

COMPOSITION, ORIGIN AND ECONOMIC POTENTIAL OF KAKUL, LAGARBAN AND TARNAWAI PHOSPHORITE DEPOSITS OF HAZARA, PAKISTAN*

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The carbonate fluorapatite, dolomite, calcite, quartz, hematite, magnetite, feldspar, kaolinite, montmorillonite and illite were important minerals identified by XRD and microscopy. Apatite mainly occurs as microphosphorite and ovoidal or disc shaped pellets of variable size. The P_2O_5 content of these phosphorites ranges from 22 to 36% with major impurities of silica, magnesium, iron oxides, alumina and alkalis. All field and laboratory data generated on these phosphorites suggest that Hazara phosphorites were formed authigenically and underwent various phases of deformation, variable degree of weathering and recrystallization to produce pelletal or granular phosphorites.

Key words: Phosphogenesis, Hazara, Pakistan.

Introduction

The phosphate rock occurrences at Hazara in Pakistan are a part of Cambrian-Jurassic sequence which hosts rock phosphate associated with dolomite and chert.

The geology of the phosphate bearing district of Hazara which is situated in Northern Pakistan has drawn attention of leading geologists of the subcontinent for over a century. Important contributions to the geology of Hazara were made by Middlemiss [1] and Wadia [2]. After the independence of Pakistan, extensive studies on geology of the area were made by Marks and Ali [3] and Calkins and Matin [4]. The Abbottabad district of Hazara assumed further importance when phosphate was discovered by Latif [5,6]. A number of studies on Hazara phosphorite deposits were made by British Mining Consultants and Sarhad Development Authority [7-13].

Despite the known and proved reserves of over 7 million tons of good quality rock phosphate deposits in Hazara the production is very low. Pakistan's rock phosphate import is about 100,000 tons per annum from Jordan and Morocco to meet local fertilizer industry's requirements. Besides, huge quantities of finished phosphatic fertilizers are also being imported every year.

The present work is a part of the study being carried out by authors in collaboration with Sarhad Development Authority and other national and international organizations on exploration and development of Hazara phosphorites. The study comprises the main sedimentological, geochemical and mineralogical characteristics of phosphorites and associated authigenic minerals like dolomite. A discussion on the genesis of the phosphatic sediments of Hazara has also been included.

*This paper is also a contribution to IGCP Project-325 on correlation of palaeogeography of phosphorites with associated authigenic minerals.

Materials and Methods

Experimental. Twelve representative samples were collected from Tarnawai, Kakul and Lagarban deposits of Hazara district. The samples were studied for their petrographic, mineralogical and geochemical characters. The chemical analysis was carried out using standard analytical methods (14) to determine SiO_2 , Al_2O_3 , Fe_2O_3 , P_2O_5 , K_2O , F and loss on ignition (Table 1).

The samples were powdered to 200 mesh on rock crusher Siebtechnik type 250 for whole rock mineralogy of each sample using X-ray powder diffraction (XRD). Samples were irradiated with CuK radiation for 6 hrs. at 35 KV and 20mA.

Results and Discussion

Hazara phosphorites are large with estimated reserves of 20 million tons having commercially exploitable contents of P_2O_5 and impurities. Despite vast economic potential of these phosphorites in making the country self sufficient in phosphatic fertilizers, Pakistan is a major rock phosphate and fertilizers importing country.

The phosphate bearing area of Hazara is structurally very complex due to Himalayan orogeny which began in the early and middle Tertiary and resulted in the deformation of rocks. Phosphorites occur on the western flank of Hazara-Kashmir syntaxis which was initially defined by Wadia [2]. Besides, Hazara-Kashmir syntaxis, there are three main regional structural features of this area (1) Tarnawai fault (2) Jhelum fault and (3) Garhi Habibullah syncline. In addition to these faults there are many other smaller strike-slip faults.

Phosphate occurs mainly in two stratigraphic horizons, a lower and an upper horizon. Most of the phosphate deposits are found in the lower horizon which is exposed at Kakul,

Lagarban, Lambidogi, Kaludi Bandi, Sirban, Tarnawai and Sobangali, where it is mostly associated with cherty dolomite of the Sirban formation. The upper horizon occurs in association with hematitic siltstone of Hazira at Dalola and Sirban areas.

Sirban dolomite exposed at Kakul mine section is about 1660 meters thick but only the upper most 167 meters thick part is exposed along mine ridge [11]. Dolomites are interbedded with grey chert which is sometimes nodular. The dolomites are generally laminated but massive variety is also present (Fig. 1). Cherty dolomite grades upwards into banded chert over which thin limestone layer occurs, followed by 8 meters thick dolomite layer interbedded with chert. Overlying is phosphorite which is thin to medium bedded and pelletal. Above, there are siliceous phosphate layers which have an upper conformable contact with overlying cherty shale, which passes upwards into siltstone. Above it, there is a non-conformity marked by conglomerate layers on which lies arenaceous limestone belonging to Samana Suk Formation of Jurassic age.

The phosphate deposits at Lagarban and Tarnawai occur along two overturned limbs of Garhi Habibullah syncline extending to three kilometres along strike. The stratigraphic succession at Lagarban-Tarnawai is overturned, the ore beds strike north east and dip to the east [9, 15]. The hanging wall of Tarnawai phosphorite is massive dolomite but the footwall consists of thin bedded dolomite and phosphorite beds having contact with the silt and shale of Hazira Formation [15].

The geology of the whole phosphate bearing area is very

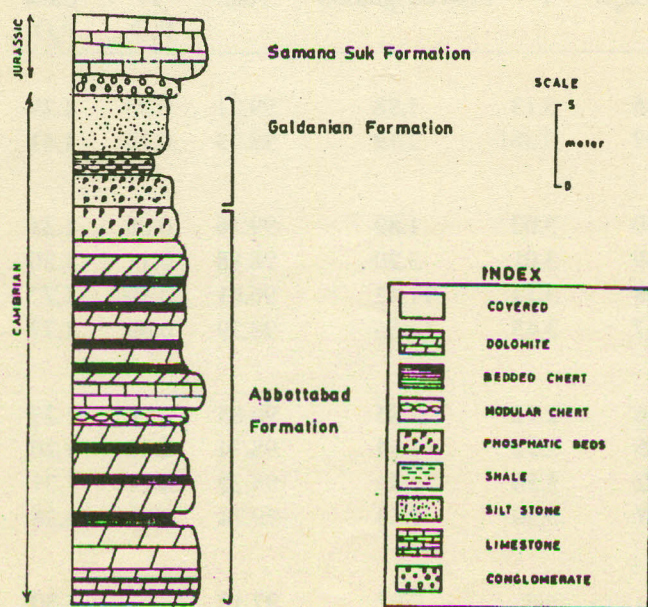


Fig. 1. Measured stratigraphic section of Abbottabad & Galdanian formation exposed near Kakul, Abbottabad (After Rubina 1995).

complex due to thrusts which are generally parallel to the strike and divide the succession into discrete thrust sheets and bringing into juxtaposition the rocks of widely different facies [16].

The cyclic repetition of strata in the study area may be due to transgressive and regressive conditions prevailing at the time of deposition [13].

According to Baqri *et al* [17] many major phosphorite deposits have a close link with marine transgressions. The concomitant and often extensive reworking of sediments and weathering are major factors in concentrating phosphate in large economic deposits [18].

The phosphorite samples from Kakul, Tarnawai, Batakna and Lagarban phosphorite deposits are studied by XRD. Important minerals identified in these samples include apatite, dolomite, calcite and quartz (Fig. 2). Minor amounts of hematite, magnesite, feldspar (albite and orthoclase), kaolinite, montmorillonite and illite are also present. The most important peaks (d^oA) at 100 intensity have been identified as 2.78, 2.79 (apatite) 2.67 (dolomite) 1.927 (calcite) 2.867 (illite and 3.302(feldspar) respectively.

The inter-element relationship of the chemical data given in Table 1 shows that P₂O₅ has random correlation with SiO₂, CaO, MgO and negative relationship with Na₂O (Fig. 3). However, Mg and Na are known to substitute for Ca in the apatite structure [19, 20]. But in the case of these phosphorites, random correlation of P₂O₅ with MgO and SiO₂ is due to diagenetic and silicification effects [21]. As both are major constituents of apatite positive relationship between CaO and

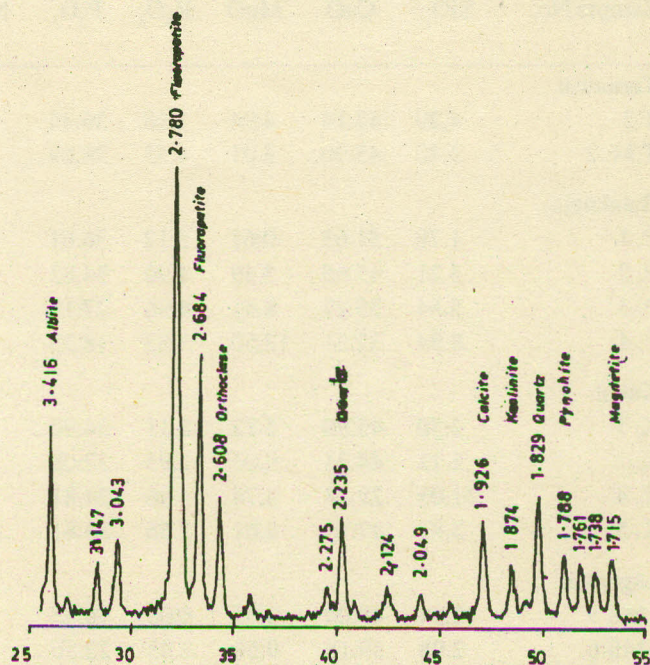


Fig. 2. X-ray diffractogram of phosphorite sample from Tarnawai deposit.

P_2O_5 is natural. But this correlation is random in case of Hazara phosphorites due to diagenetic and calcitization effects also noticed in thin section of these samples.

It can be seen from Table 1 that apatite is mainly carbon-

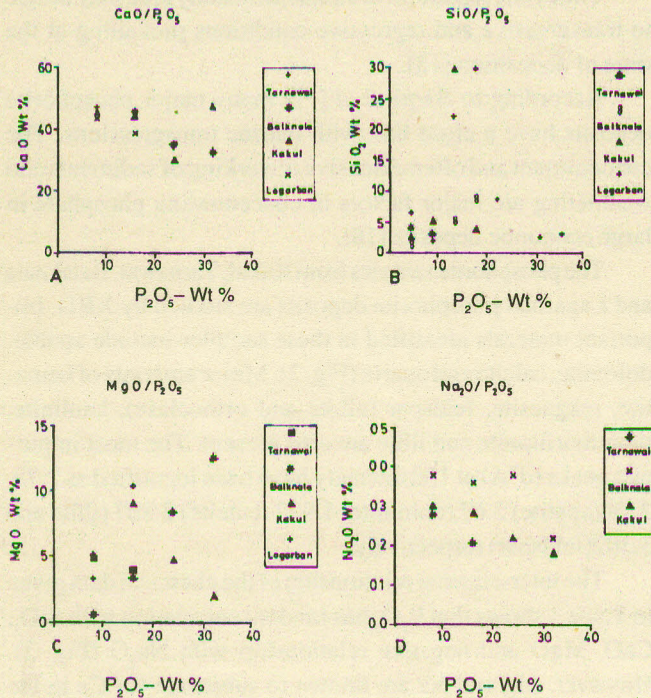


Fig. 3. Relationship between P_2O_5 and other oxides.

TABLE 1. MAJOR ELEMENT COMPOSITION (WT %) KAKUL, LAGARBAN, TARNAWAI AND BATAKNALA PHOSPHORITE DEPOSITS OF HAZARA.

Sample No.	SiO ₂	CaO	MgO	R ₂ O ₃	P ₂ O ₅	Na ₂ O+K ₂ O	F	Loss on ignition	Total	F/P ₂ O ₅	CaO/P ₂ O ₅
Tarnawai											
T 2	4.20	47.14	4.94	1.48	36.34	0.35	3.13	1.98	99.21	0.08	1.29
T.M. 2	3.10	45.90	3.91	4.55	34.89	0.37	0.381	2.19	98.73	0.10	1.41
Batakna											
P. 1	1.78	51.63	0.61	3.12	36.61	0.40	3.02	1.89	99.16	0.08	1.31
P. 2	3.21	45.65	3.49	4.90	34.83	0.59	3.01	3.20	98.88	0.11	1.30
P. 3	5.54	35.27	8.41	4.96	27.12	0.78	3.14	11.42	96.61	0.19	1.77
P. 4	8.94	32.51	12.50	3.33	18.33	0.57	3.45	18.56	98.29	0.09	1.77
Kakul											
K. 1	2.50	45.90	5.12	2.11	34.90	0.36	2.92	2.85	96.85	0.09	1.37
K. 2	5.12	44.24	9.03	2.95	32.08	0.45	2.92	1.94	98.74	0.09	1.20
K. 4	31.03	29.88	4.74	1.96	24.81	0.82	3.56	1.46	98.29	0.14	1.31
K. 5	3.81	47.15	2.01	2.56	36.81	0.37	3.50	1.43	99.74	0.09	1.28
Lagarban											
LMS 5	2.54	48.00	3.05	4.00	36.85	n.d.	n.d.	2.67	97.13	—	1.30
LMS 6	2.98	39.18	9.58	2.43	22.56	n.d.	n.d.	20.88	97.61	—	1.73

MgO wt % Na₂O wt % SiO₂ wt % CaO wt %

ate-fluorapatite as CaO/P_2O_5 ratio average is above 1.30 characterizing fluorapatite [18]. However, the average (0.10) is suggested by Lucas, *et al.* [22] for fluorapatite. The mean of CaO/P_2O_5 ratio in these phosphorite samples is 1.42 due to increased lime contents and slight weathering effects in phosphorite facies. The ratios of F/P_2O_5 and CaO/P_2O_5 (Table 1) have been derived from the weight percentage of these elements.

Major chemical impurities in these phosphorites are silica, iron and magnesium. Kakul phosphorites are blended with Lambidogi phosphorites to reduce silica content to the desired level for ensuring smooth supply to the single super phosphate plant at Haripur. In Batakna phosphorites, magnesium and iron are major impurities which need to be taken care of when deposits would be mined in near future.

Microscopic features of the phosphorite samples have been described according to petrographic nomenclature adopted by Riggs [23].

a. *Orthochemical phosphorites.* (i) Microphorite apatite occurs as light brown colour microcrystalline primary phosphate mud in Kakul, Tarnawai and Batakna phosphorite deposits.

b. *Allochemical phosphorites.* (i) Intraclasts, In Tarnawai and Kakul, the intraclasts of calcite and quartz are common which occur between pellets and microphorite (Fig. 4a).

(ii) Pellets. Apatite occurs dominantly as pellets which are generally oval shaped (Fig. 4b). The pellets occur in

aggregates with interconnecting boundaries, having a size generally less than 2mm and showing bedded character and aligned behavior. Other minerals like quartz are also alligned in the same direction and look deformed internally and on margins. The fractured pellets may be due to wave agitation within basin of deposition. The pellets occur separately and in clusters and show highly abraded margins and lot of terrigenous material as inclusions.

(iii) Pseudo-oolite. In Kakul and other localities disc-shaped or oolitic pellets are also common which like other apatite pellets are also embedded in microspherite (Fig. 4c).

c. *Cryptograined component of phosphate macrograine:*

(i) Matrix. It consists of calcite, quartz, chert, feldspar, silt and chlorite etc. (Fig. 4d).

(ii) Colouring matter. It is of dark brown to light brown coloured hematitic material which is distributed throughout in variable amounts as droplets, coatings and stains on pellets and microspherite and also as fracture fillings. Dark colour of the rock may also be due to pyrite grain scattered throughout the rock.

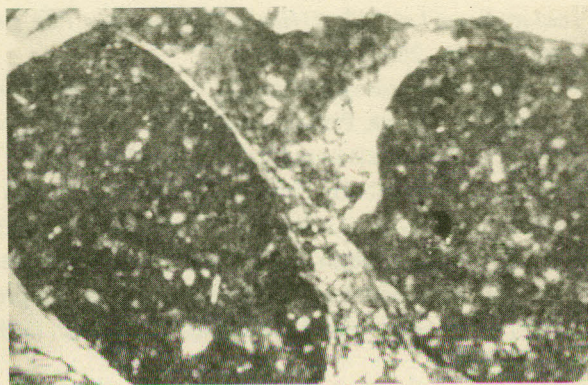


Fig. 4A. Sparry calcite and intraclasts of quartz occurring between apatite pellets having ferruginous inclusions (CP x 25).

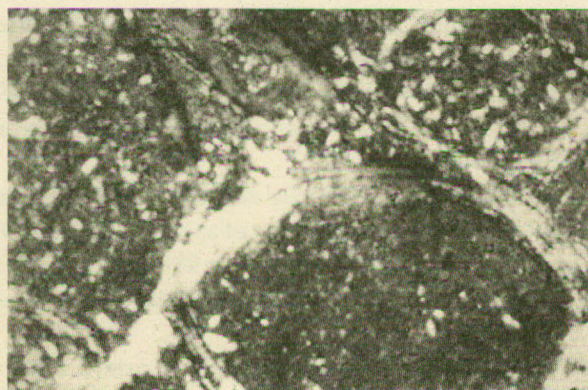


Fig. 4B. Oval shaped apatite pellets with recrystallized apatite bands and recrystallized quartz as inclusions or apatite replacing material (CP x 25).

d. *Micrograined components:* Rods, veins and veinlets of calcite, quartz and chert are common which cut across apatite pellets and microspherite. The carbonate inclusions of calcite and dolomite are also commonly noticed in pellets and microspherite. Clastic phosphate grain inclusions are quartz, chert and feldspar. Terrigenous inclusions are sand, silt and clay. Carbonate replacement by recrystallized silica and calcite is noticed. Recrystallized bands of apatite on the margins of apatite pellets are also seen.

Genesis. The sedimentary phosphate deposits of Hazara like some other phosphorites of the world may have formed at greater depths than the eventual site of deposition and the upwelling currents were responsible for bringing the phosphate to the present site of accumulation where it formed economic deposits [24]. These marine deposits were formed directly from solution and not by replacing pre-existing calcareous material [25]. The MgO values are generally low because dolomite is seen only in the ground mass. While, percentage of quartz and feldspar is high because both occur

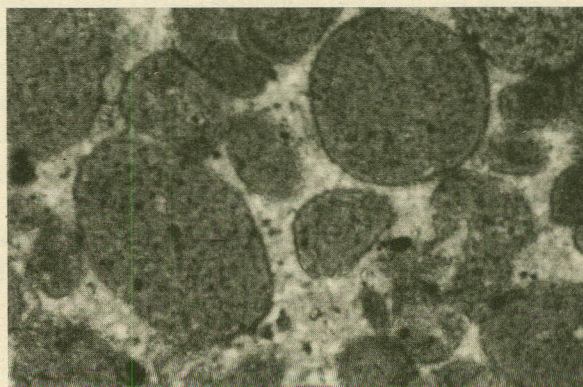


Fig. 4C. Disc shaped apatite pellets embedded in light coloured microspherite and droplets of iron oxide distributed throughout (CL x 25).

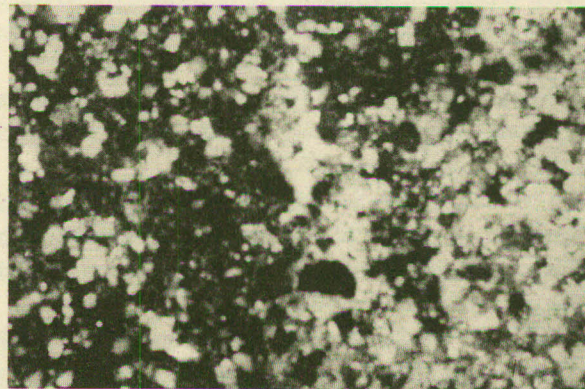


Fig. 4D. Dark coloured microspherite with ferruginous matter being replaced by recrystallized quartz and carbonate grains showing sharp contact with light coloured carbonate and quartz grains of primary and secondary origin (CP x 25).

as grains and matrix of primary and secondary origin [16]. The variable Fe_2O_3 content in these phosphorites is mainly due to varying degrees of weathering in phosphatic horizons. Sometimes, the deep brown colour of the phosphate is due to hematite resulted from leaching of overlying iron rich rocks.

Hazara phosphorites are of two textural and genetic types (microsphorite and allochems) having same mineralogical and chemical composition [13, 16].

Microsphorite is primary phosphate precipitate composed of CFA minerals formed physico-chemically or bio-chemically *in situ* in the marine environments and show little evidence of transporation [26-30]. In many cases CFA appears to have precipitated directly from the dissolved phase, perhaps passing through an intermediate non-crystalline phase [31-33].

Granular phosphate is formed when high energy conditions prevail. This granular type is chemically similar to microspherite which suggest that this variety has formed from the reworking of phosphatic mud or microspherite.

Granular phosphorites composed chiefly of phosphatic particles (pellets) generally show the evidence of transportation and deposition under the influence of bottom currents. Cements are commonly carbonate, siliceous, phosphatic and clayey matrix. The isotopic analysis of separate pellets from many other phosphorites show them early diagenetic precipitates [34-38]. The spherical and oval shapes of pellets in Hazara phosphorites suggest that these pellets were formed after the re-working or diagenesis of microspherite [11, 13, 16].

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