

Texture and composition of cave rock phosphate in Peninsular Malaysia

AW PECK CHIN

Geological Survey of Malaysia
Ipoh

Abstract : The three types of cave rock phosphate namely encrusted phosphate, replacement phosphate and sedimentary phosphate are described and discussed in terms of their relative importance. The primary source of phosphate for all the three types is the bat guano deposited in certain limestone caves. The encrusted phosphate was formed by the deposition of phosphate cement from phosphate-rich solution derived by rain water seepage through the guano. The phosphate cement which was deposited on the limestone surfaces on which the phosphate-rich solution flowed down, is made up of a variety of texture and colour, reflecting its subaerial origin. The replacement phosphate was formed as a result of prolonged contact of wet/moist guano with the receptive limestone wallrock that is thinly bedded, jointed or fractured. The sedimentary phosphate was formed by authigenic and allogenic sedimentation from phosphate-rich solution collected in depressions at the base of the guano cave.

The encrusted phosphate exhibits mainly laminated and colloform textures, consisting of cryptocrystalline to opaque cement and/or weakly birefringent, fine-grained apatite in radiating fibres or spherular masses. Besides the cryptocrystalline phosphate, four phosphate minerals have been identified by X-ray diffraction. The most common is apatite, which by comparison to the chemical analyses, is probably carbonate-apatite and/or hydroxylapatite. The other three minerals are crandallite, whitlockite and montgomeryite. Crandallite occurs in small amounts in some samples, whereas whitlockite and montgomeryite are rare.

The common non-phosphate minerals are calcite, rancieite and pyrolusite, depositing together with the phosphate cement. Calcite and quartz also occur as crystals lining the vugs. In the sedimentary phosphate, goethite is the common authigenic mineral occurring as ooids, whilst quartz is the common allogenic mineral.

INTRODUCTION

Rock phosphate, together with guano derived from certain limestone caves in Perlis, Kedah and Perak, is being exploited and processed for use as a fertilizer (Aw, 1985). The rock phosphate may be divided into three types, based on their modes of formation. The most prominent type is called encrusted phosphate which is formed by rain water percolating through the guano with accompanying leaching of phosphate and other solubles, followed by deposition on suitable rock surfaces and crevices below. It was formed by accretion from deposition by solution from the seepage of the guano in the cave. The second type is called replacement phosphate, formed by replacement of limestone, either in contact

with guano or by the phosphate solution at favourable sites. The third is called sedimentary phosphate, formed by sedimentation of phosphate-rich water collected in certain depressions below the guano cave. The types of rock phosphate and the geological setting in which they are found are shown hypothetically in Figure 1.

This paper describes the variation of texture and composition of the three types of rock phosphate. This study is based on a synthesis of field observations and data from X-ray diffraction, petrography and chemical analyses.

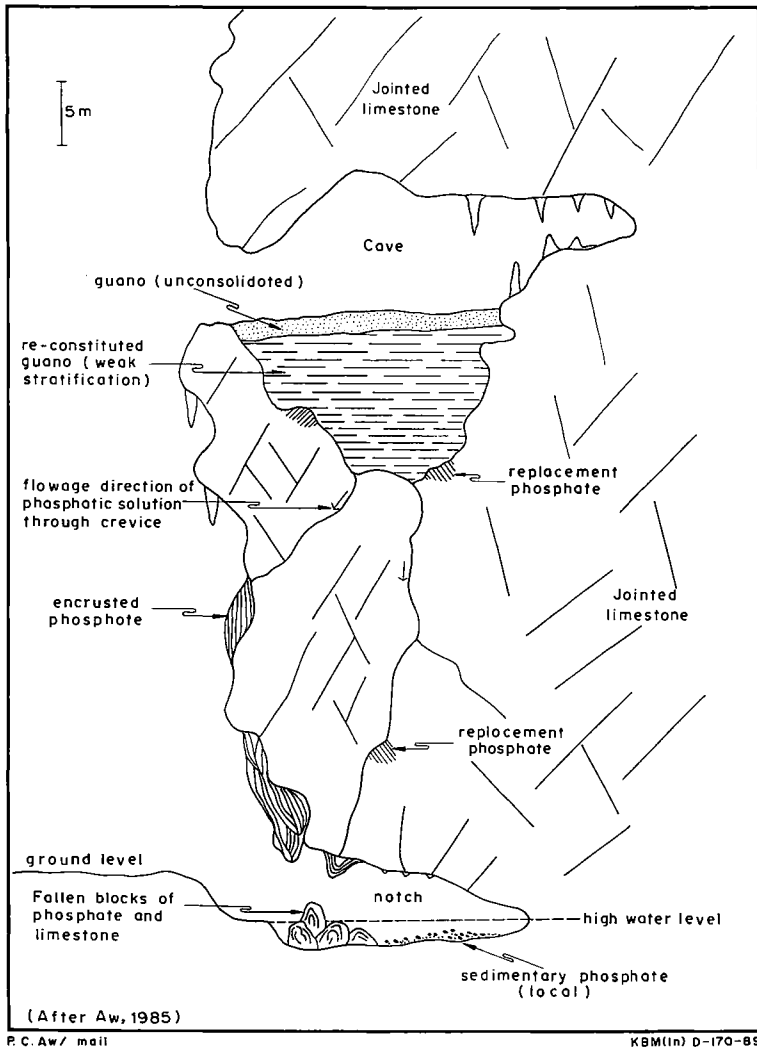


Figure 1: Hypothetical cross-section of a cave showing the spatial distribution of the guano and the rock phosphate

FIELD DESCRIPTION

Encrusted Phosphate

The encrusted phosphate is deposited in opening along fractures, surfaces and crevices along which the phosphate-bearing solution flows down from the guano containing cave (Figure 1). It is of various sizes and shapes. Some are small and of irregular shapes as seen from the roof of a small cave (Figure 2). The big encrusted phosphate bodies as observed on the side of the limestone hill in Bukit Chuping, Perlis (map reference QN 538188) are up to 5 m in wide, about 8 m in length and half a metre in thickness.

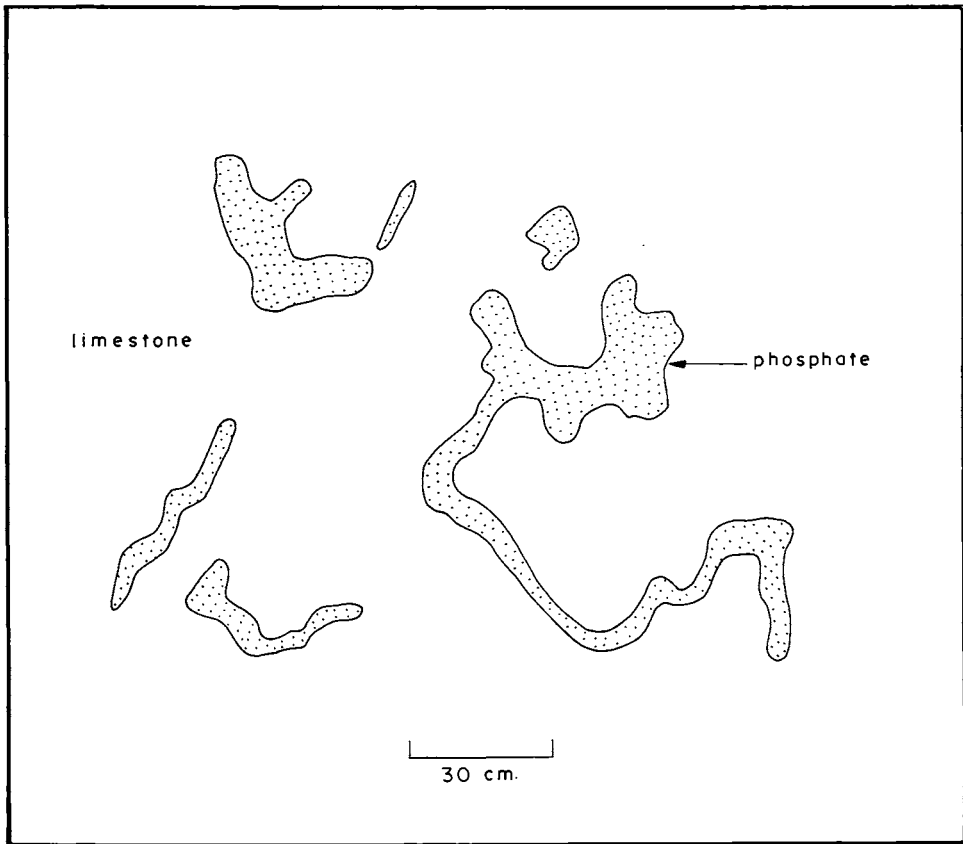


Figure 2 : Irregular-shaped phosphate bodies on the roof of a cave, Bukit Chuping, Perlis.

The shape and size of the encrusted phosphate are dependent on the form of the limestone substratum and the intervening space. It is usually banded in various shades of white and black indicating the different growth bands. The direction of encrustation is outward from the limestone substratum. Within the layers, there may be vugs, some of which are lined with calcite or quartz crystals (Figure 3).

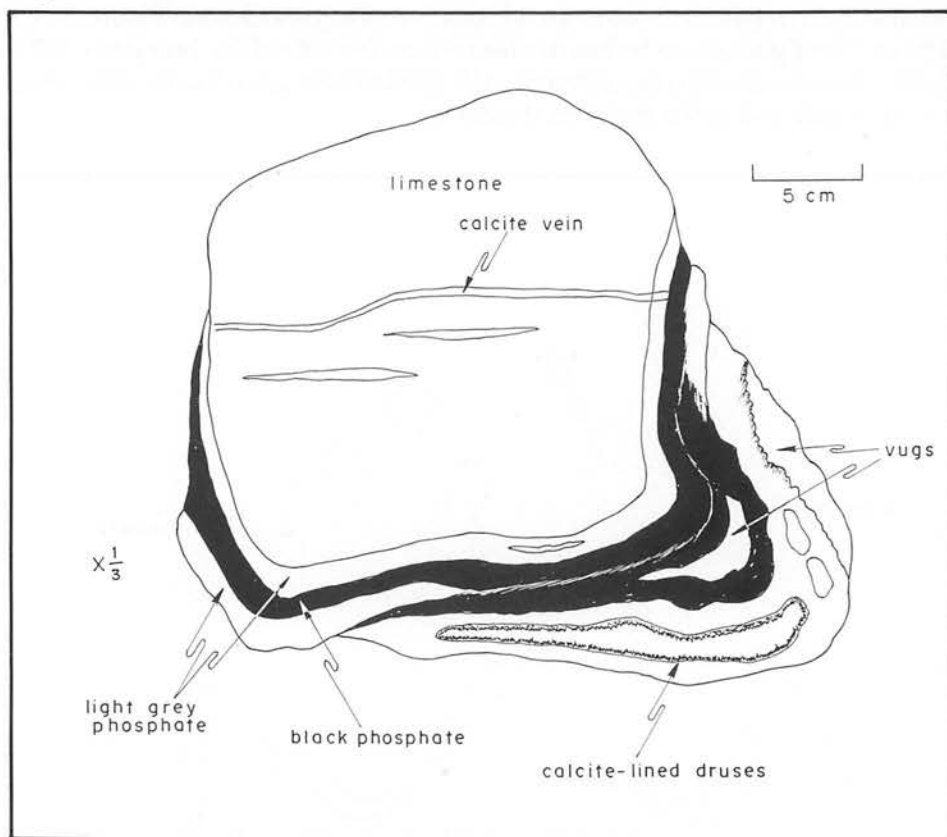


Figure 3: Limestone block with layers of encrusted phosphate.

REPLACEMENT PHOSPHATE

Rock phosphate derived from the replacement of limestone has been observed in three places in Gunung Keriang, Kedah. In one of the caves high up on Gunung Keriang (map reference QS 6133850) a section was observed as shown in Figure 4. It consists of a layer of thinly bedded limestone between two massive limestone beds. Much of the guano in this cave has been removed to expose this section of the cave wall. On closer examination, the thinly bedded limestone was found to be differentially phosphatized. Samples analysed show the phosphate content to range from 2.80 to 27.2 percent. However, the massive limestone, above and below the thinly bedded layer shows no sign of phosphatization at all.

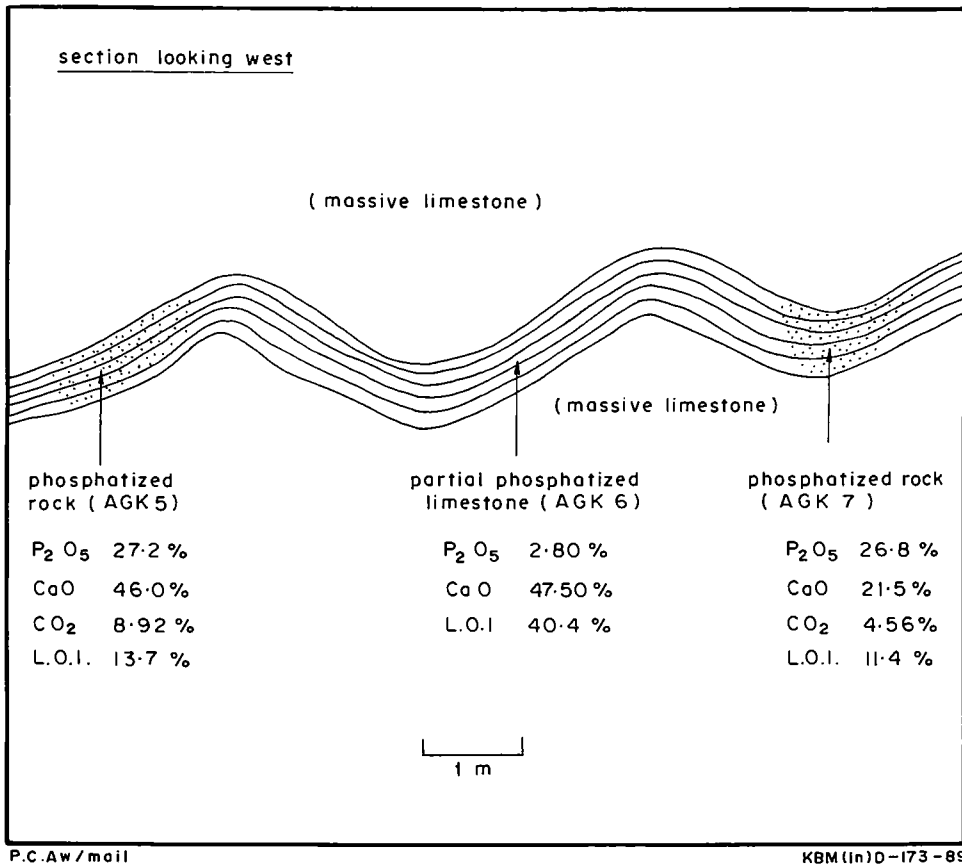


Figure 4 : Partial phosphatization of thinly bedded limestone as confirmed by chemical analyses.

The second locality (at map reference QS 615855) is in another cave at the base of Gunung Keriang. On one part of the limestone wall where the guano has been extracted is a section shown in Figures 5a and 5b. Phosphatization is complete except for some remnants of small limestone 'islands'. These limestone islands were subsequently eroded to various extents, forming vugs in which phosphate cement and, in places, calcite were later deposited.

The third locality (about 50 m to the north of the first locality), which is enigmatic in appearance, is a section half way to the top of Gunung Keriang (Figure 6). It is probably part of a cave where the roof has been eroded away. The remnant of the section (at the time of observation in 1983, excavation of phosphate was still in progress) gives the appearance that the phosphate is sedimentary in origin.

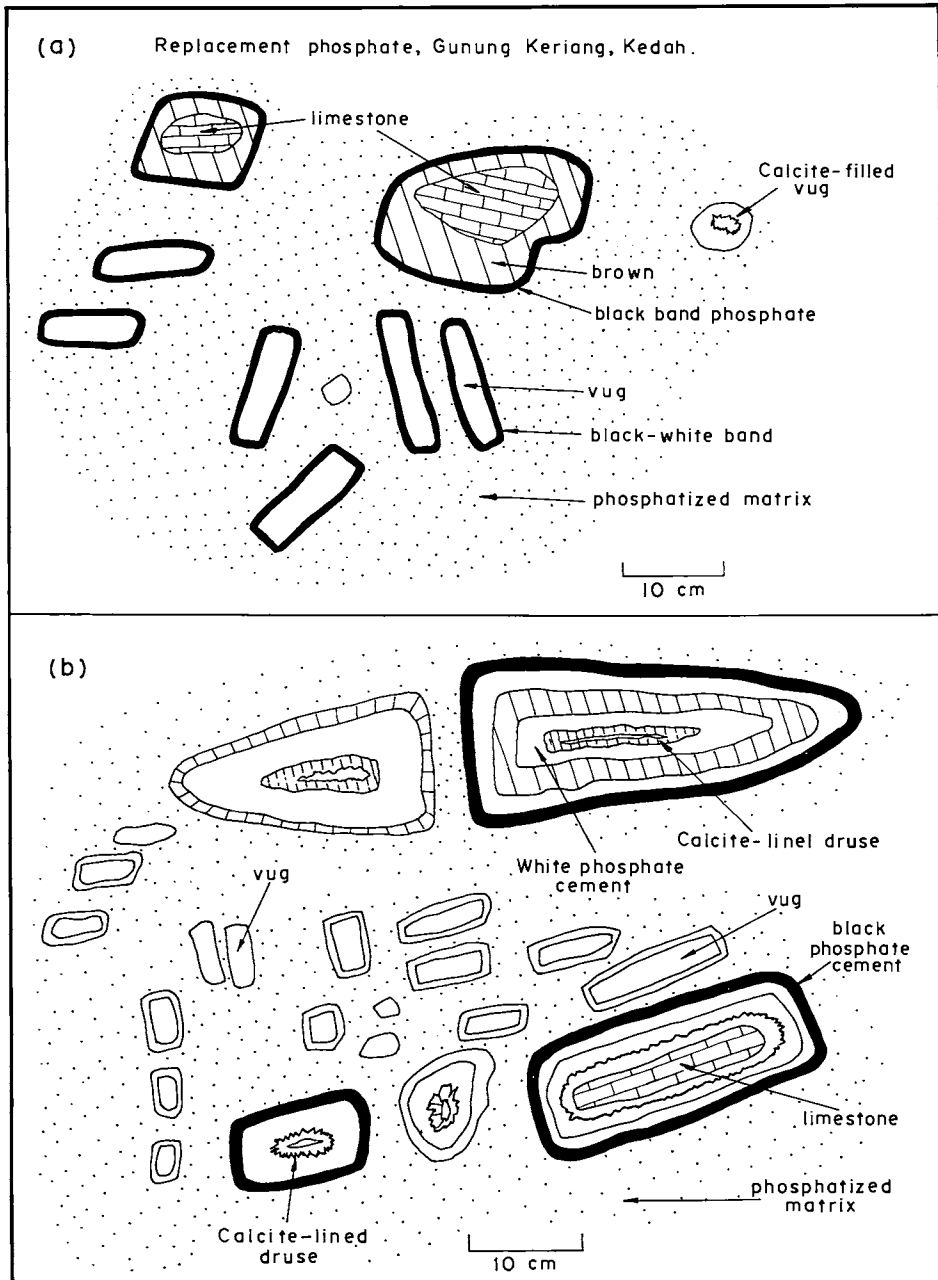


Figure 5 : Replacement phosphate and phosphate cement deposition.

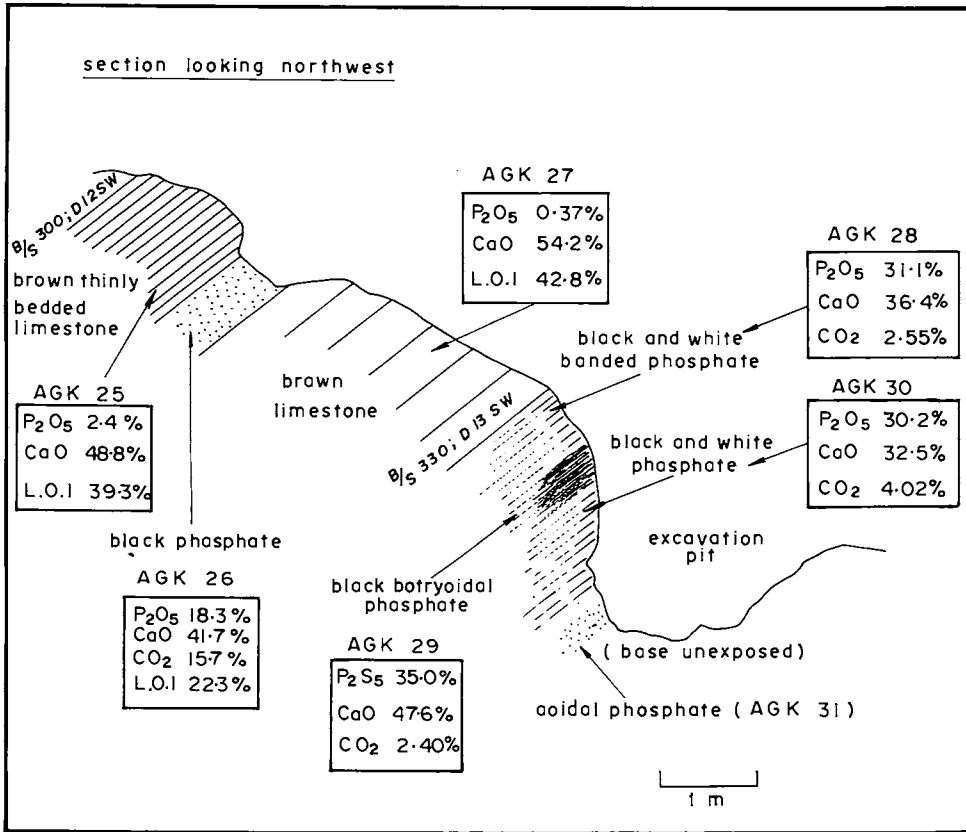


Figure 6 : A section in Gunung Keriang, Kedah showing partial analyses of the samples.

The base of the section is not exposed. What was seen is a layer of greenish brown ooidal phosphate (AGK 31). Overlying it are two layers of black-white banded phosphate (AGK 28 & 30) sandwiched by a black botryoidal phosphate (AGK 29). This is then followed by a bed of brown limestone (AGK 27) and a layer of black phosphate (AGK 28). A brown thinly bedded limestone (AGK 25) caps the top of the exposed section.

The attitude of the banded phosphate is the same as the limestone beds. If it is based only on this outcrop, it may be interpreted that the banded phosphate and the limestone are contemporaneous. But no other similar outcrops has been found in all the limestone hills in Kedah, Perlis and Perak. Its localized nature and attitude suggest that its formation is by selective replacement of the limestone.

The ooidal phosphate near the base of the section is, however, believed to be formed by local sedimentation, the details of which are given in the section below.

Sedimentary Phosphate

The ooidal phosphate is about 20 cm thick (Figure 6). The ooids consist of rounded brownish black and dark brown goethite in a matrix of phosphate and brown iron oxide. In the second locality (map reference QS 615855) at the base of the cave, there is also a small outcrop of ooidal phosphate. However, the ooids are bigger, some of them are up to 7 mm in diameter (Plate 1). There is another small outcrop nearby which is made up of angular fragments of "phosphate breccia" (Plate 2).

TEXTURE

The encrusted phosphate exhibits a great variety of textures. It varies in colour from different shades of white to brown and black. Externally, it forms a very rough irregular crust, from earthy to botryoidal in form (Plate 3). Internally, some of the textures are laminated (Plates 4 and 5), with some of the laminae less than 1 mm in thickness. In some phosphates, dendritic growth of pyrolusite can be seen (Plate 6). Colloform texture is also common, in places (Plate 7). Internal cavities are common (Plate 8). In some, the druses are lined with quartz crystals (Plate 9).

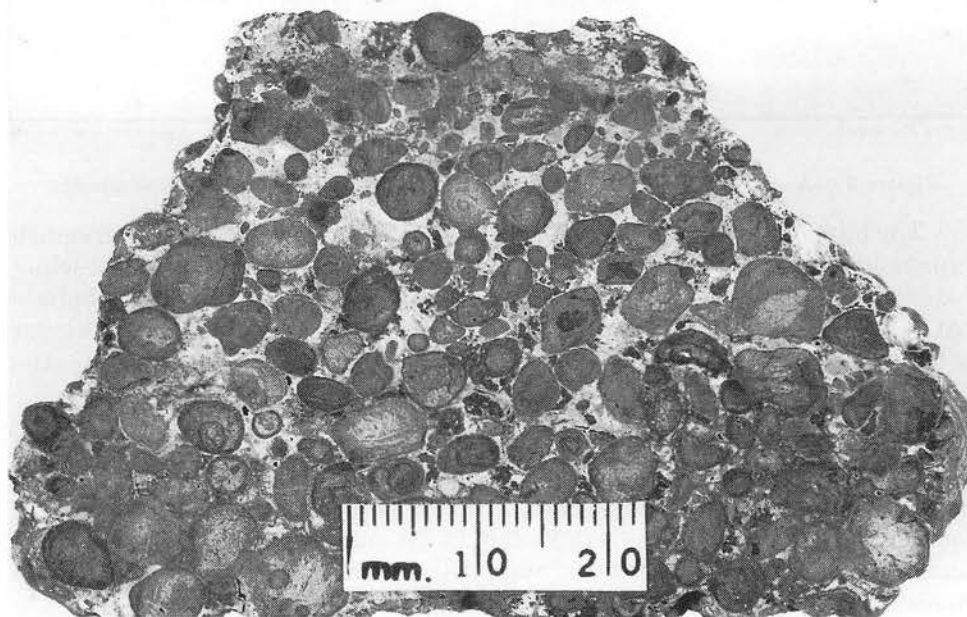


Plate 1 : Ooidal phosphate, ooids, dark brown.

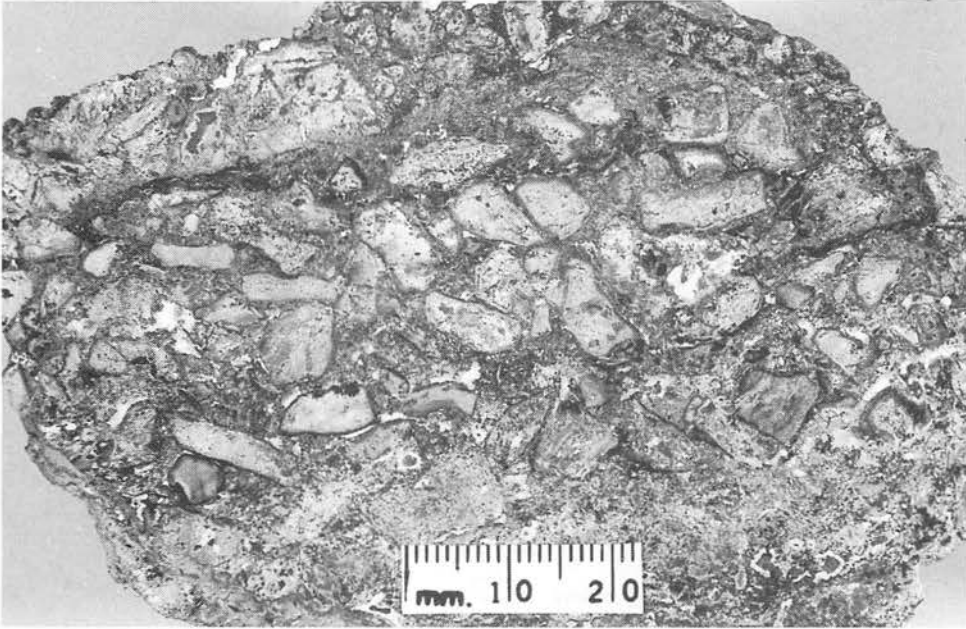


Plate 2 : "Phosphate breccia", making up of angular clasts of phosphate.

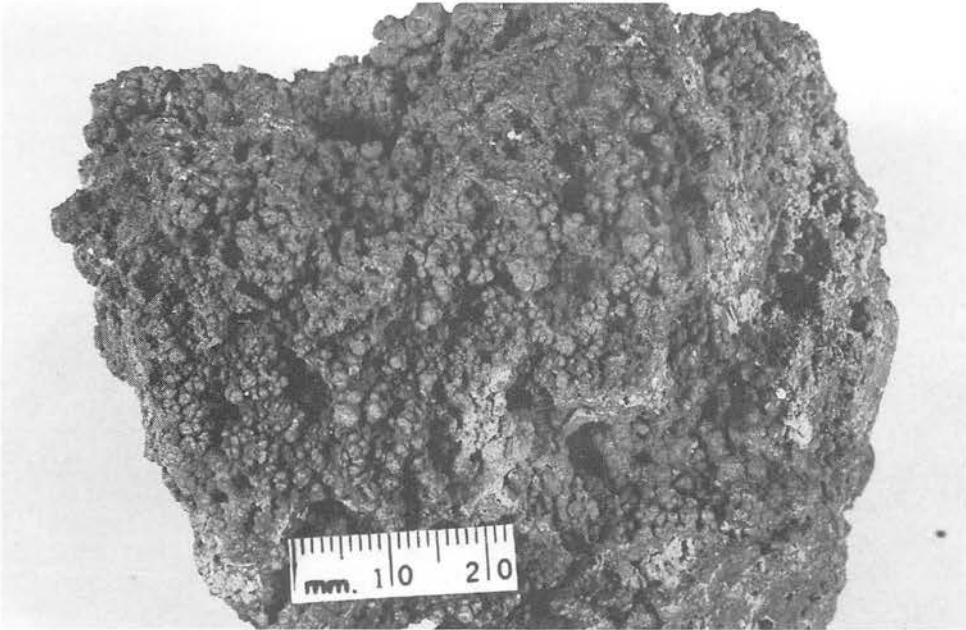


Plate 3 : Black botryoidal crust of phosphate.

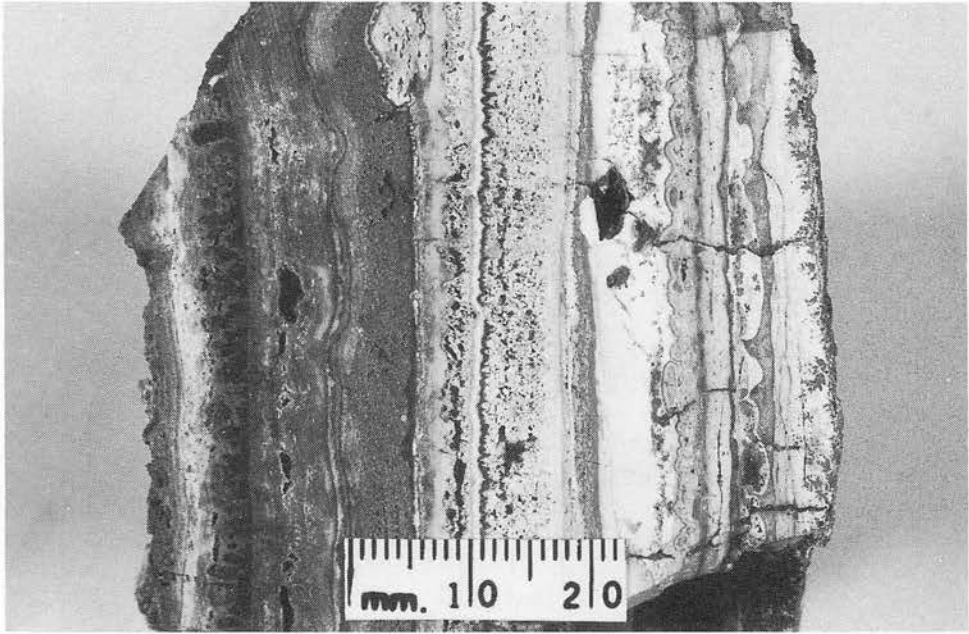


Plate 4 : Black and white laminae of phosphate cements.

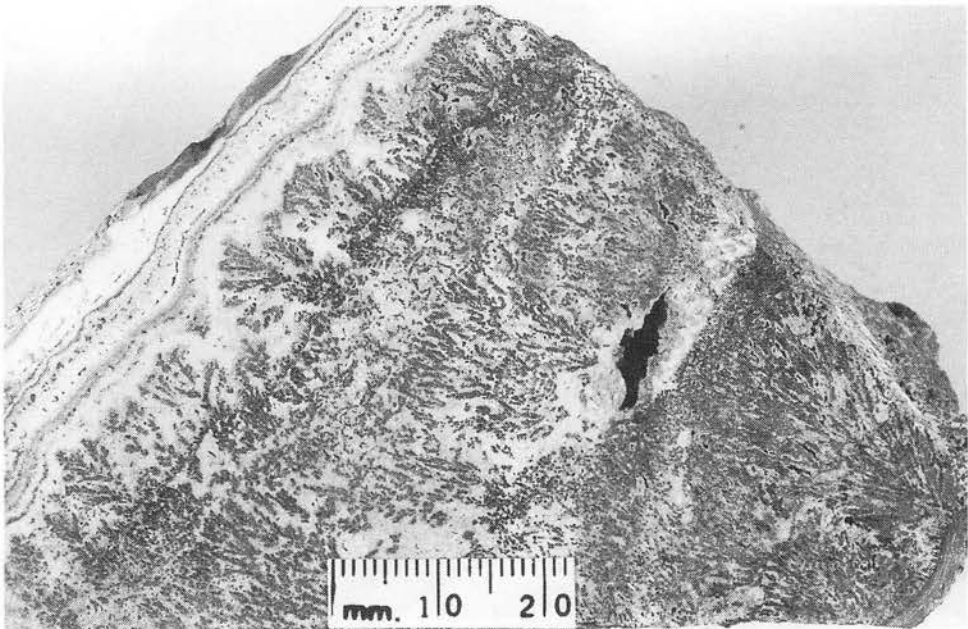


Plate 5 : A hand specimen of a laminated phosphate the direction of growth of the laminae is from right to left.

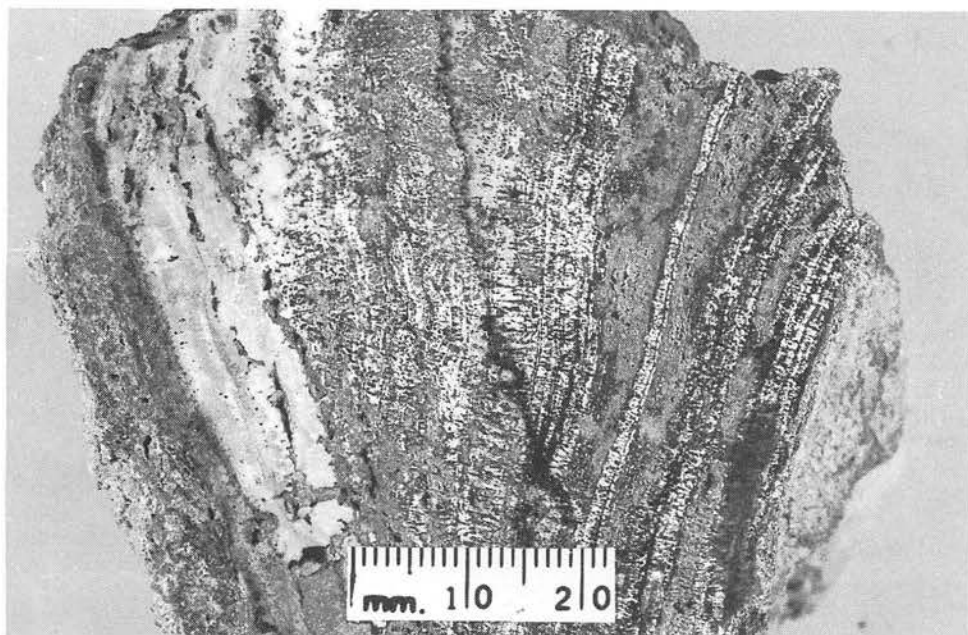


Plate 6 : A hand specimen of encrusted phosphate, showing the dendritic growth of pyrolusite.

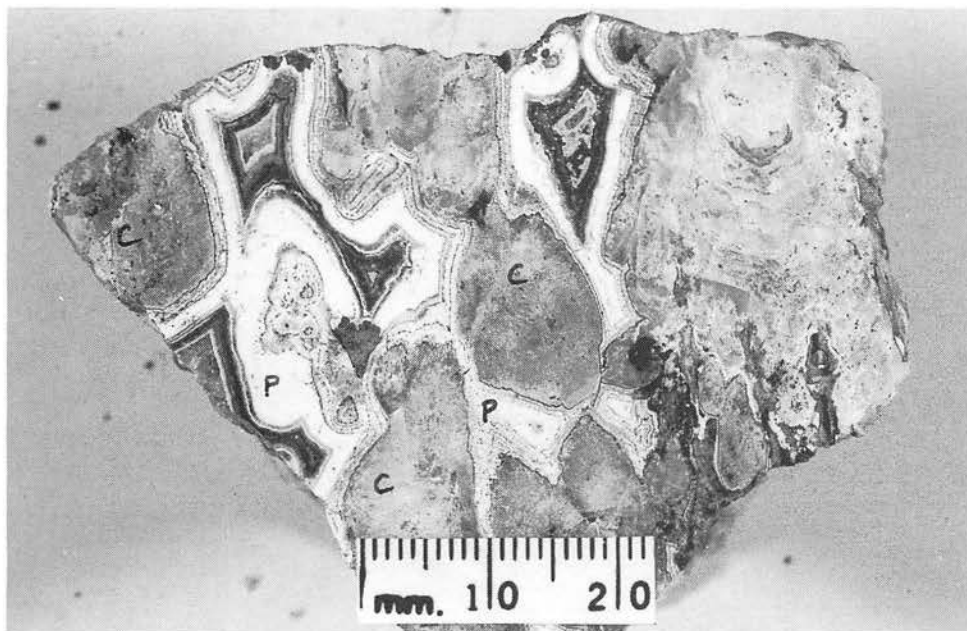


Plate 7 : A hand specimen of phosphate with colloform texture, phosphate cement (p), and calcite (c).

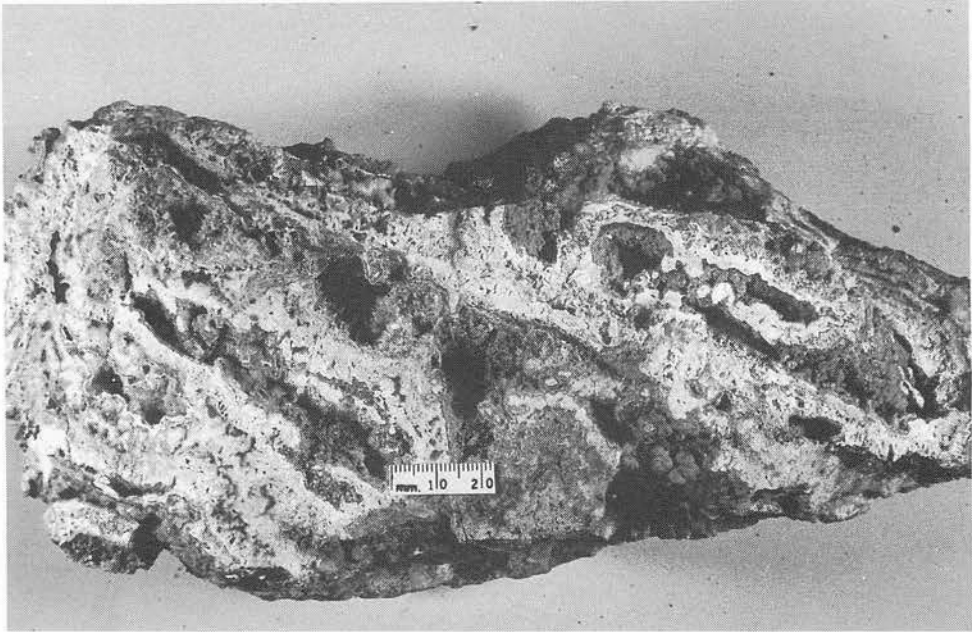


Plate 8: A hand specimen of phosphate showing irregular laminae and internal cavities (vugs).

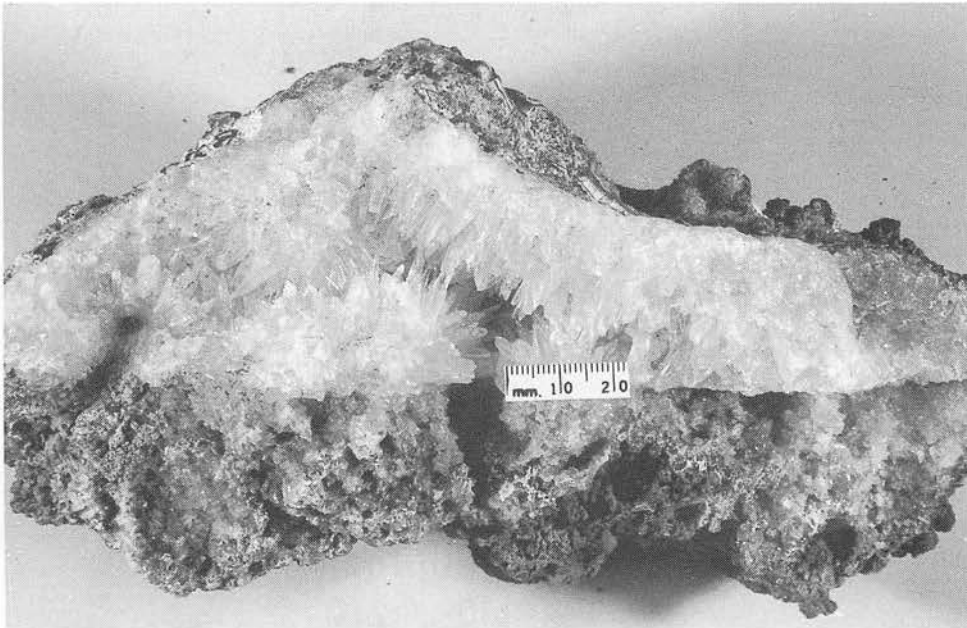


Plate 9: A hand specimen of vuggy phosphate showing a druse lined with quartz crystals.

PETROGRAPHY

The same diverse variety of textures is seen under thin section for the encrusted phosphate. There are two types of phosphate cements; one is cryptocrystalline and the other is weakly birefringent. The cryptocrystalline variety is light grey to golden brown, but some are so darkly stained as to be virtually opaque (Plate 10).

The weakly birefringent cement shows first order white and grey consistent with apatite. It occurs in minute, banded subradiating texture (Plate 11). Under crossed nicols, it shows a radial fibrous texture. Fibres are optically continuous from zone to zone and waves of extinction move normal to the depositional surfaces (Plate 12). In certain cases, bundles of fibres form spherular masses (Plate 13). Some of the vugs are filled by calcite (Plate 10).

In thin section, the sedimentary phosphate is made up of black and brown ooids in matrix of both cryptocrystalline and crystalline phosphate cement and iron oxide (Plate 14). There are some minor quartz grains which are apparent under crossed nicols. In some of the ooids, under high magnification, can be seen golden brown micro-ooids in the central cavities (Plates 15 and 16). Just like the ooids, the micro-ooids also show faint concentric structure. The ooids have been identified to be goethite (Leong Kok Hoong, per. comm.).

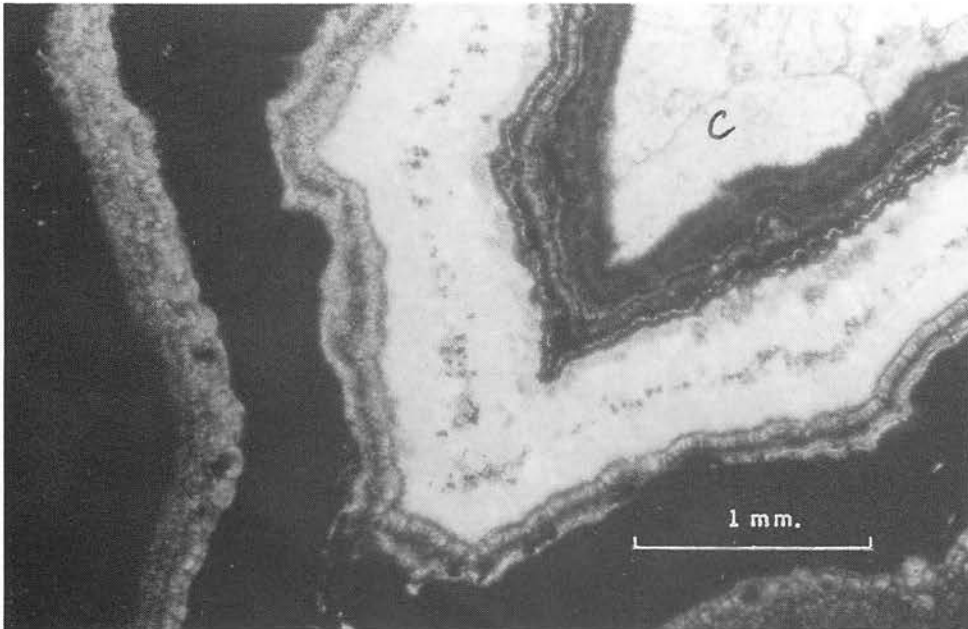


Plate 10 : A photomicrograph showing colloform texture; cryptocrystalline cement in black and apatite cement (grey) and calcite (c). In plane polarized light.

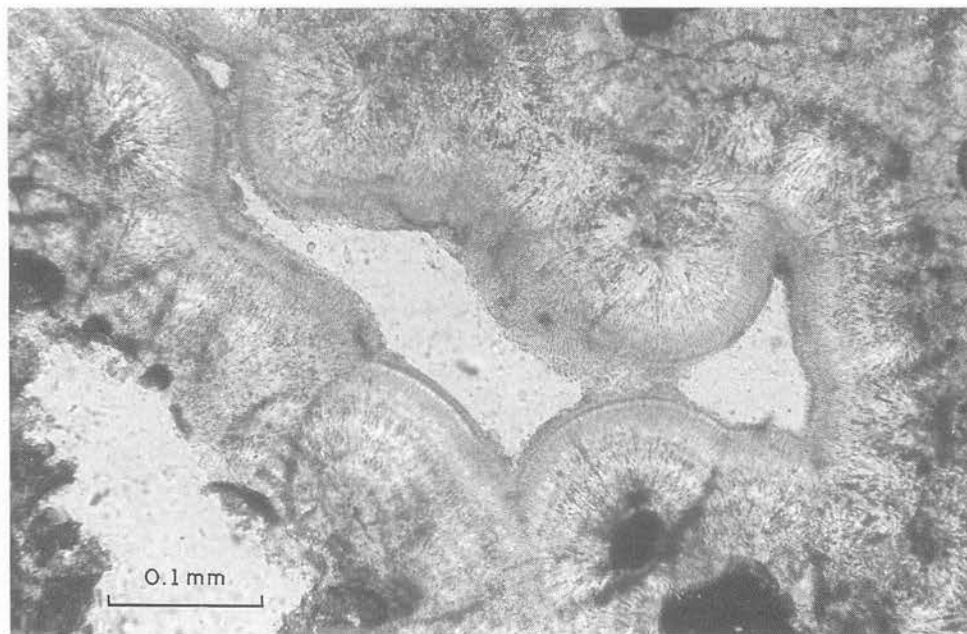


Plate 11 : A photomicrograph showing the banded subradiating texture of apatite. Plane polarized light.

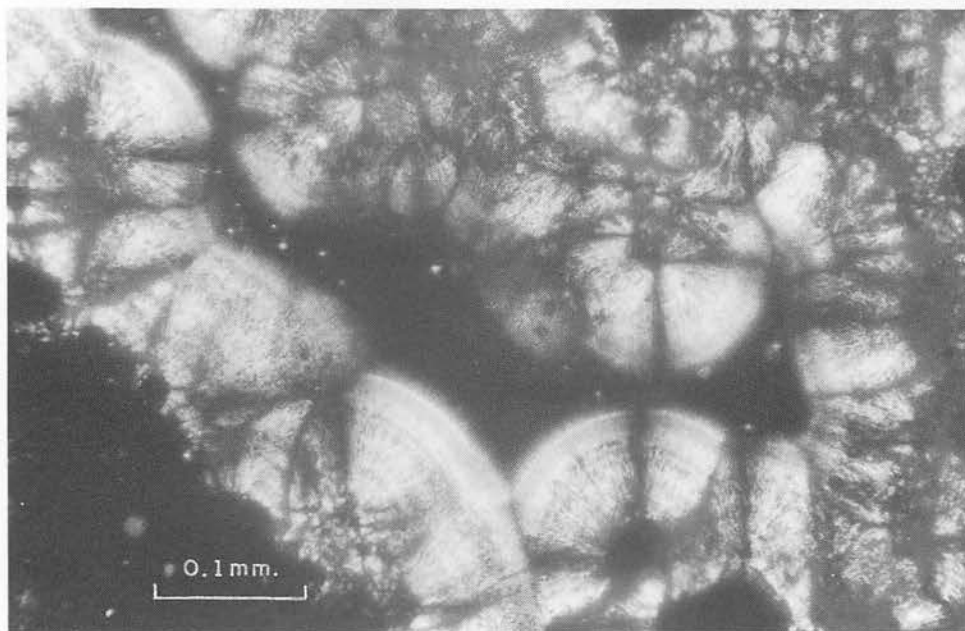


Plate 12: A photomicrograph showing the straight extinction normal to the growth direction. Crossed nicols. Scale same as Plate 11.

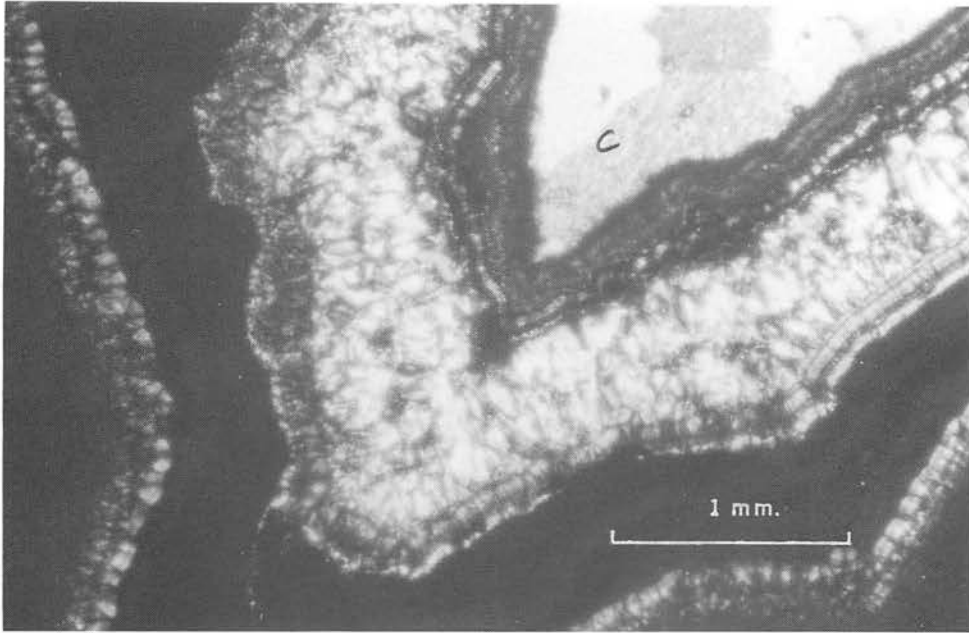


Plate 13 : A photomicrograph of colloform phosphate cement under crossed nicols, showing spherular masses of apatite and calcite (c). Scale same as Plate 10.

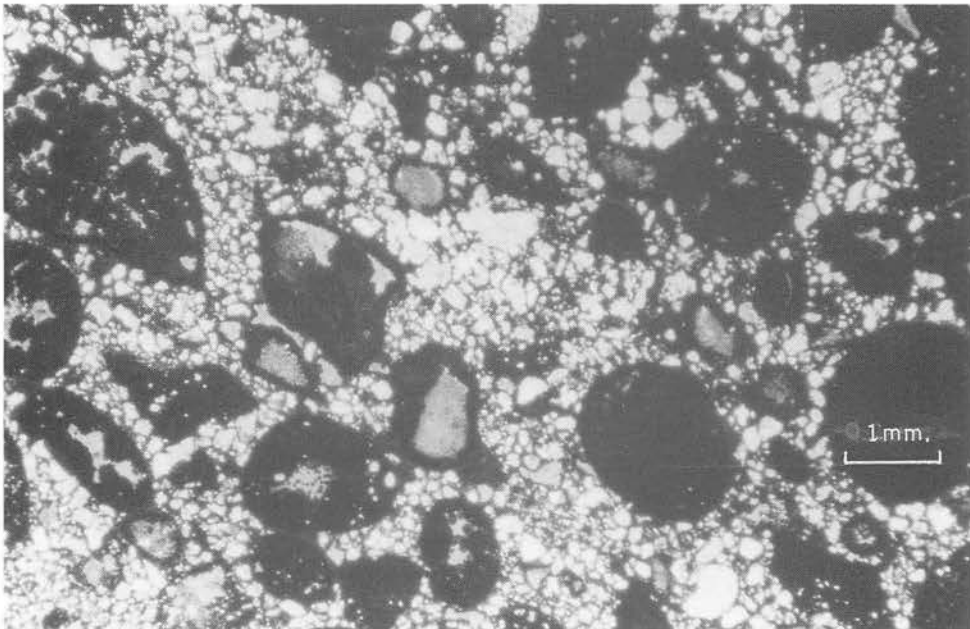


Plate 14 : A photomicrograph of ooidal phosphate, showing ooids (black), phosphate clasts quartz grains in white in a phosphate cement. Plane polarized light.

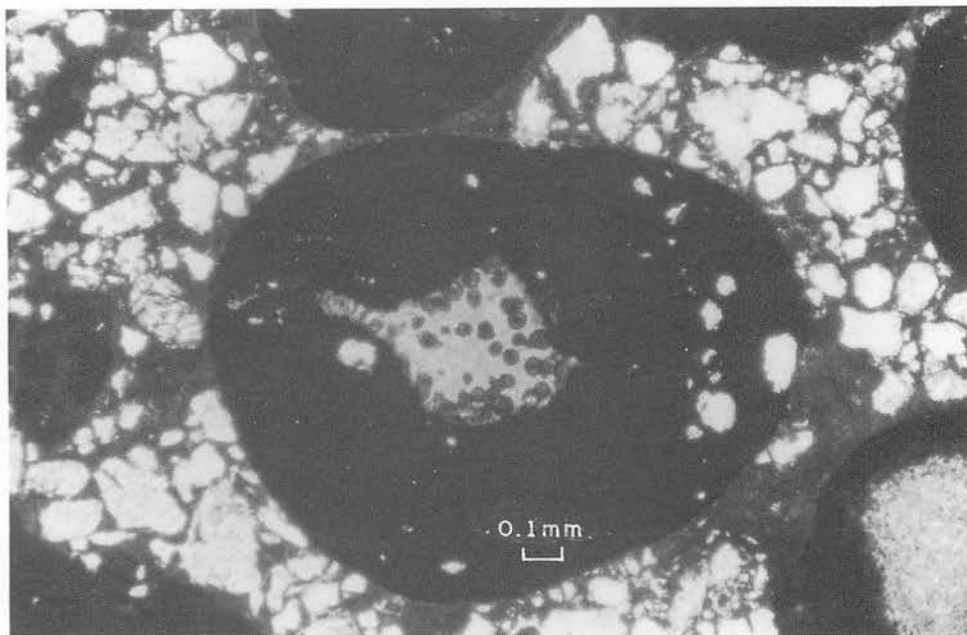


Plate 15: A photomicrograph showing an ooid with micro-ooids in its central cavity. Plane polarized light.

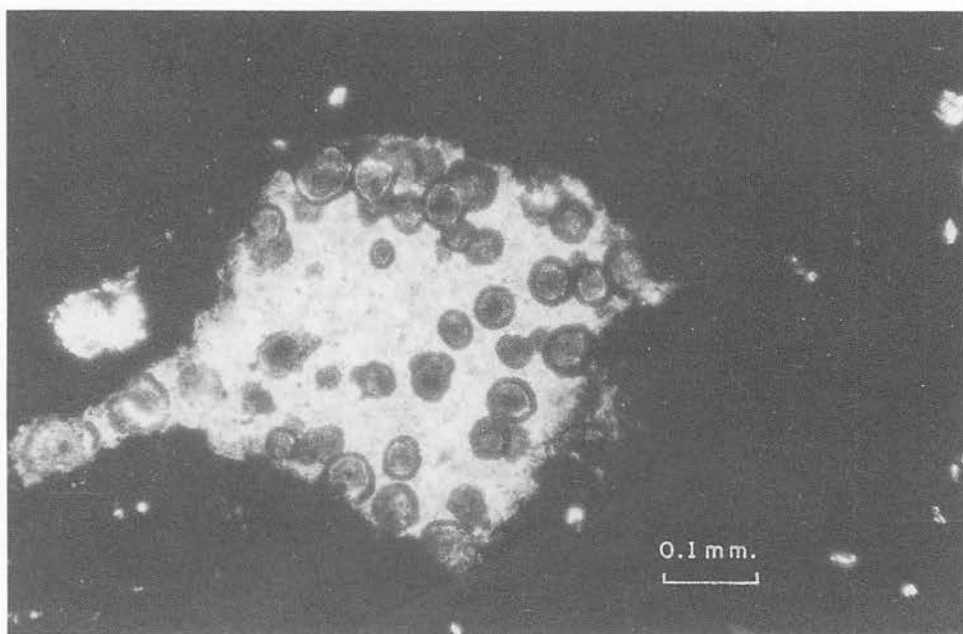


Plate 16: Photomicrograph of an ooid showing the close-up of micro-ooids with faint internal structural. Plane polarized light.

CHEMICAL COMPOSITION

Encrusted Phosphate

The chemical composition of the encrusted phosphate is shown in Table 1. The phosphate and CaO contents are the highest, whilst SiO₂ and Fe₂O₃ contents are the lowest in encrusted phosphate compared to the replacement and the sedimentary phosphates.

Table 1 : Chemical composition of encrusted phosphate (five samples).

	Range (%)		Average
	Min.	Max.	
P ₂ O ₅	24.2	36.1	31.3
SiO ₂	0.23	1.77	0.72
Fe ₂ O ₃	t	0.17	0.06
MnO	0.58	7.75	3.81
CaO	46.0	53.3	49.6
MgO	0.09	1.24	0.54
CO ₂	2.89	16.0	5.87
H ₂ O ⁺	1.76	3.66	2.58
H ₂ O ⁻	0.47	0.99	0.72
F ⁻	0.65	4.38	2.50
Cl ⁻	t	t	t
L.O.I.	0.65	18.8	8.32

t is less than 0.01%

Analyst: Lee Kim Hock

Replacement Phosphate

The chemical composition of the replacement phosphate is shown in Table 2. The phosphate and CaO contents, are intermediate compared to the encrusted and the sedimentary phosphates.

Table 2 : Chemical composition of replacement phosphate (six samples).

	Range (%)		Average
	Min.	Max.	
P ₂ O ₅	18.3	35.0	28.5
SiO ₂	0.36	7.25	2.37
Fe ₂ O ₃	0.75	5.02	2.22
MnO	0.96	7.75	3.56
CaO	21.5	47.6	39.6
MgO	0.09	0.30	0.21
CO ₂	2.01	15.7	6.02
H ₂ O ⁺	2.52	6.60	4.20
H ₂ O ⁻	1.27	2.05	1.51
F ⁻	2.36	4.71	3.3
Cl ⁻	t	t	t
L.O.I.	6.77	22.3	12.12

t is less than 0.01%

Analyst: Lee Kim Hock

Sedimentary Phosphate

The chemical composition of sedimentary phosphate is shown in Table 3. The iron and silica contents are the highest whilst the phosphate and the CaO contents are the lowest compared to the replacement and the encrusted phosphates.

Table 3 : Chemical composition of sedimentary phosphate (three samples).

	Range (%)		Average
	Min.	Max.	
P ₂ O ₅	11.5	30.2	22.2
SiO ₂	0.79	8.71	5.87
Fe ₂ O ₃	9.86	32.4	8.90
MnO	2.07	2.79	2.31
MgO	0.09	0.50	0.25
CO ₂	t	4.02	1.51
H ₂ O ⁺	7.28	9.81	8.59
H ₂ O ⁻	1.10	2.72	1.80
F ⁻	0.13	1.67	0.66
Cl ⁻	t	t	t
L.O.I.	10.3	14.5	12.6

t is less than 0.01%

Analyst: Lee Kim Hock

MINERALOGY

Owing to the fine-grained nature, the only practical means available to the writer of studying the mineralogy of the phosphate rock is by X-ray diffraction. Whole rock samples were pulverized and the samples of the composite powder were sent for analysis. Besides this, powder from individual phosphate laminae was also analysed to determine its mineralogy.

Besides the cryptocrystalline phosphate which could not be detected by X-ray diffraction, four phosphate minerals were identified. The most common is apatite. Crandallite, CaAl₃(PO₄)₂(OH)₅H₂O, occurs in small amounts together with apatite. Whitlockite, Ca(Mg, Fe)(PO₄)₆(PO₃OH), is rare. Montgomeryite, Ca₄MgAl₄(PO₄)₆(OH₄)12H₂O, was detected only in one out of 82 samples analysed.

The three strongest diffraction lines used to identify the four phosphate minerals are shown in Table 4.

Table 4: The three strongest diffraction lines of the phosphate minerals identified.

	1	2	3
Apatite	2.81	3.42	2.72
Crandallite	2.94	2.16	1.89
Whitlockite	2.84	2.57	1.70
Montgomeryite	12.0	5.11	2.90

Analyst: Leong Kok Hoong.

The true apatite mineral cannot be determined from the X-ray diffraction pattern. However, from the chemical analyses, chlorine is negligible, therefore, chlorapatite can be ruled out. As most of the analysed phosphates contain small amounts of fluorine and combined water, the apatite is either carbonate-apatite and/or hydroxylapatite. Fluorapatite can be discounted as it has no combined water. Comparison is made of the chemical analyses with phosphate minerals given in Nriagu (1984).

Calcite is the most common non-phosphate mineral detected. The next common is probably rancieite, a calcium manganese oxide hydrate. Pyrolusite in detritic form is found in some samples. Another manganese mineral, todorokite was also detected in one sample. Goethite is the only major non-phosphate mineral found in the sedimentary phosphate.

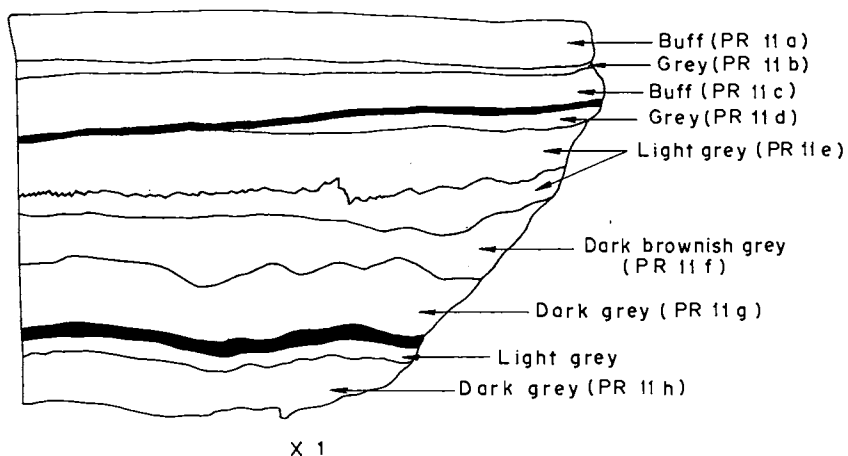
The mineralogy of the individual laminae from two hand specimens is given in Figures 7 and 8. Apatite is the dominant mineral in most laminae, though in a number of laminae, calcite, rancieite and whitlockite are dominant. Dark grey laminae generally indicate the presence of rancieite. Apatite may occur in laminae of all shades of colour.

DISCUSSION

The phosphate rock under discussion has both similarities and differences compared with the phosphorites from a small island of Esprit, to the north of Madagascar, in the Indian Ocean (Braithwaite, 1980). The primary source of the phosphate in Esprit is believed to be avian guano deposited on the eroded limestone surface, whereas the source of the phosphate under discussion is from bat guano deposited in limestone caves. On Esprit, the geological setting is not only affected by the rate of precipitation and the erosion of the limestone bedrock, but also influenced by rise and fall of the sea-level.

There is no doubt that in both examples, the phosphate rock was deposited subaerially. On Esprit, the phosphate-rich derivatives were carried downwards by surface wash processes and precipitated in a series of caves in the limestones excavated at the water-table and drained as sea-level fell. In the Malaysian situation, the percolating rainwater seeped through the cave guano and carried the phosphate-rich derivatives downwards depositing on the limestone surface. The major difference in the two cases is the different sites of deposition.

In the Espritian case where the phosphorites were deposited in caves, the phosphate-rich solution periodically filled the cave floor sufficiently long to permit both authigenic and allogenic phosphate sediments to be deposited. The oolitic phosphates are the most common. Associated with them are lithoclast-bearing rocks, fine-grained phosphorites, bioclastic deposits and internal sediments, all of which are also phosphatic. In drier periods, the occasional wetting and drying of the cave flood led to either deposition of phosphate cement or erosion and reworking of these rocks.



Sample No.	Dominant minerals (by X.R.D.)
PR 11 a	Apatite, calcite
PR 11 b	Apatite
PR 11 c	Apatite
PR 11 d	Apatite, rancieite
PR 11 e	Apatite
PR 11 f	Apatite
PR 11 g	Apatite, whitlockite
PR 11 h	Ranciete, whitlockite

Figure 7: Mineralogy of the laminae in a hand specimen.

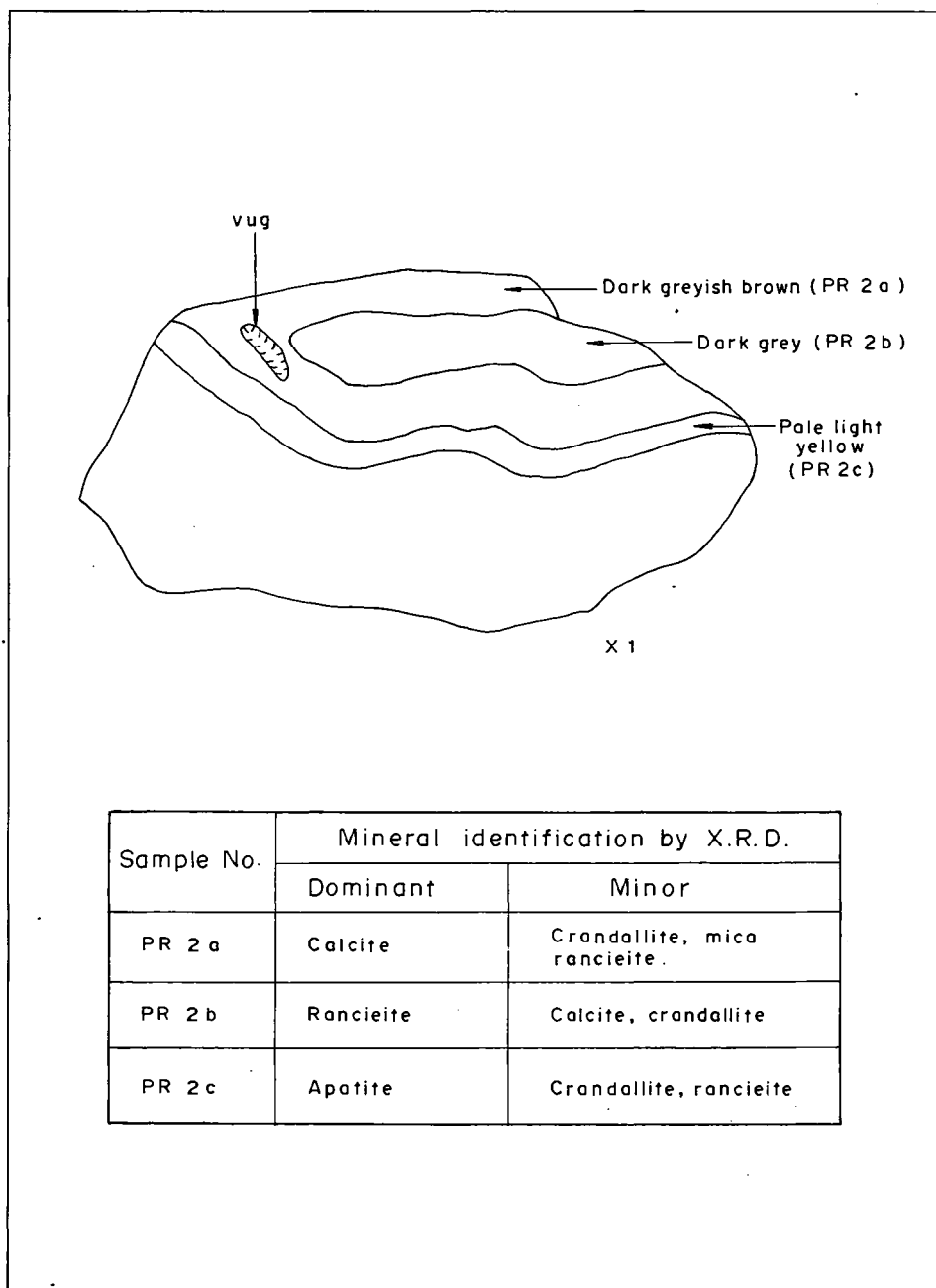


Figure 8: Mineralogy of the laminae in another hand specimen.

In contrast, most of the Malaysian phosphate rock was deposited on limestone surfaces and crevices in the form of phosphate cement. Such sites of deposition were periodically wetted by the phosphate-rich solution following rainfall. The phosphate cement was deposited by accretion. Only rarely were there cavities or depressions at the bottom of the caves, where the authigenic and allochthonous phosphate sediments were deposited.

The textures of the phosphate rocks, particularly the cements of the two examples are similar. In both cases the most common phosphate cements are colloform, they form botryoidal crusts with a banded structure lining cavities. The colour varies from shades of grey, brown to black. The cements are of 2 varieties. One is cryptocrystalline to near opaque. The second variety is weakly birefringent, showing first order white and grey, with fibrous structure or spherular masses, under crossed nicols.

In the sedimentary phosphates, the oolitic phosphorites of Esprit can be compared to the ooidal phosphate under discussion, whilst the lithoclast phosphate is similar to the phosphate breccia. However, whilst the oolites are phosphatic, the ooids are goethitic. The phosphate breccia is made up of phosphate fragments transported from nearby source.

Some of the encrusted phosphates contain appreciable amounts of manganese oxide in the form of pyrolusite or rancieite. Iron oxide content is low in the encrusted phosphate. On the other hand, the replacement phosphates contain small amounts of both manganese and iron oxides. In the sedimentary phosphate, the iron oxide is greater than the manganese oxide. In addition, the sedimentary phosphate also contains some silica in the form of clastic quartz grains.

Phosphatization of the limestone is not common. There is a clear demarcation between the encrusted phosphate and the limestone substratum, indicating that phosphatization is minimal, at best. In most of the caves where guano has been removed, the limestone wall/basement which was in contact with the guano hardly shows any sign of phosphatization. However, in places, the thinly bedded limestone shows preferential phosphatization. Replacement of the limestone by phosphate seems to be facilitated along bedding planes, joints and fractures, the grey crystalline limestone changes into variegated phosphate. In places, where dissolution of limestone took place as well, vugs were formed, some of which were filled by phosphate cement and/or calcite.

The type of sedimentary phosphate under discussion is rare because its formation is dependent on the fulfillment of three conditions. One is the availability of phosphate-rich solution. Second, there should be a natural depression to contain the phosphate-rich water. Third, the depression is not open to dilution by rain water, so that deposition of authigenic and allochthonous phosphate sediment can take place.

Since bats did not appear in evolution until the early Tertiary (Cook, 1984), the bat guano could not be formed earlier than early Tertiary. It is likely that the rock phosphate derived from bat guano was formed since the late Tertiary.

ACKNOWLEDGEMENTS

I wish to express my grateful thanks to the following colleagues: Mr. Foo Khong Yee for reading the original draft, Mr. Lee Kim Hock for the chemical analyses, Mr. Leong Kok Hoong for the X-ray diffraction, photographs and photomicrographs. Mr. Ismail Ghazali drafted the text figures and Ms Mary Chan word-processed the paper.

REFERENCES

- AW, P.C., 1985. Cave phosphate deposits and their role in the fertilizer industry in Peninsular Malaysia. *Annual Report 1983*, Geological Survey of Malaysia.
- BRAITHWAITE, C.J.R., 1980. The petrology of oolitic phosphorite from Esprit (Aldabra), western Indian Ocean. *Philosophical Transactions of the Royal Society of London*, Volume 288.
- COOK, P.J., 1984. Spatial and temporal controls on the formation of phosphate deposits – A review. *In* Nriagu, J.O. & Moore, P.B. (Eds.) *Phosphate Minerals*. Springer-Verlag.
- NRIAGU, J.O., 1984. Phosphate minerals: their properties and general modes of occurrence. *In* Nriagu, J.O. & Moore, P.B. (Eds.) *Phosphate Minerals*. Springer-Verlag.

BULETIN PERSATUAN GEOLOGI MALAYSIA

BULLETIN OF THE GEOLOGICAL SOCIETY OF MALAYSIA

KANDUNGAN (CONTENTS)

- 1 **Polyphase deformations and quartz development at Bandar Baru, Bangi (South), Selangor**
H.D. Tjia & Zaiton Harun
- 21 **Depth of penetration of geophysical exploration methods as applied in shallow engineering geological investigations**
Abdul Ghani Rafek
- 29 **Estuarine sediment geochemistry**
Tan Teong Hing
- 41 **A comparative study of the mineralogy of rice soils of the Kedah and Kelantan coastal plains of Peninsular Malaysia**
S. Paramanathan
- 59 **Magnesium and calcium concentrations in limestone groundwaters, Peninsular Malaysia**
J. Crowther
- 85 **Structural geology of Datai beds and Macincang Formation, Langkawi**
H.D. Tjia
- 121 **A brief account of lead mineralization at Phaungdaw Prospect, Pyawbwe Township, Mandalay Division, Burma**
Khin Zaw & P.J. Goosens
- 133 **The Wang Phar tungsten deposits**
Tan Say Biow
- 147 **The occurrence of turquoise and faustite in Tras, Pahang**
K.N. Murthy
- 157 **Conservation of geological features in Peninsular Malaysia**
Frank Yong Siew Kee
- 199 **Palynology of the lowland Seberang Prai and Kuala Kurau areas, NW Peninsular Malaysia**
Kamaludin bin Hassan

Editor
G.H. TEH



AUGUST 1989

Price: M\$35.00 (US\$15.00)

No. 23

Cheques, Money Orders or Bank Drafts must accompany all orders. Please add US\$1.30 for bank charges.

Orders should be addressed to: The Hon. Assistant Secretary
GEOLOGICAL SOCIETY OF MALAYSIA
c/o Dept. of Geology
University of Malaya
59100 Kuala Lumpur
MALAYSIA

BULETIN PERSATUAN GEOLOGI MALAYSIA

BULLETIN OF THE GEOLOGICAL SOCIETY OF MALAYSIA

KANDUNGAN (CONTENTS)

- 1 **Some characteristics of the heavy detrital minerals from Peninsular Malaysia**
Wan Fuad Wan Hassan
- 13 **Groundwater supply studies in Northern Kelantan**
Tan Eng Heng & Mahan Singh
- 27 **Diagnostic resistivity sounding curves of karstic aquifers in the Chuping Limestone**
Mohammad Sayyadul Arafin & C.Y. Lee
- 43 **Contoh penggunaan kaedah kerintangan geoelektrik untuk penjelajahan bawah tanah**
Abdul Ghani Rafek
- 57 **Significance of palynology in Late Quaternary sediments in Peninsular Malaysia**
Kamaludin bin Hassan
- 67 **Processing of illite powder in Bidor, Perak : A study of the process and the potential uses of illite clay**
Fan Choon Meng & Aw Peck Chin
- 79 **K/Ar mica dates for granites from the Bujang Melaka area**
Kwan Tai Seong
- 87 **Biostratigraphy and paleoecology of fusulinids from Bukit Panching, Pahang**
M.B. Idris & M.S. Azlan
- 101 **Chemical variation of biotite and hornblende in some Malaysian and Sumatran granitoids**
C.S. Hutchison
- 121 **Beberapa aspek penggunaan teknik analisis pengaktifan neutron dalam kajian geologi**
Mohd. Suhaimi Hamzah, Abd. Khalik Hj. Wood, Zaini Hamzah & Che Seman Mahmood
- 135 **Struktur sedimen dalam Formasi Crocker di kawasan Tamparuli, Sabah**
Tajul Anuar Jamaluddin
- 159 **Pembinaan perigi-perigi mendatar di Kampung Paloh, Bahagian Sarikei, Sarawak**
Henry Litong Among
- 173 **Penyiasatan terperinci hidrogeologi di kawasan Jebungan, Mukah, Sarawak**
Yusuf b. Bujang

Editor
G.H. TEH



OCTOBER 1989

No. 24

Price: M\$35.00 (US\$15.00)

Cheques, Money Orders or Bank Drafts must accompany all orders. Please add US\$1.30 for bank charges.

Orders should be addressed to: The Hon. Assistant Secretary
GEOLOGICAL SOCIETY OF MALAYSIA
c/o Dept. of Geology
University of Malaya
59100 Kuala Lumpur
MALAYSIA