Geology and geochemistry of the Jurassic carbonate hosted barite deposits, Northeast Zakho, Iraq

Adil A. Al-Kaaby   Ali M.N. Al-Azzawi**   Faraj H. Tobia****
**Ministry of Natural Resources, Kurdistan Region_ Erbil*
***State Company for Geological Survey and Mining _ Baghdad*
**** College of Science - University of Salahaddin*
Received:10/1/2011, Accepted:8/2/2011

Abstract

Barite deposits located in Marsis locality of about 25km northeast of Zakho City were hosted in Jurassic dolomitic rocks. The barite is extending for about 6km and limited within about 38m thickness of dolomitic rocks. The thickness of the barite veins varies between few centimeters to 2.5m which increases downward. The major mode of occurrence of barite is as vein and cavity-filling. The barite and other minerals of vein and cavity-filling deposits are typical of suite precipitated from low-temperature hydrothermal solutions associated with igneous activity. Carbonate-hosted barite deposits contain 0.237% BaO, 103ppm Zn, and 83 ppm Pb. These rocks are deficit in Fe and F. Most of carbonate rocks are dolomitized, which provide appropriate physical and chemical conditions that permitted the passage of mineral-bearing fluids. These deposits are formed in carbonate platform setting and commonly developed in foreland thrust belt.

Introduction

The carbonate-hosted barite deposits represent the Jurassic formations. The boundaries between these formations are obscured, because most of the rocks are dolomitized that cause difficulty in identification of the fossils. This is the case of many parts of the Northern Thrust Zone (Buday, 1980).

Mineralization in these formations was recorded at Marsis locality. The global positioning system measurements of latitude, longitude, and elevation are: 37º 17' 31'', 42º 50' 58'', and 1410m, respectively. Marsis locality is situated of about 25km northeast Zakho City, near the Iraqi-Turkish boarders (Fig.1). The study area is highly mountainous and characterized by the cliffs and steep

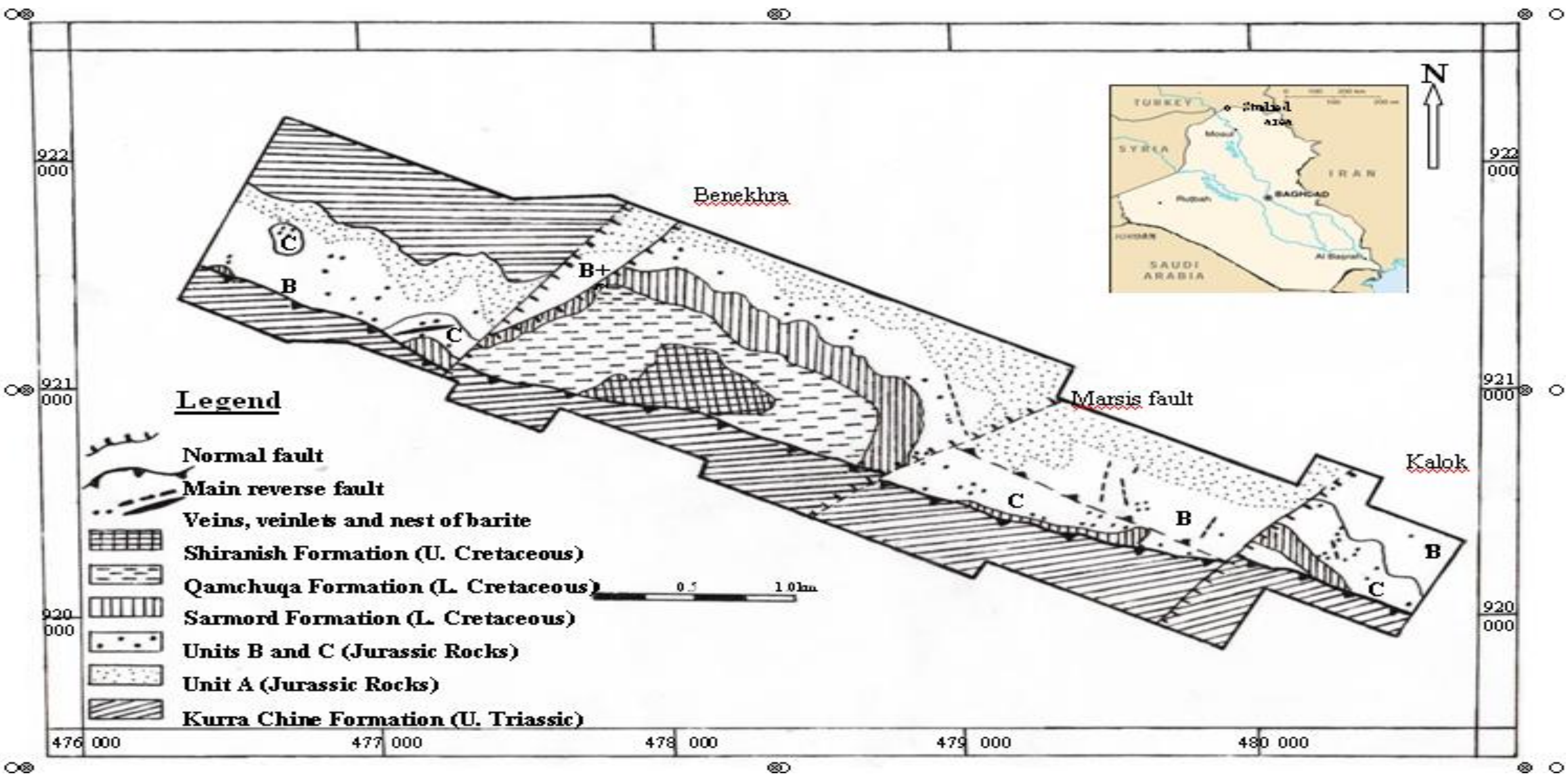

Fig.(1): Location map and distribution of barite deposits in Jurassic rocks, Marsis location, North Zakho, Iraq.

slopes. The area is crossed by three main valleys that intersect to form Basa-Agha valley which flows to the west.

Most of the previous studies between the beginnings of the fifties to 1986 were focused on the barite occurrence during the reconnaissance trips of Webber (1952), and the regional geological survey with scale 1:100000 by McCarthy and smith (1954). The later study concludes to the invaluable of this area for other mineral explorations. The following studied recommended for more assessment of this location (Buday and Vanecek, 1979; Al-Bassam, 1986). During 1989, the mineral exploration teams of Iraqi geological survey and mining established the work on detailed geological survey in this area with a scale 1:20000 (Ma'ala et al., 1990; Hassan et al., 1991), and then followed by mineral exploration (Al-Kaaby and Al-Azzawi, 1992).

No author discussed the Jurassic formations as host rock for mineralization except Al-Kaaby and Al-Azzawi (1992) and Tobia (2010). Most of the recent papers are deals with Upper Cretaceous carbonate hosted barite deposits at Lefan and Banik localities in the Northern Thrust.

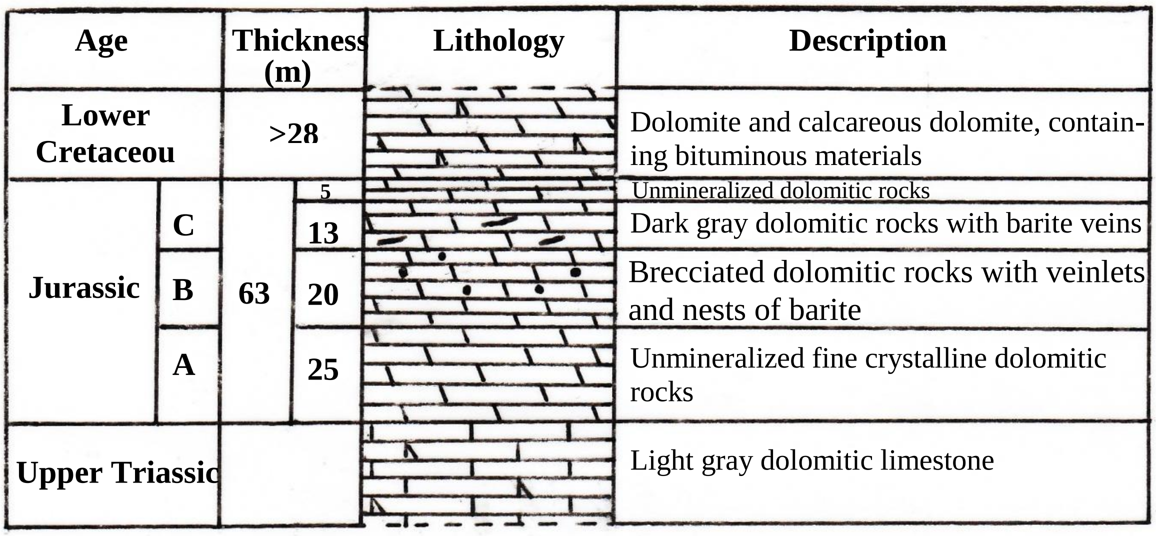

Fig. (2): Typical columnar section for barite deposits in Marsis location/ Zakho.

Sarmord Formation (Lower Cretaceous):

The formation is composed of dolomite and calcareous dolomite, light to dark gray in color, containing bituminous materials, the thickness of this sequence is about 28m. This is overlain by gray thin bedded dolomitic rocks (without bituminous materials) with breccia of 30cm thick and detrital limestone with iron oxides of 15cm thick which extend along the area. The total thickness of this sequence is about 26m. The later is overlain by dark gray to black thin bedded dolomite containing ammonite fossils; and its thickness is about 29m.

The upper part of the formation consists of dolomite and marly dolomite, light gray to white in color, thin bedded with iron oxide concretions decreasing upward. The thickness of this part is about 17m; and the total thickness of the formation is 98m. The formation was deposited in a deep inner shelf to outer shelf environment (Jassim & Goff, 2006).

Qamchuqa Formation (Lower Cretaceous):

This formation comprises of limestone and dolomitic limestone, gray to pale gray in color, coarsely crystalline of granular texture. It is thin bedded in the lower part and becomes thick upward and very hard which forms cliffs and steep slopes. The thickness of the formation is about 7m. The formation was deposited in a purely marine neritic sometimes shoal environment (Buday, 1980).

Aqra/ Bekhme Formation are missed in this location, and this confirm with Kassab (1972) that the sediments of the latest Maastrichtian age are absent.

Shiranish Formation (Upper Cretaceous):

Is the youngest formation in the Mesozoic (Buday & Jassim, 1987) and emplaces on the top of the stratigraphic sequence. This formation appears as platy and thin bedded of olive green to blue marl. The exposed thickness is about several meters. The Shiranish Formation is typical deeper open sea sediment (Buday, 1980).

Structural setting of Marsis location

The study area is located within the imbricated Zone, a part of Alpine Geosynclinal Belt (Buday, 1980) which is board to High Folded Zone in North Zakho.

The area is affected by Alpine Orogeny at Late Miocene and reaches the maximum intensity at Late Pleistocene. The two main reverse faults (Northern thrust fault and Southern thrust fault) are the result of this activity (Ma'ala *et al.*, 1990).

The most predominant structure elements in Marsis area are found during the detail geological survey with scale 1:5000 (Al-Kaaby & Al-Azzawi, 1992). These elements are represented as follows:

Main reverse fault:

It extends along several kilometers in NW-SE direction. The northern block comprises the rocks of Shiranish, Qamchuqa, Sarmord Formations and most of Jurassic rocks. The later becomes in contact with Kurra Chine Formation (Upper Triassic) located in the southern block of the fault which thrusts on the northern block (Fig.1). There is another small reverse fault located to the north of the main fault and extend to the same general direction. This fault thrusts the rocks of unit A and became in contact with the rocks of unit C and with Sarmord formation in some places. These two faults are the oldest in the area and are also subjected to another displacement lately.

Normal faults:

The area is affected by other movements that formed many normal faults with a general trend NE-SW. These faults are (from the east to the west): Kalok, Marsis, and Benekhra faults. The two latter faults formed Marsis-Benekhra Graben which preserves the big younger rocks compared with the surrounding area (Fig.1). These faults displaced A, B, and C units from each other by several tens of meters. These faults (especially in unit B and C) are associated with barite veins of different thickness and extension.

Fracture zone:

Six locations of the fracture zone were determined. They are located within the northern block of the main fault and are affected on the rocks of unit B and C only. These fractures are nearly of vertical dip and have an extend NNW and NNE. The aerial extend is between 100 to 250m (Fig.1). There are traces of scratching vertical to the associated barite surfaces.

Stratigraphic setting of barite deposits

The deposits of barite geologically are classified by their mode of occurrence into three major types: the vein and cavity-filling deposits, the residual deposits, and bedded deposits (Brobst, 1983). Vein and cavity-filling deposits are those in which barite and associated minerals occur along various kinds of fractures, joints, bedding plane and solution structure that commonly occur in carbonate rocks. The vein and cavity-filling deposits commonly have sharp contacts with the enclosing rocks and, large scale replacements of the host rocks beyond the controlling structures are rare. The barite deposits in Marsis area are located within the Jurassic rocks. The thickness of these rocks is about 63m, which are underlain by Triassic rocks and overlain by dolomitic rocks of Lower Cretaceous. Fig.2 represent the occurrence of barite deposits within the columnar section. The Jurassic rocks are divided into three units (A, B, and C); unit B and C are associated by barite deposits. The thickness is about 38m and extends along Marsis location to about 5km.

The unit B comprises a dolomitic bed that extends along the area with a thickness between 16-20m that contains a barite as veinlets or as pore space filling. While the unit C of about 18m thick is characterized by the presence of the main barite veins.

The barite veins are irregular and have different thickness and extension. The maximum aerial extension for these lentil veins is more than 250m with a maximum thickness of about 2.5m with high dip angle (i.e. nearly vertical to the beds of the host rocks that have a dip between 10°-20°).

The barite deposits are restricted to a fairly limited stratigraphical range within the Jurassic rocks (units B and C); therefore, they are considered as strata-bound deposits. It is possible to find a new barite occurrence within the same rocks in other areas. The barite deposits originate from saline basinal brines. They are located in carbonate platform setting, typically in relatively undeformed orogenic foreland rocks, commonly in foreland thrust belts (Leach & Sangster, 1993).

Benekhra vein in Marsis location:

There are many large veins of barite, Benekhra vein is one of them (Figure 1). This is studied in detail because it includes most of the features that may be observed in barite deposits within the study area. The direction of the vein is NE-SW, the surface extension is about 15m, its traces can be followed to about 100m, and its maximum thickness is 2.5m. The dip of the vein ranges between 70°-76° SSE within the dolomitic beds of the Unit C which subject to intense fractures in the northern part of the fault. The dip of the dolomitic beds is between 15°- 19° of the same general direction of the vein (i.e. SSE); so the vein is in concordance with the country rocks.

The petrographic section of the vein is divided into three zones:
1) The dolomitic country rocks: they mostly comprise of light grey dolomite crystals with dark impurities. The crystals are very fine (between 0.01-0.02mm) and are rarely 0.05mm.
2) Mineralized zone: The barite is as vein of about 2.5m thickness; the lower and upper contacts of the vein are surrounded by a thin zone (about 15cm thick) of highly fractured dolomitic rocks with veinlets of barite or small vertical veins parallel to the main vein.

The barite in this zone is characterized by white color and whitish grey and sometimes with fetid odder in some places. The barite growth on the wall of the cavities is as rose like shape; there is a carbonate with a hexagonal quartz crystals growth in the center of these cavities. The near center parts of the cavities may be subjected to the replacement processes where there is a barite within the carbonate and quartz crystals.
3) The upper part zone: It represents the lens of breccia with no clear lateral extension; it consists of rock fragments of dolomite rhomb form with between 0.1-0.2mm sizes. It is also worth noting that there is an increase in

the size of the crystal compared with the crystals of the country rocks. The rock fragments are cemented mainly with barite and with some quartz and fluorite as well as secondary dolomite with traces of opaque minerals (probably sulphide minerals).The mineral composition of Benekhra vein is characterized by the abundance of barite mineral of very high purity not less than 97%, and the other compounds are dolomite and quartz, while fluorite is as traces.

Geochemistry of carbonate hosted barite deposits

Carbonate host rocks are mainly composed of dolomite with little amounts of calcite. The averages of CaO and MgO are 29.75 and 20.80%, respectively, and also they include 0.24% BaO as average which is about 23 times that of Rose *et al.* (1979). The Jurassic carbonate hosted barite deposits in Marsis area include 155ppm Zn and 235ppm Pb as averages (Table 1). Zinc and lead contents mainly are come from sphalerite (ZnS) and galena (PbS), respectively, and their alteration products, such as smithsonite ($ZnCO_3$), cerussite ($PbCO_3$), and anglesite ($PbSO_4$).

Table 1: Geochemical results of Jurassic carbonate-hosted barite deposits in the Marsis locality, North Zakho.

Sample no.	Fe_2O_3 %	CaO %	MgO %	L.O.I %	I.R %	BaO %	Total %	Zn ppm	Pb ppm	Cd ppm	F ppm
M1	0.05	30.05	21.57	46.20	0.96	0.03	98.86	٣٠	13	7.5	18
M2	0.19	29.04	20.86	45.96	0.56	0.11	96.72	87	210	7.7	20
M3	0.38	29.42	19.64	44.61	3.26	0.02	97.33	30	240	7.5	52
M9/1	0.12	29.88	20.26	45.70	0.62	0.02	96.60	34	28	7.3	19
M9/2	0.16	29.70	20.16	45.58	1.61	0.01	97.22	58	7	7.8	32
M13	0.04	29.66	21.17	45.75	0.16	0.02	96.80	40	5	7	12
N1	0.01	34.85	17.34	45.20	1.26	0.07	98.73	62	55	6.5	42
N4	0.05	24.73	25.40	45.53	0.35	0.11	96.17	35	5	7	21
N14/2	0.44	30.12	19.95	45.27	1.85	0.10	97.73	65	5	٧	46
N19	0.08	30.30	21.40	46.80	0.20	0.43	99.21	982	220	15	140
N20	0.06	30.60	21.20	46.94	0.24	0.12	99.16	251	18	11	62
N12	0.10	28.60	20.60	45.10	2.74	1.80	98.94	191	2015	10	36
Range	0.01-0.44	24.73-34.85	17.34-25.40	44.61-46.94	0.16-3.26	0.01-1.80		30-982	5-2015	7-15	12-140
Average	0.14	29.75	20.80	45.72	1.15	0.24		155	235	8.4	41.7
Rose *et al.*(1979)	1.09					0.012		21	5	.035	250

L.O.I: Loss on ignition
I.R: Insoluble residue

The Pearson's correlation coefficient was used; the critical value of *r* is 0.58 at 0.05 levels and 0.771 at 0.01 levels which is affected by the number of the samples. The negative correlation coefficient between CaO and MgO (Table 2) refers to the dolomitization process that supports the formation of a high permeable zone which participate the ore reception. Cadmium perfectly correlates with Zn (+0.945). Obviously, this positive correlation support that the Cd is substitutes Zn in the sphalerite (Ramdohr, 1969). The Jurassic rocks are deficit in fluorine relative to Rose et al. (1979), but perfectly correlates with Zn (+0.929), which F is considered as a pathfinder for Zn-bearing deposits. Finally, BaO correlates with Pb (+0.978). There are galena grains associate barite ($BaSO_4$) deposits in some veins within Unit C.

Table 2: Correlation coefficient matrix for some elements of Jurassic carbonate-hosted barite deposits in Marsis locality, North Zakho.

F	Cd	Pb	Zn	BaO	I.R	L.O.I	MgO	CaO	Fe_2O_3	
									1	**Fe_2O_3**
								1	-.087	**CaO**
							1	-.881**	-.240	**MgO**
						1	.316	.049	-.480	**L.O.I**
					1	-.777**	-.427	.054	.610*	**I.R**
				1	.397	-.156	.013	-.158	-.120	**BaO**
			1	.255	-.281	.583*	.092	.097	-.180	**Zn**
		1	.118	.978**	.519	-.290	-.061	-.153	-.041	**Pb**
	1	.266	.945**	.390	-.208	.636*	.137	.023	-.199	**Cd**
1	.873**	.034	.929**	.149	-.064	.422	-.080	.224	.049	**F**

no. of samples= 12
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Discussion and conclusions

The Jurassic formations mainly consist of dolomitic rocks represent shallow neritic condition with frequent lagoonal evaporitic influences in the lower parts and euxinic marine environment with some layers showing shallowing in the upper parts.

The presence of dolomite with lagoonal evaporitic facies during the opening of the Neo-Tethys Ocean, which was shallow at begin of the opening in the Jurassic. While in the Late Jurassic a geodynamic inversion of regional tectonic regime took place. Extensional tectonism was replaced by compressional one and the Neo-Tethys start to contract (Jassim & Goff, 2006).

Carbonate hosted barite deposits are mainly composed of dolomite, where Table 1 shows high contents of MgO. Dolomitization and recrystallization are the main diagenetic processes that provided permeable strata, and dolomite is extremely brecciated and highly fractured; thus it has provided a good conduits and traps for the mineral-bearing fluids, especially in unit B, which barite is localized as a strata-bound type, with an aerial extend for about 6km (Figure 1).

Absent of any large scale Pb-Zn-Fluorite mineralization in association with barite and the present of rose like shape in the barite are a good indications for the deposition at low temperature (Sharma et al., 2003; Paradis et al., 2004). In addition, the barite and other minerals of the vein and cavity-filling deposits are typical of suite precipitated from low temperature solutions associated with igneous activity (Brobst, 1983).

Carbonate hosted barite deposits of Jurassic age, generally, have elevated levels of BaO, Zn, and Pb; but have low contents of Fe_2O_3 and F (Table 1). Lead perfectly correlates with Zn and also the later correlates with Cd, this indicates that Cd is present with sphalerite (Lin & Tiegeng, 1999). Fluorine positively correlates with Zn; this is the reason for using F as a pathfinder for Zn-bearing deposits.

Most of barite deposits are originates from saline basinal brines. They are located in carbonate platform setting, typically in relatively undeformed orogenic thrust belts (Leach & Sangster, 1993). Depending on the $^{87}Sr/^{86}Sr$ ratios, Tobia (2010) conclude the Late Cretaceous age for the barite mineralization that hosted in Jurassic rocks, so that may be related to the Laramide Orogeny, the same age was concluded by Awadh (2006) for the Upper Cretaceous mineralization.

References

- Abdul-Karim, S.K., Ahmed, A.M., Rasul, A.K, Anwar, H. A., (2007): Geophysical and mineralogical study of some ore deposits in Shiranish area, Northeast of Zakho City, *J. Dohuk Univ.,* Vol.10, No.2, pp.10-16.
- Al-Ka'aby, A. A., Al-Azzawi, A. M., (1992): The detailed investigations for strata- bound barite deposits in Marsis locality, North Zakho, Iraq. *GEOSURV*, Internal report no. 2071, 95p. (in Arabic).
- Al-Bassam, K.S., (1986): Metallogenic aspects of Iraq, *Jour. Geol. Soc. Iraq,* Vol. 19, pp.183-199.
- Awadh, S.M., (2006): Mineralogy, geochemistry and origin of the lead-zinc-barite deposits from selected areas from north of Zakho, Northern Iraq, University of Baghdad, *Unpub. Ph. D. Thesis,* Iraq, 191p.(in Arabic).
- Awadh, S.M., Habib, H.R., Al-Bassam, K.S., (2008): Upper Cretaceous carbonate hosted zinc-lead-barite deposits in Northern Thrust Zone, Northern Iraq: petrography and geochemistry, *Arab J. Geosci.,* Vol. 1, pp.75-85.
- Brobst, D.A., (1983): Barium Minerals Industrial Minerals and Rocks, 5th ed., Vol. 1, S.J. Lefond, ed., AIME, New York, pp.485–501.
- Bellen, V.R.C., Dunnington, H.V., Wetzel, R., Morton, L., (1959): Lexique stratigraphique international, Vol. III- Asia, Fasc. 10a- Iraq, *Centre National De La Recherché Scintifique,* Paris, 333p.
- Buday, T., Vanecek, M., (1979): Outline of mineral occurrences of Iraq and general mineral investigation programme for 1971-1996, *GEOSURV,* Internal report no. 509.
- Buday, T., (1980): The regional geology of Iraq, stratigraphy, and paleontology, Vol.1, *Dar Al-Kutib Publ. House*, Mosul, Iraq, 445p.
- Buday, T., Jassim, S.Z., (1987): The regional geology of Iraq, In: Kassab I.M. and Abbas (eds) Tectonism, magmatism, metasomatism, Vol.2, GEOSURV, Iraq, 352p.
- Hassan, K. M., Fouad, S. F., Misconi, H. Sh. , Qadouri, N. A., Al-Aaraji, H., Amir, R., Al-Jawari, H. O., Al-Hazaa, S. H., Ma’ala, K. A., (1991): Detail geological survey of Hazil Su- Khabour area, *GEOSURV,* Internal report no. 1979.

- Jassim, S.Z., Goff, J.C., (2006): Geology of Iraq, Dolin, Prague and Moravian Museum, Printed in Czech Republic, 341p.
- Kassab, I.M., (1972): Micropaleontology of Upper Cretaceous- Lower Tertiary of North Iraq, Ph. D. Thesis, London University, 310p.
- Leach, D.L., Sangster, D.F., (1993): Mississippi Valley-type lead-zinc deposits. in Kirkham RV, Sinclair WD, Thorpe RI, Duke JM, eds., Mineral Deposit Modeling: *Geological Association of Canada Special Paper 40,* pp.289-314.
- Lin, Y., Tiegeng, L., (1999): Sphalerite chemistry, Niujiaotang Cd-rich zinc deposit, Guizhou, southeast China, *Chinese Journal of Geochemistry*, Vol.18, No.1, pp.62-68.
- Ma'ala, K.A., Hassan, K., Misconi, H. Sh., Al-Azzawi, A., Lawa, F., Qadouri, N.A., Yakta, S., Sattar, A., Al-Mukhtar, L., Hammoudi, B., (1990): Detailed geological survey of Sunat- Marsis area, *GEOSURV*, Internal report no. 1974.
- McCarthy, M.J., Smith, J.S., (1954): Report on geological investigation of the area NE of Zakho, *GEOSURV*, Internal report no.264.
- Paradis, S., Chi, G., Lavoie, D., (2004): Fluid inclusions and isotopes evidence for the origin of the Upton Ba-Zn-Pb deposits, Quebec Appalachians, Canada, *Econ. Geol.*, Vol.99, pp.807-817.
- Qadouri, N.A., (1992): Jurassic sediments in Iraq, *Jour. Geol. Soci. Iraq*, Vol.9, No.3 (7IGC).
- Ramdohr, P., (1969): The ore minerals and its intergrowths, Pergamon press, Oxford, London.
- Rose, A.W., Hawkes, H.E., Webb, J.S., (1979): Geochemistry in mineral exploration, 2^{nd} ed., *Academic Press*, 687p.
- Sharma, R., Verma, P., Sachan, H.K., (2003): Strontium isotopic constrains for the origin of barite mineralization of Tons Valley, Lesser Himalaya, *Current Science,* Vol.85, No.5, pp.653-656.
- Tobia, F.H., (2010): Strontium isotope ratios as a tool for the origin of barite mineralization of Marsis and Lefan deposits, Northeast Zakho, Iraq, *Iraqi Journal of Earth Sciences*, (in press).
- Webber, B.N., (1952): Geological reconnaissance of the metallic minerals and sulfur deposits in Iraq, *GEOSURV*, Internal report.

جيولوجية وجيوكيميائية الصخور الجوراسية الحاضنة لترسبات البارايت، شمال شرق زاخو، العراق

عادل عبد الجبار ألكعبي*   علي محي نايف العزاوي   فرج حبيب طوبيا*****

*** وزارة الموارد الطبيعية في إقليم كردستان/ أربيل**

**** الشركة العامة للمسح الجيولوجي والتعدين/ بغداد**

***** كلية العلوم ــ جامعة صلاح الدين**

تاريخ الاستلام:٢٠١١/١/١٠، تاريخ القبول:٢٠١١/٢/٨

الخلاصة

تقع ترسبات البارايت لمنطقة مارسيس شمال شرق مدينة زاخوبحوالي ٢٥ كم وان الصخور الدولومايتية هي الصخور الحاضنة لهذه الترسبات. يصل سمك هذه الصخور إلى حوالي ٣٨م وتمتد التمعدنات إلى أكثر من ٦كم. يتراوح سمك عروق البارايت من عدة سنتيمترات إلى ٢,٥م ويزداد باتجاه الأسفل. إن النمط الرئيسي لتواجد البارايت هو على شكل عروق وملئ للفراغات وان ترسبات البارايت والمعادن الأخرى تمثل المجموعة المثالية للترسيب من المحاليل الحرمائية ذات الحرارة المنخفضة. تحتوي الصخور الكاربونايتية الحاضنة للبارايت على ٠,٢٣٧% من اوكسيد الباريوم و ١٥٥ج.م.م من الخارصين و ٢٣٥ج.م.م من الرصاص. إن هذه الصخور تحتوي على كميات واطئة من الحديد والفلور. معظم الصخور الحاضنة مدلمتة إذ أعطت ظروف فيزيائية وكيميائية مناسبة لمرور المحاليل الحاملة للمعادن. تكونت هذه الترسبات في السطحية الكاربوناتية والتي تطورت في نطاق الزاحف المواجه لليابسة.