

Mineral characterisation of some Indian phosphatic deposits and its influence on their processing problems

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INTRODUCTION :

Phosphatic mineral deposits are extensively used in the manufacture of fertilisers which are so essential for agriculture and also in chemical and other industries. Phosphorus is widely dispersed in the earth's crust but it is most economically concentrated in the form of few minerals of which apatite and collophane are of commercial importance. The presence of these minerals are quite appreciable in many magnetite-quartzites, quartz-chlorite schists, rock phosphatic deposits and phosphatic limestones. The other natural sources of phosphorus are phosphatic nodules and guano.

Even though the occurrence of apatite rock and phosphatic nodules have been known for a long time, India has incurred a considerable loss of foreign exchange in importing these raw materials until in recent times. Findings of potential rock phosphate deposits will minimise these imports.

The total reserves of all varieties of phosphatic deposits in the country (Table No. 1) are about 273 million tonnes⁽¹⁾, of which about 20 million tonnes are of high grade variety (+30% P₂O₅) and the rest are of low grade variety with an average of about 10—20% P₂O₅ content. The bulk production comes mainly from Jhamarkotra deposit of Rajasthan, and for self-sufficiency and increasing requirement of phosphate, demands beneficiation of the known low grade ores. The beneficiation characteristics

of an ore and quality of the end products ultimately depend upon the mineral characterisation which broadly includes mineral assemblages present, their locking nature (textural relationship) and liberation size.

An attempt has been made in this paper to project various mineralogical characteristics and how they have influenced the methods of processing of the different types of Indian phosphatic ores.

Classification of Indian phosphatic deposits :

Geologically, Indian deposits can broadly be classified into two types, namely, (i) igneous and (ii) sedimentary. These are further subdivided, based on major mineralogical (chemical) constituents; the former as ferruginous and siliceous, while the latter as calcareous (calcitic) and siliceous variety. A third mixed type contains different proportions of siliceous and ferruginous or calcareous and siliceous mineral assemblages.

MINERAL ASSEMBLAGES AND TEXTURAL CHARACTERISTICS :

Igneous Type :

In this type, apatite with basic formula Ca₅(PO₄)₃(F:Cl)⁽²⁾ is the only widespread phosphorus bearing mineral in igneous rocks with common association of magnetite, quartz and ferromagnesium minerals like chlorites, micas, amphiboles etc., with occasional presence

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of vermiculite (in Kasipatnam area of A. P.). Subordinate amounts of feldspar, sericite, trace amounts of limonite, hematite etc., are also not uncommon.

The texture and the proportion of particular mineral assemblages may vary from deposit to deposit which have originated during the formation of the ores or may differ from zone to zone in the same deposit.

Ferruginous variety :

In this variety of deposits, anhedral to subhedral apatite grains are generally found associated with intergranular magnetite⁽³⁾ (Sungri, Bihar and Kasipatnam, A. P.) as the chief gangue. Depending upon the intensity of weathering and oxidation, the apatites are found more associated with secondary iron oxides like goethite, limonite, martite/hematite, lepidocrocite and ochre, resulted from the alteration of magnetite (Purulia, W. Bengal). Such hydrated iron oxides in the highly oxidized ore act as matrix, as rims (coatings) around the segregated apatite grains (Fig. 1) and as filling the fracture planes of apatite (Fig. 2) and sometimes replacing it ⁽⁴⁾ (Fig. 3). The magnetites are found highly martitized to form hematite. The apatite is present as subhedral as well as grain-aggregates in the iron oxide and chalcedonic matrix.

Siliceous variety :

The siliceous varieties are generally highly enriched either with quartz (Itagarh, Bihar) or ferromagnesium silicates (Garidih, Samaidih, Bihar). In the schists medium grained segregated anhedral apatite either follow the schistose planes and or enclosed by the intergranular chlorite, biotite and quartz gangue. In Ghatsila copper belt, the same apatite is present as fine inclusions in the quartz.

Sedimentary type :

This type mostly consists of collophane, which is a generic name used to denote very

fine, microcrystalline and cryptocrystalline minerals having apatite composition mixed very much with impurities like clay CaCO_3 , SiO_2 and water with general formula $\text{Ca}_{10}(\text{PO}_4)_6\text{CO}_3 \cdot \text{H}_2\text{O}$. In some areas both apatite and collophane are commonly in association with calcite/dolomite and quartz.

Subordinate amounts of pyrite (Mussoorie, U. P.) chert, gypsum, sericite, shale and ferromagnesium minerals along with trace amounts of mica, uranium minerals, occur as associated gangue minerals. Limonite and goethite are also noticed along cracks and grain boundaries, sometimes as coatings on phosphatic mineral (at Maton, Karbaria blocks of Rajasthan).

Siliceous variety :

In this variety, collophane and / or apatite occur as patches, (Karbaria block, Rajasthan) coarse subrounded nodules (Masrana block, U. P.), interlocked mainly with major gangue mineral quartz. Quartz sometimes occurs as very fine grain inclusions in collophane (Karbaria) and fine veins cutting across the collophane nodules (Masrana, U. P.).

Calcareous/calcitic variety :

In this variety collophane occurs as anhedral to subhedral phenocrysts (Dakankotra, Rajasthan) or disseminated inclusions and bands (Jhamarkotra) or lamellar, lenticular, tabular or elongated bodies, oolites, pellets (Maldeota, U.P.) having an intimate association with calcite/dolomite which is the major gangue cementing material. Apatite occurs mostly as isolated individual coarse to medium sized grains or as clusters of fine grains embedded in carbonate matrix as well as interlocked in quartz grains (Maton block, Rajasthan). It also occurs as grain aggregates in association with vein quartz and inclusions in quartz which is the subordinate gangue mineral. Collophane sometimes occurs with a network of calcite veins. The common major textural relationships between mineral assemblages come across in this variety of

deposits are oolitic, pelletic, ovaliform, lamellar, polynucleated and interstitial textures. In some deposits pyrite is present in subordinate amounts as fine disseminated grains or grain aggregates or fine stringers occupying intergranular space along with calcite/dolomite (Fig. 4).

Mineralogical, textural (liberation) results and their influence on processing :

The various processes, like washing and scrubbing, gravity, magnetic separation, flotation and thermal beneficiation or combination of any of them, which are commonly used to upgrade phosphatic ores have been adopted for Indian phosphatic ores at National Metallurgical Laboratory, Jamshedpur. The results of the beneficiation tests are compared and discussed in relation to their mineralogical and textural characteristics. The detailed mineralogical, textural (liberation), beneficiation methods and results of the various samples are given in Table No. 2.

In the Table No. 2, it is shown that the deposits of Samaidih, Pathargora areas of Bihar, yielded very good grade and recovery by simple fatty acid flotation method^(3,13) because of the coarse grained nature of apatite in association with intergranular siliceous gangue showing schistose and/or porphyroblastic texture which are simple. Another sample from Singhbhum district (mixed sample) with same texture and mineralogy with additional presence of magnetite, though simple, necessitates magnetic separation followed by flotation. Likewise, the ore minerals associated with Singhbhum Copper belt with same mineralogy but as fine inclusions of apatite in quartz necessitated fine grinding and resulted in low yield and recovery⁽⁵⁾.

In the case of other siliceous deposits of India where collophane is present besides apatite, though the required grade and recovery for fertiliser industry are achieved, the presence of very fine quartz veins in collophane nodules (Masrana block, U. P.) or as fine disseminations (Maton block, Rajasthan) diluted the grade.

In the case of Purulia deposits of West Bengal, secondary iron oxides are associated intimately and intricately with coarse apatite grains as thick scales, films, rims and/or as matrix, with a ground mass of chalcedonic material. Though the liberation of gangue cannot be complete, as such the study suggests fine grinding texturally and high intensity magnetic separation mineralogically. But because of the presence of siliceous gangue as well as economic considerations straight flotation after desliming⁽⁴⁾, has to be adopted to obtain the required grade.

The deposits associated with calcareous/calcitic gangue, the mere presence of calcite/dolomite, even with simple texture, complicate their processing. Over and above, complex texture further complicates the problem. In this line, National Metallurgical Laboratory and other research organisations have been extensively working to study various possibilities until suitable economic method is found out.

The Jhamarkotra phosphate deposits in which phosphatic constituents occur either as interstitial grains or grain aggregates, patches and bands intimately associated with transecting veinlets and veins of calcite and quartz, showing network texture etc., gave better grade with poor recovery by tal oil flotation⁽¹⁰⁾. The poor recovery is due to the presence of fine interstitial apatite and collophane which were lost in tailings. The same sample by calcination followed by quenching and desliming⁽⁹⁾, yielded better grade as well as recovery which is perhaps costlier processing method presently. Kanpur deposits have been tried by calcination route followed by flotation method⁽¹¹⁾ and could not achieve good recovery because of the very fine apatite inclusions in the gangue.

Karbaria block of Rajasthan deposits with mixed calcareous and siliceous gangue, though fine interstitial apatite and inclusions of quartz reduced the grade and recovery to some extent, yielded economic grade by flotation, grinding and refloatation⁽¹⁴⁾ because of its simple texture. In the case of Maldeota (U. P.) deposits with same mineralogy and with an extra presence of

finely disseminated pyrite, carbonaceous matter and shaly material along with different multi textures such as interstitial, pelletal and polynucleated etc., yielded product below acid grade and with fairly good recovery, by a combination of calcination, regrinding, desliming and differential flotation⁽¹²⁾ which is of course a costly process.

Conclusions :

In conclusion, it is noted from the above studies that type of minerals present, grain size

and their textures (locking nature) virtually dictated the method of processing and amenability for upgradation of phosphate ores.

Acknowledgements :

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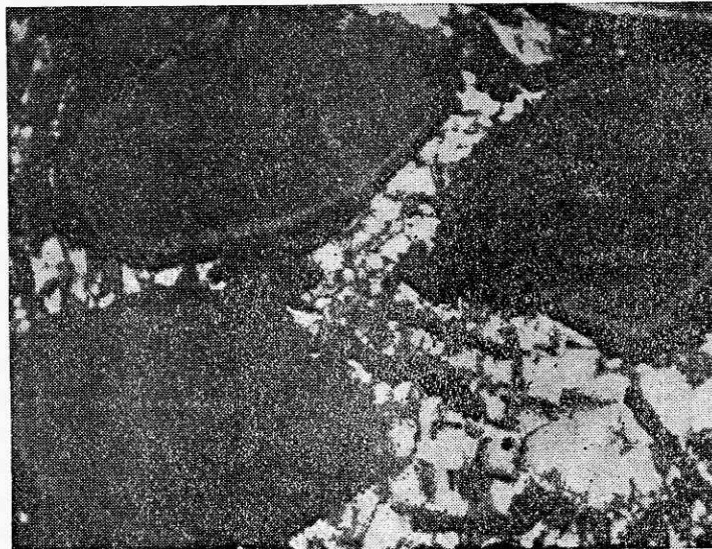


Fig. — 1 Photomicrograph showing limonite - goethite (black as thick to thin rims around segregated apatite (dark grey) grains in chalcedonic ground mass (white). $\times 60 + \text{nicols.}$

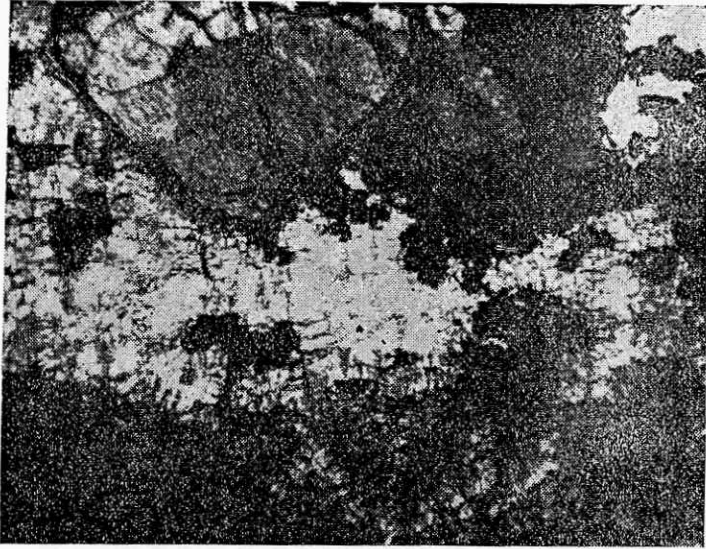


Fig. — 2
Photomicrograph of thin section showing ferruginous (black) material forming fracture filling in apatite and skeletal and anhedral patches on chalcedony. $\times 32 + \text{nicols.}$

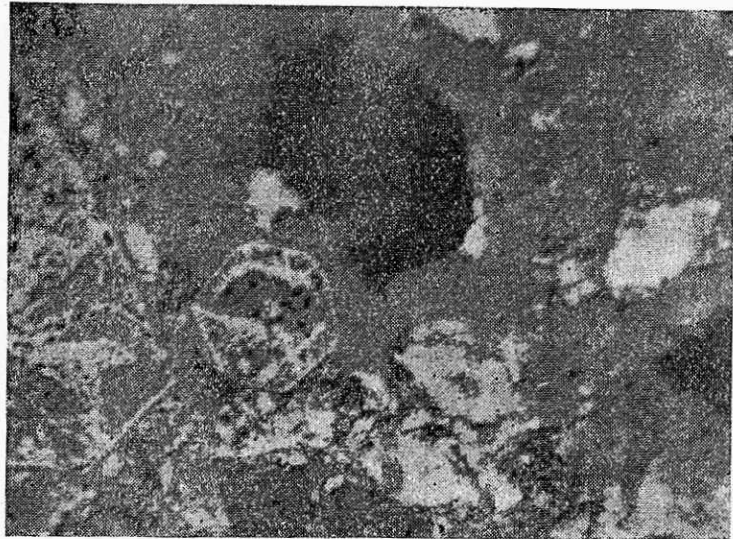


Fig. — 3
Photomicrograph showing crystallographic replacement of apatite (dark grey) by magnetite (white).
Refl. Illum $\times 150.$



Fig. — 4
Photomicrograph showing fine disseminated pyrite (white) in rock phosphate (greyish black).
Refl. Illumn $\times 140.$



Fig. — 5
Photomicrograph showing inclusions
of quartz (white) in collophane nodule
(black).

× 56 Tran. Illumn + nicols

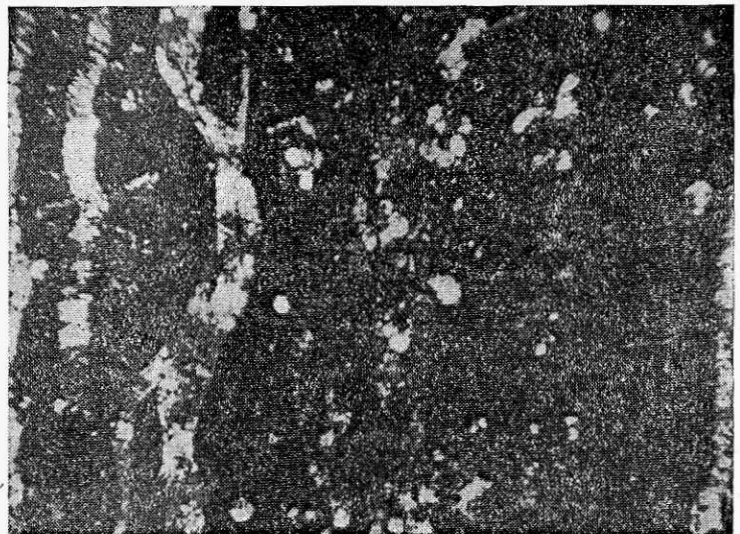


Fig. — 6
Photomicrograph showing veins, net
works and segregated calcareous
mineral (greyish white) in the rock
phosphate (black).

× 60 Tran. Illumn + nicols.

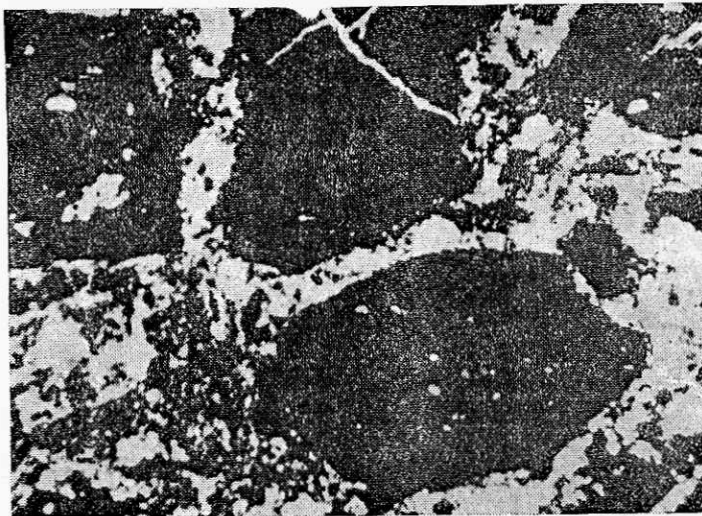


Fig. — 7
Photomicrograph showing seggre-
gated patchy collophane (black) in
calcitic matrix along with quartz
(white).

× 60 Tran. Illumn + nicols

Phosphate and apatite deposits of India as on 01.01.1980
(Quantity in million tons)

R e s e r v e s

State	Measured	Indicated	Inferred	Total	Grade
1. ROCK PHOSPHATE :					
Rajasthan	64.187	4.230	12.274	80.691	All grades
Uttar Pradesh	3.430	12.890	19.000	35.320	All grades
Madhya Pradesh	2.000	9.550	2.310	13.860	14 - 28% P ₂ O ₅
All India Total	69.617	26.670	33.584	129.871	
2. APATITE :					
Andhra Pradesh	—	—	1.720	1.720	25 - 42% P ₂ O ₅
Bihar	—	—	1.780	1.780	All grades
Rajasthan	—	1.158	—	1.158	All grades
Tamilnadu	—	—	0.240	0.240	27 - 39% P ₂ O ₅
West Bengal	—	3.480	0.402	3.882	All grades
All India Total	—	4.638	4.142	8.780	All grades
3. OTHERS :					
(Guano & Phosphatic Nodules)	—	—	4.5168	4.5168	All grades

In addition, 94 million tons from Bihar and M. P.

2.5 - 32.5% P₂ O₅

Table 2 : Mineralogical, textural (liberation) and beneficiation results of phosphatic ores

Sl. No.	State / Locality	Assay of ROM P ₂ O ₅ %	Mineralogical and textural (liberation) data	Method of processing	Assy of conc. % P ₂ O ₅	Recovery % P ₂ O ₅	Remarks
A. SILICEOUS VARIETY							
1.	Samaidih, Bihar	23.26	Coarse apatite with intergranular chlorite, showing schistose texture (48 mesh).	Flotation	41.0	95.5	Simple Ore
2.	Pathargora, Bihar	10.03	Coarse apatite with ferromagnesium minerals and quartz (65 mesh).	Flotation with 4 cleanings	36.6	85.0	Very low grade simple ore
3.	Singhbhum Dist., (mixed sample), Bihar	17.3	Coarse apatite with intergranular magnetite, quartz and ferromagnesium minerals (65 mesh).	Magnetic separation followed by flotation	41.6	79.6	Magnetite is also gangue mineral
4.	Maton block, Rajasthan	35.46 SiO ₂ : 10.56	Anhedral crystals of apatite associated with intergranular disseminated and vein quartz (about 200 mesh).	Flotation with 2 cleanings	40.51 SiO ₂ : 2.37	75.0	0.067 mm size quartz grains as disseminations in apatite
5.	Masrana block, Uttar Pradesh	21.5 SiO ₂ : 35.92	Nodular collophane with interstitial fine grained quartz (Fig. 5) (below 200 mesh).	Flotation followed by fine grinding (325 mesh) with 3 cleanings	38.4 SiO ₂ : 8.61	72.4	0.0051 mm size quartz veins cutting across the collophane nodules
6.	Singhbhum copper belt, Bihar	1.49	Fine apatite grains in quartz (400 mesh).	Flotatian with 1 cleaning.	28.31	50.0	0.03 mm size apatite inclusions in quartz.
B. CALCAREOUS VARIETY							
7.	Jharkotra, Rajasthan	17.49	Collophane as ovulitic, lensolitic, and apatite intimately in association with intersecting veinlets of calcite mainly with subordinate amounts of quartz (fine grinding).	1. Calcination at 950°C followed by quenching & desliming. 2. Tal oil flotation followed by 3 cleanings with katha.	35.69	91.0	Segregated calcite and veinlets (0.01 mm size) trapped in collophane. (Fig. 6)
					31.2	40.5	

Table — 2 : (Contd.)

Sl. No.	State / Locality	Assay of ROM% P ₂ O ₅	Mineralogical and textural (liberation) data	Method of processing	Assay of conc. % P ₂ O ₅	Recovery% P ₂ O ₅	Remarks
8.	Kanpur block, Rajasthan	12.66	Very fine apatite as grain aggregates, and cryptocrystalline collophane as interstitial grains with vein calcite and quartz (150 mesh).	Calcination followed by tal oil flotation with 2 cleanings	34.06	58.1	0.0051 mm size apatite grains as inclusions.
C. MIXED VARIETY							
9.	Karbaria block, Rajasthan	22.74	Collophane as patches. (Fig. 7) apatite as inclusions with interstitial and intergranular network calcite, dolomite and quartz (100 mesh).	Flotation, re-grinding and re-floatation with 3 cleanings.	34.0	76.9	0.024 mm size veinlets of calcite and quartz in collophane and 0.018 mm size interstitial apatite in quartz.
10.	Maldeota (composite sample) Uttar Pradesh	16.8	Collophane intimately associated with calcite, chert / quartz, shale, carbonaceous matter and pyrite showing poly-nucleated, interstitial texture (very fine grinding).	Complex method.	28.33	79.0	Ultrafine disseminated pyrite grains present in phosphetic constituent.
D. FERRUGINOUS VARIETY							
11.	Purulia, West Bengal	24.33 Fe : 14.56 SiO ₂ : 10.18	Intimate association of secondary iron oxides as thick scales, films and incipient intergrowth on and around apatite grains (below 100 mesh). Chert/quartz also present as matrix.	Flotation after de-sliming.	35.0 Fe : 3.47 SiO ₂ 4.30	32.6	Apatite loss in tailings.

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DISCUSSION

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Hindusthan Zinc Ltd.

Question 1 : What is your % wt of P_2O_5 concentrate to the ore treated at Maton ?

Author : The wt% of the concentrate is 64.2 which assays 40.5% P_2O_5 .

Question 2 : What is the method you adopted to get conc grade 40.51% P_2O_5 with recovery of 70% P_2O_5 ?

Author : The method employed is soap flotation with two cleanings.

Question 3 : What is the size of flotation feed and its % liberation of P_2O_5 ?

Author : The size of flotation feed employed is 86.2% — 200 mesh. Apatite is fairly liberated at this size.

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Question 4 : What do you mean by mixed variety ?

Author : Mixed variety means—association of Phosphatic mineral constituents with more than one gangue mineral like Quartz, Calcite/dolomite, secondary iron oxides etc.

Question 5 : If any work done to beneficiate the mineral found in South Singhbhum say SUNRGI and where apatite is said to have appreciable values of Uranium ? If so, the result thereof in terms of grade and recovery and method of processing ?

Author : Sunrgi sample is not separately tested.