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Geochemistry of Baska Formation (Early Eocene) in the Vicinity of Zindapir Anticlinorium, Eastern Sulaiman Range, Middle Indus Basin, Pakistan

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Abstract. The early eocene Baska formation hosts the gypsum deposits in several parts of the Eastern Sulaiman Range (ESR) of middle Indus Basin. This study is aimed at evaluating its geology and geochemistry at different localities like Rakhi Nala (RN), Vidor Nala (VN), Zindapir (ZP), Barthi (BR) and Mangrotha (MG), which are located within the Zindapir Anticlinorium. X-ray mineralogy reveals that these deposits are mainly composed of gypsum, anhydrite, magnesite and dolomite, while XRF results of gypsum samples acquired from five different locations of ESR and correlated with other areas of Indus Basin of Pakistan and with Zagros Basin (Zeloi oil field, Iran), Siirt Basin (Turkey) and Morata de Tajuna (Madrid, Spain). From the XRF analysis, the major oxides in the selected samples vary in descending order as SO_3> CaO> MgO > SiO_2 > Fe_2O_3> Al_2O_3>K_2O. The major cation oxide is CaO present up to 33.08, whereas major anion is SO_3 forming up to 41.47 wt. %. The average value of Silica (SiO_2), Alumina (Al_2O_3), Iron (Fe_2O_3) and Magnesium (MgO) contents of gypsum are 0.27, 0.14, 0.23 and 0.7 wt. %, respectively. Geochemically, the Baska Gypsum deposits of ESR have relatively lower SiO_2, Al_2O_3, Fe_2O_3, MgO and lower K_2O relative to other parts of Indus Basin and with Zagros Basin (Zeloi oil field, Iran), Siirt Basin (Turkey) and Morata de Tajuna (Madrid, Spain). Based on geochemical studies gypsum mineralization of eastern Suliman Foldbelt are more suitable for the production of cement, plaster of Paris, solid wallboard, ceramics and ammonium sulphate fertilizer.

Keywords: geochemistry, gypsum, baska formation, Zindapir anticlinorium, Sulaiman range

Introduction

Pakistan is endowed with two sedimentary basins named as Indus and Baluchistan, separated by left-lateral Bela Ornach - Chamman transform fault system the onshore and Murray ridge in the offshore, engraved with spectacular platform, foredeeps and folds belts areas from east to west (Nazeer *et al*., 2013). Greater Indus basin occupied major part of sedimentary basin mainly comprises of upper, middle and lower part from north to south. The north-south trending Zindapir anticlinorium is part of Sulaiman fold belt which lies in the central part of Indus sedimentary basin of Pakistan. Sulaiman range is north-south trending foldbelt of band of rugged mountains terrain with average elevation ranges from 1000 to 3,400 m (11000 ft) above sea level, occupying political boundary of three provinces of Pakistan, which name as Punjab, Baluchistan and Khyber Pakhtunkhwa.

Gypsum is mined from Baska formation (early eocene) various locations nearby the Zindapir anticlinorium in political boundary of Punjab. Gas condensate fields are also located in Zindapir anticlinorium with production from Chiltan limestone (Jurassic), Goru sands (early cretaceous) and Ranikot formation (early paleocene). The shale of Sembar and Goru formations are considered source rocks. Figure 1 is showing the location of study area.

This paper is based on the geochemical analysis of gypsum sample which are collected from five stratigraphic section of eastern Sulaiman fold belt (ESR) and it chemical composition has been compared with gypsum mined from other locations of Indus basin (Lakha Rakhni, Bala Dhaka Karher, Nisau Vitakri, Chamalang Marri, Ishani, Kodi More Nodo and Manjhail Kharar) and with Zagros basin (Zeloi oil field, Iran), Siirt basin (Turkey) and Morata de Tajuna (Madrid, Spain).

Material and Methods

The scientific investigation is based on the chemical composition of gypsum which was collected from the five different stratigraphic sections in the project area of eastern Sulaiman fold belt. The selection of these sections was taken at part of section with maximum

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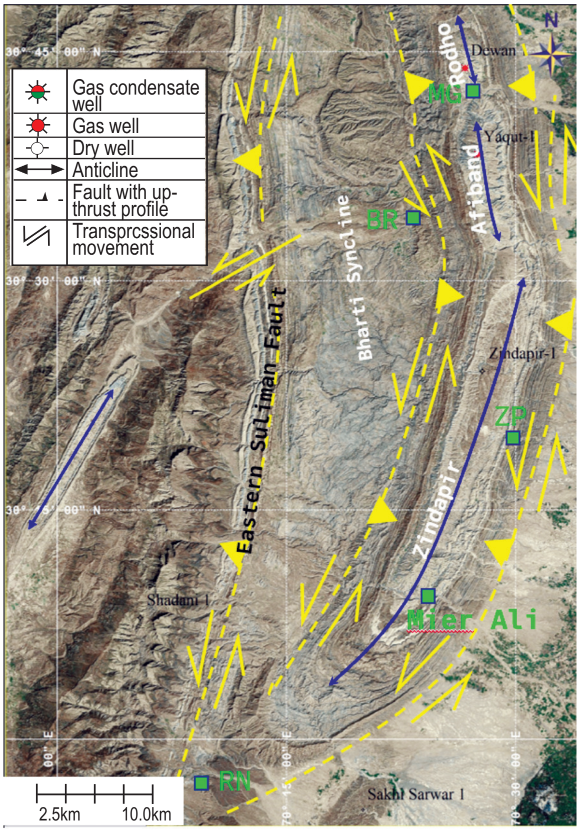

Fig. 1. Location of study area, gas condensate field, dry wells and structural elements in eastern Sulaiman fold belt after (Nazeer *et al*., 2018 and 2013).

coverage facies changes, the facies changes from north to south after extensive reconnaissance. Geochemical analysis (XRF, XRD) done by Geoscience advance research laboratories (GARL) of geological survey of Pakistan (GSP) Islamabad. The gypsum samples were gathered in solid form, from the research area. PVA (polyvinyl alcohol) added to the sample and powder pill produced by pressing the sample powder by HTP 40 (HERZOG Machine fabric GmbH Co., Osnabruck). To prepare the powder pill, following steps are involved which shown in (Fig. 2).

Geological setting. The study area comprises of Zindapir Anticlinorium and its surrounding area, as Safed Koh range called by locals, they are part of Wrench related thick-skinned tectonics formed due to oblique collision of the Indo-Pakistan plate with Eurasian plate which rotated the Indo-Pakistan plate anticlockwise by opening of Kirthar basement fault, Sulaiman basement fault and Jhelum basement fault and segmented Indo-Pakistan

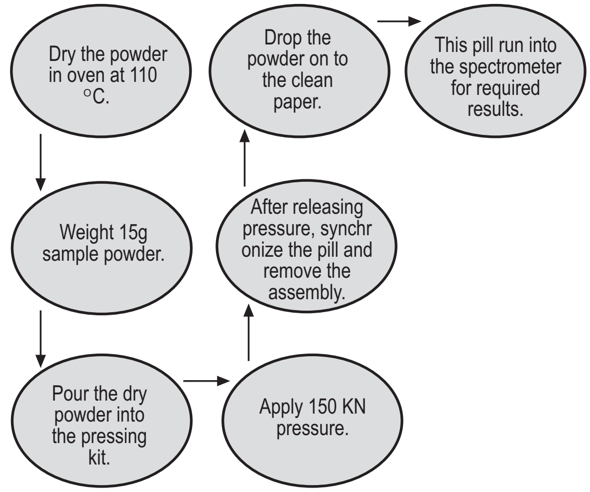

Fig. 2. Flow chart for the preparation of powder pill.

plate into several basement blocks. Different tectonic patterns on individual basement blocks were formed as result of the movement of these block and ongoing collision. The Sulaiman fold belt developed in the latetertiary time as a consequence of left and right lateral transpressional regime related to wrench tectonics in the east and west respectively. Wrench related positive flower structures have also been interpreted by Nazeer *et al*. (2013) in the eastern part of Sulaiman fold belt. He described the young age (late tertiary) and fast uplift rate of the Sulaiman fold belt. Nazeer *et al*. (2013) considered interpretation of landsat imagery of eastern Sulaiman fold belt which indicates left-lateral trans-pressional regime. However, Banks and Warburton (1986) and Jadoon *et al*. (1992) have proposed passive roof duplex model related to thin-skinned tectonic for Sulaiman fold belt. Hydrocarbon potential of Zindapir Anticline, eastern Sulaiman fold belt. Figure 3 is showing the structural elements of easter Sulaiman fold belt.

The Zindapir Anticlinorium is bounded in the east by Sulaiman depression and in the west by Barthi Syncline comprises of Dhodak Anticline, Rodho Anticline, Afiband Anticline and Zindapir Anticline from north to south. The anticlinorium covers an area of approxi-mately 6000 sq.Km with Eocene formations exposed in the core of Dhodak, Rodho and Afiband structures, whereas Zindapir Anticline has Paleocene rocks in its core. The carbonates of Chiltan formations (Jurassic), sandstones of lower Goru (early cretaceous) and Pab formations of late Cretaceous, Ranikot Sands and

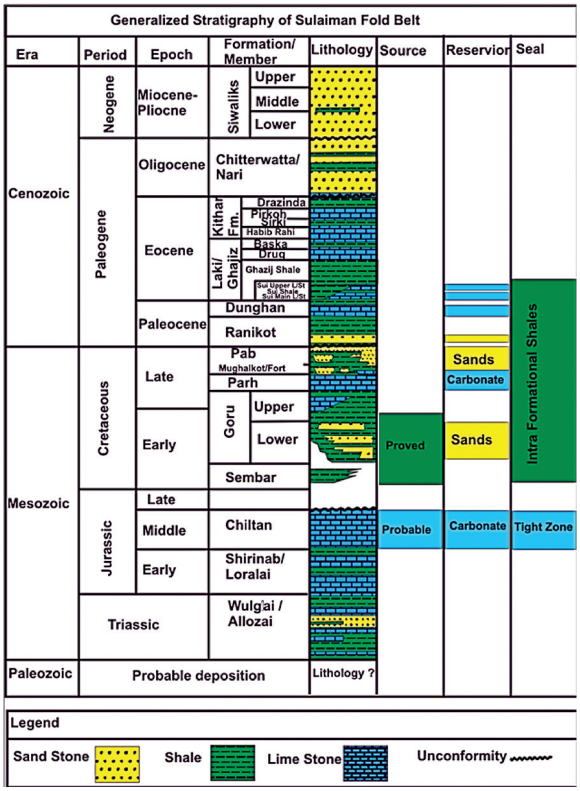

Fig. 3. Generalized stratigraphy Sulaiman fold belt (Nazeer *et al*., 2013).

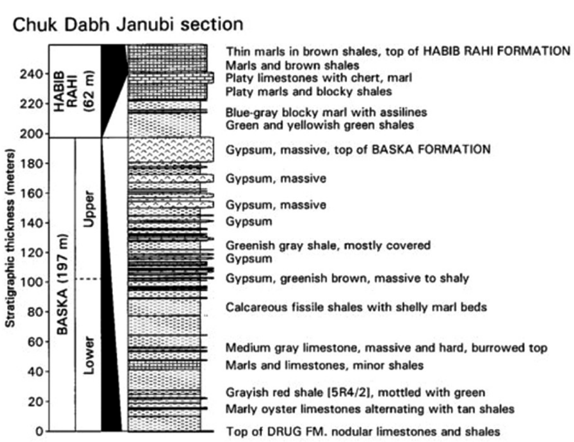

Fig. 4. Chuk Dabh Janubi stratigraphic section of the 197m thick Baska formation and the 62-m thick Habib Rahi formation. Sea level interpretation is shown by the width of the black band in the third column, this is widest during times of high sea stand, and narrow west during times of low sea stand after Gingerich *et al*. (2001).

Dunghan Limestone of Paleocene are proved reservoirs of Zindapir Anticlinorium.

Baska formation. Baska formation type section which is about 2 Km east northeast of Baska village (lat. 310 29′ N, long. 700 08′ E). Baska formation consists of green shales beds and clay stones containing alabaster in nodules and veins (Shah, 2009). According to Malkani (2010), Baska formation consists of gypsum, shale, limestone, marl and rare siltstone. The gypsum is grey to grayish white, medium to thick bedded and massive. Shale is grey, khaki and calcareous. The marl is cream white, thin to medium bedded and porcelaneous. The siltstone is greenish grey to grey and thin to medium bedded. Its thickness is estimated variable from 100 m to 30 m. Gingerich *et al*. (2001) studied Chuk Dhab Junubi section (Fig. 5). There is a 2.8 m thick tongue of grayish red shale 25-28 m above the base of the Baska formation. The lower part of the formation is shale rich and valley forming. The upper part of the formation is forming massive gypsum beds that thicken up-section.

Results and Discussion

Thirty representative samples were collected from Baska formation during Geological excursion. XRD and XRF technique is used for geochemical analysis. Results shows that gypsum and anhydrites are present in every sample but in varying amount. However, dolomite, quartz, calcite dolomite and magnesium is also reported in some samples. Mineralogical identified by XRD are shown in Table 1-2 is showing geochemical composition of gypsum sample of Baska formation, nearby Zindapir Anticlinorium eastern Sulaiman fold belt.

Previous studies of (Khan *et al*., 2004; Alizai *et al*., 2001; Malkani, 2000) shows only two beds of gypsum,

Table 1. XRD results of five selected sections of Baska formation, nearby Zindapir Anticlinorium, eastern Sulaiman fold belt

Section	Identified minerals
Rakhi nala	Gypsum, Anhydrite
Bharti	Anhydrite, Gypsum
Mangrotha	Gypsum, Anhydrite
Zindapir	Gypsum, Dolomite, Anhydrite
Mier Ali	Quartz, Calcite, Magnesium gypsum, Anhydrite dolomite

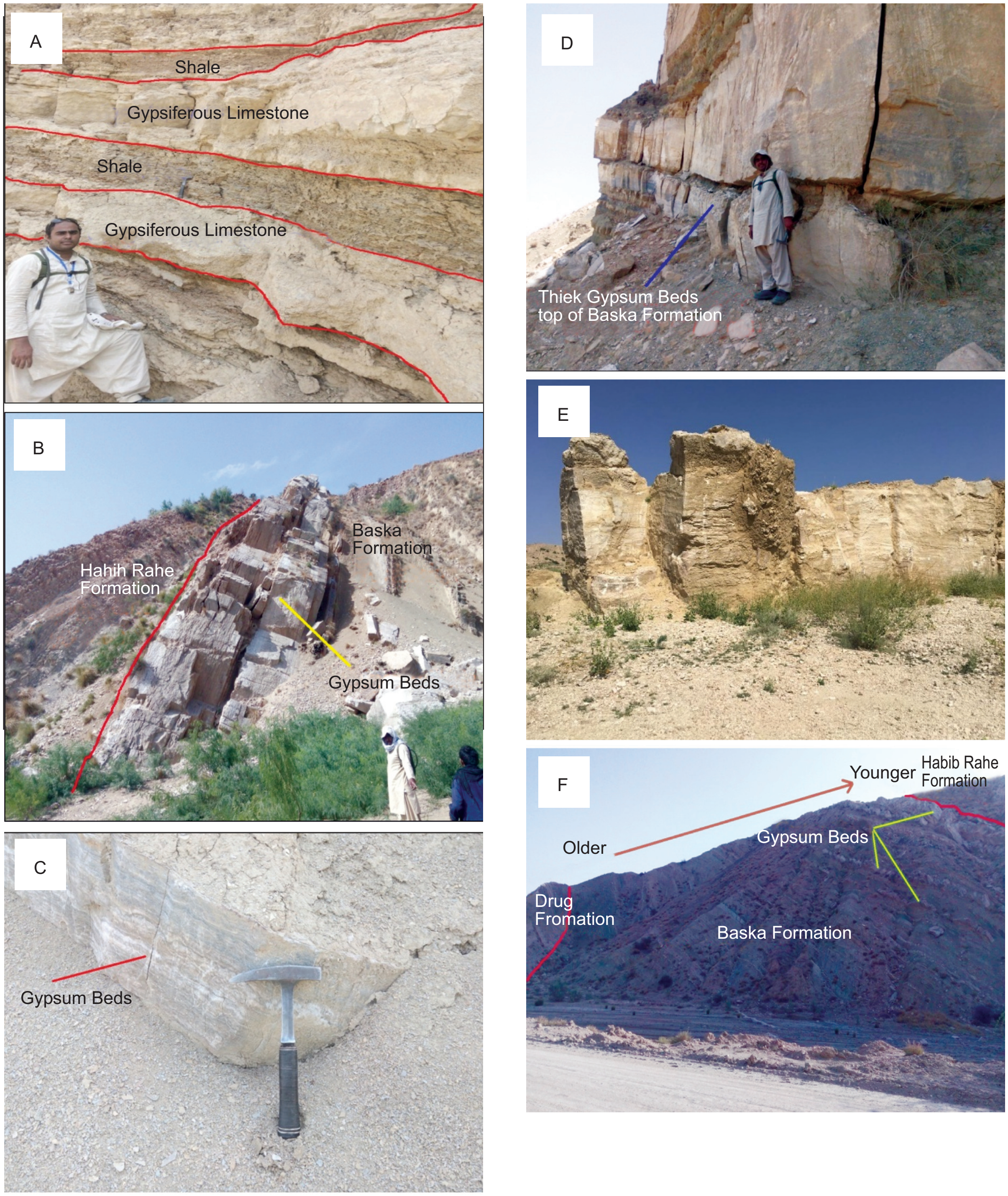

Fig. 5. A, B, C, D, E and F showing the photographs of Basaka formation.

while in current studies seven beds including five thin and two thick beds (previously known) of gypsum deposits have been discovered.

Table 2 and Fig. 6 the geochemical composition of gypsum sample of Baska formation, nearby Zindapir Anticlinorium eastern Sulaiman fold belt, it is based on oxide only and Table 2 represents the average values.

From Table 2 and Fig. 7 shows the quality of gypsum is very good in Barthi area and value of SO_3 in Mier Ali is less, it shows that it is not pure having more

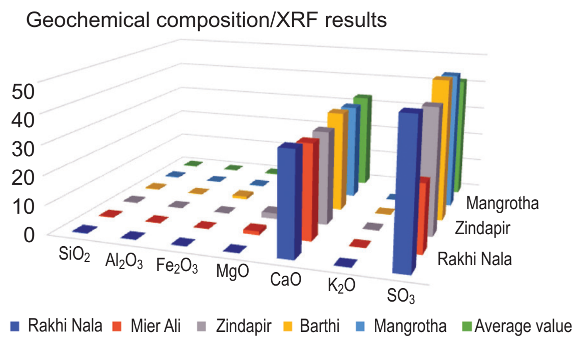

Fig. 6. Bar chart showing comparison of geochemical composition of oxides.

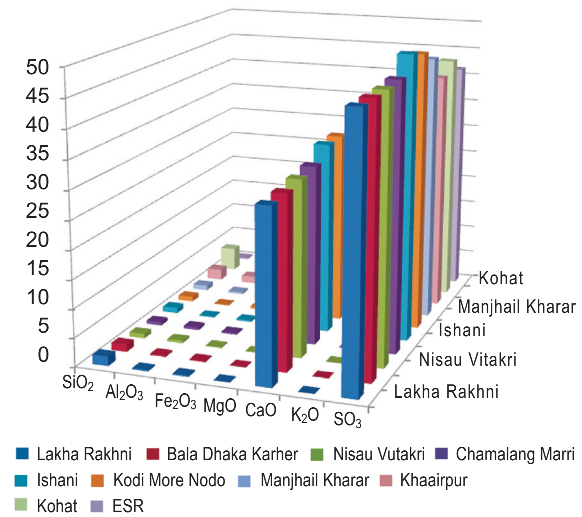

Fig. 7. Bar chart showing the comparison of gypsum deposits of ESR with other areas of Pakistan.

clastic contents, so the order of purity of gypsum is as follow, BT>RN>MG>ZP>MA.

Table 3 shows that value of gypsum *i.e.* SO_3 and CaO are matching with other localities of Pakistan except the value of SiO_2 which is quite variable among other localities of ESR. For example, value of SiO_2 is much higher in KPK that shows the gypsum is not of pure quality having more clastic influence in the material/composition.

Table 4 and Fig. 8 shows that the quality of gypsum is same in comparison to Turkey and Spain which are top producing gypsum countries by BGS except Iran, where

Table 2. Geochemical composition of gypsum samples

Major oxides	Rakhi nala	Mier Ali	Zindapir	Barthi	Mangrotha	Average value
SiO_2	0.27	0.23	0.24	0.26	0.34	0.27
Al_2O_3	0.14	0.15	0.14	0.15	0.11	0.14
Fe_2O_3	0.06	0.09	0.08	1	0.24	0.3
MgO	0	1.32	1.99	0	0.19	0.7
CaO	34.53	32.07	31.68	34.29	32.85	33.08
K_2O	0.07	0.09	0.09	0.07	0.07	0.08
SO_3	47.58	22.8	42.52	47.94	46.51	41.47
Total	82.65	56.75	76.74	83.71	80.31	76.04

Table 3. Comparison of gypsum deposits of ESR with other areas of Pakistan (Khan *et al*., 2004; Alizai *et al*., 2001; Malkani, 2000)

Major oxides	Balochistan							Sindh	KPK	Punjab
	Lakha Rakhni	Bala Dhaka Karher	Nisau Vitakri	Chamalang Marri	Ishani	Kodi More Nodo	Manjhail Kharar	Khairpur	Kohat	ESR
SiO_2	1.69	1.32	0.82	0.62	1	0.88	0.9	1.97	4.16	0.27
Al_2O_3	0.27	0.28	0.46	0.48	0.2	0.15	0.38	1.29	0.42	0.14
Fe_2O_3	0.24	0.22	0.2	0.32	0.3	0.4	0.22	0	0.2	0.23
MgO	0.07	0.05	0.03	0.07	0.15	0.22	0.06	0.32	0.17	0.7
CaO	30.04	30.25	30.82	31.33	33.5	33.5	31.34	34.57	31.71	33.08
K_2O	0	0	0	0	0	0	0	0	0	0.08
SO_3	46.48	46.51	46.54	46.88	49.9	48.81	46.8	42.28	44.18	41.47

Table 4. Comparison of gypsum deposit of ESR with Iran, Turkey and Spain (Yesilova *et al*., 2016; Lopez-Delgado *et al*., 2014; Bahadori *et al*., 2011)

Major oxides	Zeloi oil field, Iran	Siirt basin, Turkey	Morata de Tajuna, Madrid Spain	Eastern Sulaiman range Pakistan
SiO_2	8.5	0.39	3.28	0.27
Al_2O_3	2.27	0.06	0.95	0.14
Fe_2O_3	2.05	0.11	0.42	0.23
MgO	4.03	1.08	3.93	0.7
CaO	20.25	32.25	42.74	33.08
K_2O	0.43	0.02	0.19	0.08
SO_3	25.9	42.18	47.63	41.47

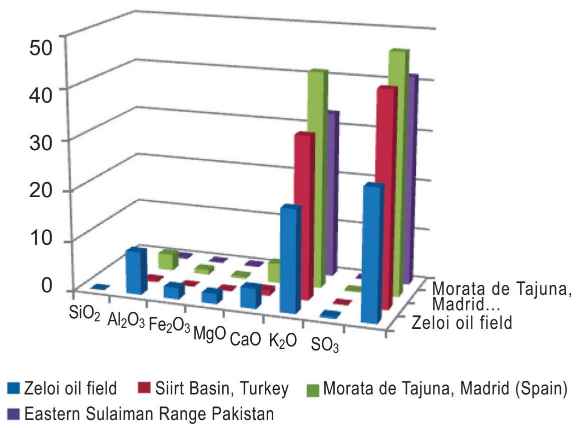

Fig. 8. Bar chart showing the comparison of gypsum deposit of ESR with Iran, Turkey and Spain.

SiO_2 content is greater leading to somewhat impure quality. It is also worthwhile to mention here that Barthi locality has a great potential of pure gypsum but the gypsum is not being mined here in a scientific way rather in a haphazard manner, if proper techniques are applied then things may flourish with the local people being utilized in the mining work.

Conclusion

- The Baska formation is well exposed in Zindapir, Vidor Nala and Rakhi Nala, Barthi and Mangrotha in eastern Suleiman range and generally consists of shale, claystone, gypsiferous limestone, sandy limestone and gypsum beds.
- The deposits are composed of minerals like gypsum, anhydride, magnesite and dolomite as revealed by XRD. Among chemical constituents, these are rich in CaO and SO_3 followed by MgO, SiO_2, Fe_2O_3, Al_2O_3 and K_2O are added in the form of detrital constituents (mostly less than 1%). In general, the SiO_2, Al_2O_3, Fe_2O_2, MgO, CaO, K_2O and SO_2 values vary from 0.34 to 0.23, 0.11 to 0.15, 0.06 to 1.00, 0 to 1.99, 31.68-34.53, 0.07-0.09 and 22.8-47.94 (wt. %), respectively.
- Previous studies of shows only two beds of gypsum while in current studies seven beds including five thin and two thick beds (previously known) of gypsum deposits have been discovered.
- All the laboratory results of ESR are comparable with each other, indigenous areas and top listed international countries (Iran, Turkey and Spain) by gypsum production but the SiO_2, Fe_2O_3, Al_2O_3 and MgO content of this research area is lesser than other areas. That shows the quality of gypsum is very good. Therefore it is the need of time to make a proper attention to this industry which will ultimately generate great revenue for Pakistan and for the betterment of local people as well.

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Conflict of Interest. The authors declare they have no conflict of interest.

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