Structural Control and Genesis of the Fluorspar Deposit near Dilband and the Surrounding Areas

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Abstract: Geological and structural details of Dilband Fluorspar deposits in Jurassic limestone have been studied. A speculative explanation of the genesis of the deposits is that it was formed during the gradual compression and diagenesis of calcareous zones of the axial belt. These Fluorspar deposits which are scattered over a wide area, confirm to the pulsatory nature of the tectonism in this region during the development of the axial belt — and are not the product of hydrothermal solutions from a deep seated igneous body as has been described earlier.

SCOPE OF STUDY

The purpose of this report is to present all the available geological data on Dilband Fluorspar deposits including that collected during 1978–79 field work and analysed for developing a speculative model of the genesis of the deposit. Attempt has also been made to evaluate the probable resources. The geological mapping in 1978–79 was done on topographic base map of scale 1:50,000 and on aerial photograph of scale 1:40,000.

Field work included surface mapping, pitmapping and observing the general replacement pattern of fluorspar in the Chiltan Limestone (Jurassic), which acted as the host rock.

INTRODUCTION

The Dilband Fluorspar mineralization is noted in the north-south trending calcareous zone of the axial belt. The fluorspar deposits of the area have been described by Bakr (1962), Ahmed (1969), Mohsin and Sarwar (1974) and also briefly mentioned in the Hunting Survey Report (1960). The previous work is generally restricted to description of the geological features and the stratigraphic sequence of the area. Bakr (1962) ascribed this fluorspar mineralization to a hydrothermal origin. Mohsin and Sarwar (1974) in their paper with a fuzzy reasoning, adopted the same conclusion, assuming that there is a deep-seated igneous body. In fact there is no intrusive outcrop in a radius of 150 miles, which is an enormous distance to be considered as a source for hydrothermal solution. Although there is no evidence for a magmatic source in this area, it is understandable why the previous authors had difficulty to determine the precise source of the mineralizing solution. By attributing the hydrothermal origin to the deposit, the previous workers restricted the terminology to the solutions originated from an igneous body, and by doing this, limited the scope of their work. Because, according to Smith (1954), hydrothermal in a wider sense implies fluids of any source that have migrated probably from deeper and warmer rocks. Nevertheless, this paper does not intend to preclude other hypotheses, and particularly those proposing a magmatic hydrothermal source. It does, however, provide a possible alternative, since the existence of the presumed magmatic source could not be demonstrated in the area.

Numerous field trips to the area had long before convinced the author to regard these fluorspar deposits as a Mississippi valley-type, and this belief has recently been validated by Sillitoe (1979). This can further be substantiated by the works of Bastin (1939) and Ohle (1959) who describe the salient features of the Mississippi valley-type deposits as follows:

1. They occur in limestone and dolomite.
2. Consist primarily of veins, bedded replacement.
3. Mostly occur at shallow depths relative to the present surface.
4. There is a general absence of igneous rocks as potential source of mineralizing solutions.
5. Solution activity, brecciation, slump, collapse and thining are common evidences.

Most of these criteria described by Ohle (1959) fit well in the jigsaw puzzle of the Dilband mineraliza-

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tion process, and to support the suggestions made in this paper, most of the above observations will be retained and evaluated in favour of/or against the various proposals forwarded for the origin of this fluorspar deposit. Sillitoe (1979), while describing the fluorspar deposits in Jurassic limestone of this area, proposes that this sequence belonged to the continental shelf on the edge of the Indian Plate and says that mineralization occurred from connate brines released during the rifting of India from Gondwanaland in Late Jurassic-Early Cretaceous period. He further suggests that the then environment represented a greater degree of heat flow.

The author partly agrees with the hypothesis suggested by Sillitoe (1979), and in particular his remarks about the environment with an enhanced activity of heat flow.

However, this cannot be taken as a conclusive statement for the fluorspar deposits in Baluchistan, as there still remain many unanswered questions about the genesis of the mineralized area. Through this paper it is suggested that at the early stages of rifting, fluorine charged connate fluids were released from the sub-marine volcanism. These fluids were deposited in the marine sediments. Fluorine, which existed in a metastable form, was separated by the tensional forces produced at the time of rifting. With the development of axial belt and the continued crustal shortening, the above discussed marine sediments further passed through successive stages of compression and diagenesis —thus enabling the fluorine to be deposited under stable conditions.

Location

The Kalat District quadrangle No. 34 0/3 (Fig. 1) is in the N.W. part of Baluchistan, the investigated area within this quadrangle lies between latitude 29° 25′ and 29° 28′ N., and long. 67° 8′ and 67° 11′ 50″ E.

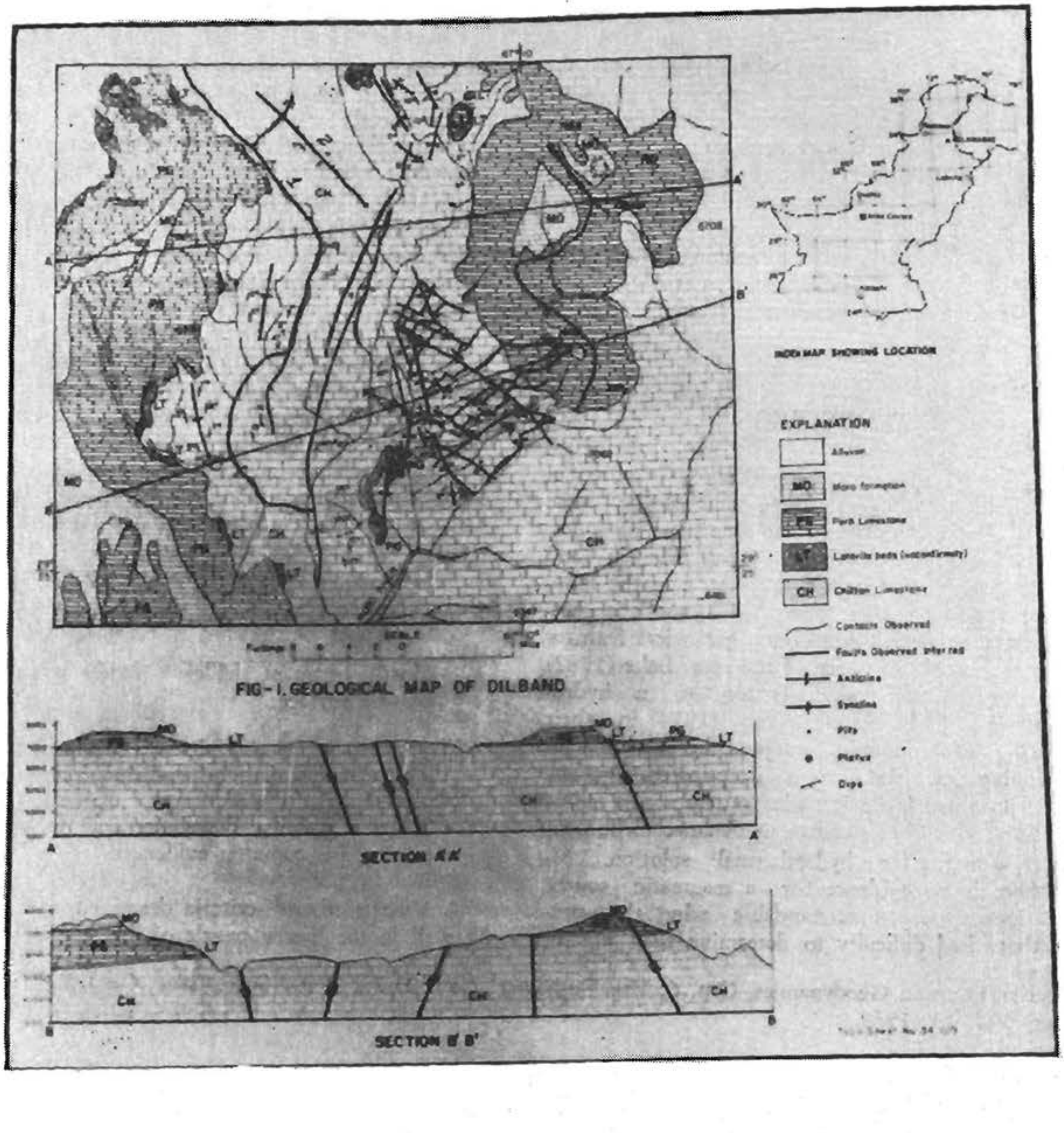

FIG-1. GEOLOGICAL MAP OF DILBAND

GEOLOGIC CHARACTERISTICS

The Dilband, Koh-i-Maran and Koh-i-Saih fluorspar deposits are in the Jurassic limestone (Chiltan formation) along the eastern flanks of the axial belt, which forms an important feature in the geology of Baluchistan. These are important fluorspar areas about 175 km from Quetta. The geological features of the area have been described in previous papers by Bakr (1962), Ahmad (1969) and Mohsin and Sarwar (1974). A more detailed information about the lithological division of this area can be had from the report published by the Hunting Survey Corporation of Canada (1960). A prominent feature in the area is an unconformity, consisting of a laterite bed of dark reddish brown to greenish black oolitic bed and clayey material. This separates the Jurassic limestone of Chiltan formation from the Cretaceous limestone (Parh and Moro formations).

Laterite bed which signifies the marine unconformity between Jurassic and Cretaceous groups of limestone, is of particular interest in the present discussion as the texture, colour and conditions required for the formation of this bed, also abundantly indicate a marine origin (Lindgren, 1933). Such environmental conditions most probably occurred during the Late Jurassic and Cretaceous period.

General Subsurface Character

The fact that the scattered distribution of the fluorspar deposits in this area are encountered at various levels can be explained in two ways.

(1) The deposition took place in a highly mobile and disturbed area, and was confined to a shallower depth. In this case, presumably, the upper part has been eroded.

(2) More likely, as seen in the mining pits, the thickness of the fluorspar bearing veins gradually increases with depths, thus extending to a greater depth. Accordingly, the possibility of developing the present mining for further economic returns is very encouraging, if detailed geophysical work combined with some drilling is done to delineate the lateral extent of the deposit that might possibly be present.

Depositional Characteristics of Mineralization

The observations, recorded in a number of pits and opening, generally show that fluorspar occurs as lenticular bodies in calcite. However, it has been also noted that there is a diversity in the mineralizing trend which can be observed in the same pit or from one pit to another. In some places limestone has been replaced either (1) selectively along beds or (2) the solution entered fractures and filled cavities or replaced limestone. Various small openings, such as cleavage cracks in calcite and intergrain boundries are site of deposition and replacement. Occasionally well preserved rhombohedra of calcite are also found surrounded by the fluorspar in cavities and fillings, indicating the fluorspar to be of epigenetic origin. Well developed cubic crystals of fluorite are also found in the mining pits. Fluid inclusions have been observed in the fluorite crystals, those observed usually contain two fluid phases — a liquid and a small bubble. These fluid inclusions need further investigations by freezing stage method to determine the salinity of the liquid, as suggested by Nash and Theodore (1971). This should help to know the general characteristics of the deposit.

Structure

The structure of the Dilband area can be classified into three categories on the basis of elements as follows:

(a) Tectonic: The forces that produced the larger faults of this fluorspar district, probably produced the fractures and minor faults.

(b) Deep Solution: Solution of underlying limestone deeper than the known producing horizons initiated movements on the tectonic fracture planes.

(c) Secondary Solution: The Chiltan Limestone forms a shallow syncline at the northeast end of the investigated area, in which the younger formation of Parh group are scatteredly exposed and are separated by an unconformity. The field observations strongly suggest it to be a down dropped block, as it is the steeper dipping limb of the Moro anticline. The numerous faults in the central part of the area dominantly represent a strike slip movement extending east-northeast across much of Shakarap area, therefore, suggesting that the mineralized area lies in a strike slip fault zone. Intensive fracturing of the Chiltan Limestone is encountered in most of the mining area. There are two sets of fractures, one striking in the N.W. direction and the other in the E.N.E. direction.

The two sets of fractures (Fig. 2) representing two different compressive phases which helped in the development of these fractures. It is suggested (Fig. 2) that the first compressional phase with a maximum compression took place in the E.W. direction, creating the east-northeast striking fractures which show a right lateral movement. The main fold axis in the area which has north-south striking direction is related to this first phase of compressional movement. The second phase must have occurred at a different time interval in an approximate N. S. direction, developing the second set of northwest striking fractures also showing a right lateral movement. It is also most likely that the plunge in the syncline was developed at the time of the second phase of compression. Various large and minor faults in the southern part of the investigated area could have resulted during the movement taking place while the forces of second phase of compression were at work. Poles plotted on the Lambert equal area stereograph (Fig. 3) also confirm to a low plunging syncline having an axis in the north-south direction and the bedding shows gentle dip.

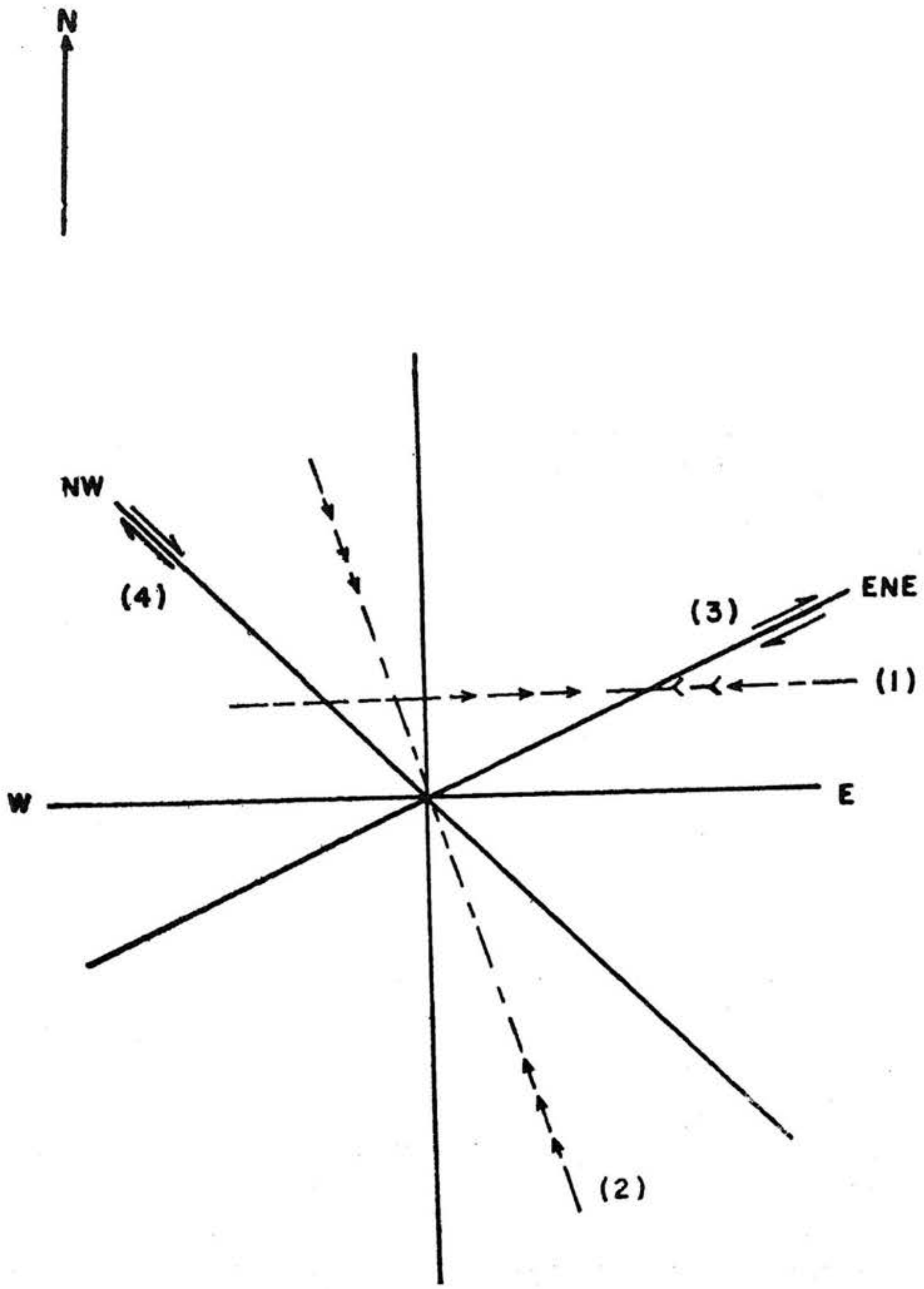

Fig. 2. (1) Development of First Maximum compressional phase.
(2) Max. compression during the 2nd phase (after completion of First phase).
(3) Development of First Fractures in E.N.E. direction.
(4) Development of 2nd Fracture in N.W. direction.

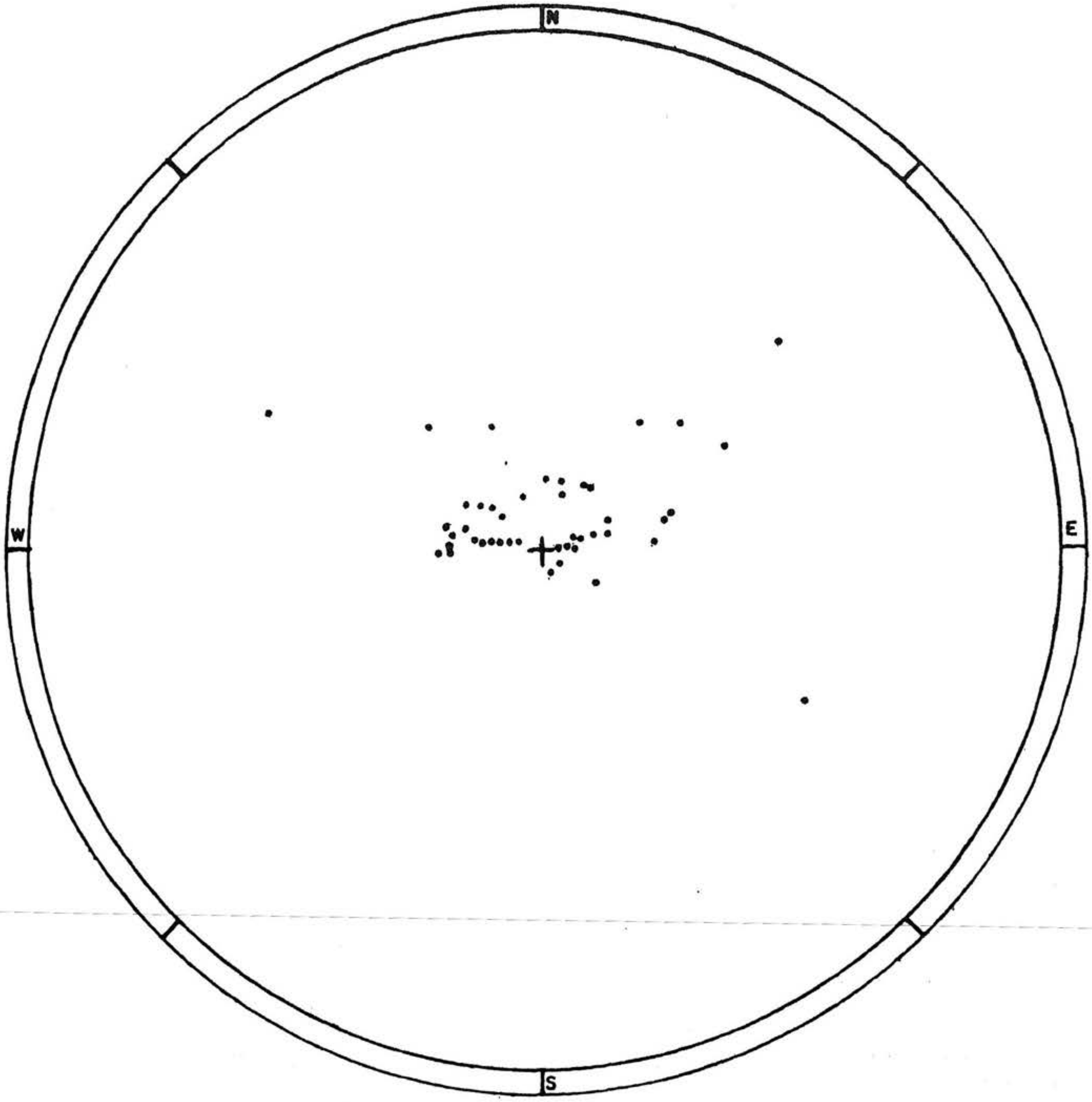

Fig. 3. Upper hemisphere stereographic projection showing attitude of beddings of Dilband area.

Faults: Observed faults in the investigated area are virtually confined to the Chiltan Limestone. All these faults have steep dip angles (Fig. 1), range in displacement from few feet to few tens of feet, and predominantly exhibit a right lateral movement. An angulate fracture zone (Fig. 1) has developed in the area of intensive faulting and most of the present mining activity is around these fractured zones, which are the site of fluorspar deposition. Two larger faults in N.W. part of the mining area, were truncated at an approximate right angle in the down thrown direction of the syncline. These faults which are denoted by number 1 and 2 (Fig. 1) must have formed earlier to the movements which plunged the syncline toward south, and simultaneously dragging these faults in the direction of the plunge. The axis of this plunging syncline trends north-south.

Folds: Traverses along Reko, Moro River and Hoshi revealed broad undulating anticilines and synclines. Dip on the flanks of these folds is generally moderate, although steeply dipping synclinal limbs were also observed. Folds observed in the Parh group (Cretaceous) are somewhat strongly undulating. Small scale undulations are also very common in Dilband area.

Joints: Joints are more abundant in the Chiltan Limestone than those of Parh group. Throughout the Chiltan Limestone in the main investigated area, it has been observed that many of the joints contain calcite and fluorspar veins, but in some places joints of one set contain veins of calcite and fluorspar, while the second set of joints does not contain any veins. It is most likely that they are not members of a single system. These must have, therefore, developed at different time interval during the successive and gradual compression experienced by this area with the continuing instability of the axial belt.

Unconformity: As described earlier, an unconformity of a laterite and clayey beds exist in the north-central part of the quadrangle. These beds unconformably overlie the Chiltan Limestone (Jurassic) and are at the base of Cretaceous rocks. The thickness of this laterite bed varies between few feet to more than 25 feet and attain a maximum thickness in S.E. of Khadai. The deposition of this bed could have taken place in a shallow basin adjacent to submarine flanks of the Indian plate.

ORIGIN OF THE MINERALIZING SOLUTIONS

It is most likely that fluorine initially formed on the sea bottom from fluids escaping through lavas during periods of exhaltive and sometime explosive volcanism. These sub-marine volcanic activities could have taken place, as suggested by Sillitoe (1979), during the rifting of India from Gondwanaland and causing deep seated faults on the margin of the Indian Shield. Thus the hot fluorine-charged fluids which were released through the above process found limestone, due to its chemical characteristics and prevailing temperature and pressure conditions, somewhat favourable to exist under metastable form, until later times when the conditions were changed, to be deposited under more stable form.

Also during that time interval, the tectonic movements that were acting in this region, and are still active, were accompanied by various deformation of the sedimentary rocks. This can be witnessed in the various formations of the axial belt. Thus the continued northward movement of the Indian plate produced immense activity in the region and resulted in the crustal shortening. This could have possibly also reactivated the old structural lines. The effect of these movements must have been different at different times, depending upon the intensity of tectonic forces which were active in this region. However, it is most probable that the combination of above factors and the continued compression produced the following sequences of the mineralization:

1. Initially favouring a diagenetic differentiation of the limestone material, by conversion of original carbonate to calcite.

2. Faults and fractures were produced.

3. Heat must have been generated to facilitate the isomorphous reaction of metastable fluorine to change its relative position.

4. Deposition of fluorspar under stable condition.

Maxwell and Verall (1953) suggested that the favourability of such a replacement in limestones becomes more condusive, when heating of limestone causes permanent expansion and greatly increases the permeability. The increase in permeability would permit entry of solutions (as in present case the solution of fluorine) and will greatly help in replacement. This type of chemical reaction under higher temperature and pressure conditions is quite possible, if the ionic radii of the substituting atoms were closely similar. Vlasov, Kuzmenko and Eskova (1959) support this assumption by suggesting that because of the close similarity of ionic radii of fluorine (1.33 Å) and oxygen (1.36 A), the isomorphous replacement of oxygen by fluorine easily takes place. This isomorphous reaction could have roughly taken place as below:

$$CaCO_3 + 2\,HF \longrightarrow CaF_2 + H_2CO_3$$

$$H_2CO_3 \xrightarrow{\text{Easily decomposed}} H_2O + CO_2$$

Here in $CaCO_3$ oxygen atoms in proportion to the available fluorine are isomorphously replaced by flourine ions, forming fluorspar (CaF_2) and releasing carbon dioxide to escape. Nockolds (1966) also draws attention to the fact that where the bonding energy of the two elements were closely similar, this may possibly be just sufficient to change their relative positions.

However, the amount and the intensity of such a replacement will not only depend on the ionic radii and the bonding energy but also on the degree of tolerance under different temperature and pressure conditions. We have also to keep note of the fact that temperature and pressure are proportional to the changes in diagenesis, our study area under discussion has ample evidence of experiencing intensive diagenetic processes in the past as well as continuing in recent times, whereupon creating the condition for exhilerated temperatures which are required for the above discussed isomorphic replacement to take place.

SUMMARY AND CONCLUSIONS

The investigated area of Dilband discussed here represents only a selected part of the total assemblage of widespread mineralized occurrences in the Dilband, Koh-i-Maran and Koh-i-Saih areas. In each of these localities the fluorspar mineralization occurs more consistently and in larger amounts in the fractured zones of the Chiltan Limestone. The earlier suggestions by Bakr (1962), Ahmad (1969), Mohsin and Sarwar (1974) that these deposits originated from a deep seated magmatic body could not be accepted. There is neither any intrusive outcrop nor any other field indication which could support their assumptions.

Since the rifting of India from Gondwanaland in Late Jurassic-Early Cretaceous period, the northward movement of the Indian plate continuously subjected the sediments to compression. The compression of these sediments has continued since then, and the recent studies carried out on the plate movement in this region have recorded various successive movements experienced by this region during different epoch in the Tertiary and Quaternary periods. Although the exact intensities of these pulsatory compressions are not known, field evidences do suggest variations in movement and compression which took place from Paleocene to early Pleistocene. The abundance of faults with different sets of fractures showing variations in strike direction in the mineralized area are most probably the result of the pulsatory nature of tectonism active in this area. The progressive compression and crustal shortening of the region resulted in the diagenesis followed by the deformation of the calcareous sediments of the axial belt, which also affected the temperature and pressure conditions. The fluorine charged fluids which were originally released during rifting, and initially existed in a thermodynamically metastable phase until the time when diagenesis and compression generated heat and helped expansion of the host rock to form new phase under stable conditions. It is, therefore, suggested that the fluorspar mineralization of the Dilband and the surrounding area did not originate from a magmatic differentiation. The changes involved were only rearrangements of components already present.

The bulk of the mineralized zone at Dilband is prominently situated in a gently dipping syncline and within this syncline a number of minor anticlines and synclines are also present. The Dilband syncline was developed first, which later with the development of the major faults of Moro and Hoshi was down thrown and showing an approximate north-south plunging direction. When this plunging process was taking place the area was further severely faulted and fractured. The reason for this could also be assigned to the fact that during compression of this area the Parh group of limestone were intensively folded due to being incompetent, while the Chiltan Limestone which acted as a competent strata resisted the folding and was consequently fractured and faulted, becoming more condusive to mineral deposition. Fractures striking east-northeast are consistantly richer in mineralization than those striking northwest. Within the mining area the drainage forms an angulate pattern. Both of the above discussed factors are important and have direct bearing on the mineral exploration now being conducted in the area, and these factors alone provide a major incentive to propose these conclusions — and should help in exploring for and in further developing of fluorspar deposits which exist in the neighbouring localities.

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