

MINERAL RESOURCES OF KURDISTAN REGION, IRAQ

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ABSTRACT

Kurdistan Region is characterized among the rest of Iraqi territory, by the presence of metallic mineral deposits such as Zn, Pb, Cu, Cr-Ni and Mn, together with some unique non-metallic minerals and industrial rocks such as barite, asbestos and marble. The formation of these mineral deposits is associated with the geological and tectonic development of northern Iraq including the major tectonic events associated with the Tethys development and movement of the Arabian Plate. Most of the metallic mineralizations were developed during the Cretaceous Period. Some Zn-Pb deposits are older and may be related to the Triassic and Jurassic Periods.

The actual mineral wealth of the region is not really known, in view of the lack of detailed geological mapping, geochemical survey and air-born geophysical survey. However, based on the available information it is expected that the province is promising for Zn, Pb, Cu, Cr, marble and barite deposits. Building raw materials are available to maintain cement industry and other construction materials. It is essential to start a comprehensive exploration program in Kurdistan Region in order to have a better view of its mineral potential.

الموارد المعدنية في إقليم كردستان، العراق

خلدون صبحي البصام

المستخلص

يتميز إقليم كردستان عن باقي مناطق العراق بوجود رواسب للخامات الفلزية مثل الخارصين والرصاص والنحاس والكروم والنيكل والمنغنيز، فضلاً عن بعض الخامات المعدنية اللافلزية والصخور الصناعية المتميزة مثل الباريت والأسبست والمرمر. يرتبط تكون هذه الرواسب المعدنية مع التطور البنيوي والجيولوجي لشمال العراق والأحداث البنيوية التي ارتبطت بتطور محيط التيثيس وحركة الصفائح العربية. إن معظم الخامات المعدنية الفلزية تكونت خلال العصر الطباشيري، غير أن بعض رواسب الخارصين والرصاص أقدم عمراً ويمكن أن تعود إلى العصرين الترياسي والجوراسي.

إن الثروة المعدنية الحقيقية للإقليم غير معروفة بشكل دقيق بالنظر لانعدام المسوحات الجيولوجية التفصيلية لأغراض الاستكشافات المعدنية والمسوحات الجيوكيميائية والمسح الجيوفيزيائي الجوي للمنطقة. غير أنه بالنظر إلى المعلومات المتوفرة يمكن التوقع بأن الإقليم يحتوي على رواسب مشجعة من الخارصين والرصاص والنحاس والكروم فضلاً عن المرمر والباريت. وتوجد مواد أولية للصناعات الإنشائية بشكل يكفي ويديم صناعة الأسمنت والمواد الإنشائية الأخرى. من الضروري المباشرة بتنفيذ برنامج استكشافي متكامل للحصول على فكرة أفضل عن الإمكانية المعدنية لإقليم كردستان.

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INTRODUCTION

This paper is based on information compiled by Al-Bassam (1984) and was updated here. It includes data available in GEOSURV reports, which represent more than 60 years of geological exploration in Kurdistan Region. In the early times, most of the mineral exploration projects were carried out by the Site Investigation Co. (UK). Many metallic mineral showings were reported and investigated in short reconnaissance surveys, which showed encouraging potential for Pb, Zn and Cu mineralization in Kurdistan.

In the early sixties, of the last century Technoexport (former USSR) carried out more work in the region and investigated some Fe and Pb-Zn deposits in details, including drilling and preliminary reserve estimation. Iraqi geologists (GEOSURV) continued exploration and prospecting works in Kurdistan, especially in Marabasta and Serguza deposits. However, the exploration work was interrupted many times and for several years, which left most of the mineral showings uninvestigated.

The region is covered by 1: 100 000 geological maps and only a small area north of Zakho and Mawat vicinity by 1: 20 000 maps. The full potential of the mineral resources in Kurdistan is not really known in view of the lack of detailed geological survey and mineral exploration. However, the region is promising on the basis of the numerous showings of mineral deposits and the active tectonic nature of the area (Fig.1).

The mineral deposits and occurrences reported here represent the findings of exploration works carried out in the region since the early fifties of the past century. They do not represent the full mineral potential of the region in any way. It is expected that Kurdistan contains more mineral resources, which need to be explored and evaluated. The discontinuous nature of the geological works in the past and the lack of air-born surveys and the limited geochemical surveys in this interesting minerogenic province have delayed the accurate estimation of the full potential of the mineral resources in Kurdistan.

METALLOGENIC ZONES

Kurdistan is characterized by endogenic metallic mineralization of Triassic – Jurassic, Late Cretaceous, and Paleogene ages. It includes mineralization of magmatic, hydrothermal, metamorphic and sedimentary origins, which may be related to regional orogenic phases. The province is divided into two metallogenic zones on the basis of tectonic framework (updated after Jassim and Goff, 2006 and Fouad, 2013) and metallogenic features (Al-Bassam, 2007) (Fig.2):

▪ Imbricate Zone of the Western Zagros Fold – Thrust Belt

They are characterized by low-temperature hydrothermal vein and strata-bound, unmetamorphosed Zn, Pb, Cu, Ba, pyrite and siderite deposits, and placer deposits of Cr, Fe, Mn and Cu. Two metallogenic districts are recognized here; Ora and Balambo – Tanjero.

— **Ora Zn, Pb, Ba District:** It is characterized, from a metallogenic point of view, by low-temperature hydrothermal vein Zn, Pb, Cu, Ba, pyrite and siderite deposits and syngenetic strata-bound Zn, Pb, pyrite deposits in carbonate rocks. The Late Triassic, Early Jurassic and the Late Cretaceous are the main metallogenic periods in this district for strata-bound deposits.

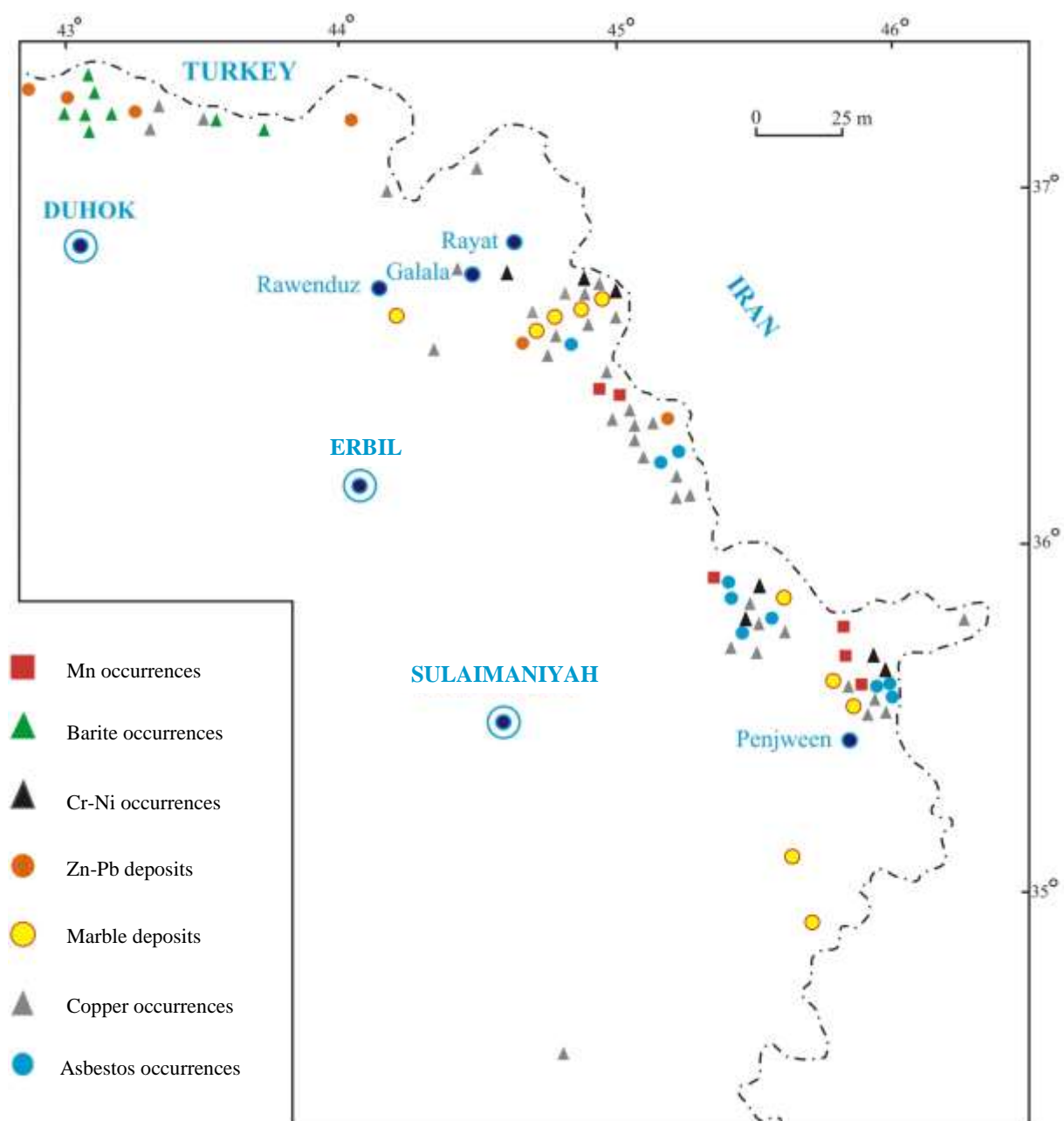


Fig.1: Mineralization map of Kurdistan Region

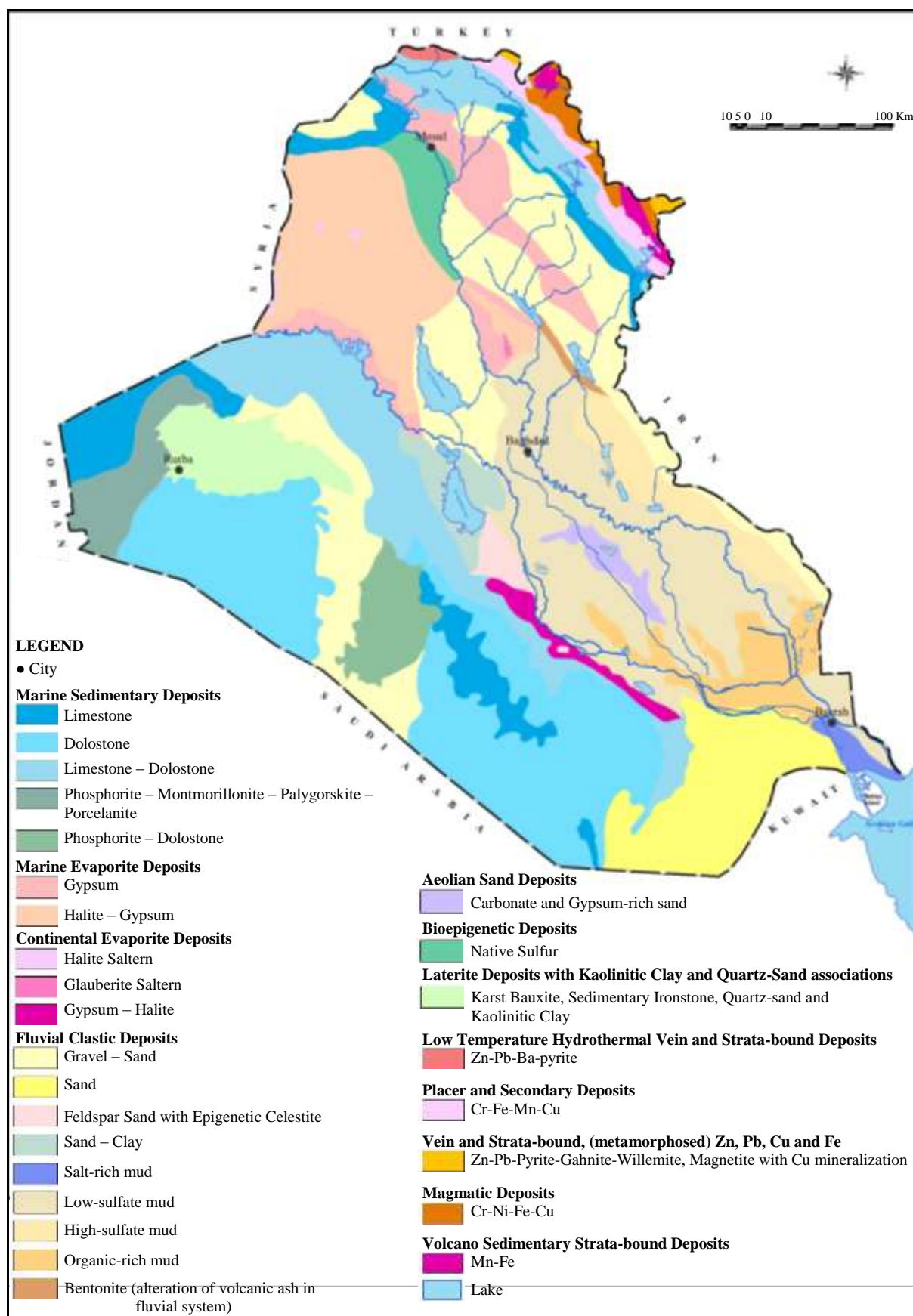


Fig.2: Minerogenic map of Iraq (Al-Bassam, 2007)

The Mesozoic mineralization is associated with rifting events related to subduction of old Neo-Tethyan oceanic crust. The Late Cretaceous carbonate units are remarkable ore-bearing hosts in this district; mostly for the vein type mineralization. However, despite the lack of proper dating, the Late Cretaceous phase of mineralization is suggested here to be related to the tectonic events associated with the concluding stages of the Neo-Tethys. Some sedimentary Fe deposits also occur, but to a very limited and minor extent in the Cretaceous rocks.

— **Balambo – Tanjero Cr, Fe, Cu, Placer District:** It is characterized by mechanically formed deposits (placer) of Cr, Mn, Fe, and secondary Cu minerals, which were transported from their primary sources and redeposited in the Tertiary Red Beds. However, the geological information on this type of mineralization is not complete and requires more work.

▪ **Zagros Suture Zone**

They are characterized by magmatic, volcanic, metamorphic and hydrothermal (associated with magmatism) types of ore minerals. The main phases of mineralization in these zones are of Cretaceous and Paleogene age and are associated with the main igneous activity in the area, which is related to the tectonic events at the margins of the Arabian Plate and the concluding stages of the Neo-Tethys. It includes three metallogenic districts, which have tectonic identity.

— **Qulqula – Khwakurk Mn-Fe District:** It is characterized by volcano-sedimentary Mn-Fe deposits, stratigraphically bound within the Early Cretaceous part of the Qulqula Series (Jurassic – Cretaceous) and is associated with radiolarian chert.

— **Penjween – Walash Cr, Ni, Cu, Fe District:** This district consists of the Qandil Series (Early Cretaceous), Basic and Ultrabasic Igneous Complexes (Late Cretaceous) and Walash and Naopurdan Groups (Tertiary). It is characterized by magmatic Cr, Ni, Fe and Cu, hydrothermal Cu and Ni, (associated with magmatism); contact metasomatic Fe, marble and asbestos deposits.

▪ **Shalair Terrain**

— **Marabasta Zn, Pb, Fe, District:** This district is mainly of Cretaceous age with Triassic imbricates, and includes the Shalair Group and the Katar Rash Volcanic Group. It is characterized by metamorphosed Zn, Pb and pyrite strata-bound deposits of Jurassic age (isotopic-dating) in Triassic carbonate rocks, Fe and Zn skarns, volcanogenic(?) Cu and Fe mineralizations and marble of Cretaceous age.

▪ **High Folded Zone**

— **Shaqlawā – Tasluja Limestone District:** This district is rich in limestone deposits of Cretaceous and Paleogene age suitable for cement industry (Fig.2).

METALLOGENIC HISTORY

The metallogenic stratigraphy of Kurdistan Province is complicated due to less geological knowledge and incomplete or non-existing accurate dating of mineralization. A few isotopic datings exist for some Zn-Pb deposits, but the ore-country rock relation was mostly used to estimate the age of the mineralization, together with the relation to the major tectonic events and igneous activities in the area, which are attributed to regional orogenic phases.

Low-temperature hydrothermal vein deposits of Zn, Pb, Cu, Ba, pyrite and siderite are common in Permian, Triassic and Late Cretaceous carbonates in the Ora District. Whereas, the syngenetic strata-bound Zn-Pb ores are restricted (at the present level of knowledge) to the Triassic carbonates. The most important of the latter deposits (Serguza) is believed to be strata-bound, within the Triassic dolomites and is comparable to other strata-bound Zn-Pb deposits of the same age in the Mediterranean Belt on the basis of Pb isotopic dating, geochemical characteristics and ore morphology (Al-Bassam *et al.*, 1982).

The Triassic – Jurassic strata-bound Zn-Pb mineralization phase was also recorded and accurately dated (by Pb isotopic dating) in the Shalair District as the Marabasta deposit (Hak *et al.*, 1983). The ore in this deposit, however, suffered low-grade regional metamorphism, which resulted in skarn mineralization of Zn and Fe, in addition to marble formation in the Triassic, Cretaceous and Paleogene units.

The main phase of magmatic ore mineralization in Kurdistan is related to the Cretaceous basic and ultrabasic igneous activity in the Penjween – Walash District. This event can be related to the obduction of ophiolite-like complexes and associated igneous intrusions in the Zagros Suture. The mineralizations, which may have direct relation to this event, include magmatic Cr, Ni, Fe and Cu, contact metasomatic Fe, and hydrothermal Cu vein deposits. In addition, volcano-sedimentary Mn-Fe mineralization formed at the same time within the Qulqula Series.

The Paleogene igneous activity in the Zagros Suture Zone provided new phases of ore formation, which included Cu and Fe mineralizations in the Walash and Naopurdan Groups. As a result, marble was consequently formed in these units. Later processes of serpentinization in the ultrabasic igneous rocks led to the development of some asbestos mineralization.

The Neogene tectonic movements in the Zagros Suture Zone initiated a new uplift and subsequent erosion, which brought several ore minerals into placer concentrations within the Tertiary Red Beds of the Balambo – Tanjero District, including Cr, Mn, Fe and oxidized Cu ores.

Aqra – Bekhme, Chia Zairi and Kurra Chine formations are the main Zn-Pb-pyrite-barite-bearing formations in the Imbricate Zone of the Western Zagros Fold – Thrust Belt. Whereas, the Shalair Group is the main and probably the only Zn-Pb bearing unit in the Shalair Terrain. The Basic and Ultrabasic Igneous Complexes (Late Cretaceous) and the Walash Group (Paleogene) are the main Cu and Cr-Ni bearing units in the Suture zone. The Qandil Series, however, is also an important unit for Cu mineralization. The upper part of the Qulqula Series (Cretaceous part) is the most important unit for Mn mineralization in the Suture Zone.

Iron, in its various mineral associations, is widely distributed in Kurdistan. However, most of the contact metasomatic magnetite – hematite occurrences in the Suture Zone and Shalair Terrain were reported in the Shalair and Walash Groups followed by the Qandil Series. On the other hand, the low-temperature hydrothermal pyrite and siderite (including their oxidation products) were found mostly in Ora District of the Imbricate Zone; mostly in the Chia Zairi, Kurra Chine and Aqra – Bekhme formations. In addition, the Shalair Group in the Zagros Suture Zone contains similar types of Fe mineralization.

Most of the asbestos is found within the Basic and Ultrabasic Igneous Complexes of the Suture Zone, with minor showings in the Walash and Naopurdan Groups. Marble, on the other hand, is restricted to the Qandil Series and Walash Group. Orthomarlite is mostly found in the Pila Spi Formation of the High Folded Zone.

METALLIC MINERALS

▪ Oxides

— **Iron:** Iron ore deposits in Kurdistan Region are generally small and are genetically classified into three types: endogenic contact-metasomatic replacement, magmatic segregation and sedimentary ironstone. Iron, as pyrite, is a common associate of most Zn-Pb deposits and occurrences together with its oxidation products (as limonite and goethite).

Several deposits and showings of contact-metasomatic iron (magnetite) deposits were reported in the Qandil Series and Walash Group. The most important of which is Asnawa, where the iron ore is confined to the external contact zone of a diorite intrusion, penetrating the Late Cretaceous – Paleogene Qandil Series. The ore mineralization has an irregular shape and consists of two parallel sublatitudinal zones separated by barren rocks (Fig.3). The mineralogy of the ore is dominated by magnetite with subordinate amounts of pyrite, pyrrhotite, chalcopyrite and arsenopyrite. The average chemical composition was reported by Teretenko and Khadikov (1961) as: Total Fe 40.1%, SiO₂ 24.4%, Al₂O₃ 5.82%, TiO₂ 0.1% and P 0.14%. Deposits and occurrences of the same origin were reported in Mishau and Marabasta areas.

Iron mineralizations (magnetite) of magmatic segregation origin were also reported in the Basic and Ultrabasic Igneous Complexes of the Zagros Suture Zones. The mineralization is found as irregular bodies within serpentinized peridotites, occasionally associated with chromites (Buday and Vanecek, 1971).

Sedimentary ironstone is not common in Kurdistan Region. Benavi, 20 Km NW of Amadia, is one of a few iron deposits of this type, occurring as an elongated E – W body 2.2 Km long and (15 – 30) m thick within Jurassic – Cretaceous sequence in the Ora District. The ironstone is composed of oval to elliptical greenish – yellow oolites of iron minerals (limonite, goethite and hematite) associated with limestone breccia.

The chemical analysis shows (in %): Fe₂O₃ (17.8 – 26.2), CaO (27.4 – 32.7), SiO₂ (4.4 – 4.94), Al₂O₃ (2.05 – 2.49), P (0.21 – 0.43) and S (0.12 – 0.21). The geological reserves were estimated by (15 – 20) m.t. (Geozavod, 1981).

— **Chromium and Nickel:** Almost all known Cr and Ni ore mineral occurrences of Kurdistan Region are connected, from genetic point of view with intrusions of ultrabasic rocks, which are in many cases serpentinized. The chromites of Mawat were suggested, on the basis of mineral association, to be typical Alpine-type (Buda and Al-Hashimi, 1978). Association of Cr and Ni mineralizations were reported in the magmatic deposits of the Zagros Suture and Imbricate Zone, mainly in the Penjween and Rawanduz areas (Buday and Vanecek, 1971). Chromite occurrences, often associated with magnetite, were reported in the basic and ultrabasic igneous rocks (mostly serpentinized peridotites) of several localities near Rawanduz such as Shetna – Sheikhan and Derbend, with about 50% Cr₂O₃ and 0.14% Ni (Polnikov and Nikolayev, 1962). Several chromite bodies were also reported in the Walash Group near Bardi Zard area ranging in size from (1.5 × 0.2) m to (2.5 × 0.4) m. Average Cr₂O₃ in these chromite bodies is 39.24%.

In the same area, about 9 occurrences were reported to contain small veins (1 – 5) m long and few centimeters thick, containing niccolite, rammelsbergite, arsenopyrite, pyrite and secondary Ni minerals. The Ni content varied between 0.3% and 4.38%, averaging 1.45% Ni (Vasiliev and Pentelkov, 1962).

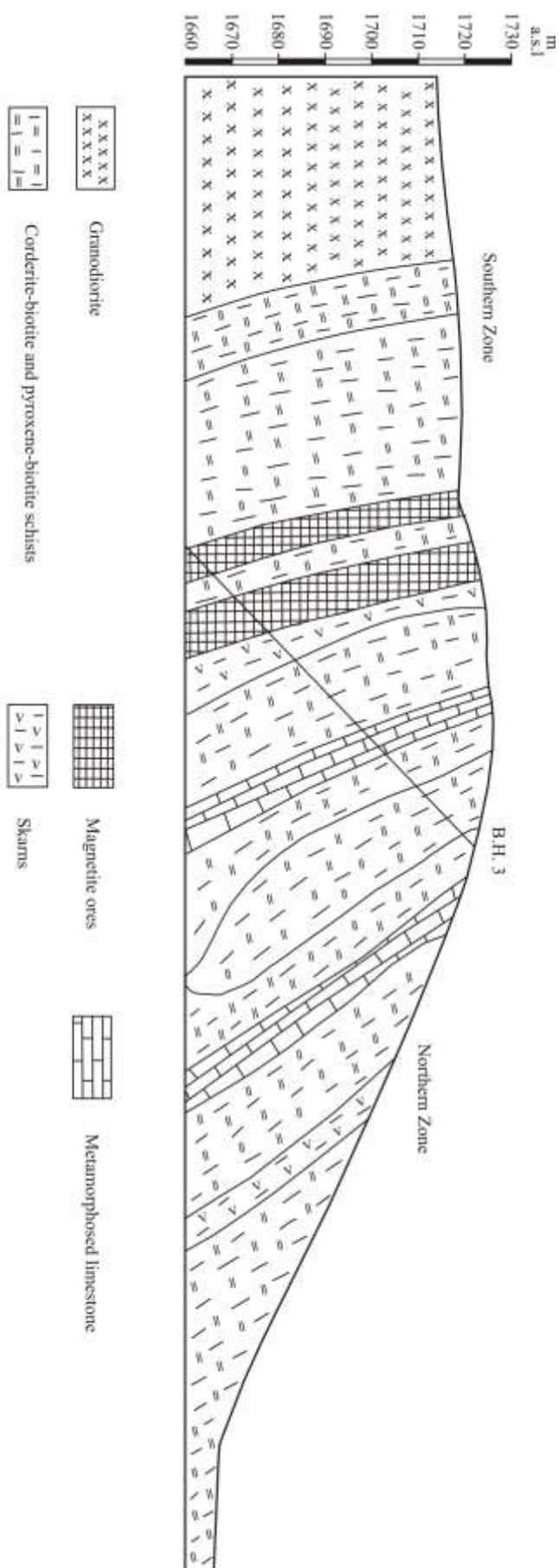


Fig.3: Geological cross section in the Asnawa deposit

Within the Penjween Igneous Complex, more than 20 chromite bodies were reported near Boban, ranging in thickness between (0.2 – 0.5) m and their length from (5 – 15) m. Teretenko and Khadikov (1961) distinguished two types of chromites: a massive variety containing (41.6 – 52.2) % Cr_2O_3 and (9.0 – 4.9) % FeO, and an impregnated variety with about 31.6% Cr_2O_3 and (11.0 – 15.3) % FeO. Some nickel concentrations, associated with cobalt, were described from the same area in serpentized peridotites, with 0.5% Ni and 0.01% Co. Other chromite bodies were reported near Kani Manga (30 – 35) % Cr_2O_3 and Kani Gabla 52.2% Cr_2O_3 .

— **Manganese:** Manganese occurrences in Kurdistan are mostly related to the Qulqula Group (Late Jurassic – Middle Cretaceous), outcropping between Sulaimaniyah and Penjween and also reported in the area NE of Rania. The origin of these Mn-mineralizations is not clear, but due to their close connection with siliceous rocks, they are believed to be of volcano-sedimentary origin like many of these deposits in the world (Buday and Suk, 1978). The mineralization consists of manganese oxides and hydroxides, such as psilomelane, pyrolusite and manganite.

Buday and Vanecek (1971) described the main Mn-occurrences in Kurdistan. Most of the occurrences are manganiferous and associated with cherts and cherty clays. The major occurrences were reported in the Rania and Penjween areas. An Mn occurrence was described near Sirma village (4 × 60) m in size and contains (3.5 – 21.9) % Mn and (12.3 – 16.9) % Fe. Manganiferous cherts, with up to 20% Mn were described from Pushtashan area north of Rania. Up to 47.5% Mn was reported in samples of clayey cherts near Mawat. Volcano – sedimentary Mn mineralization contained 34.05% Mn and 10.2% Fe was reported by Smirnov and Nelidov (1962) in the locality of Gola, NW of Penjween. A mineralized crush zone in the shales of the Qulqula Series was reported near Kani Saif village south of Penjween. It is (80 – 100) m thick and about 1 Km long. Pisolomelan, pyrolusite, manganite and limonite were reported in this mineralization by Buday and Vanecek (1971).

▪ Sulfides

— **Zinc and Lead:** At the present state of knowledge, there are two main Zn-Pb deposits, which have reserve estimation after they were partly explored in some detail, relative to the other Zn-Pb occurrences in Kurdistan. These are Marabasta in the Zagros Suture Zone and Serguza in the Ora District. In addition, there are about ten other Zn-Pb occurrences distributed mostly in the Ora District, within carbonate rocks of Mesozoic age and are controlled stratigraphically and tectonically (Fig.4). These occurrences, however, are not studied in detail yet and hence no conclusive evaluation can be made on their potentiality.

Marabasta Zn-Pb Deposit: This is the most important and scientifically interesting Zn-Pb deposit in Iraq. It is situated about 1.5 Km from the Iraqi – Iranian borders, about 6 Km behind the thrust front and about 36 Km NE of Qala Dizeh, at an altitude ranging from (2000 – 2400) m (a.s.l.).

The rocks at Marabasta are part of the Shalair Group, they were divided by Buday (1971) into two units; Marabasta and Qandil. The former is of very low or no metamorphism and composed mostly of carbonate rocks, whereas the latter is completely metamorphosed into marble and phyllites (Fig.5). The Marabasta Unit is probably Triassic imbricates within the Shalair Group; the latter is of Aptian – Albian age (Jassim *et al.*, 1984). Triassic remnants within the Shalair Group are also known from the Shalair valley (Buday and Suk, 1978).

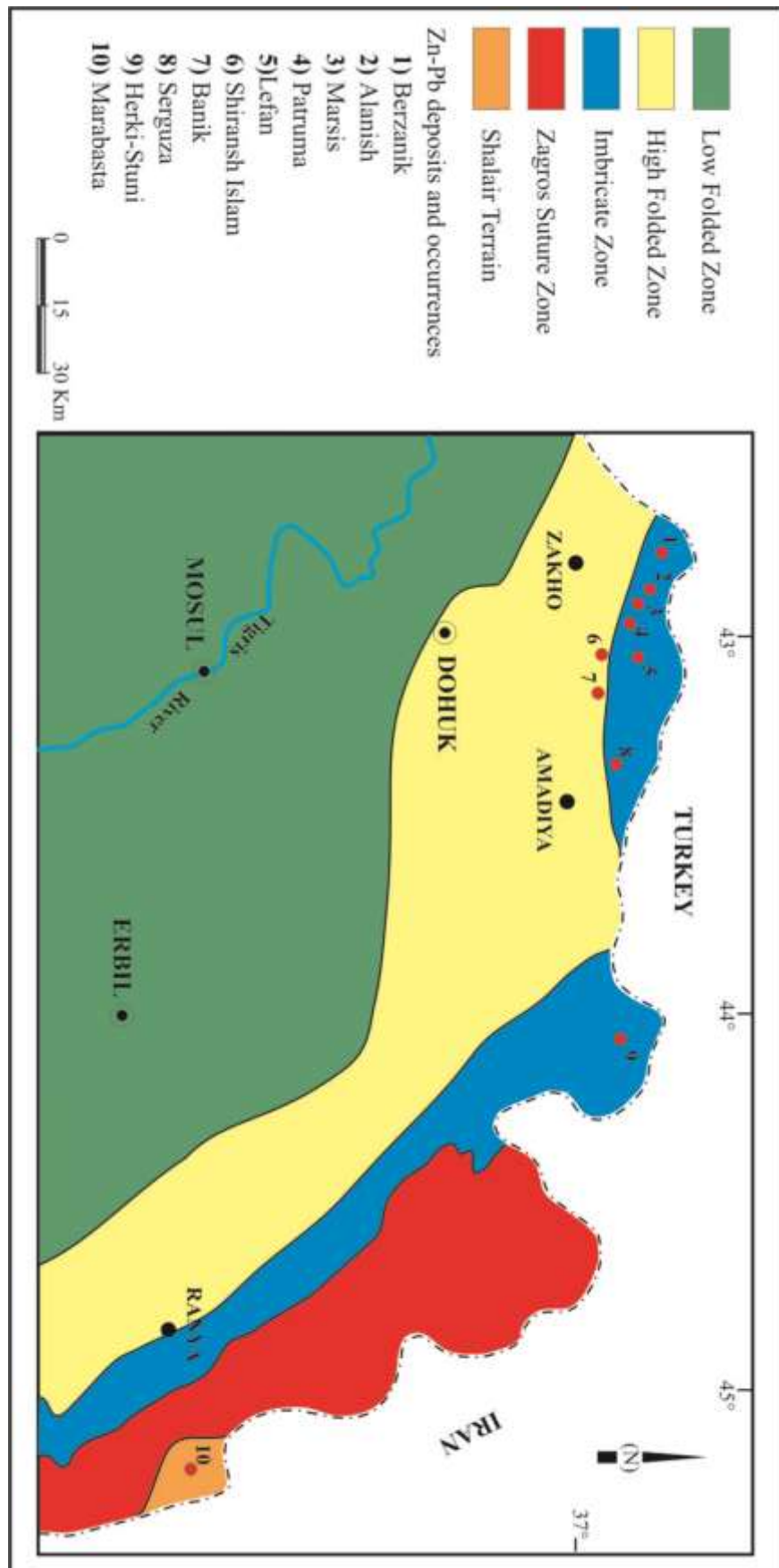


Fig.4: Tectonic sketch map and location of main Zn-Pb deposits and occurrences (Al-Bassam *et al.*, 1982; Jassin and Buday, 2006 and Fouad, 2013)

The ore is present within the Marabasta Unit as small scattered occurrences of complicated and irregular shape, concentrated in three main localities. The mineralization consists of two different mineral assemblages; one of galena, sphalerite, pyrrhotite, pyrite, marcasite and rare arsenopyrite; and the other is a skarn type assemblage, consists of magnetite, willemite, gahnite and rare garnet and nickeline (Hak *et al.*, 1983). Secondary minerals include smithsonite and cerussite. These two assemblages exhibit different textural features; the former represents oriented or lineated textures of massive and banded sulfides, whereas in the latter the sulfide assemblage is mixed with the skarn mineralization, rich in zinc and iron (Al-Bassam and Akif, 1977).

Isotopic dating of galena showed an age range of (180 – 200) million years, (Hak *et al.*, 1983). The drilling has shown that the ore body has subsurface extension, of the same dip and strike as the enclosing limestones and was continuous down to 42 m depth (Fig.5). More than one attempt has been made to estimate the reserves of the ore deposit of Marabasta. The last estimate showed that the C1 reserves are 608953 tons of ore containing 100520 tons of Zn and 18117 tons of Pb. The C2 reserves were estimated by about 141000 tons of ore containing 23265 tons of Zn and 4230 tons of Pb. The density of the ore varied from (2.7 – 3.7) gm/cm³ (Akif *et al.*, 1973 and Akif and Mustafa, 1974).

Serguza Zn-Pb Deposit: This deposit is the second, in importance after Marabasta. It is situated 17 Km NW of Amadia, at about (1600 – 2000) m (a.s.l.). The area is built of Middle and Late Triassic limestones and dolomites thrust over dolomites, mudstones and siltstones of Miocene and Eocene ages. The Triassic rocks represent the high mountains and cliffs in the area, whereas the Tertiary rocks, which are usually softer, represent the lower plains and valleys. The emplacement of the predominantly oxidized ore in Serguza extends in an area of about 3 Km². The main part of the sulfide ore body is situated at the tectonic contact between the Tertiary and Triassic rock units (Fig.6). Two main systems of faults were recognized; in E – W and N – S directions. Another system of NE – SW trend was also recognized within the ore deposit area (Akif *et al.*, 1971; Masin and Saeid, 1971; Abbas, 1971 and Mironov and Sitchenkov, 1962).

The ore emplacements, defined as zinc and lead concentrations in pyrite or goethite limonite bodies, are located in the dolomitic limestone of the Middle – Late Triassic age (Kurra Chine Formation). These ore bodies have bedded or lenticular shape of variable thicknesses (Fig.6). The ore mineralogy is relatively simple, dominated by sphalerite, galena and pyrite. Secondary minerals include limonite, goethite, cerussite and smithsonite (Al-Bassam, 1972 and Al-Qaraghuli and Lange, 1978). The ore textures show features of banding, lamination, microfolding and other sedimentary structures (Al-Bassam *et al.*, 1982).

Three ore bodies were recognized; western, northern and southeastern. The western ore body extends partly along the Triassic – Miocene tectonic contact for about 130 m, the ore-bearing horizon is (5 – 10) m thick, 350 m long and 200 m wide, dipping (10 – 20)° N. The northern ore body is highly oxidized, extends for about 200 m in outcrop, 150 m wide and about 5 m in thickness. The southern ore body can be traced in outcrops for about 300 m and is about 60 m wide with average thickness of 6.3 m. The reserves were estimated (Geozavod, 1981) on two categories; C1 and C2. The C1 reserves were estimated by 1971000 tons of ore containing metal reserves 42968 tons of Zn and 36069 tons of Pb. The C2 reserves were estimated as 37000 tons Zn and 31000 tons Pb.

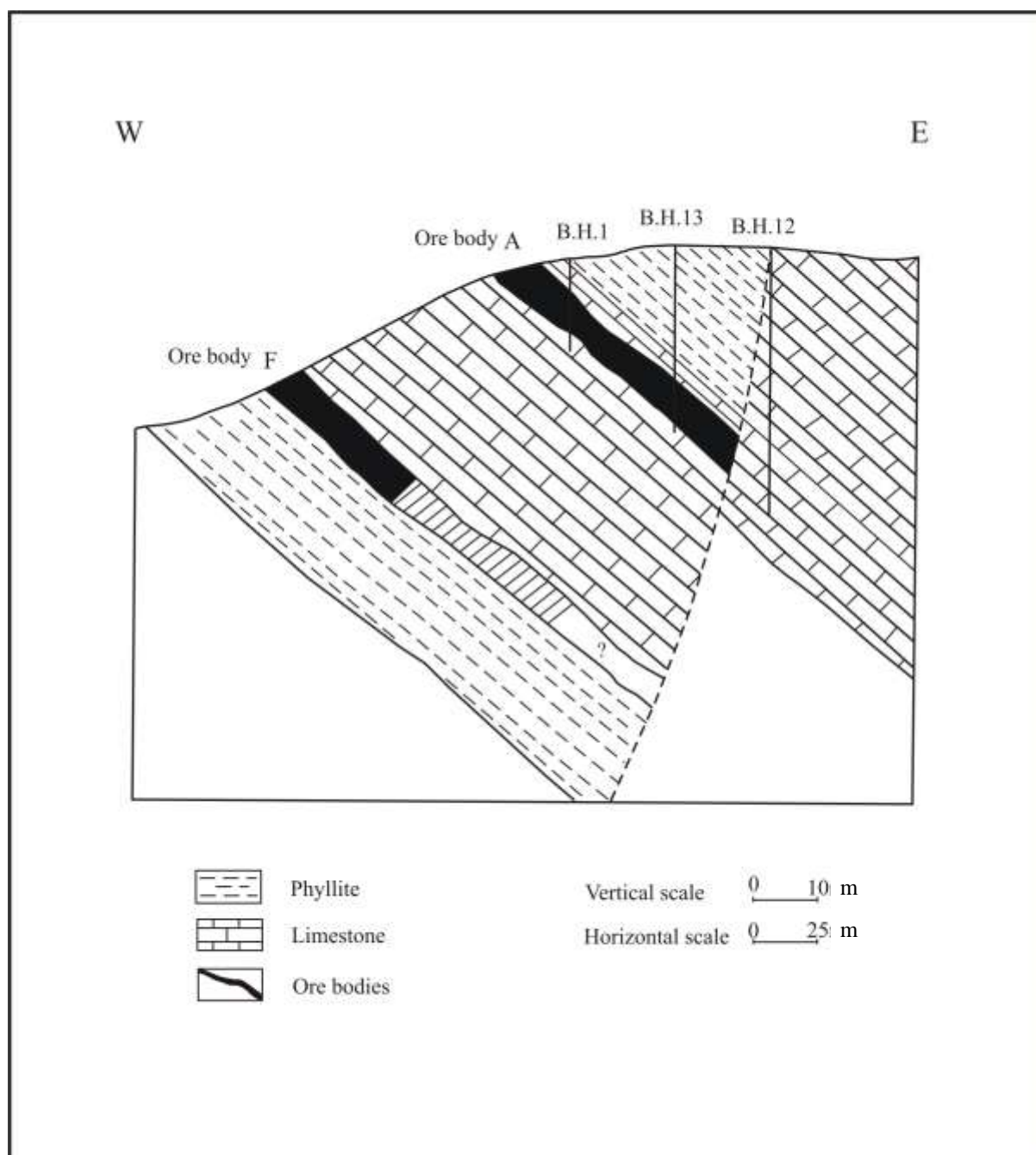


Fig.5: Geological section in the Marabasta deposit (Seh Kutchika)
(Akif and Mustafa, 1974)

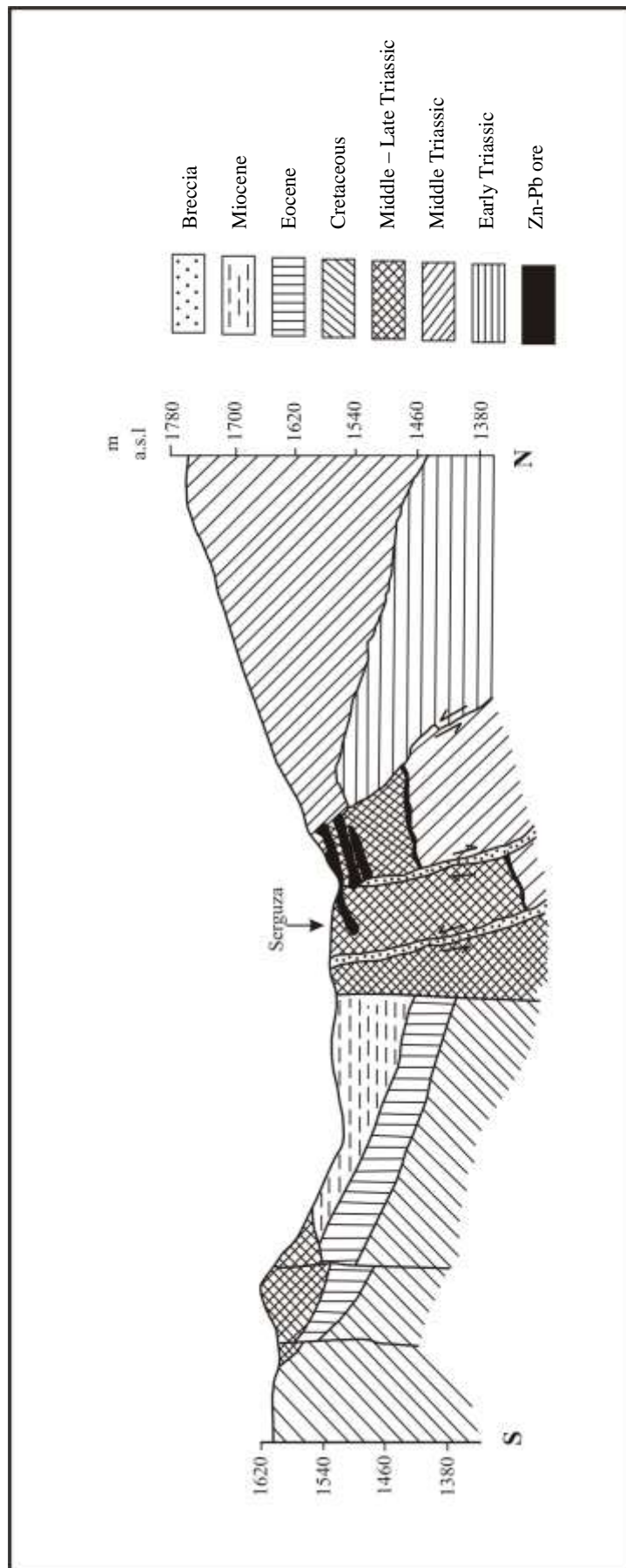


Fig.6: Geological cross section in the Serguza Zn-Pb deposit (Geozavod, 1981)

Berzanik Zn-Pb Occurrence: It is situated about 25 Km N of Zakho, in a rough mountainous area, about 2000 m (a.s.l.) (Fig.4) dominated by sedimentary rocks of Carboniferous, Permian and Triassic ages. The major structural feature of the area is a major NE – SW thrust fault dipping (70 – 75)° NW, with a vertical displacement of about 500 m.

Three marked outcrops of gossan and barite occur along a thrust fault, which separates the Triassic from the Permian rocks. They are up to 75 m long and 3 m wide. The ore minerals occur mostly in the scree and crushed rocks of the Triassic rocks. Sphalerite, galena, smithsonite and barite were recorded. Chemical analysis of three samples showed up to 36.5% Zn, 2.1% Pb, 0.3% Cd and for barite up to 50.6% Ba (McCarthy and Smit, 1954). In 1980, the area was covered by geochemical soil exploration, which was the only effort since the early sixties to explore the deposit, which still lacks subsurface data and geophysical exploration. Several important geochemical anomalies of Pb and Zn were identified in the 1980 work, most of which coincide with the contact zone between Triassic and older rocks (Al-Bassam, 1981).

Alanish Zn-Pb Occurrence: It is situated 24 Km NE of Zakho and about 6 Km SE of the Berzanik occurrence (Fig.4). A fairly well defined vein (?) of dark brown iron-rich gossan was found associated with barite and dolomite. The overall length of the exposure is about 600 m and is (3 – 5) m wide. It was related to a major NW – SE thrust fault, which separates Late Permian rocks from the Jurassic rock units.

The Triassic rocks occur as a narrow strip to the north of the line. A second mineralized outcrop was found parallel to the first and to the east of it; it extends for 150 m and is 3 m wide. Two other exposures on the same trend were also found, 100 m long each and about 2 m wide. McCarthy and Smit (1954) suggested continuity between these exposures and considered the Alanish occurrence the most extensive found in the area NE of Zakho.

Patruma – Masis Pb Occurrence: It is situated 23 Km NE of Zakho (Fig.4). The mineralization occurs in the fracture zone marking a tectonic contact between the Late Triassic Kurra Chine Formation and the Early Cretaceous Sarmord Formation. It extends in a sporadic and discontinuous form for about 5 Km, coinciding with the major WNW – ESE fault zone. Siderite, barite, limonite and galena were reported (McCarthy and Smit, 1954).

Banik Pb Occurrences: It is located about 28 Km ENE of Zakho where a small E – W shear zone appears within the Late Cretaceous Aqra – Bekhme and Shiranish formations (Fig.4). The mineralization is oxidized into a dark material, associated with barite, which extends for a distance of 60 m with average width of 10 m. Visible blebs of galena were noticed in the gossan and in the barite (McCarthy and Smit, 1954).

Lefan Zn-Pb Occurrence: It is located about 21 Km NE of Zakho within Late Cretaceous carbonate rocks (Fig.4). A shallow depression, appears to be the site of old workings, was found rich in galena, sphalerite and barite. Much of the float gossan has been derived from shallow depth. Irregular veins of siderite and limonitic gossan were found near the crest of a ridge above Lefan, in the limestones of Qamchuqa Formation.

The Lefan occurrence was visited in 1952 by Stevens and four samples were analyzed (reported in Paver and Scholtz, 1954) and the results showed (2.33 – 32.9) % Zn, (0.56 – 11.24) % Pb and (4.0 – 92.0) % BaSO₄. Smithsonite was also indicated by UV fluorescence. A lenticular body was suggested by McCarthy and Smit (1954), which has

limited extent. GEOSURV investigations in the early nineties showed very encouraging results after drilling of 36 m deep borehole in the area. Ore-bearing limestones, 19 m thick, were discovered with an average of 6.5% Zn and 0.8% Pb (Al-Ka'aby and Al-Azzawi, 1991).

Benavi Pb Occurrence: It is situated 10 Km W of the Serguza Zn-Pb deposit, within the Triassic – Jurassic limestones and dolomites. The mineralization is present as fragments and about 2 cm pebbles of galena embedded in scree. Based on the fact that galena has low mechanical strength and high specific gravity, the source is expected to be very close to these showings. A major E – W thrust fault is situated very close to the ore occurrence (Mironov and Sitchenkov, 1962).

Ora Pb Occurrence: It is located about 6 Km from Ora village, near the contact of the Early Triassic Mergi Mir Formation and Middle Triassic Geli Khana Formation with the Permian Chia Zairi Formation. A small fracture was reported by Paver (1955) and ancient mining works were suggested by the much waste rocks and a 20 m long tunnel in a mineralized zone. The mineralization occur within bedded quartzite, sandstone and limestone forming transition from massive dolomites of Chia Zairi Formation to the softer rocks of Mergi Mir Formation. Blebs of galena were noticed together with malachite, azurite and chalcocite.

Herki Pb Occurrence: It is located about 2.5 Km S of Herki village. A zone of limonitic gossan, 90 m long, indicates the outcrop of a vein-type deposit of metallic minerals including galena and residual blebs of pyrite, but the nature of the mineralization below the gossan is known. The occurrence follows a shear zone in the highly cleaved marls of the Shiranish Formation (Late Cretaceous). Other minor gossan outcrops were found in the area, but without galena (Hall, 1954).

— **Copper:** Most of the copper mineralization in Kurdistan Region is of hydrothermal origin and only few occurrences of copper are of sedimentary origin (Buday and Vanecek, 1971). The former is present either as disseminated mineralization in mafic and ultramafic rocks, or occurring in quartz veins. The former occur as disseminated mineralization or veins in various types of rocks. A few were reported in carbonate rocks, but the majority were reported in mafic and ultramafic igneous rocks as disseminations and in metamorphic rocks as veins. Copper mineralization in quartz veins is also common.

Copper occurrences are wide spread all over the area of the Zagros Suture Zone, but only a few of them were recorded in the Ora District. Many of the former occurrences are related to the serpentinized ultramafic rocks and gabbros of the Penjween, Mawat and Bulfat Massives, whereas in the latter they are found as veins in carbonate rocks of various formations (Buday and Vanecek, 1971).

Copper Veins in Carbonate Rocks: A few copper occurrences were reported in the Paleozoic rock units of the Ora District, mostly as vein deposits.

A copper-lead occurrence, 6 Km W of Ora village was recorded as an outcrop of a vein, about 1 m thick, striking 116° with a dip 76° N. The occurrence is located near the contact between Chia Zairi and Mirga Mir formations. The mineralization consists of malachite and azurite along joints and fractures with chalcocite containing galena blebs (McCarthy, 1955). A small copper occurrence associated with lead minerals in limonitic gossans, was reported to occur in the Chia Zairi Formation, near Sereru village and near Sar Zairi village, reported to contain (0.2 – 0.6) % CuO and (0.04 – 0.10) % PbO.

Copper Mineralization in Volcano – Sedimentary Sequences: Copper mineralization was reported from volcanic rocks of the Walash Group at Jebal Kalandar. From the same mountain, there were described impregnations of fine grained pyrite and chalcopyrite in flysh-like rocks of the Naopurdan Group (Vasiliev and Pentelkov, 1962). Some quartz – calcite veinlets and impregnations of native copper, cuprite, tenorite and malachite in red color argillites were reported near Kargauz village and near Warbastir village by Vasiliev and Pentelkov (1962). More than ten copper showings were reported to occur near Jira village E of Qala Dizah. They are associated with sericite – chlorite and epidote schist, cut by some granitic dikes. The mineralization consists of malachite and Cu-bearing pyrite with concentration of Cu varying from (0.1 – 3.4) %.

A copper mineralization at Bir Achminda – Benoza, related to the Bulfat Massif, consists of chalcocite, chrysocolla, malachite, limonite (after pyrite) and quartz in sericite schists of the Walash Group, containing some interlayers of crystalline limestone and meta-andesite.

A mineralization zone, few hundred meters long and about 35 m wide, was found near Waraz village, NW of Chowarta. It is formed by chloritic schists containing malachite, pyrite and quartz. Webber (1952) reported a thickness of about 4 m and an average content of Cu of 0.2%. A grab sample containing 37.1% Cu was described from this locality by Smirnov and Nelidov (1962).

Copper Mineralization in Basic and Ultrabasic Igneous Rocks: A sample associated with serpentines and andesite was reported near Nawanda valley with 0.7% CuO and 0.9% Ni. Another sample collected near Dilza village was reported to contain 0.4% Cu and samples collected from Kawarta village showed 0.83% Cu and (0.1 – 0.3) % Ni (Williams, 1949). Copper and nickel mineralization is known to occur in the Galala area, E of Rawanduz in serpentinite bodies, outcropping for a distance of about 8 Km. Few samples collected near Galala village gave an average of 0.5% Cu and (0.2 – 0.3) % Ni. Traces of copper mineralization were described from serpentines and epidiorites occurring E of Qala Dizah near Delo Shaikh Awdalan and Ahmandan villages.

In the Mawat Massif, chalcopyrite, pyrite and malachite were reported in gabbro near Mirawa village. Quartz veins with chalcocite, chalcopyrite, pyrite and malachite occur in mafic and ultramafic rocks near Kurra Dawi village. One of the samples described as gray epidiorite contained 7.8% CuO, 72.5% Fe₂O₃ and 0.6 gm/ton Au (Williams, 1948). Many copper showings are known from a crushing zone in gabbro SW of Kurra Dawi village and from granodiorites, pyroxenites and gabbros south of Konjirin village. The mineralization consists of chalcopyrite, pyrite, malachite and azurite, with Cu content between (2.84 – 23) % (Smirnov and Nelidov, 1962 and Al-Hashimi and Al-Mehaidi, 1975).

Stains of malachite were described near Roshan village in the serpentinitized peridotites and gabbros of the Penjween Massif. Four samples were analyzed and contained up to 1.8% Cu.

Copper Mineralization Associated with Quartz Veins: Impregnations of malachite and bornite in minor quartz veins were reported SW of Ari village in the Kani Rash area (Cobbett, 1957). Quartz veins with copper mineralization are abundant in green phyllites, gabbros and epidiorites around Penjween.

Four vertical quartz veins, about 6.5 m thick and 500 m long, with some malachite mineralization were reported near Kazara village (Vasiliev and Pentelkov, 1962). Malachite in

sandstone and in ferruginous dolomitic limestone was reported near Qandil village and quartz veins with malachite occurring in dolomitic limestones of the Qandil Series near Sar Merga village.

Sedimentary Copper Mineralization: Sedimentary type copper mineralization occur in some old workings in sandstone or conglomerate containing malachite, near Shaqlawa town and near Kifri town, reported by Macfadyen (1935). Some occurrences were described in the Qulqula Series near Qulqula village and near Suragala village. A grab sample from the latter, mineralized by malachite and azurite, gave 11.8% Cu.

RADIOACTIVE MINERALS

Kurdistan Region is not covered by air-born radiometric survey. However, geochemical and foot-born radiometric surveys in selected areas showed very interesting anomalies of uranium and thorium. These anomalies are mostly related to igneous and metamorphic rocks of Qandil Series and Walash Group, as well as to black shales of Naokelekan and Barsarin formations (Late Jurassic).

▪ Penjween Area

Geological and radiometric surveys were carried out in the Shalair valley in several locations where granitic(?) intrusions were found, including Weena, Darukhan, Awlan, Mishau and South Laladar villages. The country rocks are dominated by the Qandil Series (Cretaceous) and the Walash Group (Paleogene), High radiation was noticed near and around the granitic(?) bodies (Al-Shibel and Kettaneh, 1972).

▪ Qala Dizeh Area

Several areas near Qala Dizeh showed anomalous radiation and high uranium and/ or thorium concentrations. Most of these anomalies are related to rocks of the Qandil Series. In Shaikh Rasht Mountain up to 3500 cps was recorded in pegmatite veins (Qadir and Jemil, 1975). Selected mineralized samples showed 9.7% Th and 0.35% U (Hermezi *et al.*, 1976).

In Geli Kubi Mountain (Perus Peak; 2134 m) up to 700 cps was recorded in the serpentines with 860 ppm Th and (3.2 – 4.2) ppm U. In Dwaiza Mountain (5.5 Km NE of Hero village) up to 2700 cps was recorded in the olivine-bearing rocks with (210 – 830) ppm U.

In Kani Muesh (1 Km NE of Belko village), up to 3000 cps was recorded, with (67 – 222) ppm U and (50 – 630) ppm Th in the biotite synite rocks.

In wadi Nisi (3.5 Km NE of Hero village) up to 1200 cps was recorded, with (650 – 1590) ppm U and (3140 – 10170) ppm Th in the olivines. Thorianite was identified.

▪ Rawanduz – Galala – Rayat Area

Radiometric surveys in this area covered the Jurassic black shales of Naokelekan and Barsarin formations. The radiation was in the range of (200 – 400) cps and up to 56 ppm U was recorded in the black shales (Al-Kazzaz *et al.*, 1972).

NON-METALIC MINERALS

▪ Barite

These are found in Berzanik, Alanish, Banik, Shiranish Islam, Lefan, Bosol and Ora localities. Almost all barite occurrences in Kurdistan Region are located in the Ora District within the Chia Zairi (Permain) and Aqra – Bekhme (Late Cretaceous) formations, usually associated with zinc-lead-pyrite occurrences. Eight of these Ba-occurrences were reported by Buday and Vanecek (1971).

The numerous and encouraging occurrences and showings of barite in Kurdistan Region suggest that there is a good possibility to have a small to medium size barite deposit in the Ora District. Most of the exploration should be concentrated in the area between Berzanik village in the northwest and Banik village in the southeast, where the main showings were reported in the Chia Zairi, Aqra – Bekhme and Shiranish (?) formations.

▪ Asbestos

The main occurrences of asbestos in Kurdistan Region are located in Chwarta, Mawat and Penjween areas. They were briefly described by Vanecek (1970) and Al-Rawi and Mansour (1971).

Almost all the reported occurrences are found in serpentinized ultrabasic igneous rocks. The most prominent of these occurrences are located in the Shetna area, Baba Kraw and Hero villages (Rawanduz area) where (1 – 2.5) cm long chrysotile fibers were reported in veins and veinlets of serpentine. In Chwarta – Mawat area several occurrences were reported near Miraw and Sarawa villages (Lehner, 1954) in small pockets and as slip-fiber chrysotile of low tensile strength.

Near Kurra Dawi village (Mawat area) pockets of slip-fiber chrysotile, up to 7 cm long, associated with shear zones were reported in serpentinites, pyroxenites and gabbros. Within the Penjween Massif near Penjween and Kani Manga village, four main zones of asbestos were reported by Smirnov and Nelidov (1962). **Zone I** is situated on the W and NW slopes of a hill near Penjween, where (1 – 3) m long and few millimeters thick streaks of cross fiber asbestos are developed, but the recovery of asbestos fibers was reported to be very low. In **Zone II**, which lies parallel to the SW border of peridotites, cross-fiber asbestos was observed in (1 – 2) mm thick streaks up to 0.7 mm long. In **Zone III**, near Penjween – Sulaimaniyah road E of Kani Manga village, several slip-fiber asbestos occurrences were reported. The fiber is brittle and talcose and is up to 7 mm long. **Zone IV** is situated NW of Penjween, it possesses small streaks of low quality slip-fiber asbestos.

INDUSTRIAL ROCKS

▪ Marble

True marble or metamorphic marble is restricted to the Zagros Suture Zone, whereas ordinary or ortho-marble is dominant in the High Folded Zone (Mansour *et al.*, 1979). Some of the marble deposits in the Sulaimaniyah region lie in the High Folded Zone and others lie in the Zagros Suture Zone. The main marble deposits of the former are located between Derbendi Bazyan and Derbendi Khan, having NW – SE trend and occur mostly within the Eocene rocks (Pila Spi Formation). Whereas in the latter, the main deposits are in Penjween and Mawat, where the Qandil Series is the main source for true marble. There are several marble deposits in the Arbil region, located within two main districts; Salahuddin – Bekhme, where ordinary marble is dominant, and the Rawanduz – Haj Umran where true marble is

dominant. The Pila Spi and Sinjar formations are the main source of the former and Walash Group represents the main source of the latter.

▪ **Limestone**

There are numerous formations composed of limestone in Kurdistan Region. The largest limestone reserves are in a continuous belt of Cretaceous formations extending from Halabcha to Amadia. The Triassic formations also contain limestone units, especially in the Ora District. The Jurassic limestone-bearing formations are relatively less important, similar in this respect to the Paleozoic rock units. Limestone-bearing formations of Paleogene age are widely distributed in the province, they extend from Halabcha to Koisanjaq, Ain Sifni and Amadia, but the limestone is affected by dolomitization in some horizons (Mansour and Petranek, 1980). Sinjar and Khurmala formations are the most important in this respect. The Serikagni, Euphrates and Fatha formations (Miocene) are important limestone-bearing units in the Folded Zone, but the thickness and quality are variable. Based on recent exploration works; carried out by GEOSURV, huge reserves of limestone deposits suitable for cement industry can be found in Kurdistan Province especially in Sulaimaniyah Governorate.

▪ **Gypsum**

Kurdistan Region contains limited resources of gypsum deposits, almost all of which (the exposed deposits) are in the Middle Miocene Fatha Formation, which has wide geographic distribution in the Folded Zone. Usually, several gypsum horizons are recorded in this formation, they are of very high quality and variable thickness, and alternate with claystone and limestone. The main deposits are located in Makhmour and Derbendi Bazyan areas (Al-Ka'aby, 1977 and Touni, 1979). Although the investigated gypsum resources in Kurdistan are limited, but are enough to meet the present demand of cement industry in the region. However, new reserves should be looked for to meet the future expansion of this industry and to supply necessary raw material for plaster and other gypsum industries, which are not developed in Kurdistan Region. The Fatha Formation (Middle Miocene) is the main gypsum-bearing rock unit in Kurdistan Region, as well as in most parts of central and northern Iraq.

▪ **Industrial Igneous Rocks**

Igneous rocks, in general, are of limited distribution in Kurdistan Region; they are restricted almost entirely to the Zagros Suture Zone (zone of magmatic, skarn, hydrothermal and volcanogenic-hydrothermal deposits). Three main igneous complex units were described by Buday and Suk (1978); these are Penjween, Mawat and Bulfat.

— **Granite:** True granites are rare in Iraq; small bodies of intrusive rocks penetrating the Katar Rash Volcanic Group were said to be composed of granite porphyry, granitoid bodies and diorite (Al-Rubaie, 1976), whereas according to Buday and Suk (1978) these are rhyolite porphyry thick flows. However, industrial granite (in its broad industrial term according to Bates, 1969) is wide spread in NE Kurdistan Region; the most important of which is the gabbro.

Gabbro makes up the southwestern part of the Mawat complex and extends NW – SE parallel to the course of the thrust line. Two groups of gabbro were identified; uraltized pyroxene gabbro and amphibole gabbro. The former is coarse to fine grained, dark gray to green and sometimes banded. The latter is similar in color and texture, but the mineralogy is different. The majority of the central Mawat (about 170 Km²) is composed of banded

amphibole gabbro and pyroxene gabbro. The Bulfat Unit contains, among other rock types, olivine – pyroxene – amphibole gabbro and pyroxene and pyroxene – amphibole gabbro.

The ultramaphic rocks, which can be grouped here, as "granites" according to Bates (1969) terminology, are common in the three igneous units of Iraq. Dunites, pyroxenites and peridotites are covering an area of about 20 Km² in the central part of Penjween Massif. They are, however, strongly serpentinized and the Dunites are comparatively small. These rock types were also reported in the Mawat basic complex, mostly at the tectonic contact between the Mawat Thrust Block and the underlying nappe. The ultramaphic rocks of Mawat are characterized by high content of Fe₂O₃ and Al₂O₃ (Buday and Suk, 1978). In the Bulfat Complex, the ultrabasic rocks occupy only very small part of the area. They are mainly represented by serpentinites and strongly serpentinized peridotites, locally converted to different kinds of talc-schists.

— **Basalt:** It is composed essentially of plagioclase feldspar and ferromagnesian minerals, particularly augite. Basalt has essentially a single use: crushed stone, about (4/5 ths) of which is utilized for concrete aggregates and road metal, and most of the remainder for railroad ballast, roofing granules and riprap. A modern application is for high density aggregate in the concrete shields of nuclear reactors. The finely crystalline texture of basalt and diabase makes trap rock a very tough and sound stones, particularly impervious to weathering. It is some what heavier than most other varieties of crushed stone and this fact contributes to its high place value.

The igneous complexes of NE Kurdistan Region are generally rich in basalt and basaltic rocks. They occur as scattered thin lava flows with adjacent tuffs in the rocks of the Shalair Group. They form ordinary members of the stratum sequence of this group that is overlain by volcanites of the Katar Rash Series. Two types of basalt were distinguished: alkali olivine basalt and high alumina basalt (Buday and Suk, 1978). The Katar Rash Volcanic Group contains several successive effusions of basaltic andesites, dacites, rhyodacites and rhyolites, forming sheets and lava flows. Part of the Bulfat igneous rocks are the meta volcanites, which are metamorphosed igneous rocks that have preserved their original texture. The main rock types of this group are metabasalt, metadiabase and metaandesite. The volcanic rocks of the Walash Group contain basic dikes and lava flows, consist of spilitic diabase, pyroxene containing spilitic and spilite.

— **Nepheline Syenite:** It is a relatively rare rock, it lacks quartz and contains nepheline (potassium sodium aluminosilicate). Thus, the rock is silica deficient and is exceptionally high in alkalies. The essential mineral is feldspar (albite and microcline).

The valuable properties of nepheline are of the same type as those of feldspar and both minerals are put to the same uses (Bates, 1969). Hence, nepheline synites, being a mixture of the two, is therefore utilized as a bulk product. It is used as an ingredient of glass, especially container glass, in white ware and in ceramic glazes and enamels. The high alumina content and the high content of combined alkalies make nepheline synites better than feldspar.

In Kurdistan Region, nepheline syenite dikes were reported in the intrusive complex of Bulfat, which is situated in the eastern part of the unit. The exposed thickness of the complex is approximately 1500 m. The nepheline synites are associated with synites and pegmatites (Buday and Suk, 1978).

— **Pegmatites:** These are coarse to very coarse granites, industrially used as a source of feldspar, mica, lithium minerals and beryl. They may contain cassiterite, columbite – tatalite, rare alkalies and gem minerals. Pegmatite dikes were reported within the intrusive complex of the Bulfat Igneous Complex (Buday and Suk, 1978).

DISCUSSION

Kurdistan Region is obviously rich in many mineral raw materials and industrial rocks. The information presented in this paper reflects the preliminary nature of the exploration work carried out so far. However, it is possible, at this stage, to discuss the possibilities and prospects of the mineral resources of the region, keeping in mind that the actual mineral potential is not accurately known.

The investigated iron ore deposits and occurrences are not encouraging as a source for steel industry. Several problems exist with the Kurdistan iron deposits; they are first of small size with respect to reserves. The second problem is the poor grade, i.e. the low iron content for the most of the investigated deposits. Commercially, iron ore should be about (60 – 70) % Fe to be considered as suitable for steel industry. The prospects of discovering rich iron ore deposits of large reserves is poor in Kurdistan Region, based on the available facts on the geology and metallogenic features of the region. However, the available reserves can be used in cement industry for a long time.

The information presented in this paper on the rock associations of Cr and Ni mineralization suggests that there are favorable prospects for locating small to medium size ore deposits of Cr and Ni in the peridotite and serpentinite intrusions of the Penjween and Mawat complexes. The Boban occurrence should be investigated in more detail, together with the Cr-Ni occurrences of Bardi Zard. Moreover, the Ni-Cu association of some mineralization localities deserves further exploration works.

The available information presented here show that the upper parts of the Qulqula Group (Albian – Aptian) of the Zagros Suture Zone is the main Mn-bearing rock unit in Kurdistan Region. The reported occurrences are strata-bound and controlled by a well defined mineralization phase. Deposits of medium or small size may be found in the Albian – Aptian part of the Qulqula Group, after careful mapping and prospecting, especially in the Penjween area. The local economic importance of manganese, however, is extremely lowered by the absence of rich and commercial iron deposits necessary for steel and iron industries where manganese is needed.

The potential of Zn-Pb deposits is encouraging in Kurdistan Region. This conclusion is based on a number of facts, which include the positive results obtained in two of the Zn-Pb deposits; Marabasta and Serguza, where the total metals reserves of Zn and Pb (on category C1) are 0.143 and 0.054 million tones, respectively. The exploration in these two deposits is still far from the end and what was done, so far, is only a minor effort of what should be done to evaluate the full potentiality of these Zn-Pb deposits. Nevertheless, the results obtained, so far, indicate that both localities are actually ore fields and the mineralization occurs in strata-bound lenticular horizons within the Triassic carbonates and have subsurface extensions. The grade is high and it is expected that more fresh (unoxidized) ore may be found at deeper intervals at the Serguza and Marabasta deposits. On the other hand, the mineralization in Lefan seems very encouraging, especially in view of the subsurface results obtained in 1991, both in thickness and grade, which require detailed investigation. The numerous Zn-Pb showings in the Ora District, and especially in the area between Berzanik and Banik (Fig.4)

where about ten of these occurrences occur in an area of only 400 Km², obviously suggests a highly potential Zn-Pb ore field.

It is of extremely important priority to continue mineral exploration for zinc and lead mineral deposits in Kurdistan Region on the basis of the highly encouraging results and observations recorded until now. The Ora District should be given more priority due to the presence of almost all the Zn-Pb occurrence there, but Marabasta remains the most important deposits of all and it requires much more exploration work to outline its full potential.

The close association of barite with Zn and Pb mineralization in carbonate rocks provides better opportunity for lower prospecting and exploitation expenses. It is preferable to synchronize exploration for Ba deposits with the exploration for zinc and lead mineral deposits in this part of Kurdistan Region. Berzanik and Lefan occurrences appear to be the most important reported showings so far (Al-Bassam, 1983).

The potential of copper deposits in Kurdistan Region is encouraging based upon the numerous showings and due to the presence of suitable suit of host rocks. Several countries are producing copper from similar rocks in the region. A program of exploration (geochemical and geophysical) should be started as soon as possible in the Mawat, Bulfat and Penjween massives. Hydrothermal Cu-mineralization is promising in these igneous complexes, mostly associated with quartz veins, as well as in the Walash and Naopurdan Groups (Paleogene) and Qandil Series (Cretaceous). The Zagros Suture Zone appears to be more promising for Cu-mineralization than the Ora District.

The geological surveys carried out in Kurdistan Region for radioactive mineralization revealed high potential. Qandil Series and Walash Group deserve detailed investigation, especially in the areas where acidic igneous intrusions are found. Moreover, the Late Jurassic black shales contain anomalous radiation and should be considered as a target for exploration. It is highly recommended to carry out a regional aerospectrometric survey in Kurdistan Region to identify and locate potential areas and rock units for radioactive mineralization.

On the basis of the numerous asbestos showings presented here and the wide spread suitable host rocks or parent rocks (serpentines and peridotites) in the igneous complexes of the Zagros Suture Zone it is very likely to find small asbestos deposits in the region, especially in the Penjween Massif where more potential occurrences have been reported. The quality of Kurdistan asbestos, however, is low, due to the dominant slip-fiber variety of chrysotile over the better quality cross-fiber. Moreover, the fibers are generally short and sometimes brittle. The Penjween occurrences of **Zone I** and **Zone II** appear to be the best reported so far with respect to quality and extension. More work is recommended in these areas to outline more accurately the potential of the asbestos, but it is preferable to carry out such work in conjunction with other exploration targets in this region to minimize the cost and efforts.

The presence of very high quality marble is lacking in Kurdistan Region. However, the available data on known deposits indicate the presence of very large reserves of medium quality metamorphic marble and lower quality ortho marble. Sinjar and Khurmala formations represent strategic resources of high-quality limestone for cement industry in this region. Thick and extensive gypsum beds are available in the Fatha Formation, especially in the Folded Zone of the region. However, there are serious mining problems in some of these deposits due to high dip of the strata. Further exploration should be concentrated near the plunge of anticlinal structures, where the dip is as low as possible.

The industrial potential of igneous rocks in Kurdistan Region is not encouraging mainly due to the remoteness and complexity of the areas where they are located and exposed on surface. Serpentinization along shear zones and at margins of the igneous bodies reduces to a great extent the value of most ultrabasic rocks. Most basalts in the Zagros Suture are highly sheared and altered, whereas true granites appear to be absent. However, the available igneous rocks can be of great use in road building and dam construction, but only locally.

Some of the more valuable and important types of igneous rocks may be worth transporting from their place of origin to the industrial centers of the country, since Iraq lacks the uniform areal distribution of these rocks. Nepheline syenites are very important as a source for feldspar minerals in the ceramic industry and pegmatites are important for rare elements extraction. However, more detailed mapping is required for these types of igneous rocks, which should lead to a more accurate evaluation of their industrial potential.

CONCLUSIONS

- Kurdistan Region is rich in numerous occurrences, showings and deposits of metallic minerals and to some extent non-metallic minerals and industrial rocks. The presence of metallic mineralization in addition to barite, asbestos and marble is restricted to Kurdistan Province within the Iraqi territory.
- The main mineral deposits in Kurdistan Region are Zn-Pb, Cr-Ni, Fe, Mn and Cu among the metallics and marble, asbestos and barite among the non-metallics.
- The mineralization in Kurdistan was affected by two metallogenic periods related to regional (continental) tectonic events associated with the development of the Neo-Tethys. The first is the Late Triassic – Jurassic, which gave rise to the strata-bound Zn-Pb mineralization in the Triassic carbonates. The second is the Late Cretaceous, which developed the Cr, Ni and Cu-bearing basic and ultrabasic complexes of the Zagros Suture Zone and the formation of the vein and strata-bound, low-temperature Zn-Pb – barite – pyrite – siderite mineralization in carbonates of Cretaceous age in the Imbricated Zone.
- The available information on Kurdistan Region mineral resources are promising and the potential for future mining and mineral industries is high. However, mineral investigation and detailed geological, geophysical and geochemical surveys should be completed as soon as possible in order to have accurate data necessary for reasonable planning.
- Exploration priorities for metallic mineral deposits should be given to: Serguza, Lefan and Marabasta (Zn-Pb), Waraz, Konjirin, Kurra Dawi and Qala Dizah area (Cu) and Mawat igneous complex (Cr-Ni).
- Non-metallic minerals and building raw materials may be found in the Qandil Series and Walash Group (marble), Sinjar, Khurmala and Fatha formations (limestone), Injana, Mukdadiya and Bai Hassan formations (clays for cement), Aqra – Bekhme Formation (barite), and Fatha Formation (gypsum).

EDITORIAL NOTE

This paper was originally prepared to be part of a special issue of the bulletin on Kurdistan Region. It was accepted for publication more than four years ago, but not published then due to the delay in producing the Kurdistan issue. The paper is published now upon the request of the author to avoid further delay.

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