than 20% MgO, have a platinum group element. In addition to the basic element Ni-Cu in Suwar magma focus should be made on the associated elements like cobalt and platinum group elements and those are found in Jinchuan magmatic bodies (China) and in the host rock that include a high percentage of MgO ,and these elements are extracted during the process of basic elements extraction.

The characteristics of the nickel-copper sulfide mineralization and its host rocks at Suwar, are associated with the ultramafic component of large differentiated, noritic, gabbroid intrusive. Well documented mines and deposits of this type are the Jinchuan mine in China (Chai and Naldrett, 1992b) and Kambalda deposits in Western Australia (Naldrett, et.al, 1977).

Major characteristics of this type of deposit are:

1-Majority of the sulfides is massive pyrhotite, pentlandite and chalcopyrite.

2-The sulfides are closely associated with ultramafic sections of the Intrusive usually within the ultramafic rock.

3-It contains magnesium oxide with percentage of (20-30%).

4-The main sulfides are concentrated with the host ultramafic rocks in structural traps.

CONCLUSIONS

Through geological and geochemical study of host rocks of Ni-Cu in Suwar, we got these results:

1-The deposits of nickel and copper are similar in some features for mineral and chemical composition for ore.

2-In the huge and differentiated magmatic bodies, there is possibility of concentration ores directly in crystallization area when temperature gets down.

3-The host magmatic rocks for Ni-Cu which contains the percentage (MgO 15-33%) have a high grade of Ni and a low grade of Cu.

4-The results of chemical analysis for host rocks of Ni-Cu in Suwar area showed that they contain (MgO 20-30%) and have a high grade of Ni reached up to 2.03 gm/ton in some areas and a low grade of Cu.

5-Through the comparison of the geological and geochemical features between the similar global magmatic bodies and that of Suwar area, we found out that magma of Suwar is similar somehow to Ginchuan deposit of Ni and Cu in China and in Kambalda at Australia.

6-When we keep on studying the ore in Suwar area, it is possible to predict an increase of concentration Ni with the increasing percentage of Mg in host rocks.

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الدراسة الجيولوجية والجيوكيميائية للصخور المضيفة للنيكل والنحاس في منطقة سوار شمال غرب اليمن

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ملخص

يقع مكمن سوار لسلفيدات النيكل والنحاس شمال غرب اليمن ،على بعد 18 كم من مدينة حجة. الصخور المضيفة في سوار ترتبط بمركبات فوق قاعدية لمندسات الجابرويد المتمايزة.

نتائج التحليل الكيميائي للعناصر الأساسية في الصخور المضيفة للنيكل والنحاس في منطقة سوار أوضحت إن نسبة أكسيد المغنيسيوم تتراوح من20 إلى 0 3% وأكسيد السيليكا بمتوسط 40 % واكاسيد الحديد تتراوح بين 14.4 و 18%.

من دراسة المقارنة لسلفيدات النيكل والنحاس في منطقة سوار مع المكامن العالمية المشهورة تبين وجود إمكانية كبيرة لتجمع السلفيدات وان الصخور المضيفة في سوار تنتمي إلى المجموعة التي تحتوي على أكسيد المغنيسيوم بين 15 إلى 33% والتي تتميز بنسبة عالية للنيكل ومنخفضة للنحاس وتتشابه مع الأجسام المجمائية المتمايزة في جنشوان وكمبالده في كل من الصين واستراليا على التوالي . علاوة على ذلك تبين إن النيكل يزداد في الخام مع ازدياد أكسيد المغنيسيوم في الصخور المضيفة. لهذا توجد إمكانية لازدياد نسبة تركيز النيكل في خام سوار عند مواصلة الدراسة.

كلمات دليلة: سوار، شمال غرب اليمن، التحليل الجيوكيميائية ،النيكل، النحاس، أكسيد المغنيسيوم والصخور المضيفة.