

PETROGRAPHIC AND GEOCHEMICAL STUDIES OF SOME PHOSPHORITE DEPOSITS OF HAZARA, PAKISTAN

VIQAR HUSAIN, SAFDAR SULTAN*, RUBINA BILQUEES, ABDUL MATEEN** AND BAHRAWAR KHAN***

PCSIR Laboratories, Jamrud Road, Peshawar, Pakistan

(Received March 28, 1993; revised December 19, 1993)

Samples from Kakul mine and trenches of several phosphorite deposits were studied. These phosphorites occur in gradational contact with siltstone, dolomite and chert belonging to Abbottabad Cambrian System. Thinly bedded phosphorites occur mostly as pellets and microspherulite, while the intraclasts and pseudo-oolites are rare. Fluorapatite is abundant in all the samples, while quartz, calcite, dolomite, feldspar, illite and hematite occur in minor phases. These phosphorites are primary marine sediments formed mostly by direct precipitation. Recrystallization is due to intense diagenesis, whereas ferruginization suggests weathering of phosphatic horizons in Hazara.

Key words: Petrography, Geochemistry, Phosphorite.

Introduction

The rock phosphate deposits of Hazara are the only known commercial deposits occurring in Pakistan. These deposits, after their discovery by Latif [1] have been studied by Ghaznavi and Karim [2], Hasan and Ghaznavi [3] and Hasan [4]. The British mining Consultants [5] undertook detailed exploration studies, which lead to the development of the phosphate mine at Kakul by Sarhad Development Authority. These rock phosphate deposits occur at Kaul, Kalur, Kakul west, Lambidogi, Tarnawai, Galdanian, Kaludi-Bandi, Lagarban, Dalola and many other localities in a linear belt near Abbottabad city (Toposheet: 43 F/7,8,9, Fig.1). Hazara phosphorites occur as a folded, thrust and faulted sedimentary sequence belonging to Cambrian - Jurassic age. This sequence forms a part of the Garhi - Habibullah syncline on the western flank of the Hazara Kashmir syntaxis, a major structural element of the southern part of the Himalayan orogenic belt [6].

The geology of the whole phosphate bearing area is very complex due to thrusts which are approx. parallel to the strike and divide the succession into discrete thrust sheets. The difference in the depositional environment of each phosphate deposit in the area suggests that large horizontal movements have taken place along the thrust planes which brought into juxtaposition the rocks of widely different facies [7].

Hazara phosphate deposits remain least understood because of insufficient geological data generated and published on these phosphorites, so far. There is a need to do further stratigraphic, petrological and geochemical studies on

Hazara phosphorite deposits to improve our understanding about their origin. This will increase chances of fast developing and mining of already known deposits like Kakul west, Dalola, Lagarban etc. and of discovering new phosphate deposits in the region.

The present work in continuation of earlier studies by Husain *et al.*, [8-10], is concerned with petrography and geochemistry of Kakul, Kakul west, Kalur and Lambidogi phosphorite deposits.

Materials and Methods

Geologic setting. Hazara rock phosphates comprise about 20 deposits occurring over a vast area in the vicinity of

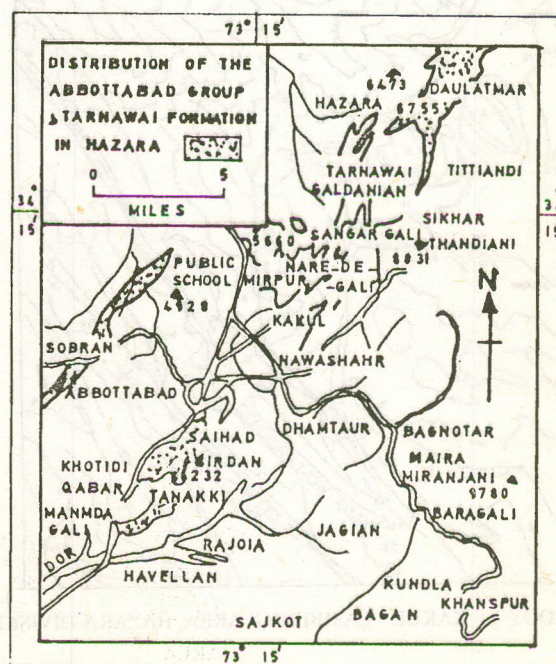


Fig. 1. Location map of Hazara phosphorite deposits.

*Mineral Testing Laboratory, SDA, Peshawar.

**Centre for Nuclear Studies, PINSTECH, Islamabad.

***Kakul Phosphate Mines (Pvt.) Ltd., SDA, Abbottabad.

Abbottabad city. The probable reserves of rock phosphate in this area are about 20 million tons. The rocks exposed in the region range in age from Precambrian to Recent. (Table 1).

The bedded phosphorite deposits of Hazara occur, associated with dolomite, chert and siltstone belonging to Abbottabad Cambrian System (Fig.2). There are gradational and sharp contacts between siltstone, phosphorite and chert between phosphorite and dolomite throughout Kakul Lambidogi phosphate deposits [11]. At places there is a repetition of phosphate bearing sequences as in Lambidogi, suggesting cyclic sedimentation in the area.

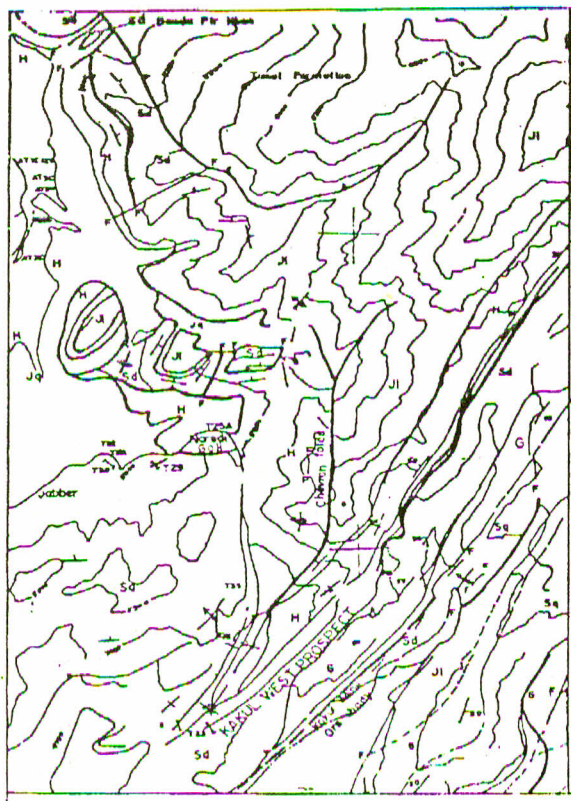
In the area between Kakul and Manshra-Abbottabad road, the predominant structures are open parallel type folds plunging shallowly to gently concave, but the synclines are more tightly folded, angular and commonly faulted along the axes. Kakul west prospect is situated along the southeast of such a syncline, the western limb of which is intensely sheared. More intense deformation resulted in zones of closely spaced faults often associated with chevron folds. Folding was associated with strike slip faulting and thrusting which have effected the phosphorite horizons between Kakul west and Lambidogi extensively [7].

Experimental

The samples of phosphorite were collected from trenches made by exploration teams of British Mining Consultants and Sarhad Development Authority in Kakul north, Kakul west, Kalur and Lambidogi phosphorite deposits. At Kakul mine, phosphorite samples were collected from various underground levels. These samples representing various phosphor-

TABLE 1. STRATIGRAPHIC SUCCESSION IN PHOSPHATE BEARING DISTRICT OF HAZARA [5, 12].

Group/System	Formation	Member	Lithology
Quaternary			Alluvial deposits
Cretaceous	Kawagarh		Limestones
	Chichali		Shales
Jurassic	Samana Suk		Limestone
UNCONFORMITY			
Abbottabad cambrian	Tamawai	Hazara Galdanian	Phosphorite, quartzite, siltstone, hematitic bed phosphorite, chert, hematitic beds, dolomite, calcareous siltstone hematitic beds, dolomite
	Sorban		
	Kakul		
UNCONFORMITY			
Hazara precambrian	Hazara		Slates, grawacke and siltstone



GEOLOGY OF KAKUL - LAMBIDOGI AREA, HAZARA DIVISION

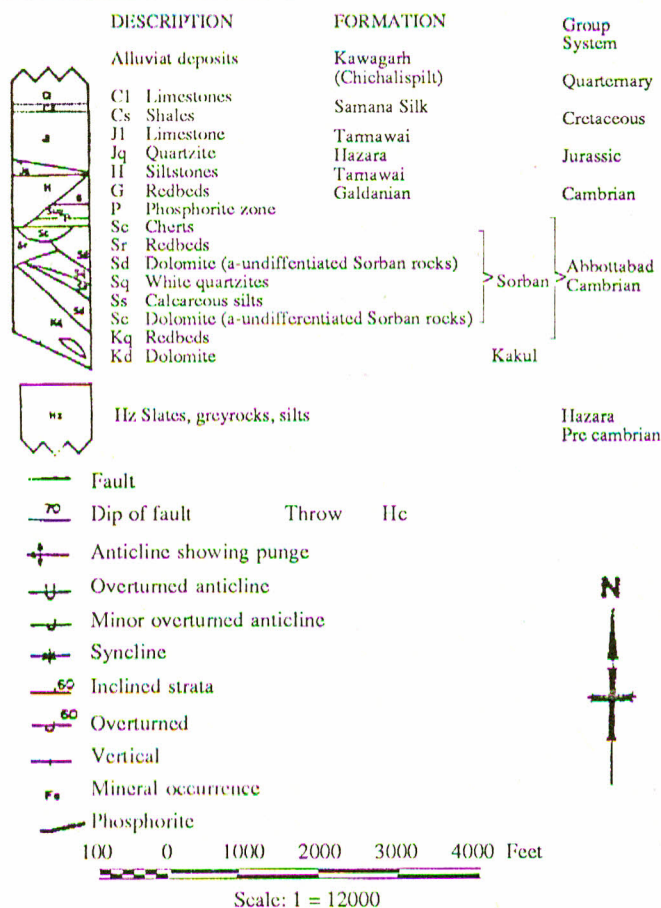


Fig. 2. Geological map of Kakul and Lambidogi, phosphorite deposits (after British Mining Consultants and Sarhad Development Authority, 1977).

its deposits were studied for their mineralogical, petrographic and geochemical characteristics.

Results and Discussion

Petrographic description. Ten thin sections of the phosphorite samples collected from Kakul north, Kakul west, Kalur, Lambidogi and some underground levels of Kakul mine have been studied. For petrological description of these bedded phosphorites, systematics proposed by Folk [13], Prevot [14] and Riggs [15] have been adopted after some modifications.

Two basic types of macroscopic phosphorite have been recognized within Hazara phosphorites—orthochemical and allochemical phosphorites both are authigenically formed primary marine sediments.

(a). *Orthochemical phosphorites.* Microspherite occurs as irregular and fragmented bodies being replaced by deep brown-red coloured secondary iron oxide.

Fine grained siliceous, carbonate and iron oxide inclusions are noticed in the fragmented microspherite. The cryptograined matrix of quartz, silt, dolomite and calcite is also seen mixed with iron oxide pockets replacing the microspherite. The microspherite and iron oxide constitute about 90% of the rock and the remaining 10% comprises pellets (ranging in shape from spherical to oblong), matrix and terrigenous inclusions. (Fig.3A). The formation of the microspherite is thought to take place in relatively low energy environments. However, eroded bodies of microspherite along with oblong pellets indicate periodic high energy storm events and subsequent transportation within the basin of deposition [15].

(b). *Allochemical phosphorites.* In Hazara phosphorites, the most common allochems are pellets and rarely intraclasts and pseudo-oolites.

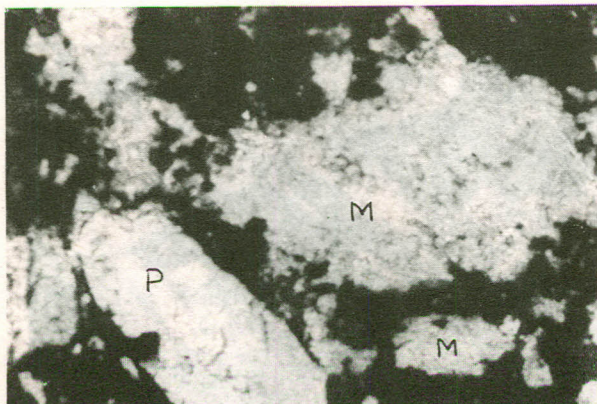


Fig.3A. Microspherite (M), apatite pellets (P) and dark coloured iron oxide (CPx25).

The pellets in Hazara phosphorites occur in a variety of shapes. The size of each pellet varies from 0.1 to 1 mm or more. In this area the pellets constitute 50 to 90% of the phosphate macrograins. The remaining consists of medium to coarse quartz and carbonate intraclasts, matrix and terrigenous inclusions.

The light coloured subangular shaped and uniformly sorted pellets occur in aggregates or clusters with dark brown red colour iron oxide droplets and staining between the grains and on their boundaries (Fig.3B). Mixed with iron oxide are also recrystallized fine grains of quartz and carbonate which cement the pellets and also occur as minor terrigenous inclusions within these pellets. In some cases, very fine sized oriented pellets occur along with quartz intraclasts of the same size and matrix of chert, carbonate and iron oxide. (Fig.3C).

Some pellets are very large in size and ovular in shape constituting about 90% of the whole rock. The recrystallized bands of apatite on the pellet boundaries are quite prominent. The cryptograined quartz dominantly occurs along with small amount of silty, carbonate and iron oxide materials both as cement and inclusions within the pellets (Fig.3D).

Another variety of pellets occurring in these phosphorites is an aggregate of aureolated grains enveloped in phosphatic aureole of second generation (Fig.3E). These aureoles are cemented by micrograined and cryptograined silica. The same material composed mainly of chert occurs as inclusions within the aureoles. This variety and other varieties of aggregate grains appear to be instances of biological mediation [16].

There occurs light coloured oolitic and subrounded to rounded pellets of various size. The recrystallized quartz, carbonate grains and secondary iron oxide are main components of matrix and inclusions which occur within apatite pellets (Fig.3F). These macrograins have fine recrystallized bands of apatite and show abraded margins.

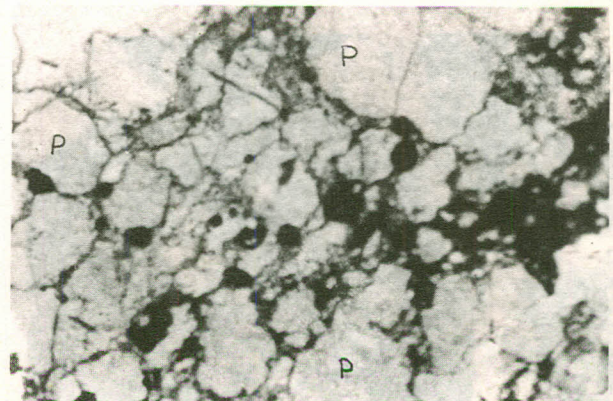


Fig.3B. Subrounded shaped apatite pellets (P) and iron oxide (CPx25).

Subrounded apatite grains with recrystallized quartz (both coarse and fine grains) constitute matrix and the inclusions. The size of recrystallized quartz varies very widely. There appears to be a sharp contact between phosphate grains and siliceous materials occurring in the cherty

phosphate rock as also noticed in the field (Fig.3G). The Fig.4A very clearly shows a sharp contact between siliceous and phosphate rocks. The light coloured part constitutes recrystallized coarse and fine grained silica corroding the borders of phosphatic grains. The Fig. 4B is another view of

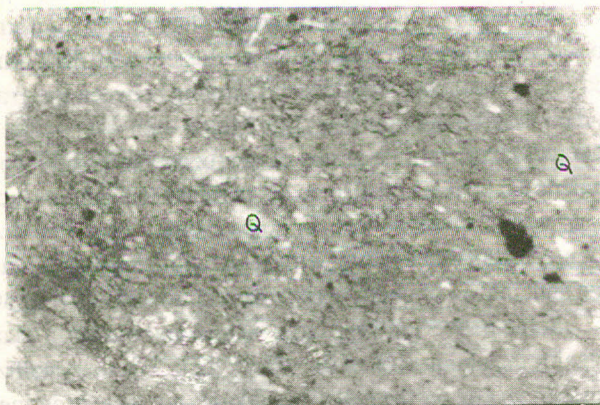


Fig. 3C. Fine sized oriented pellets along with quartz (Q) intraclasts and droplets of iron oxide (CPx25).

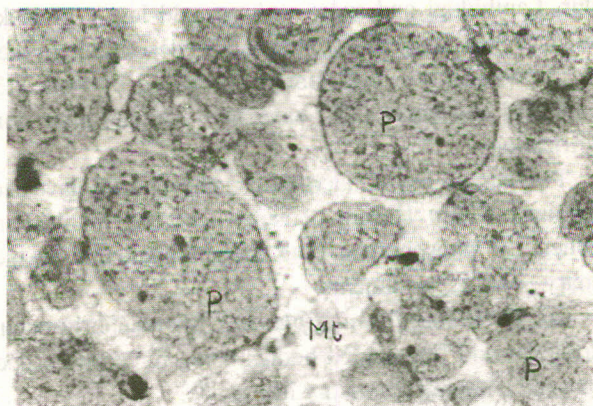


Fig. 3F. Pseudo-oolitic pellets (P) embedded in matrix (Mt) consisting of quartz, carbonate and iron oxide (CPx25).

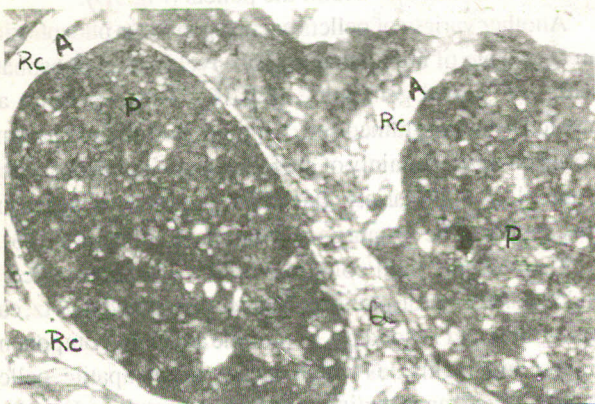


Fig. 3D. Recrystallized apatite (RcA) around apatite pellets (P) along with cryptograined quartz (Q), silt and carbonate.

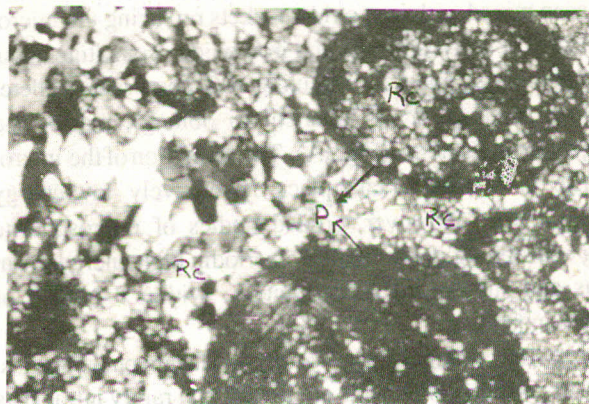


Fig. 3G. Subrounded apatite pellets (P) embedded in recrystallized (RC) siliceous and carbonate grains (CPx25).



Fig. 3E. Aureolated (A1) grains of apatite enveloped in an aureole (A2) of another generation (CPx25).

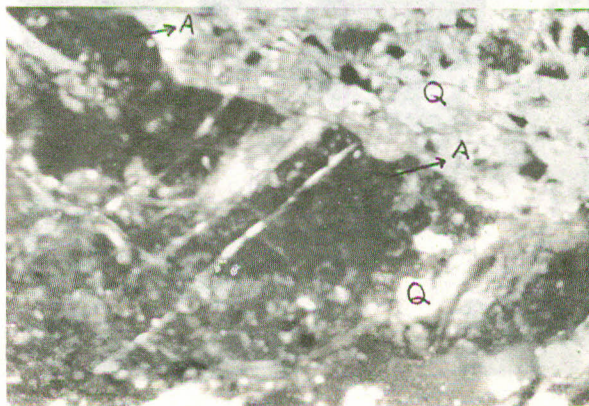


Fig. 4A. Phosphate (P) grains showing sharp contact with siliceous (Q) material (CPx25).

the phosphatic part of the same thin section which shows that apatite mostly occurs as spherical shaped pellets with recrystallized boundaries of apatite and chert as well as cherty inclusions.

Similarly in Fig. 5A there is a sharp contact between medium sized dolomite grains and phosphate grains with much recrystallized material of carbonate and siliceous composition replacing apatite grains. In Lambidogi phosphate deposits such sharp contact between dolomite and phosphate rocks are common. This sample represents such horizon of phosphatic and gritty dolomites which occurs immediately below the contact with Hazara siltstone [7].

In Fig. 5B there occurs subrounded and oval dark coloured pellets with abraded or corroded margins and cherty inclusions. These grains are surrounded by cryptograined recrystallized chert, carbonate and apatite as thick bands on their margins. The Fig. 5C shows apatite pellets of various shapes and sizes. These grains appear corroded and deformed due to intense tectonic stress which is marked by replacement

of phosphate by dark coloured iron oxide.

Mineralogy. The X-ray diffraction studies on phosphorite samples from Kakul, Kakul west and Lambidogi deposits reveal that carbonate fluorapatite is the dominating mineral. The most prominent peaks of apatite (dA°) at 100 intensity have been identified as 2.76, 2.79, 2.78 and 2.77. The second most important peaks of apatite are 2.66, 2.69, 2.68 and 2.67. These apatite peaks obtained in Hazara phosphorites are strikingly similar to the carbonate fluorapatite peaks identified in Birmania phosphorites of western Rajasthan, India belonging to Early Cambrian Age [17].

Geochemistry. The representative samples of phosphorite from different localities of Hazara were analysed for their major element composition (Table 2). The major elements do not vary greatly in different phosphorites of Hazara like other phosphorites of the world, mainly because of different sedimentary environments [18].

The statistical plotting of these data in Fig.6 ABCD shows that P_2O_5 has weakly positive relationship with CaO

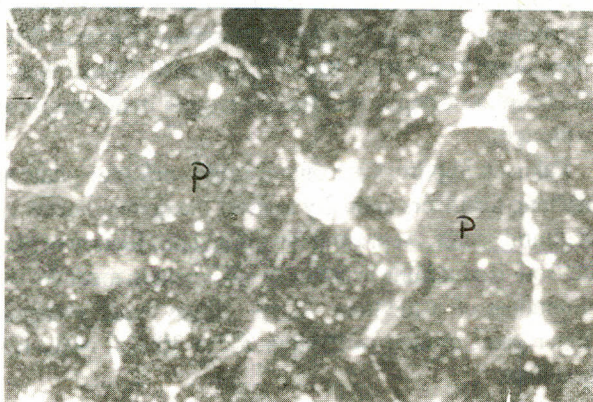


Fig. 4B. Apatite pellets (P) with recrystallized (Rc) bands of apatite on their margins (CPx25).

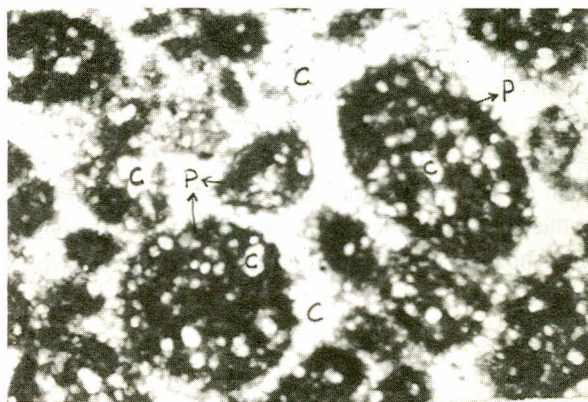


Fig. 5B. Subrounded to oval shaped pellets (P) with cherty (C) inclusions (CPx25).

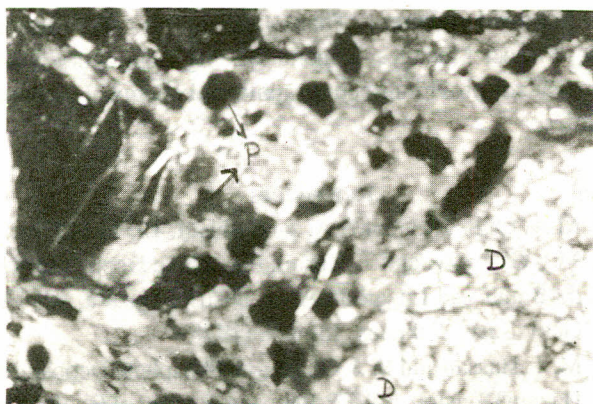


Fig. 5A. Apatite grains (P) showing sharp contact with dolomite (D) grains (CPx25).

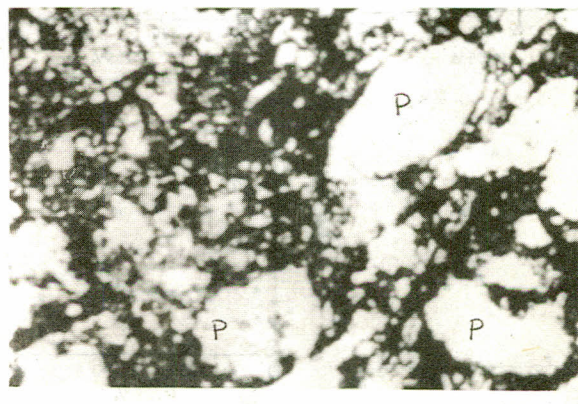


Fig. 5C. Deformed pellets (P) of apatite and dark coloured iron oxide (PPx25).

TABLE 2. CHEMICAL COMPOSITION OF HAZARA PHOSPHORITES (%).

Sample No.	Locality	P ₂ O ₅	CaO	MgO	Al ₂ O ₃	Fe ₂ O ₃	Acid insoluble	L.O.I.	Total
1.	Kakul north	30.30	49.11	Nil	1.22	10.07	6.67	1.89	99.26
5.	-do-	31.89	48.01	1.79	1.01	1.01	1.27	12.40	97.38
7.	Kakul west	31.89	41.58	2.98	0.28	0.51	17.89	4.97	99.22
8.	-do-	33.66	52.66	Nil	Nil	0.07	6.86	3.94	97.19
11.	-do-	34.11	53.77	Nil	Nil	0.54	4.70	3.73	96.85
12.	Kalur	28.35	44.35	2.99	0.28	0.91	19.03	2.91	98.82
17.	Lambidogi	24.80	48.23	9.17	Nil	1.02	3.29	12.13	98.64
23.	Kakul mine (3rd level)	34.11	53.22	0.59	0.28	0.18	6.89	3.34	98.61

and Al₂O₃ and Fe₂O₃ whereas the relationship between P₂O₅ and MgO is random.

Hazara phosphorites are marine sediments precipitated directly from solution as fluorapatite and not formed by replacing calcareous materials [20]. The MgO values are generally low except in Lambidogi, where delomite is associated with phosphorite. Low MgO content in other samples may be due to presence of dolomite only in groundmass. High SiO₂ content in most of the samples is probably due to association of chert with phosphorite, presence of quartz and feldspar, occurring as grains and matrix of primary and secondary origin.

High to low content of Fe₂O₃ in these phosphorites is mainly due to varying degree of weathering in phosphatic horizons. The deep brown coloured surface of the samples is

because of hematite which is formed due to leaching of the overlying iron rich rocks [7].

Mining and development. The phosphorite deposits under study occur within 10 km from Abbottabad city. In Hazara, only Kakul phosphate mine has been developed, which produces about 60,000 tons of rock phosphate per year. Lambidogi phosphorite deposits are being mined by open pit method for blending its ore with low grade phosphate of Kakul. While, the deposits of Kakul west, Kakul north and Kalur like so many other phosphorite deposits in Hazara remain undeveloped and unexploited.

Pakistan imports huge quantities of rock phosphate and phosphatic fertilizers annually to meet the demand of its vast agricultural sector. At present the limited production of phosphate from Kakul mine is not even sufficient to meet the total requirements of a medium sized single super phosphate fertilizer plant located in Haripur about 30 Km away from Abbottabad.

Keeping in view the local demand of phosphatic fertilizer in the country and large known resources of rock phosphate in this area concerted efforts should be made to develop and exploit other phosphorite deposits of Hazara.

Acknowledgement. Thanks are due to Mr. Sarwar Khan, Project Manager, Mineral Testing Laboratory SDA, Peshawar for providing petrographic and chemical analyses facilities.

References

1. M.A. Latif, JB.Gcol.B.A. sanderband, 15, 11 (1970).
2. M.I. Ghaznavi and T. Karim, Phosphate Deposit of Klu de Bandi and Lagarban Area, District Hazara, NWFP, Geol. Surv. Pakistan, Inf.Rel. (1978).
3. M. T. Hassan and M.I. Ghaznavi, Phosphate Deposits of Hazara Division, NWFP Pakistan, Record of Geological Survey of Pakistan, (1980), Vol.50.
4. M. T. Hasan, Proterozoic and Cambrian Phosphorite

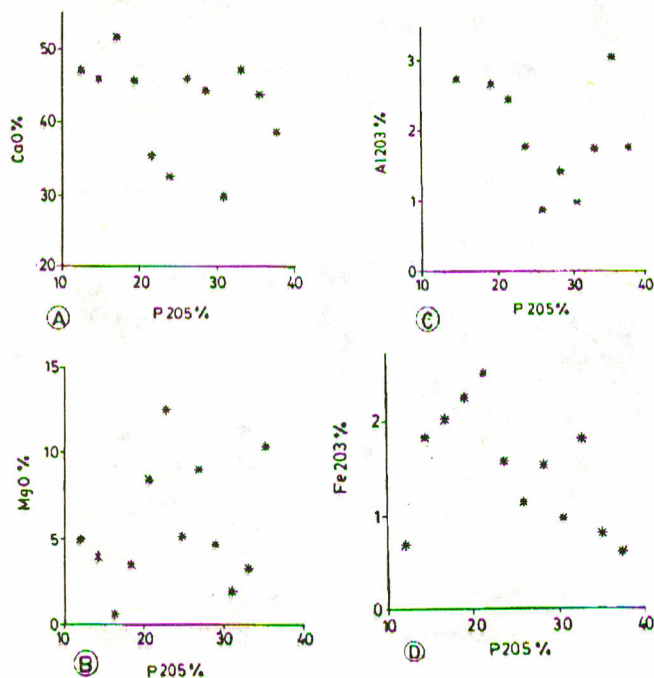


Fig. 6. ABCD Showing relationships of P₂O₅ with CaO, MgO, Al₂O₃ and Fe₂O₃.

- Deposits Hazara, Pakistan. In: P. J. Cook and J. H. Shergold (Eds.) *Phosphate Deposits of the World. Proterozoic and Cambrian Phosphorites* (1986), Vol.I, pp.190 .
5. Pakistan Hazara Phosphate Rock Deposits, British Mining Consultants and Sarhad Development Authority Reports (1977).
 6. J. A. Calkins and A. S. Matin, The Geology and Mineral Resources of Ghari Habibullah Quadrangle and the Kakul Area, Hazara District, Project Reports PK 38, US Department Survey (1968), pp.7.
 7. B. Khan and N. Ahmad, General Geology of the Hazara Phosphate Bearing Areas, Proceedings First SEGMITE Symposium V. Husain, F. Siddiqi, Abid Murtaza and Rubina Bilqees, Ed., March (1991).
 8. V. Husain, M. A. Qaiser, N. Ahmad and R. Bilqees, Petrology of Kakul Phosphorites, District Abbottabad, NWFP, Pakistan. Geol. Bull. Univ. Peshawar **20**, 153 (1987).
 9. V. Husain, N. Jan, R. Bilqees and N. Ahmad, Petrology, Mineralogy and Origin of Hazara Phosphorites, Proceedings First SEGMITE Conference on Industrial Minerals (F. Siddiqi, V. Husain, Z. Kaifi and A. Ghani, Eds.), March (1990).
 10. V. Husain, M. A. Khwaja and M. A. Khattak, Pak. j. sci. ind. res., **34**, (7-8) (1991).
 11. B. Khan, V. Husain, R. Bilqees and Safdar Sultan, Correlation of Palaeogeography with Phosphorites of Pakistan and India, First South Asia Geological Congress, Islamabad, Pakistan (Feb. 23-27, 1992).
 12. M. A. Latif, A Cambrian Age for the Abbottabad Group of Hazara, Pakistan, Geological Bulletin, Punjab University (1974) No.10, pp. 3-18.
 13. R.I. Folk, Practical Petrographic Classification of Limestones, Am. Assoc. Petroleum Geologists Bull., **43**, (1959) pp. 1-38.
 14. L. Prevot, Proposal for a Normalized Easy Description of the so called Pelletal Phosphorites, 4th International Field Workshop and Seminar on Phosphorite, International Geological Correlation Programme, Project 156, Udaipur, India, (1981).
 15. S.R. Riggs, Econ. Geol., **74**, 195 (1979).
 16. J. Lucas, L. Prevot and R. Trompette, J. Geol. Soc., London **137**, 787 (1980).
 17. V. Husain and D. M. Banerjee, Birmania Phosphorites: Petro-mineralogical Characters and Palaeogeological Implications, J. Geol. Soc., India, **27**, (5) (1986).
 18. M. Slansky, Geologie des Phosphate Sedimentaires, Fr Bur Rech Geol Minieres Mem., 114 92 (1980).
 19. Y. Nathan, *The Mineralogy and Geochemistry of Phosphorites in Phosphate Minerals* (J.O. Nriagu and P. B. Moore, Eds.) (Springer Verlag, New York, 1984) pp.422.
 20. W. C. Burnett, Geochemistry and Origin of Phosphorite Deposits from Off Peru and Chile, Geological Society of America Bulletin (1977), Vol..88, pp. 813-823.