

Geology, Petrography, and Mineralization of Sedimentary Hosted Strata-Bounded Barite Deposit at Gunga, Khuzdar District Balochistan, Pakistan

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Received: 29 April, 2021

Accepted: 11 August, 2021

Abstract: Gunga deposit is a type of sedimentary exhalative (SEDEX) deposit located in the northwest of Khuzdar Knot within the Kirthar Fold Belt (KFB) in the south-west of Khuzdar city. This deposit is formed during the late Triassic-Jurassic period due to rifting of the Gondwana supercontinent. being hosted with the Anjira Member of Jurassic Shirinab Formation, hosted the Strata bounded barite mineralization in these deposits contact with the siliceous and iron-rich gossan zones. The Baritic zone indicates the complex replacement of silica with the continuous silicification which is followed by massive to brecciated type Barite. Petrographically, barite has a very fine to coarse grain texture, anhedral to euhedral crystal shape, and forms dendritic crystal structure. In the Back Scattered Electron (BSE) images, the crystal morphology of Barite exhibits well-developed elongated crystal structures with medium to coarse grain texture. Energy Dispersive X-rays (EDX) graphs indicates the high peaks of Ba, S, and O elements associated with sub-peaks rock-forming mineral elements (Si, Al, Na, K, and Ca) along with sub-peaks of ore-forming mineral elements (Pb, Zn, Fe, P, and Ni).

Keywords: Gunga, Khuzdar, Kirthar fold belt, SEDEX mineralization, barite.

Introduction

The word SEDEX stands for the sedimentary exhalative, formation of laminated sulphides ore in the non-clastic chemical sediments, carbonaceous shale, and very fine clastic rocks (Carne and Cathro, 1982; Cook et al., 2000; Sawkins, 2013; Wilkinson, 2013). These deposits are formed by the precipitation of hydrothermal solution that has been exhaled on the seafloor (Leach et al., 2005b; Leach et al., 2010; Wilkinson, 2013). Tectonically, SEDEX deposits are related to extensional or rift-related tectonic environments within the sedimentary basin, i.e., an epicratonic, inter-cratonic region, distal back arc, and passive continental margins (Lydon, 1995; Leach et al., 2005b; Lydon and Goodfellow, 2007). Some authors favours that the SEDEX deposits are formed by the saline basinal brines and an important source of sulphides ore from the high constituents of ore fluids formed by the hydrothermal system (Hutchinson, 1980; Badham, 1981; Russell et al., 1981; Lydon, 1983, 1986; Sawkins, 1984; Goodfellow et al., 1993; Garven et al., 2001; Leach et al., 2004; Yang et al., 2004; Large et al., 2005). Structurally, the SEDEX deposits are controlled by the normal fault in the intracratonic and epicontinental basin, and structures like host and graben are associated with the first order basin, second-order basin, and third-order basin (Emsbo et al., 2016; Jaing et al., 2020; Morris, 2020).

In this paper we discuss the geology, petrology, and mineral characteristics of Sedimentary Hosted Strata-Bounded Barite in Gunga deposit of south-west part in Khuzdar of Kirthar Belt in southern, Pakistan. The findings of this research help to understand the field relation, petrological and mineralization characteristics of Barite in the sedimentary hosted Gunga deposit.

Geological Setting

Gunga deposit is located southwest of the Khuzdar city, in Kirthar Fold and Thrust Belt (KFTB). The KFTB is a major tectonic belt of East Balochistan Fold and Thrust belt and extends about 380 km long and 50 to 70 km wide zone (Kazmi and Jan, 1997). This Fold and Thrust Belt is bounded by the Chaman - Nal-Ornach Transform Fault system and Bela Ophiolite in the east and Lower Indus Basin in the west (Bander and Raza, 1995) (Fig.1). Structurally KFTB divides into several sub-structural units i.e., Kalat Anticlinorium, Kalat Plateau, Khuzdar Knot, Khude Range fold belt, and Karachi embayment zone (Kazmi and Jan, 1997). Two major tectonic events controlled the geology of Khuzdar and its surrounding. The first event occurred during the Late Triassic-Jurassic period, the rifting and extensional of Gondwanaland (Powell, 1979; Ahsan, 1995; Lydon, 1989). The sedimentary strata hosted the ore minerals deposited in response of rifting (Ahsan, 1995), the transition of vertical facies in the Firozabad group (Jurassic). The Firozabad group shows a transgressive

continental shelf environment, progradation of the platform shelf, proximal clastic, and slope carbonate environments (Ahsan and Mallick, 1999). During Late Cretaceous to Early Tertiary Period, the second tectonic event occurred when the Indian continental plate separated from the Arabian Plate. The final collision of Indian Plate with the Eurasian Plate developed the Kirthar-Sulaiman Fold and Thrust Belt. During this collision of two major plates the ophiolites (Bela-Khuzdar ophiolite, Muslim Bagh-Zhob ophiolite, and Waziristan - Khost Ophiolitic complexes) obducted on the northwest boundary of Indian plate (Powell, 1979; Ahsan and Mallick, 1999).

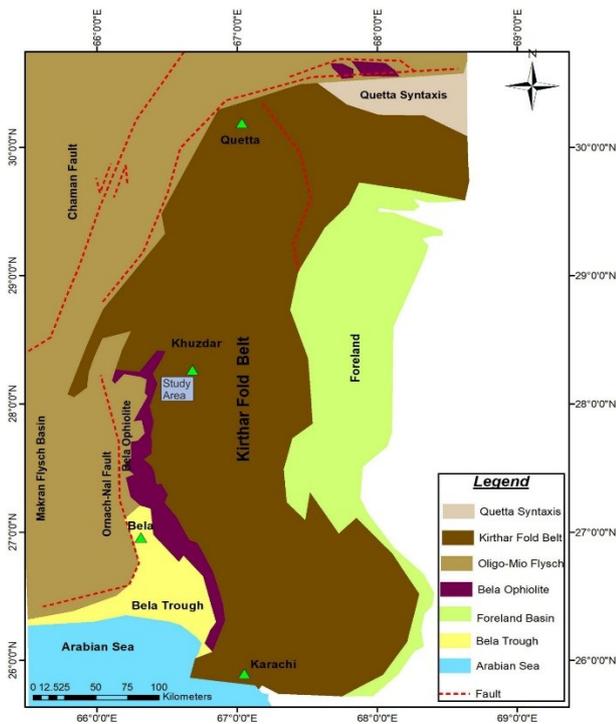


Fig. 1: Geology and Tectonic map of Kirthar Fold and Thrust Belt (KFTB) (Kazmi and Jan, 1997).

Mineralization of barite deposits in the Gunga is strata-bound within the Jurassic Anjira Member mainly composed of limestone and shale in the middle part of Shirinab Formation (Husain et al., 2002). This succession is widely exposed in the KFTB (Fatmi et al., 1986; Siddiqui and Sharp, 1993; Hussain et al., 2002; Khan and Clyde, 2013). Stratigraphically, the study area is composed of Jurassic to Cretaceous sedimentary successions. Shirinab Formation is mainly composed of limestone and shale where the lower part of the Formation is transitionally in contact with the Late Triassic Wulgai Formation (Fatmi, 1977; Ahsan and Mallick, 1999). The Shirinab Formation is subdivided into three major members i.e. Spingwar, Loralai, and Anjira Member (Fatmi et al., 1986; Siddiqui and Sharp, 1993; Hussain et al., 2002; Khan and Clyde, 2013)

(Fig.3). Spingwar Member, a basal part of Shirinab Formation, is mainly comprised of thick-bedded limestone, interbedded with calcareous shale and sandstone. The lower part of the Spingwar Member is transitionally in contact with the late Triassic Wulgai Formation and the upper part is conformably overlain with Loralai Member (Kazmi and Jan 1997). According to Williams (1959) Spingwar Member is enriched ammonite's species and based on these ammonite fossils the member presents an early Jurassic (Kazmi and Jan 1997). Loralai Member is mainly composed of medium to thick-bedded limestone. The lower part of the Loralai Member conformably contacts with the Spingwar Member and transitional contact with the Anjira Member Kazmi and Jan (1997) assigned Early Jurassic age for the Loralai Member). The Anjira Member comprises of medium bedded argillaceous limestone interbedded with the mudstone. The upper part of the member is in disconformable contact with the early Cretaceous Sembar and Goru Formations (HSC, 1960; Fatmi, 1986; Kazmi and Jan 1997). This Member presents early to middle Jurassic age based on ammonite fossils (Kazmi and Jan 1997).

Local Geology

The Gunga deposit is located 11 km southwest of Khuzdar city in Balochistan province, covered an area of 1500 Km² (Fig.1). The Gunga deposit gives rise to an especially complex geological structure that has been intensely affected by the complex tectonic structures of Khuzdar Knot (Bander and Raza, 1995; Kazmi and Jan 1997) (Fig.1). The Anjira and Loralai Members of the Jurassic Shirinab Formation host the mineralization zones of barite in the study area, which divided in to various sub-units (Fig 1 and 2).

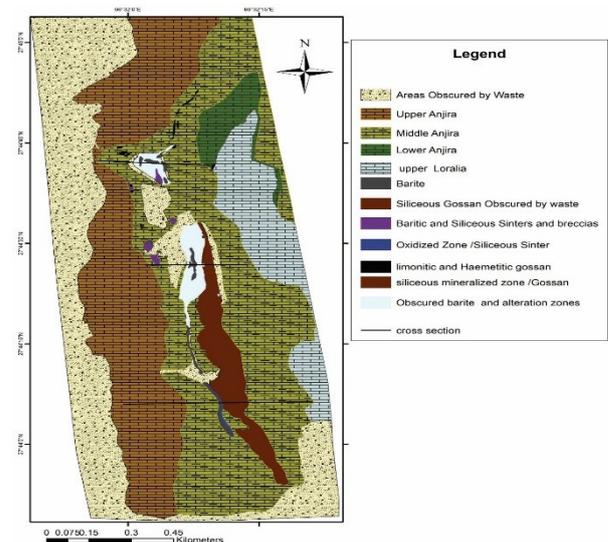


Fig. 2: Geological map of the Gunga deposit area.

The Loralai Member is subdivided into four different units (a) Lower Loralai Limestone and Shale Unit, (b) Lower Loralai Limestone Unit, (c) Middle Loralai Unit, and (d) Upper Loralai Unit. Lower Loralai Limestone and Shale Unit of Loralai member bounded by 10 to 15m thick bed of limestone with interbedded shale, while the total thickness of this unit is about 50 m. The Lower Loralai Limestone unit consists of a 2 to 5 m thick bed of limestone interbedded with grey shale and brownish micritic limestone and its total thickness is 20 to 100 m. Middle Loralai unit composed of 10-20cm thick-bedded of mottled grey fossiliferous limestone with interbedded brownish weathering limestone. This unit is associated with limonitic stained beds in the lower part of the unit. The total thickness of the Middle Loralai unit is 200 to 250m. The Upper Loralai unit is marked as the top unit of the Gunga deposit and is bounded by a thick bed of shale and highly fossiliferous limestone. This unit is marked by the overlying the lower Anjira unit while underlying with the middle Loralai unit. Orange mottled siderites pitches are associated with the upper part of the Loralai unit. The total thickness of the Upper Anjira Unit is about 30 to 75m thick (Fig.3).

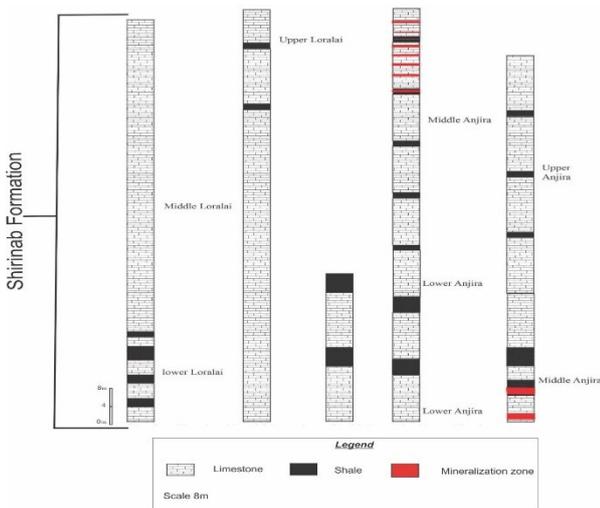


Fig. 3: Schematic geological logs are showing the stratigraphy and mineralization-hosted rocks in the deposit area.

Anjira Members are subdivided into three units; (a) lower Anjira unit, (b) Middle Anjira unit, and (c) an Upper Anjira unit. The lower Anjira unit consists of thin-bedded grain stones and poorly fossiliferous limestone with various small ferruginous nodules. The total thickness of the Lower Anjira Unit is 20 to 75m thick. Middle Anjira unit bounded by 15-20cm thick bed of limestone, interbedded with green-grey shale with poorly preserved ammonite impression. Major sulfides ore mineralization at the Gunga deposit occurred within the Middle Anjira unit, typically as strata bound lenses

of barite associated with sulfides mineralization including lead and zinc sulfides with pyrite and the total thickness is about 50 to 200m thick. The Upper Anjira unit is mainly composed of massive grain stones associated with cherty bed and conglomerate basal part of the Gunga deposit. Typically, the thickness of the Upper Anjira Unit is highly variable from 15 to 50m (Fig.3). Sembar Formation is a representative unit of the Gunga deposit mainly consisting of greenish-grey shale and disconformable contact with Upper Anjira Limestone Unit.

Gossans in Study area

Gossan is highly oxidized zone, generally expose on the surface or upper part of the ore deposit (Gilbert and Park, 1986). At the Gunga deposit, the gossan zone is exposed at the surface of the ore body. Based on their chemistry two types of Gossan zones are identified. i.e., Siliceous Gossan and Baritic Zone (Fig.4. a - b).

Siliceous Gossan

The siliceous gossan in the study area presents as ridge shape structure. The main ridge of siliceous gossan is characteristically black, purplish brown to rusty color veinlet infiltrated light grey altered rocks in stockwork and spheroidal pattern (Fig.4. c - d). The middle part of siliceous gossan is covered by dark ferruginous cover; a massive, widely extended gossan, in contact with the middle unit Anjira Member and barite mineralized zone. The siliceous gossan zone is underlying the mineralized zone, which is separated from a few meter-thick brownish interbedded shales with thin-bedded limestone in the southern part of the deposit (Fig. 2). In the northern part, the siliceous zone is very narrow because of the sequence of brecciated limestone-shale. The siliceous gossan zone is typically identified as an oxidation weathering zone that mainly consists of high constituents of the disseminated sulfides. This mineralized zone is enriched with lead and zinc sulfides (Fig.4. e).

Baritic Zone

The middle part of the Jurassic Anjira Member hosts barite mineralization (Fig.4 a & b). A complex replacement of silica where series of continuous silicification commonly occurs in the massive barite to brecciated barite. The brecciated barite has a low-density siliceous sinter matrix and completely siliceous breccia with replacements of silica in the barite clast. Beds of barite have been bleached cap by silicified shale in the northern dump area, the interlayered barites are separated by bleached shale (Fig.4. f - g). In the southern

part of the deposit area, 3 to 4m thick-bedded barite is overlain with sinter-like breccia. In the open pit mine, the massive bed of barite contacts with siliceous gossan zone, hematite and limonitic gossan, and Anjira Member (Fig.4. h - i).

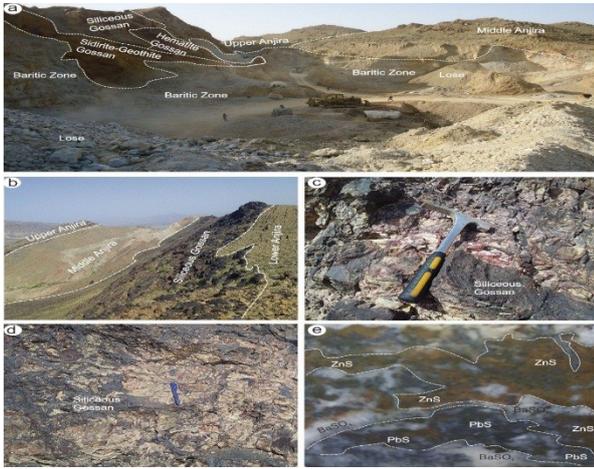


Fig. 4 (a-e): Baritic zone contact with the middle Anjira Member, siliceous gossan, and iron-rich gossan zone in the open pit area (a - b). Black, purplish-brown to rusty color spheroidal pattern ridge shape and cracks structure is a weakly mineralized siliceous gossan zone contact with lower Anjira Member (c - d). Hand specimen from siliceous gossan zone mainly consists of disseminated galena and sphalerite within the vein of barite (e).

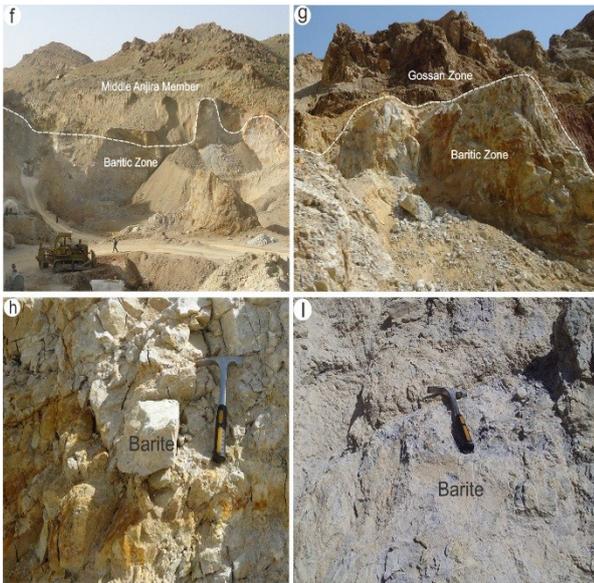


Fig. 4: (Continued) (f - i). Baritic zone in contact with the middle Anjira Member and siliceous - iron-rich gossan zone (f and g). The weathered and fresh color of brecciated to massive type of Barite with intensely silicified (h and i).

Material and Method

A fifteen-day geological fieldwork has been carried out in and surroundings of the Gunga deposit. In this fieldwork we marked the gossan zones and a detailed field investigation of ore mineralized zones. The

representative samples have been collected from both ore body and host rocks. The petrographic and textural characteristics of twenty selected samples were identified by Leica DM 500 binocular microscope in the Center of Excellence in Mineralogy (CEM), University of Balochistan, Quetta. The Scanning-Electron Microscopy (SEM) on five ore samples have been carried out on SEM-EDX (Model JSM 910) in CEM, University of Balochistan, Quetta.

Results and Discussion

Petrography

Barite

In thin sections the texture of barite varies from medium to coarse grain with fine grain groundmass. The coarse grain crystalline barite commonly exhibits radiating or prismatic subhedral to euhedral crystals shape occurs in a vein or vugs filling. The fine-grained anhedral barite is mainly abundant in the groundmass formed during hydrothermal alteration. Barite is mainly associated with fine-grained calcite, quartz, and clay minerals (Fig. 5 a - f).

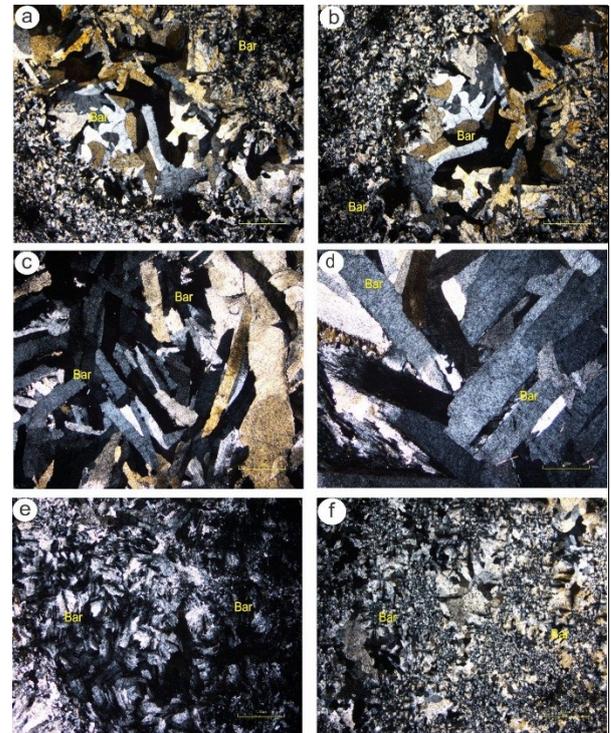


Fig. 5: Micro photomicrographs showing the texture, crystal shape, and structure of Barite. Grey to white color of Barite has a vein structure with fine to coarse grain texture (a - b). The white color of the well-developed crystal structure of Barite has a very coarse grain texture and euhedral crystal shape associated with dendritic and elongated crystal shape (c and d). Light to colorless barite has fine to medium grain texture with anhedral to subhedral crystal shape (e and f).

Scanning Electron Microscope-Electron Dispersive X-rays Spectroscopy (SEM-EDX) Technique

Barite (BaSO₄)

Barite is the primary mineral of the sulfates group chiefly consisting of Ba, S, and O. In the BSE images the crystal morphology of barite and barite grains depicts well-developed elongated crystal structures with medium to coarse grain texture (Fig.6. a - d).

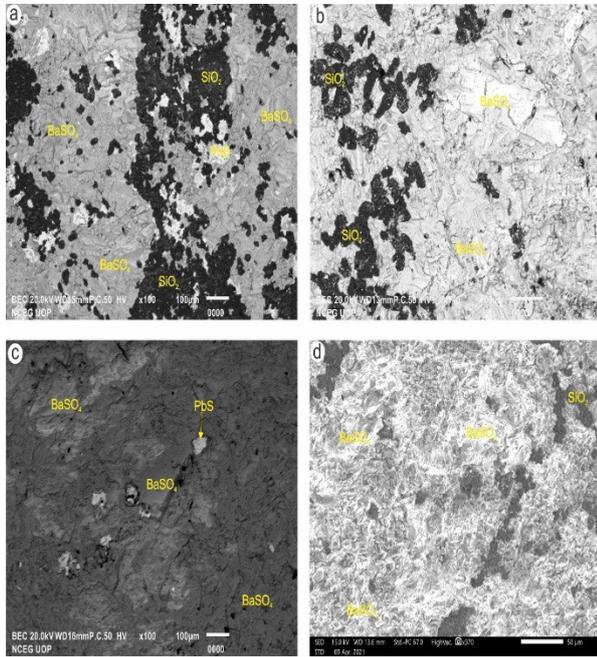


Fig. 6: Photomicrograph of BSE, SEM-EDX, and EDX map showing a crystal shape, texture, composition, and minerals grains of barite. BSE image represents the crystal morphology, crystal structures, and medium to coarse grain texture of barite (a - d).

The mineral maps from SEM-EDX analysis shows the major composition of barite associated with minor constituents of other minerals. EDX shoot point, spectra, and map represent the peaks of major elements of barite. In this analysis count the 500 to 1300 elements of Ba with 4.2 energy (KeV), count the 3500 elements of S with 2.15 energy (KeV), and count the 3000 elements of O with 0.5 energy (KeV). SEM-EDX analysis specifies high peaks of Ba, S, and O elements, the peak O element is high, and S and Ba elements are nearly equal. Along the high peaks of O, S, and Ba associated with the sub-peaks rock-forming mineral elements are including a Si, Al, Na, K, and Ca and sub-peak of ore forming mineral elements are including a Pb, Zn, Fe, P and Ni (Fig.7 a - b). The minimum value of Ba is about 40.89, the maximum value of Ba is about 81.41% and the average value of Ba is about 51.31 % in the study area (Table 1).

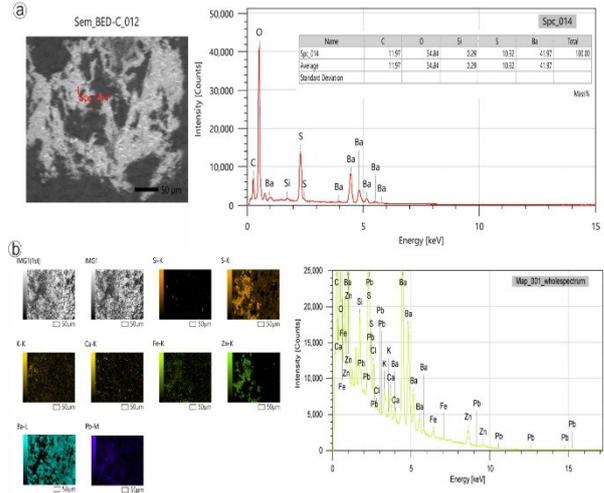


Fig. 7: SEM-EDX and EDX mineral maps are showing the high peaks major constituents and mineral grains of Barite (a - b).

Table 1: Illustrate the results of SEM - EDX shoots point analysis for barite mineralization.

SEM_EDX Shoot Point Analysis									
Sample No	Mineralized Zone	O%	Si %	C%	Ba%	Pb%	Zn%	Fe%	S%
BK-3-B	Barite	29.50	1.16	4.42	46.37	7.49	0.13	-	10.94
BK-11-C		60.23	24.99	14.77	55.25	-	-	-	10.33
BK,15-B		29.92	-	3.99	47.98	8.18	-	-	9.93
BK-20 -B		36.00	-	4.42	40.89	21.69	-	-	10.77
BK-22-C		29.18	30.95	-	46.54	10.26	-	-	11.34
BK-23-A		34.84	0.29	11.97	41.97	-	-	-	10.92
BK-25-C		7.43	0.83	4.21	81.41	-	-	-	4.68
BK-25-D		20.51	2.45	17.2	50.13	0.97	-	-	4.2
Average			30.95	10.11167	8.711429	51.3175	9.71	0.13	-

The barite is a valuable economic mineral with a wide range of applications in the industry. The chief usage of barite (~85%) is in the petroleum industry for the drilling purpose and valuable for cement industry, paints, ceramics, manufacturing of glass, and in the chemical industry (Ene and Okogbue, 2012). According to, the total estimated reserves of barite in the Gunga deposit is ~1.28 million tons (Klinger and Ahmed, 1967). The Gunga deposit is mainly comprised of barite, the minimum percentage of Ba is 40.89%, the maximum percentage of Ba is 81.41 and the average percentage of Ba is about 51.31 %, (Table.3.1).

Conclusion

1. The barite mineralization in the Gunga deposit hosted within the middle Jurassic Anjira Member.
2. The mineralization is mainly associated with siliceous gossan zone.
3. Petrographically, barite displays very fine to coarse grains texture and anhedral to euhedral crystal shape with dendritic crystal structures.

The high peaks of Ba, S, and O along with sub-peaks of major rock-forming mineral elements (Si, Al, Na, K and Ca) and ore-forming mineral elements (Pb, Zn, Fe, P, and Ni), thus the high peaks of Ba, S and O indicates that Gunga is a barite (BaSO₄) deposit.

Acknowledgement

We thank to Bolan Mining Enterprises for allowing of field work and provided accommodation. We also show our gratitude to Geologists of BME Mr. Ejaz Baloch and Mr. Jalil Shawani for discussion in the field. We thank anonymous reviewers for their comments on the manuscript.

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