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PRELIMINARY STUDIES OF FLUORITE MINERALIZATION IN KALAT REGION, BALUCHISTAN PROVINCE, PAKISTAN

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ABSTRACT

Fluorite-barite-massive sulphide mineralization has been noted in the Jurassic carbonate rocks at various localities in the collisional belt of Pakistan. Fluorite deposits are in the central part of the belt mainly in Kalat region while barite mineralization characterizes southern part of the belt. Sulphide minerals, of which only galena is notable, are associated with barite deposits. The characteristics and behaviour of fluorite deposits of Kalat region alongwith those of barite-massive sulphide deposits of the belt suggest a sedimentary origin of Mississippi-valley type.

INTRODUCTION

Fluorite occurrences have been reported from several localities in the Cenozoic-Mesozoic folded belt of Pakistan. The host rock for each of the described deposit is Jurassic limestone. The mineral association varies from fluorite-calcite, barite-fluorite to barite-galena. Most of these occurrences are mere mineral showings except those of Kalat which are of some economic significance. Thin fluorite veins and stringers in Kalat were first located by the Geological Survey of Pakistan at Koh-i-Maran [BAKR, 1962]. Later a viable economic deposit was discovered by a mining company at Koh-i-Dilband [MOHSIN and SARWAR, 1974].

REGIONAL GEOLOGICAL SETTING

The most dominant feature of the geology of the country is a folded belt running meridionally from Karachi in the south to Waziristan in the north separating Indian platform from Makran flysch zone *(Fig. 1)*. The folded belt is a part of Alpine-Himalayan Cenozoic orogenic belt and consists of well known Kirthar and Sulaiman Ranges beside several parallel, less known but distinct ranges. The folded belt has variously been named as Axial belt (Hunting Survey Corporation, 1960), Baluchistan borderland [ZUBERI and DUBOIS, 1962], West Pakistan folded arch [SOKOLOV and SHAH, 66], Collisional mountain belt [SILLITOE, 1975], QUETTA line [GANSSER, 1966] and Southern axial ophiolite belt [STOCKLIN, 1977]. The oldest rocks exposed in the axial part of the belt are of Jurassic though some are considered to be older. Many prominent ranges and high peaks which are formed by this massive and resistant Jurassic limestone, generally represent the cores of the individual anticlines. The overlying Cretaceous and lower Tertiary formations are present on the flanks constituting the intervening syncline and are expressed as valleys. Most of the barite-fluorite mineralization is found in such anticlinal ridges including Mor range east of Bela, Shekran and Monar Talar hills near Khuzdar, Koh-i-Maran and Koh-i-Dilband in Kalat and Kakar ranges in Fort Sandeman.

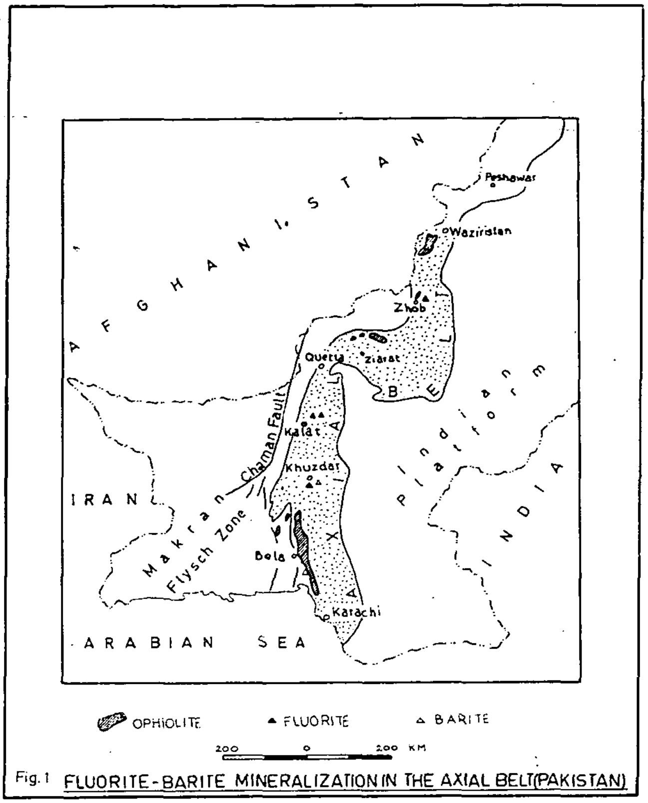

Fig. 1. Fluorite-barite mineralization in the Axial belt of Pakistan

Mesozoic rocks of several thousand meter thickness are exposed in the Axial belt. The western part of the Indian platform remained as land since the close of Vindhyan [Sastri and Datta, 1969] until the initial transgression in Triassic. By middle Jurassic marine conditions were well established and mainly carbonate rocks were deposited. The close of middle Jurassic is marked by a regressive phase and marine sedimentation again continues in the Cretaceous [Fatmi, 1977].

STRATIGRAPHY OF THE REGION

Koh-i-Maran, Koh-i-Siah, Koh-i-Negrani and Koh-i-Dilband are parallel ranges wholly made up of Chiltan limestone of Jurassic age *(Fig. 2)*. Each of these ridges represent the core of plunging or doubly plunging anticline. The fold axes are oriented NE-SW and generally plunge towards SW. Cretacous shales and limestone formations such as those of Parh group and Moro formation occupy the intervening synclines. The flanks of each of the anticline are affected by strike faults of reverse movement running parallel to the anticlinal axes. The rocks of Parh group are more severely affected by strike faulting and are repeated several times. Koh-i-Maran and Koh-i-Siah are symmetrical open folds while Koh-i-Dilband is a broad undulating gentle folded structure. The fluorite deposits are located in an area where Chiltan limestone is exposed as a very gently dipping plunging syncline flanked by similar gentle anticlines *(Fig. 3)*. The rock units encountered in the mineralized area are shown in Table 1.

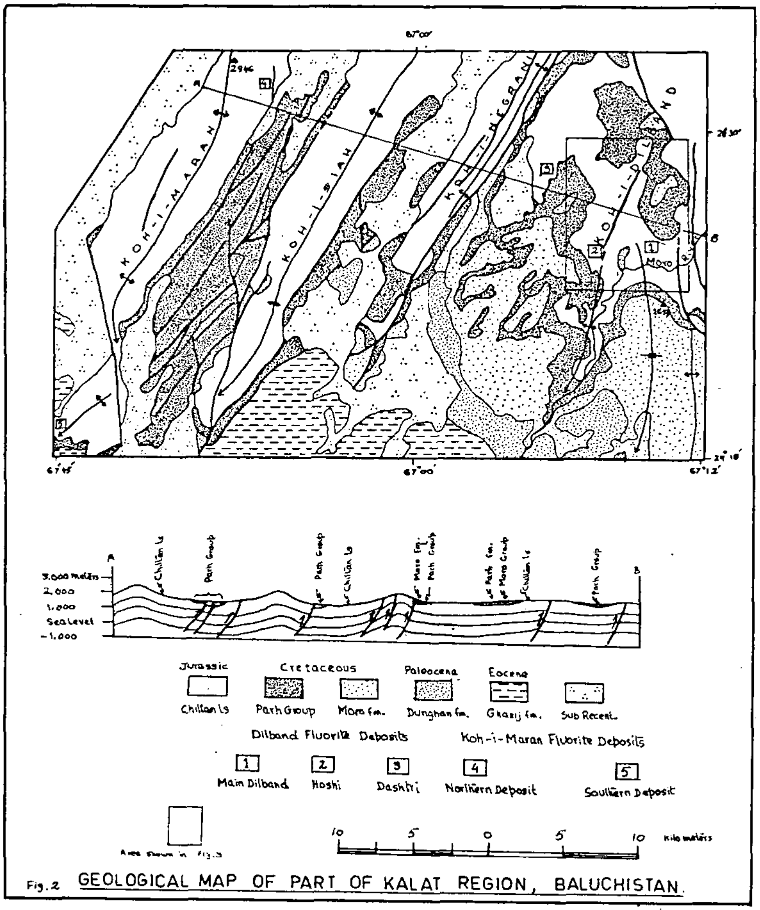

Fig. 2. Geological map of part of Kalat Region, Baluchistan.

The Chiltan limestone is well exposed in Koh-i-Maran while at Dilband about 1000 meters of limestone can be seen in the gorge of Moro river. The unit is generally unfossiliferous. However, few shell fragments were found on the top beds. Irregular patches of yellow, reddish, highly oolitic and pisolitic concretionary bed of ferruginous and clayey matter is found to mark the unconformity between Chiltan limestone and shales of Parh group. Such a bed is not a general feature of the Axial belt but is conspicuously present in the mineralized area. SHAH [1975] has also noted a ferruginous bed at the base of Cretaceous formation in Ziarat laterite area. The Parh group has been divided into three formations namely Sember formation, Goru formation and Parh limestone. In the Dilband fluorite area olive green shales of Sember formation with abundant belemnites, are poorly developed. Towards the top, the shales intercalate with clayey limestone and without any appreciable development of Goru formation, grade into Parh limestone. The upper contact of Parh limestone with Moro formation is disconformable, sharp and well exposed. Several small ridges in Dilband area are capped by Moro formation making steep excarps due to their superior resistance to weathering. Dunghan formation is not exposed in fluorite area either at Dilband or at Koh-i-Maran. However, the formation is present above Parh limestone in the synclinal structures.

FORMS OF THE ORE BODIES

Fluorite mineralization, associated with calcite, has taken place at Koh-i-Maran in the forms of veins in the upper part of Chiltan limestone. Although calcite veins are frequent in most of the rock units, fluorite has been found only in those that are

TABLE 1

Stratigraphic Sequence in Kalat Region

Age	Formation	Description	Thickness
Paleocene	Dunghan Formation	Dominantly massive, nodular, dark, gray, brown or creamy white limestone with subordinate olive coloured shale; coarse grained brownish green sandstone and minor pebbly conglomerate.	80 m
Upper Cretaceous	Moro Formation	Gray, medium-thick bedded argillaceous limestone with dark greenish gray calcareous shale; minor conglomerate and marl at the base.	100 m
Upper Cretaceous	Parh Group	Dominantly limestone of white cream, olive green or yellow colour; cherty, thin bedded, porcellaneous and argillaceous; with subordinate green shales and red marls in the lower part; ferruginous bed upto 5 m thick at the base.	
	Unconformity		
Middle Jurassic	Chiltan Limestone	Thick bedded, massive, brownish gray to bluish gray limestone.	1000 m base not exposed

in the Jurassic limestone. These veins are found in fractures and joints in limestone, widening out to lenticular bodies or branching into multiple veins [BAKR, 1962]. Some of the veins are wedge-shaped and are aligned with the fold axis [MUSLIM, 1972]. A few pockets of violet coloured fluorite crystals occur in Koh-i-Neghrani but no workable veins have so far been located.

The ore bodies, as observed in a number of pits and trenches at Dilband, are parallel to the bedding of the host rock and are flat lying tabular or lenticular masses [MOHSIN and SARWAR, 1974]. The flat nature of the bodies is obscured by the irregular contact with the limestone beds, by local bulging and by fracture filling which are inclined at steep angles to the general trend of bedding. The shallow depths of pits and trenches at present, do not reveal more than one layer in any single excavation. However, by comparison, they seem to occur at more than one level. The length and breadth of individual ore bodies may vary from few meters to a hundred meters, while the thickness of any single, tabular body ranges from a few centimeters to two meters. The ore boundary is mostly gradational though only for a short distance and wall rock consists of disseminated fluorite grains in limestone.

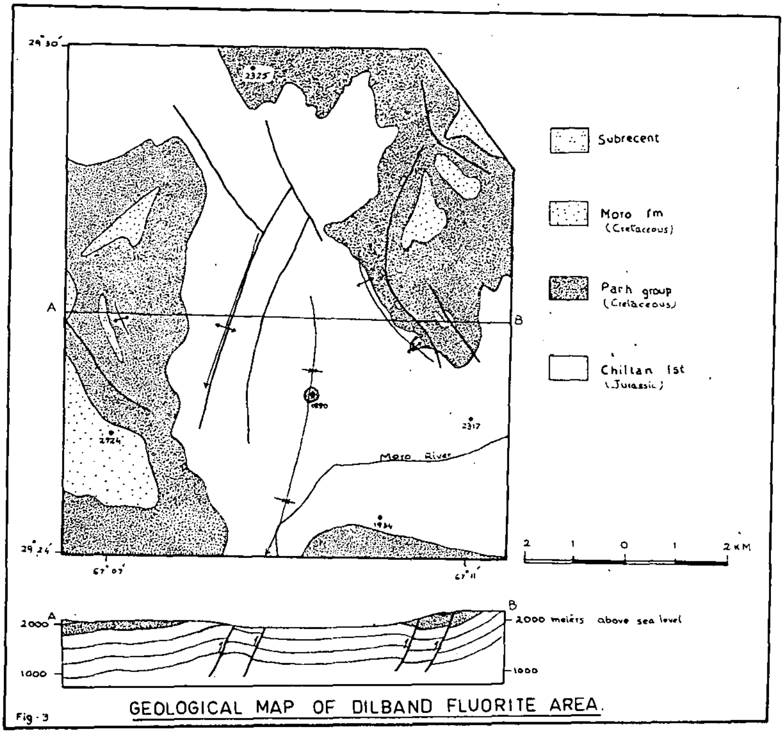

Fig. 3. Geological map of Dilband fluorite area

A number of solutional cavities filled by fluorite and calcite are found in several places in the Dilband area, One of the larger exposed ore body is oval shaped about 2 m wide and 4 m high, and appears to fill a solution cave in limestone. At few places crustified veins comprising of calcite and fluorite bands as well as fluorite bands of different hues and purity are seen. Vugs of a few centimeters to ten centimeter diameter are present in most of the thick ore bodies whether flat lying or cutting across the beddings. The vugs are lined with pink to violet coloured aggregate of cubic crystals of fluorite. The individual cubes range in size from 2 millimeter to 2 centimeter. Several layers of fluorite packed up in a comb fashion often make a thick tabular ore body parallel to the bedding.

MINERALOGY, GRADE AND RESERVES

The mineralogy of the ore is simple being composed of fluorite and calcite. Tabular crystals of barite associated with fluorite have been noted only in the veins at the southern faulted end of Koh-i-Maran anticline. Occassionally a pyrite grain can be seen in the fluorspar lumps. The lumps mined at Koh-i-Maran are milky white or buff coloured. Fluorite at Dilband varies in colour from white to yellow, pink, red, violet, colourless and brown, in transparency from opaque to transparent and in crystallinity from massive to perfect crystals. The transparent variety displays an octahedral cleavage. Calcite is either mixed with fluorite as grains or forms aggregate of rhombohedral crystals which are transparent to milky white. The ore mined at Dilband can be divided in three grades:

1. Transparent; colourless, pink or violet; crystalline variety.
2. Translucent; white, yellow, red; crystalline aggregate.
3. Opaque; brown coloured; massive variety.

The first variety is of high purity containing more than 97% of CaF_2 and is of acid grade. It does not contain more than 1.0% silica and sulphur is present only in traces. The second variety consists of varied coloured fluorspar and range in calcium fluorite content from 90 to 96%. The third variety is not very different in chemical composition from the second variety and both can be grouped in ceramic grade. Fluorite mixed with calcite or from the boundaries where it is disseminated in limestone may have as low as 40 to 50% CaF_2. The second variety is the prevalent type in Dilband area. Chemical analyses of one acid grade and three ceramic grade ores are shown in the Table 2.

TABLE 2

Chemical Analysis of Fluorspar

	1	2	3	4
CaF_2	97.89	95.47	93.22	91.77
$CaCO_3$	0.40	1.70	2.50	3.84
Fe_2O_3	0.20	0.25	2.01	0.95
SiO_2	0.26	1.48	1.88	1.49
Al_2O_3	0.94	1.51	1.03	1.00

BAKR [1962] has measured a number of lean veins and stringers of fluorite at the northern part of Koh-i-Maran and estimates about 100 tons to be present in the veins. AHMAD [1969] in the Mineral Directory has indicated 1400 tons of fluorite at Koh-i-Maran.

Fluorite deposits of Dilband were opened in 1971 when a number of pits and trenches were made and about 2000 tons were produced in that year. No further work was undertaken until the lease disputes were settled in 1978 and plans are now underway for systematic work. No exploratory holes have been drilled to ascertain the shape and size of the bodies at depths. However, to gain some insight about the quantity of the ore, the area is divided into blocks where clusters of pits and trenches are present. The blocks are about 300 m long, 100 to 125 m wide and about one meter thick. The ore body in each block is assumed to be tabular in shape. Thus as a preliminary statement of reserve 93,350 tons of fluorite is estimated in three blocks namely Main Dilaband, Hoshi and Dashtari lease holdings.

FORMATION AND LOCALIZATION OF ORE

Fluorite alongwith barite and some sulphide minerals appears to be stratabound in the Axial belt, localized within the Jurassic carbonate sediments of Indo-Pakistan platform. The host rocks are invariably brown to gray, medium-thick bedded limestone which may be massive, oolitic, nodular or reefoid at places. Dolomitization is appreciable [AHMAD, 1974]. Shales are associated as minor to subordinate constituents. Within the host rocks the ore bodies occur both as veins e. g. at Koh-i-Maran and tabular or lenticular concordant bodies e. g. at Dilband. The ore may be restricted to top beds of the Jurassic limestone and fills such distinct solutional features as have been described by CALLAHAN [1967] from the Mississippi valley. The solutional features at Dilband developed during the hiatus that preceeded the deposition of the overlying Cretaceous shales. MUSLIM [1972] has also noted that mineralization at Koh-i-Maran is confined to the top beds of Chiltan limestone which are above the intercalated shale horizon; the limestone beds below the shale are barren. But in southern areas of Khuzdar and Lesbela, the ore being generally concordant and lenticular does not appear to be restricted only to the top horizons of the Jurassic limestone [MOHSIN and SARWAR, in prep.]. The mineralization, therefore, probably follows several levels within Jurassic sequence. At Dilband, Chiltan limestone is overlain by shales of Parh group with a distinct unconformity marked by a ferruginous bed which varies from one to three meters in thickness. The ore appears to be localized below the unconformity on a mild karst topography. The ore is observed to be stratiform, though small cross cutting veins do occur; lining of cavities, filling of collapse breccia and pipe-like bodies are also common features.

The ores at various places in the belt have invariably a simple mineralogy and wall rock alteration is only slightly discernible. SHCHEGLOV [1969] mentions the presence of bitumen inclusions in fluorite from Koh-i-Maran. B. L. HODGE [personal com.] has collected samples with inclusions as big as 1 mm with air bubble in the center. This indicates a low temperature of formation, generally in the range of 100—150 °C. Both cavity-filling and replacement processes appear to have been active. The distribution of minerals in somewhat zoned veins and relationship between calcite, fluorite and unreplaced limestone in filled solutional caves, indicate the stages of mineralization. A first essentially carbonate stage when the cavities in limestone were filled by calcite and a second fluorite-calcite stage when the brines deposited fluorspar or replaced host rocks, can be identified. A final calcite stage probably completes the ore formation process.

Lateral zoning of the constituent minerals in a N-S direction parallel to the axis of the belt is quite distinct. At present it is defined by two major minerals of the belt namely fluorite and barite; the former more important in northern areas of Fort Sandeman-Quetta-Kalat while the later is prominent towards the south in Khuzdar-Lasbela region. Sulphide minerals are known to occur only in traces in the northern areas and although their proportion seems to increase southward, no economic concentrations are known as yet. Among sulphides, galena seems to be a more common minor associate fo barite while sphalerite, chalcopyrite, pyrite and tetrahedrite are so far seen only in traces.

Although igneous rocks are present within the limits of the Axial belt, they do not appear to be related with the mineralization in question. Most of these igneous occurrences are of ultramafic rocks, pillow lavas and dolerite sills and dykes known as Muslimbagh and Lasbela ophiolite complexes. These are interpreted as oceanic crust and according to ALLEMAN [1979] the obduction took place in Paleocene. If the ores are of Jurassic age, as has been argued below, then the igneous activity in the region is younger than the mineralization.

Stratabound deposits confined to particular stratigraphic horizons and concordant on large scale but discordant on a small scale, have been discussed by a large number of workers. The various possibilities of origin proposed can be grouped into two: *viz.* those related to sedimentation and those related to igneous solutions. Stratabound ores have recently been recognized in Pakistan and only preliminary studies have been undertaken. However, both possibilities of origin have already been proposed.

SHCHEGLOV [1969] has considered the fluorite deposits of Fort Sandeman and Koh-i-Maran region and barite-massive sulphide deposits of Khuzdar-Lasbela region as two distinctly different types. He argues that the former are epithermal veins of post-major folding (post-Oligocene) ages as they occupy the fracture zones cutting fold structures. According to him the fluorite deposits are endogenous being formed during the change of geosynclinal regime to the platformic one is the Neogene times. This very closely compares with the placement of fluorite by BILIBIN [1968] in his scheme of endogenetic mineralization in mobile belt where fluorite alongwith lead and zinc sulphides is considered to form telethermal deopsits at the terminal stage of evolution of a mobile belt. For the barite-massive sulphide deposits at Khuzdar-Lasbela region SHCHEGLOV [1969] favours formation during an early stage of development of Baluchistan geosyncline and assignes a late Cretaceous-late Paleogene age.

In view of the characteristics of the deposits described above, SHCHEGLOV's views do not appear to be well justified. There is no convincing evidence for considering the fluorite and barite-massive sulphide deposits as of different stages of geosynclinal evolution at widely separated time intervals. The fluorite filled fractures cutting the folded structure could indicate remobilization of a much older mineralization. Similarly evidence for fluorite-barite-sulphide mineralization being of endogenic igneous derivation is also lacking.

A number of possibilities have been envisaged regarding the deposition of stratabound ores by sedimentary processes which include direct precipitation from sea water of precipitation from submarine exhalations. Another mechanism is the transport of metals by the pore-space fluids expelled during compaction of sediments with subsequent redeposition at suitable sites [JACKSON and BEALES, 1967]. DUNHAM [1964] has gone so far as to evoke neptunist concept in deposition of stratiform Keupferschiefermarl slate at Mansfeld, Germany.

The known characteristics of fluorite deposits of Kalat region alongwith those of barite-massive sulphide deposits of the Axial belt in general suggest a sedimentary origin of late-diagentic-epigenetic type. MUSLIM [1972] has proposed that generation of the gaseous phase containing halides within Jurassic sediments could have altered the limestones. SILLITOE [1975] designates these deposits as Mississippi-valley type and suggests that these could have been precipitated by connate brine within the continental shelf bordering north of Gondwanaland prior to the separation of Indian Plate. The incipient rifting of Gondwanaland may have induced a rise in geothermal gradient which promoted the movement of brine. Although this appears to be a probable mode of origin, no related tectonomagmatic features such as grabens and alkali magmatic rocks have so far been noted in the Axial belt.

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