*Iraqi Bulletin of Geology and Mining* *Vol.6, No.1, 2010* *p 59 – 79*

# PETROGRAPHIC CLASSIFICATION OF PHOSPHATE COMPONENTS OF EAST MEDITERRANIAN PHOSPHORITE DEPOSITS

**Khaldoun S. Al-Bassam[*], Asma A. Aba-Hussain[**], Ibrahim Q. Mohamed[***] and Yehya T. Al-Rawi[****]**

Received: 23/ 12/ 2008, Accepted: 9/ 6/ 2009
Key words: Petrography, Phosphorites, Classification, East Mediterranean

## ABSRTACT

An attempt has been made in this paper to present a classification of phosphorites with precise definition and description of phosphate components based on external shape and internal structure. The proposed classification is the result of macroscopic and microscopic examination of several hundreds phosphorite samples from the East Mediterranean deposits (Late Cretaceous and Paleogene). The classification is designed in the way that can be used to predict depositional environment.

# تصنيف بتروغرافي للمكونات الفوسفاتية في صخور الفوسفورايت لرواسب شرق البحر الأبيض المتوسط

**خلدون صبحي البصام، أسماء علي أبا حسين، إبراهيم قاسم محمد و يحيى توفيق الراوي**

## المستخلص

يقدم هذا البحث محاولة لوضع تصنيف لصخور الفوسفورايت مع تعريف ووصف دقيق للمكونات الفوسفاتية بالاستناد إلى الشكل الخارجي والتركيب الداخلي. اعتمد التصنيف المقترح على الفحوصات البصرية والمجهرية لعدة مئات من العينات الفوسفاتية من رواسب في شرق البحر الأبيض المتوسط (الطباشيري المتأخر والباليوجين) وقد تم تصميم التصنيف بطريقة تسمح بالتكهن بالبيئة الرسوبية.

## INTRODUCTION

The petrography of phosphorites and phosphatic rocks has been a complicated subject for a long time. However, until now there seem to be no unified phosphorite classification, and the terminology used for the phosphate components is often misleading. This has lead to important short giving's in the common understanding of international literature on phosphorites, and many workers are applying carbonate terminology on phosphate without modifications following pioneer workers in petrology such as (Pettijohn, 1957 and Carozzi, 1960). Some of the previous classifications (e.g. Riggs, 1979) were based after Folk's classification of carbonate sediments (Folk, 1959). Whereas others (e.g Cook and Shergold, 1986) employed a classification system based on Dunham's classification of carbonates (Dunham, 1962).

---

[*] Chief Researcher, GEOSURV, Iraq, e-mail: khaldoon47@ yahoo.com
[**] Assistant Professor, Gulf University, Bahrain
[***] Geologist, private sector
[****] Professor of Geology, Gulf University, Bahrain

Several workers have attempted to provide solutions for this problem (Mabie and Hess, 1964; Freas and Riggs, 1968; Cook, 1972; Ilyin *et al.*, 1975; Cook, 1976; Riggs, 1979; Slansky, 1979; Al-Jaleel, 1983, among others). This problem was discussed in several meetings of the IGCP Project 156 (phosphorite) and it was agreed that there should be a common scientific language in phosphorite petrographic studies. Consequently, several proposals were submitted in the 10th International IGCP meeting in Tunisia (Prevot and Lucas, 1988; Al-Bassam *et al.*, 1988 and Ahluwalia, 1988). Another meeting was held in Baghdad in 1986 for the same purpose (IGCP National Committee, Iraq and WG4 – IGCP Project 156). However, it seems that there are still some unresolved problems in obtaining a generally accepted classification and/ or terminology of phosphorites and phosphate components (Cook *et al.*, 1990).

The frequency of conferences, symposiums and workshops on phosphorites has considerably declined after the remarkable IGCP 156 came to an end in the early nineties. So are scientific publications on the issue. The previous work, most of it mentioned in this paper, represent the cream of the issue.

In the present classification some of Folk's terminology for carbonates (Folk, 1959) were employed for convenience, but it must be stressed that they have no genetic implications as it is the case in the carbonate classification. They are merely descriptive terms, but can be related to energy and dominant site of deposition in the sedimentary environment.

Important phosphorite deposits are found in Egypt, Syria, Jordan, Saudi Arabia, Iraq, Turkey and Palestine. They are part of the huge Tethyan Phosphogenic Province (Late Cretaceous – Eocene) which extends from Morocco in the west to Iraq and Turkey in the East (Fig.1) and believed to contain about 70% of the world phosphorite resources (Notholt, 1985). These phosphorites are marine sedimentary deposits and have many similarities in their petrographic characteristics (Al-Bassam, 1974).

In this paper we are suggesting a classification for the East Mediterranean phosphorite deposits based on description of the phosphate components, which are precisely defined and can be used to predict depositional environment, as far as energy and dominant site of deposition in the sedimentary basin are concerned. The proposed classification includes also some genetic concepts and considered most of the commonly used and well established terms in phosphate petrography. It can be applied in the field observations (major classes) and in microscopic studies for more detailed subdivisions.

The classification is based on the petrographic study of about one thousand samples from phosphorite deposits in the region; most of them come from Iraq. Although the authors restrict the domain of the proposed classification to the East Mediterranean deposits, but the terminology can be used elsewhere, wherever the petrographic criteria described here exist.

## SAMPLES

The samples studied to develop this classification were collected from several East Mediterranean phosphorite deposits (Late Cretaceous – Eocene) of the Tethyan phosphorite province. These deposits are:

- **Iraq**:
  Rutba (Late Cretaceous) 150 samples (Mohamed, 1985)
  Swab (Late Cretaceous) 120 samples (Al-Dahan, 1977)
  Swab (Paleocene) 50 samples (Al-Bassam, 1988)
  Marbat (Paleocene) 250 samples (Aba-Hussain, 1987 and Gulli, 1989)
  Akashat (Paleocene) 200 samples (Al-Bassam, 1974 and Aba-Hussain, 1987)
  Nukhaib (Paleocene) 35 samples (Mohamed and Jassim, 1988)
  Ethna (Eocene) 50 samples (Al-Bassam and Hagopian, 1983 and Al-Jaleel, 1983)
  Wadi Ukash (Eocene) 16 samples (Al-Bassam and Al-Hashimi, 1982)

- **Egypt** (Al-Bassam, 1974):
  El-Qurn (Late Cretaceous) 23 samples
  Safaga (Late Cretaceous) 3 samples
  Quseir (Late Cretaceous) 7 samples
- **Syria** (Al-Bassam, 1974):
  Ain Lailoun (Late Cretaceous) 4 samples
  El-Sharquia (Late Cretaceous) 10 samples
- **Saudi Arabia** (Al-Bassam, 1974):
  Western Thaniyat (Late Cretaceous) 4 samples
  Turaif Basin (Late Cretaceous and Paleocene) 4 samples
- **Turkey** (Al-Bassam, 1974):
  Akras (Late Cretaceous) one sample
  Tasit (Late Cretaceous) one sample
  Bati Kasrik (Late Cretaceous) one sample
  Kilis (Late Cretaceous) one sample
  Yayladagi (Late Cretaceous) one sample
  Dogu Kasrik (Late Cretaceous) one sample
- **Palestine** (Al-Bassam, 1974):
  Ras Zuweir (Late Cretaceous) 5 samples

## BASIS OF CLASSIFICATION

Rocks can be classified according to schemes that are primarily either genetic or descriptive. The primary objective of a genetic classification scheme is to group rocks according to similarity in origin. A descriptive scheme, however, does not necessarily imply a mode of formation, its primary objective being to categorize rocks as to texture and composition.

The descriptive scheme, however, depends largely on textural features, which are important in predicting the response of the ores to beneficiation and in addition, are useful in providing clues and evidence with regard to genesis problems. Moreover, and in view of the common features in most phosphorites of being subjected to some degree of transportation before deposition, it is more useful for the sedimentologist to obtain clues on the environment of deposition rather than on the mechanism of apatite precipitation. The former has direct implication on the sedimentary facies and phosphate components and can be tied here directly with the other components of the rock, as environmental indicators.

The energy of the environment and its role in producing various textural forms and in developing internal structures of grains were considered in the proposed classification. Furthermore, the site of deposition, where each type of phosphate components is more dominant, was also considered. In view of the very frequent alteration of the cementing material of phosphorites, induced by several diagenetic and weathering processes, it was not considered as a determining factor in the present classification. Diagenetic and weathering processes have significantly modified the original cementing material in these rocks and rendered it useless in most cases as an environmental indicator of primary deposition.

The mechanism of apatite precipitation in the marine environment has been a confusing problem among phosphorite scientists. Arguments were very active about whether it is by direct chemical precipitation from sea water (Kazakov, 1937) (or interstitial water, Al-Bassam 1976) or by phosphatization of lime-mud (Ames 1959). Moreover, is it an inorganic process or a biogenic process, and to what extent is the role of bacteria in apatite precipitation in the

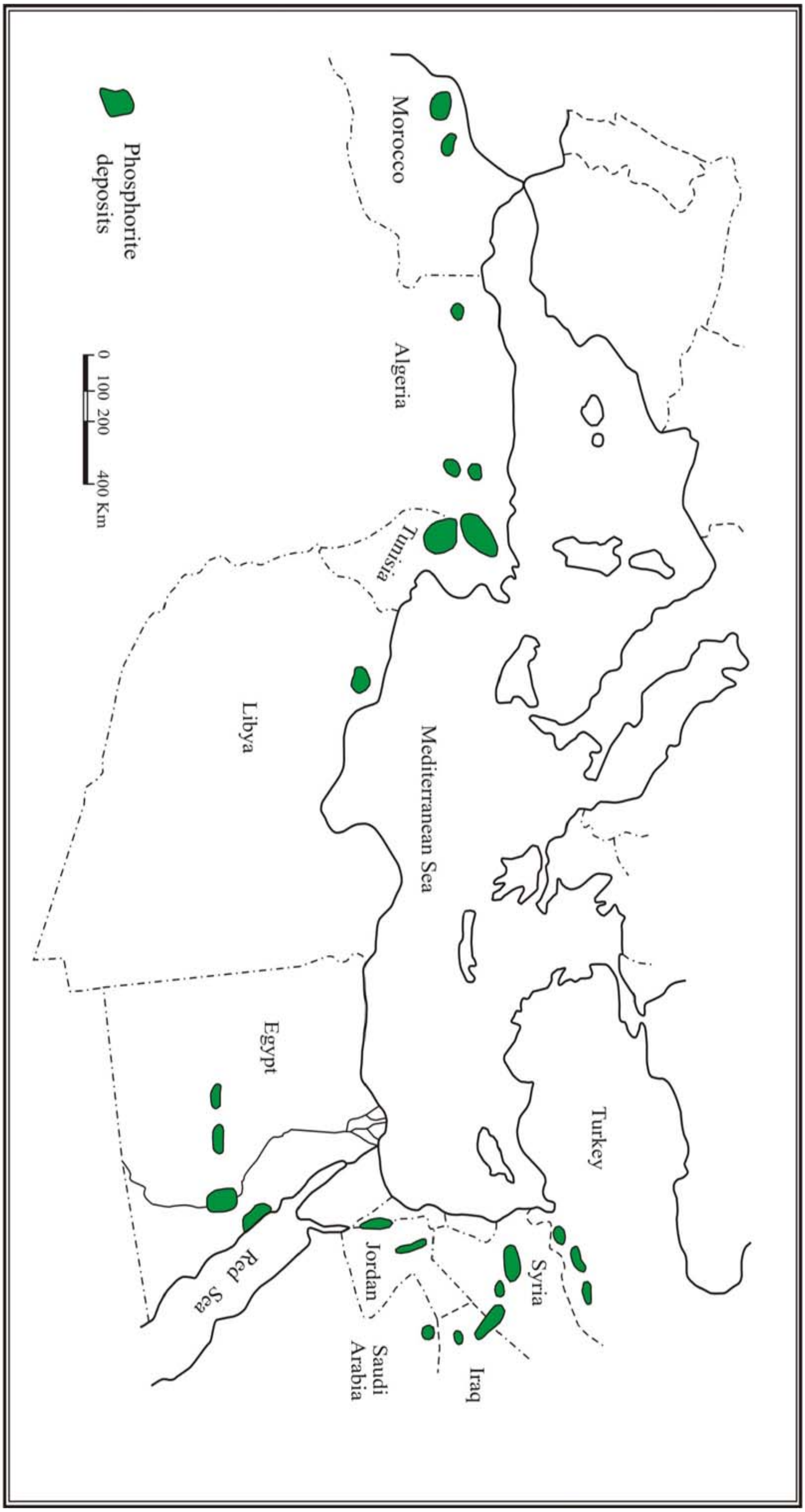

Fig.1: Phosphorite deposits of the Mediterranean area (Al-Bassam, 1974)

marine environment. Most of the phosphorite scientists believe now that it is a combination of complicated chemical and biological processes (chemobiogenic) that control the apatite precipitation in marine environment where bacteria play a major role (O'Brien *et al*., 1981; Lucas and Prevot, 1985; Zanin *et al*., 1985; Lamboy and Monty, 1987; Purnachandra and Nair, 1988; Lamboy, 1990; Abed and Fakhouri, 1990 and Al-Bassam *et al*., 2005). None of the previous workers have conclusively related mechanism of apatite precipitation to textural forms of phosphorite components in a way to serve as classification parameters.

Similar textural features, including outer form and internal structure of phosphate components may be developed by various modes of apatite precipitation and further modified by diagenesis and weathering. In view of these problematic aspects, we believe there is little use in introducing the apatite genetic confusion in any petrographic classification. Hence the present proposal does not include such genetic bases except where it is absolutely clear and obvious.

The rock name "phosphorite" is accepted here to mean a sedimentary rock with 50% or more (by volume) of phosphate components composed of carbonate fluorapatite (francolite). This means a $P_2O_5$ content range of (14 – 19) % (by weight) in the east Mediterranean phosphorites, which show their carbonate fluorapatites to contain (28 – 38) % $P_2O_5$ (Al-Bassam, 1974). Generally, the $P_2O_5$ content increases in the Tethyan apatites from younger (Eocene) to older (Late Cretaceous), following the trend of most marine sedimentary apatites of the world and influenced by the degree of phosphate replacement by carbonate in the apatite structure (McCllelan, 1980). The differentiation of phosphorite from phosphatic rocks should be feasible in the field examination with an acceptable marginal error that can be highly reduced after microscopic examination or chemical analysis. However, if the latter is used, the $P_2O_5$ content of the apatite should be determined first.

When the rock contains phosphate components between 5% and 50% (by volume) then it is phosphatic and the name of the main lithology is used as a suffix (e.g. phosphatic limestone, phosphatic claystone, etc.). In addition, the dominant textural form of the phosphate components in a phosphorite can be used in defining the rock name (e.g. peloidal phosphorite, coprolitic phosphorite, etc.), when that particular textural form represents the main phosphate component.

In the present classification the phosphate components were divided into three main groups: **1) phosphomud** (called also microsphorite and orthochemical phosphate by other workers), **2) phosphochem** and **3) phosphoclasts.** For comparison with other terms used by various authors for phosphate components see Table (1). Phosphomud is the primary in situ phosphate precipitation, which is kept from modification into other forms by the quiet environment of formation, consolidation and burial. It represents the lowest energy facies among the phosphorites and is rare or of very restricted occurrence in the Tethyan deposits in general. It can be found in different parts of the marine environment, but its presence always reflects quiet environment protected from agitation. The structure-less or laminated phosphate mud devoid of grains (matrix) may reflect deposition in the outer shelf edge. The laminated variety might be a rare possibility of an intertidal stromatolitic phosphorite, whereas that present as cementing material (intergranular and intragranular phosphomud) may reflect deposition in restricted quiet environments below sediment – water interface in shallow parts of the shelf. All types of phosphomud contain various amounts of organic material and minute inclusions of non-phosphatic materials. It is usually composed of isotropic cryptocrystalline carbonate fluorapatite (francolite).

On the other hand, phosphochem and phosphoclast are phosphate grains the size of which mostly ranges between fine and coarse sand (with a few exceptions of larger grains).

Two main grain types can be recognized according to their outer form and mode of development into grains. The first type is called here phosphochem and includes all phosphate grains formed by accretion of cryptocrystlline phosphate particles. The second type is called here phosphoclasts and represents phosphate grains formed by the disintegration (physical breakdown) of larger phosphate bodies by very active mechanical and/ or biological processes.

Table 1: Terms used by various authors to describe
phosphate components in phosphorites of the world

| **Term** | **Reference** |
|---|---|
| **Phosphomud** | This paper |
| orthochemical phosphorite | Freas and Riggs (1981) |
| microsphorite | Freas and Riggs (1981) |
| phosphate matrix | Southgate (1980) |
| phosphate cement | Braithwaite (1986) |
| phosphate mud | Braithwaite (1980) |
| collophane cement | Marshal and Cook (1980) |
| collophane mud | Trueman (1971) |
| micritic collophane | Trueman (1971) |
| collophane matrix | Trueman (1971) |
| laminated phosphorite | Marshal and Cook (1980)<br>Gulbrandsen (1960)<br>Ilyin *et al.* (1975)<br>Soudry and Champetier (1983)<br>Kidder (1985) |
| **Phosphochem** | This paper |
| **Coated phosphochem** | This paper |
| coated grains | Soudry and Champetier (1983) |
| **Ooid** | This paper<br>Mabie and Hess (1964)<br>Trueman (1971)<br>Ilyin *et al.* (1975)<br>Horton *et al.* (1980)<br>Southgate (1986) |
| oolite | Mabie and Hess (1964)<br>Trueman (1971)<br>Al-Bassam (1974)<br>Ilyin *et al.* (1975)<br>Akturk (1979)<br>Braithwaite (1980) |
| concentric pellet | Mabie and Hess (1964) |
| oolith | Cook (1976)<br>Braithwaite (1980) |
| **Cortoid** | This paper |
| nucleated pellet | Cook (1976) |

......cont. Table 1

| | |
|---|---|
| **Concretion** | This paper<br>Balson (1980)<br>Marshal and Cook (1980)<br>Bremnar (1980) |
| **Oncoid** | This paper |
| algal coated grains | Soudry and Champetier (1983) |
| oncolith | Braithwaite (1980) |
| **Composite** | This paper |
| aggregates | Southgate (1986) |
| complex ovule | Ilyin *et al*. (1975) |
| compound pellet | Mabie and Hess (1964) |
| **Non-coated phosphochem** | This paper |
| **Peloid** | This paper<br>Soudry and Nathan (1980)<br>Kidder (1985) |
| pellet | Al-Bassam (1974) |
| collophane pellet | Trueman (1971)<br>El-Shazly *et al*. (1972) |
| Structureless pellet | Braithwaite (1980) |
| ovule | Ilyin *et al*. (1975) |
| **Coprolite** | This paper<br>Freas and Riggs (1968)<br>Ghanem *et al*. (1970)<br>Marshal and Cook (1980)<br>Bremnar (1980)<br>Al-Jaleel (1983)<br>Aba-Hussain (1987) |
| faecal pellet | Freas and Riggs (1968) |
| **Nodule** | This paper<br>Al-Maleh (1974)<br>Kennedy and Garrison (1975)<br>Akturk (1979)<br>Balson (1980)<br>Kidder (1985) |
| **Phosphoclast/ bioclast** | This paper |
| skeletal debris | Southgate (1986) |
| collophane fossil fragments | Trueman (1971) |
| phosphate bioclasts | Trueman (1971) |
| fossil skeletal material | Freas and Riggs (1968)<br>Soudry and Champetier (1983) |
| **Phosphoclast/ lithoclast** | This paper |
| phosphate intraclasts | Freas and Riggs (1968)<br>Soudry and Champetier (1983) |
| collophane fragments | Trueman (1971) |

Phosphochems are common among almost all phosphorites of the world, but in the Tethyan deposits, they are especially common in the Paleogene phosphorites. Phosphochems are generally rounded, moderate to well sorted relative to phosphoclasts, and may be cemented or friable with little or no detrital components. They represent an environment of moderate to high energy and may have suffered some transportation. As a facies they may extend from inner shelf to outer shelf, depending on the various forms of phosphochems. They are composed of cryptocrystalline isotropic carbonate fluorapatite (francolite), which may have formed by various modes including direct chemical precipitation, biochemical precipitation, phosphatization, etc.

Within the phosphochem group of grains, two main varieties can be recognized according to their internal structure. These are coated and non-coated phosphochems. The former has one or more phosphate envelopes, and the latter is structure-less, but both may include organic impurities. Coated phosphochems reflect relatively higher energy environment than non-coated phosphochems and suggest dominant deposition in inner shelf, whereas the latter is more dominant in the deeper parts of the shelf, including outer shelf and shelf edge.

The two varieties of phosphochems were further subdivided according to the micro details of their internal structure or outer shape. In this way the coated phosphochems include: ooids (and pisoids), cortoids, composites, oncoids (and concretions). The non-coated phosphochems include peloids (and nodules) and coprolites. As a matter of fact, many peloids may be faucal pellets, which are of the same origin as the coprolites, but the latter is well defined by its characteristic cylindrical (rod like) and convolutionary form.

The phosphoclast grains are usually angular and poorly sorted, commonly associated with detritel components such as quartz grains and carbonate lithoclasts, and often present as friable phosphorites. Generally, they are associated with the on-set of transgressive cycles and sometimes overlying burrowed hardgrounds. They represent the shallowest and highest energy facies among the phosphorites (the nearest to the shore line). Phosphoclasts are especially dominant in the Late Cretaceous phosphorites of the Tethyan deposits.

Phosphoclasts are divided in this classification into: bioclasts (fragmented phosphate bones, scales, teeth, shells, etc.), which are mostly composed of anisotropic carbonate fluorapatite, and lithoclasts (extra-and intraclasts) which are usually composed of isotropic carbonate fluorapatite.

## DEFINITIONS

- **Phosphorite:** A sedimentary rock with more than 50% by volume of phosphate components (14 – 19 % $P_2O_5$ for east Mediterranean phosphorites). The phosphate mineral is mostly isotropic cryptocrystalline carbonate fluorapatite (francolite) present as grains or as mud.

- **Phosphomud:** In situ precipitation, non-granular, cryptocrystalline, isotropic, may contain inclusions and may be present in the following forms:

**Matrix:** Original groundmass of the rock, devoid of grains and present as:
– **Structureless:** (Fig.2a)
– **Laminated:** (Fig.2, b, c, d and e)

**Cement:** Cementing material, associated with grains of various compositions and present as:
– **Intragranular:** binding material between grains (Fig.3a)
– **Intergranular:** cavity fills (Fig.3b)

- **Phosphochem:** Fine to coarse sand-size, spherical to ovulitic, cylindrical or disc-shaped phosphate grains formed by accretion of minute phosphate particles. They include the following varieties:

  **Coated:** Phosphochem having one or more phosphate envelope and include:
  - **Ooid:** has more than one concentric phosphate envelopes and up to 2 mm in diameter (Fig.4a and b) (larger grains are called pisoids).
  - **Cortoid:** has one phosphate envelope around one nucleating grain. It is up to 2 mm in diameter, and may be further divided into **encased** (maximum diameter of the inner grain is greater than half the minimum diameter of the cortoid (Fig.5a and b) and **nucleated** (maximum diameter of the inner grain is less than half the minimum diameter of the cortoid) (Fig.5c).
  - **Composite:** contain more than one nucleating grain (Fig.5c, d and e). Two types can be identified: **aggregates** (matrix constitutes less than half of the nucleating grains), and **lumps** (matrix constitutes more than half of the nucleating grains).
  - **Oncoid:** has irregular internal laminations, up to 2 mm in diameter, and could be algal in origin (Fig.6) (larger grains are called **concretions**).

  **Non-coated:** Phosphochem without internal structure, which may include minute inclusions and irregularly distributed organic matter. Two types may be recognized according to shape:
  - **Peloid:** rounded to spherical or ovulitic and up to 2 mm in diameter (Fig.7) (larger grains may be called **nodules**).
  - **Coprolite:** fossil animal excretions, mostly cylindrical and elongated (rod like) with annular convolutions and elongated striations parallel to the elongation on outer surface, rich in organic inclusions and up to several centimeters long and 0.5 cm in diameter (Fig.8).

- **Phosphoclast:** Fine to coarse sand-size angular phosphate grains formed by physical breakdown of larger phosphate bodies and show evidence of wear and tear. They may contain inclusions of various compositions and are composed of isotropic and anisotropic varieties of carbonate fluorapatite. They include two main types:
  - **Lithoclasts:** irregular, angular and without internal structure (Fig.7a and b). They may be derived by erosion of weakly consolidated phosphate deposits within the depositional basin (**intraclasts**) or the erosion of older consolidated phosphate rocks (**extraclasts**).
  - **Bioclasts:** phosphate remains of vertebrates (bones, scales, and teeth), and invertbrates (fragmented phosphatic fossil shells). The former is usually anisotropic (Fig.9).

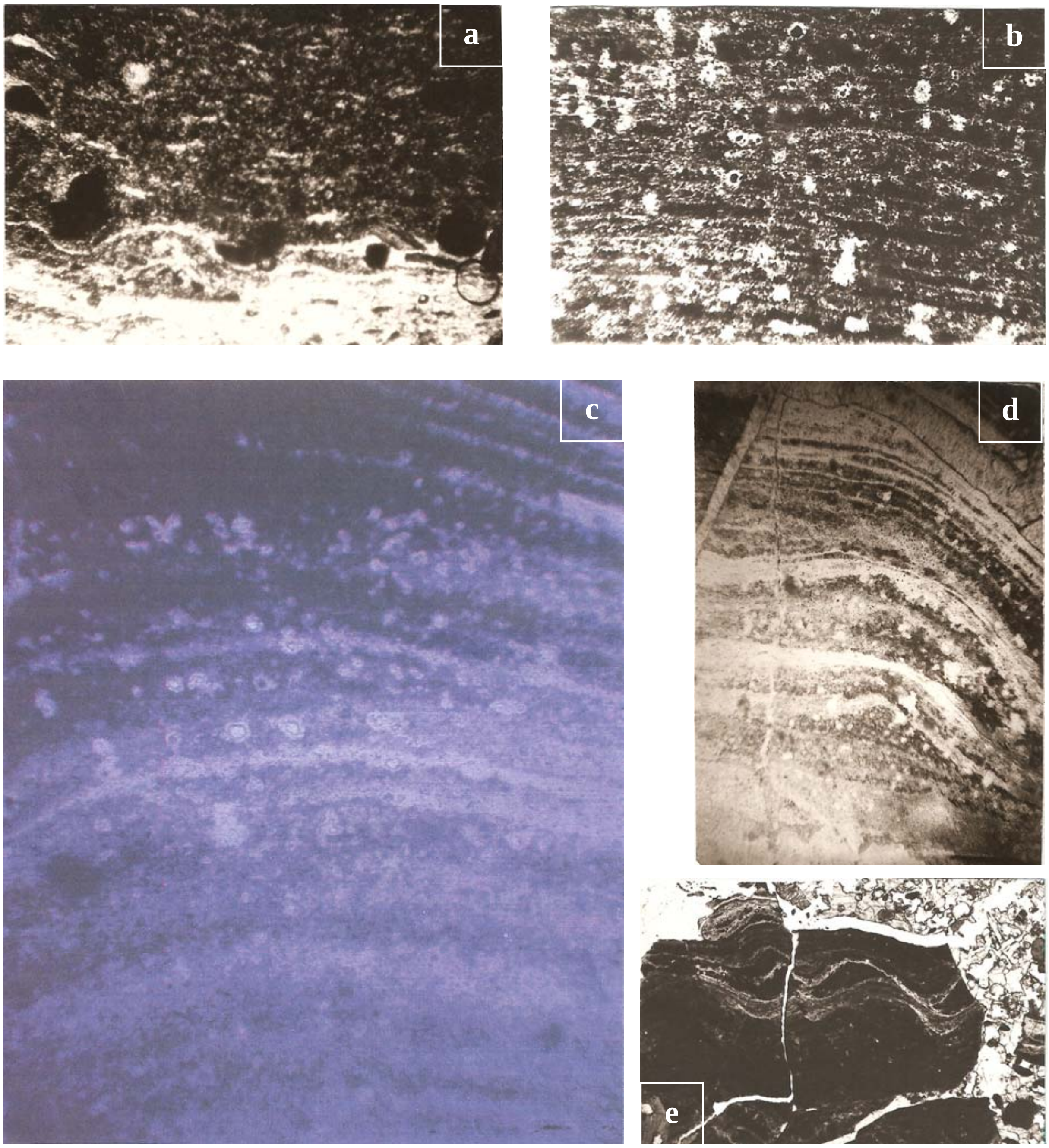

Fig.2: Phosphomud/ Matrix

(a) Structureless, Late Cretaceous, Iraq, 1 cm = 0.25 mm, xn
(b) Laminated, Late Cretaceous, Iraq, 1 cm = 0.25 mm, xn
(c) Laminated, Late Cretaceous, Iraq, 1 cm = 1 mm
(d) Laminated, Late Cretaceous, Iraq, 1 cm = 0.25 mm (stromatolitic?)
(e) Laminated, Late Cretaceous, Iraq, 1 cm = 0.25 mm (stromatolitic?)

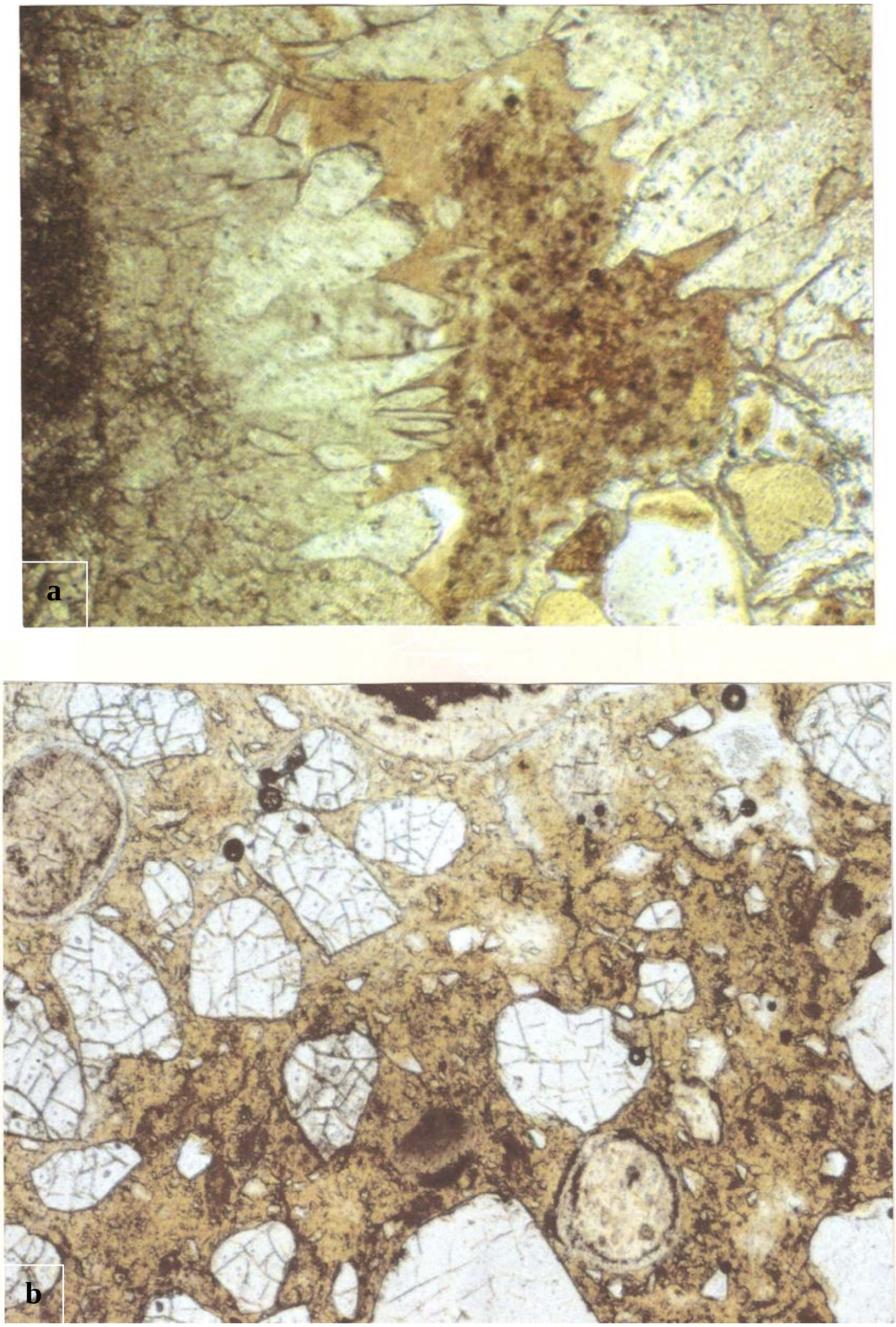

Fig.3: Phosphomud/ Cement
(a) Intragranular, Paleocene, Iraq, 1 cm = 1 mm
(b) Intergranular, Late Cretaceous, Egypt, 1 cm = 0.75 mm

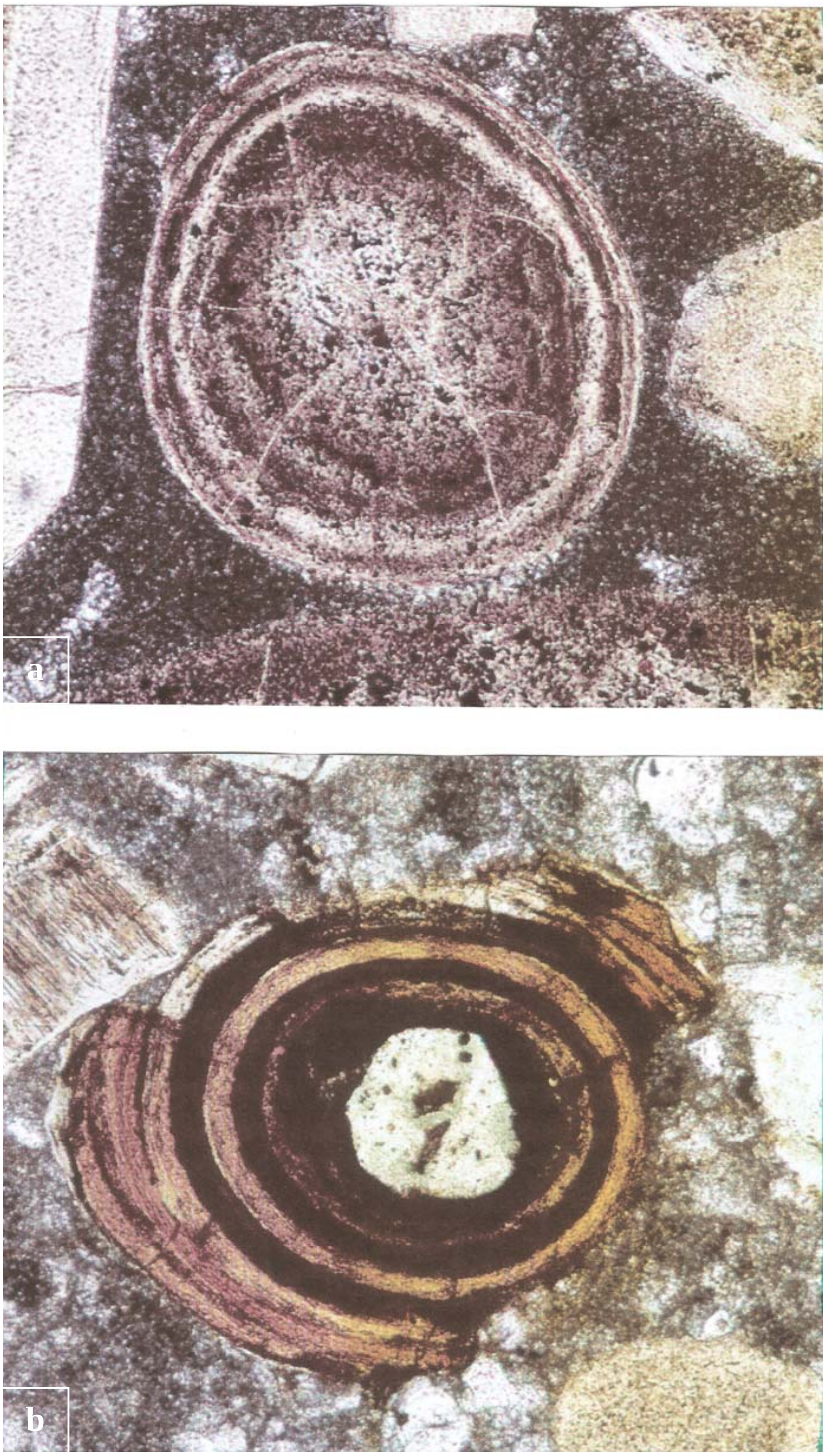

Fig.4: Phosphochem/ Coated
(a) Ooid, Late Cretaceous, Syria, 1 cm = 0.1 mm
(b) Ooid (broken), Late Cretaceous, Turkey, 1 cm = 0.1 mm

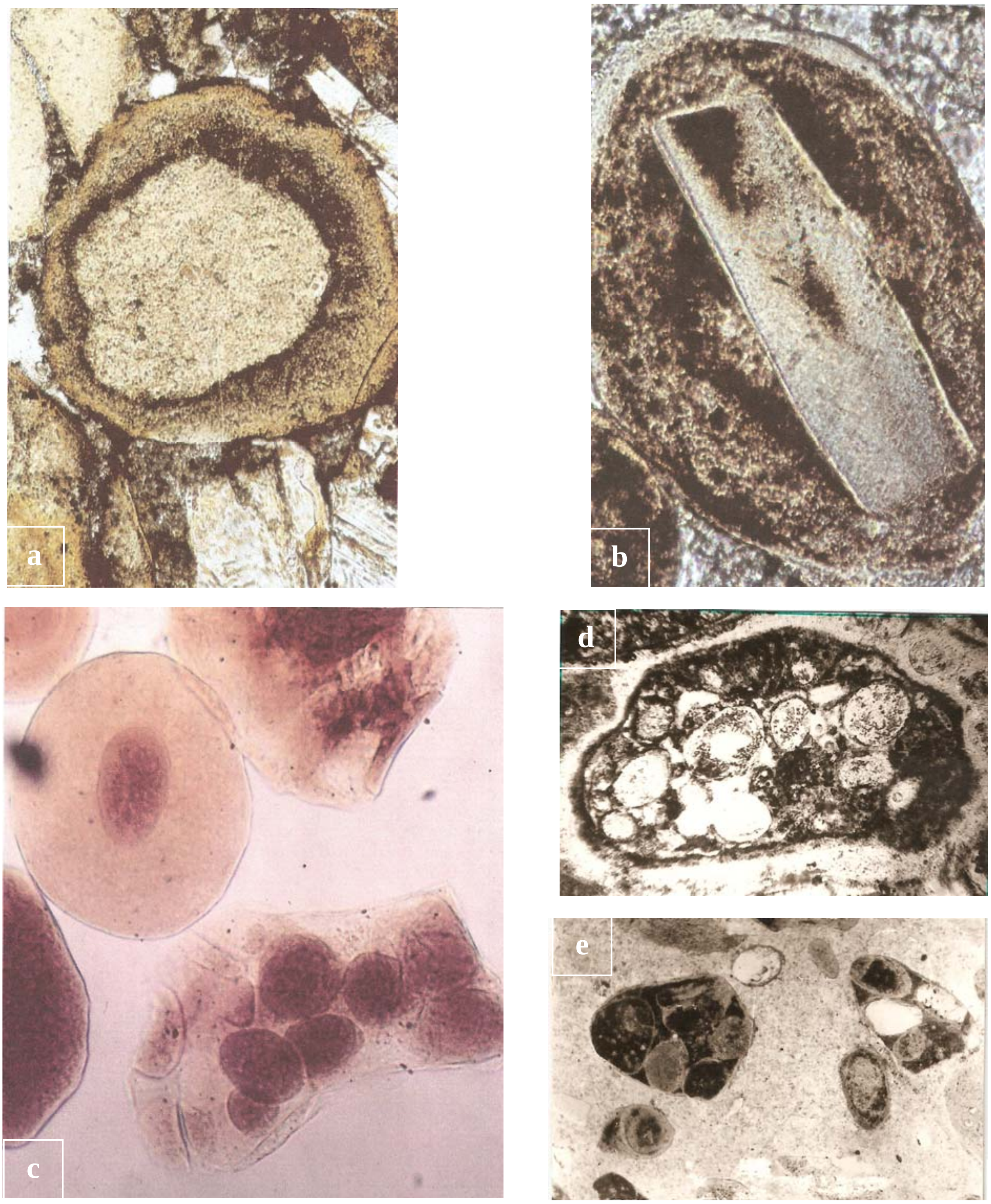

Fig.5: Phosphochem/ Coated

(a) Cortoid (encased), Late Cretaceous, Turkey, 1 cm = 0.1 mm
(b) Cortoid (encased), Paleocene, Iraq, 1 cm = 0.1 mm
(c) Cortoid, nucleated (top) and composite (bottom), Paleocene, Iraq, 1cm = 0.05 mm
(d) Composite, Late Cretaceous, Iraq, 1 cm = 0.10 mm
(e) Composite, Late Cretaceous, Iraq, 1 cm = 0.25 mm

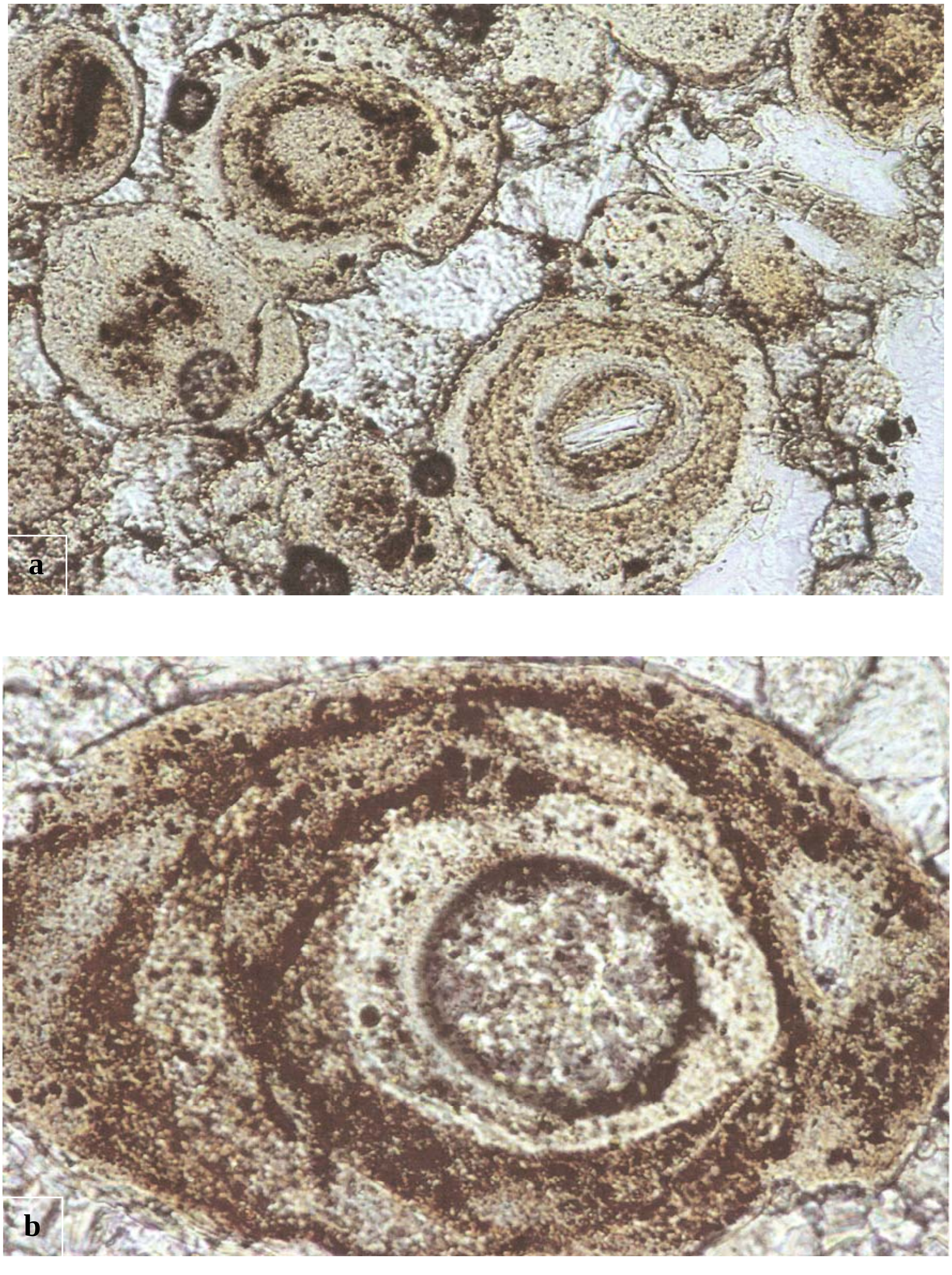

Fig.6: Phosphochem/ Coated

(a) Oncoids, Paleocene, Iraq, 1 cm = 0.1 mm
(b) Oncoid, Paleocene, Iraq, 1 cm = 0.05 mm

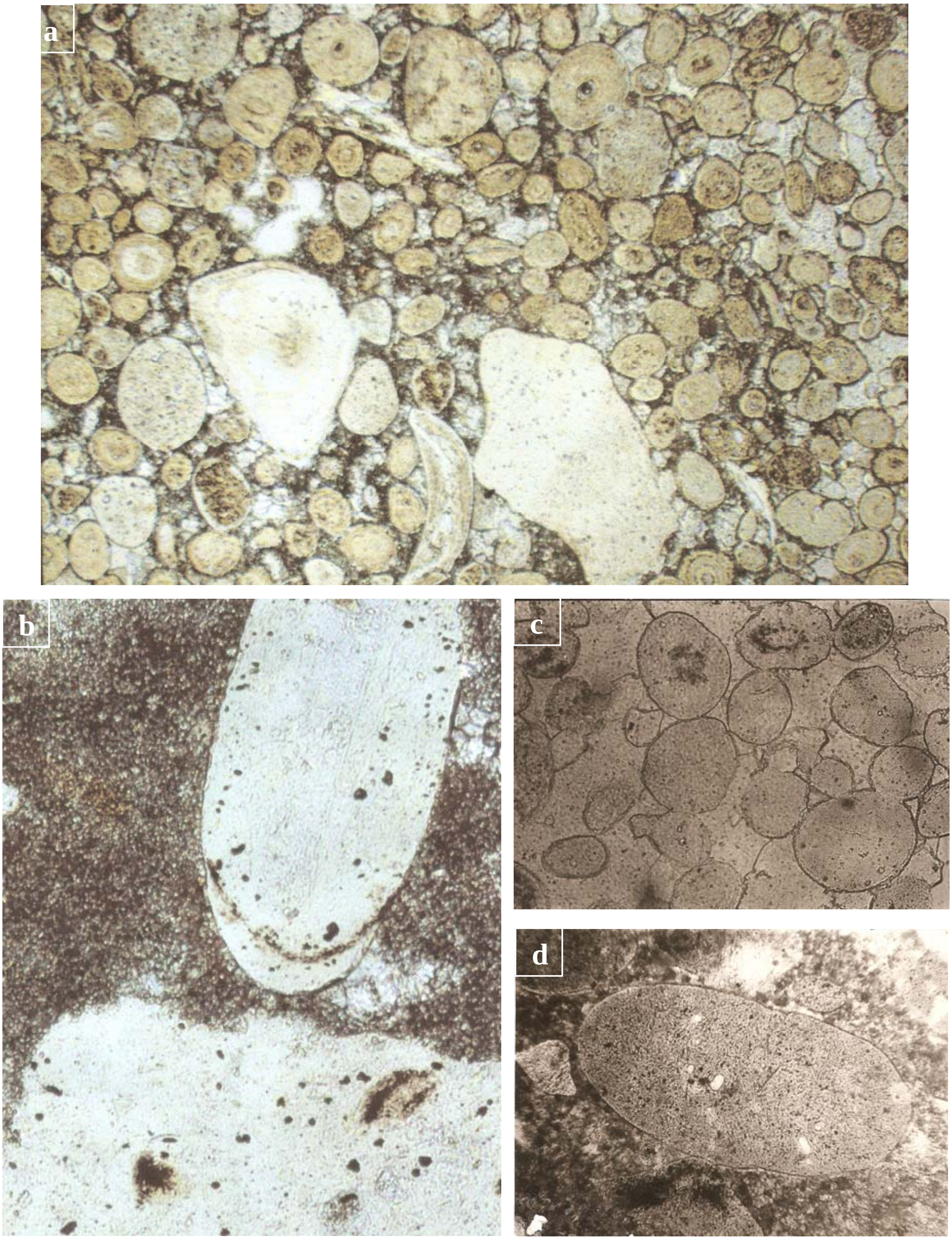

Fig.7: Phosphochem/ Non-coated
(a) Peloids (larger grains are phosphate lithoclasts), Paleocene, Iraq, 1 cm = 0.25 mm
(b) Peloid (top) and phosphate lithoclast (bottom), Paleocene, Iraq, 1cm = 0.025 mm
(c) Pleoid, Paleocene, Iraq, 1 cm = 0.05 mm
(d) Peloids, Paleocene, Iraq, 1 cm = 0.1 mm

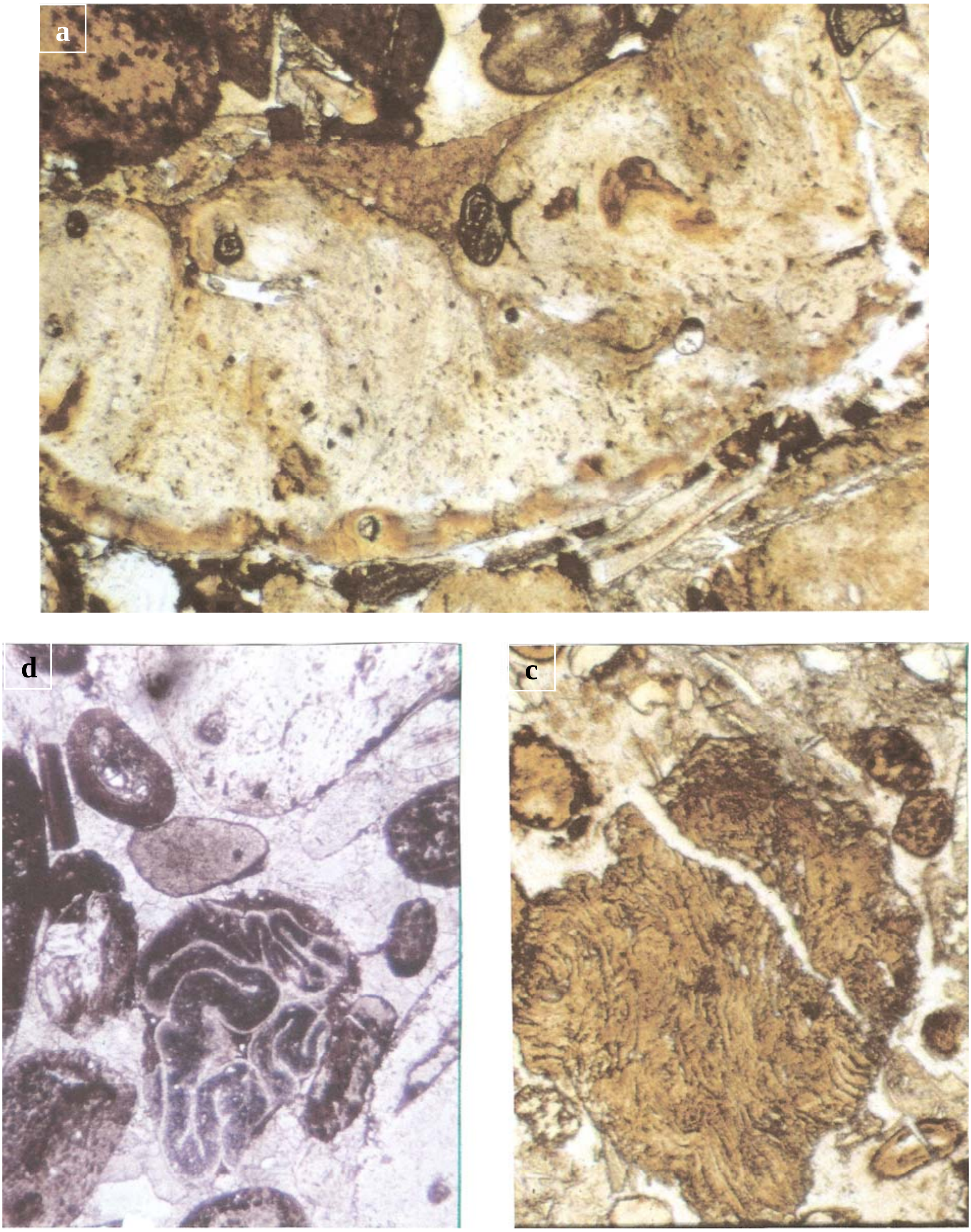

Fig.8: Phosphochem/ Non-coated
(a) Coprolite, Late Cretaceous, Egypt, 1 cm = 1 mm
(b) Coprolite, Late Cretaceous, Iraq, 1 cm = 1 mm
(c) Coprolite, Late Cretaceous, Egypt, 1 cm = 0.5 mm

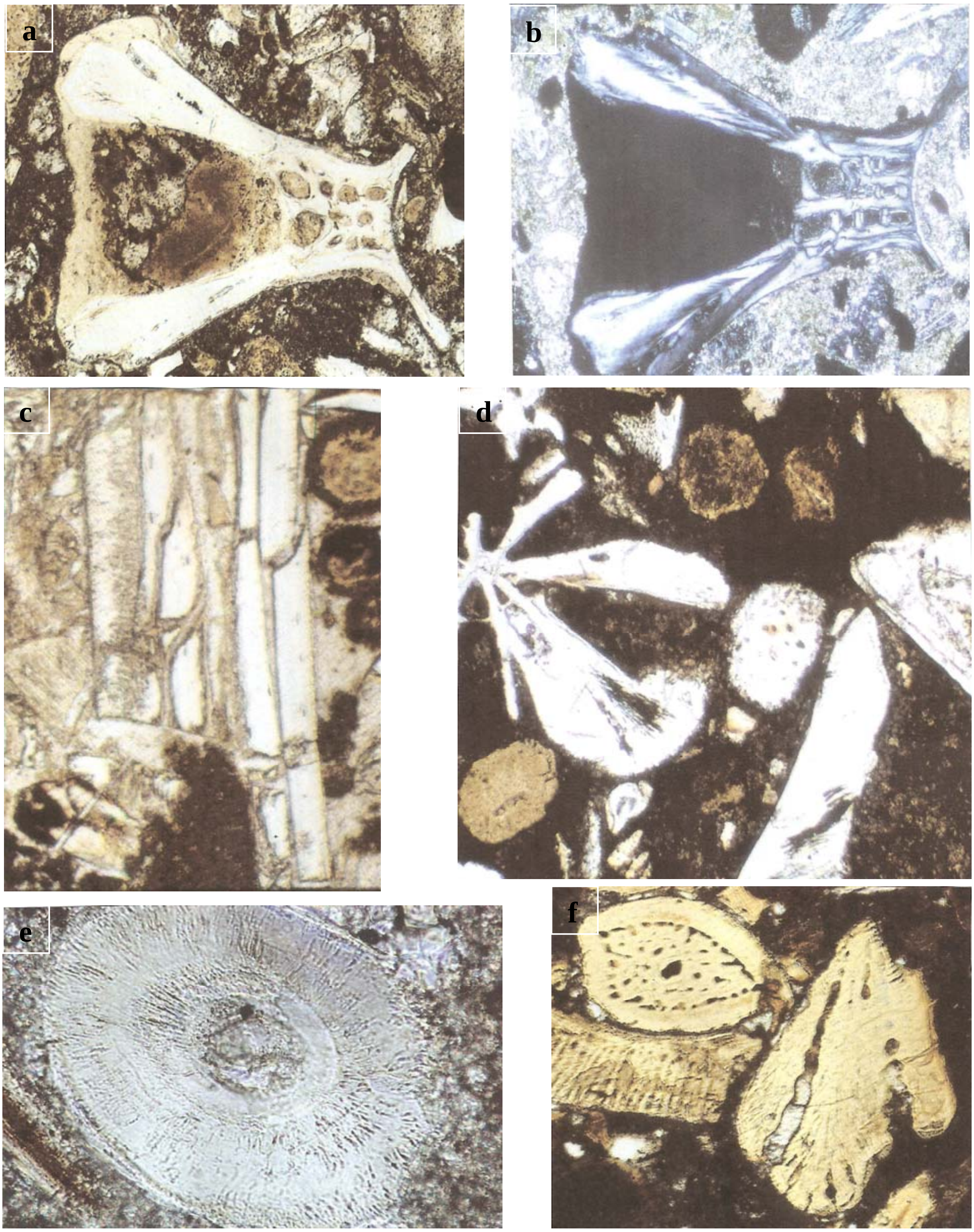

Fig.9: Phosphoclast/ Bioclast
(a and b) Phosphate fish spine, Palestine, Late Cretaceous
(a) ppl, (b) xn, 1 cm = 0.1 mm
(c and d) Phosphate fish scales, Egypt, Late Cretaceous, 1 cm = 0.1 mm
(e) Section in a fish tooth, Saudi Arabia, Paleogene, 1 cm = 0.25 mm
(f) Phosphate fish bones and section in fish tooth, Egypt, Late Cretaceous, 1 cm = 0.1 mm

## DOMINANT OCCURRENCE IN THE SEDIMENTARY ENVIRONMENT

Phosphoclasts (bio-and lithoclasts) are normally found in the highly agitated parts of the shelf (near-shore and top of shoals), usually associated with other clastics. Coated phosphochems form mostly in the inner shelf environment, under moderate energy, whereas non-coated grains (peloids) are dominant in the outer shelf. Coprolites may be found every where, but mostly in the inner shelf. Phosphomud may be found in the shelf edge as matrix or in the subtidal parts of the inner shelf as cementing material. A possible occurrence of a stromatolitic type of phosphomud, formed in the intertidal environments, can not be excluded in the East Mediterranean deposits but can not be confirmed at this stage (Fig.10).

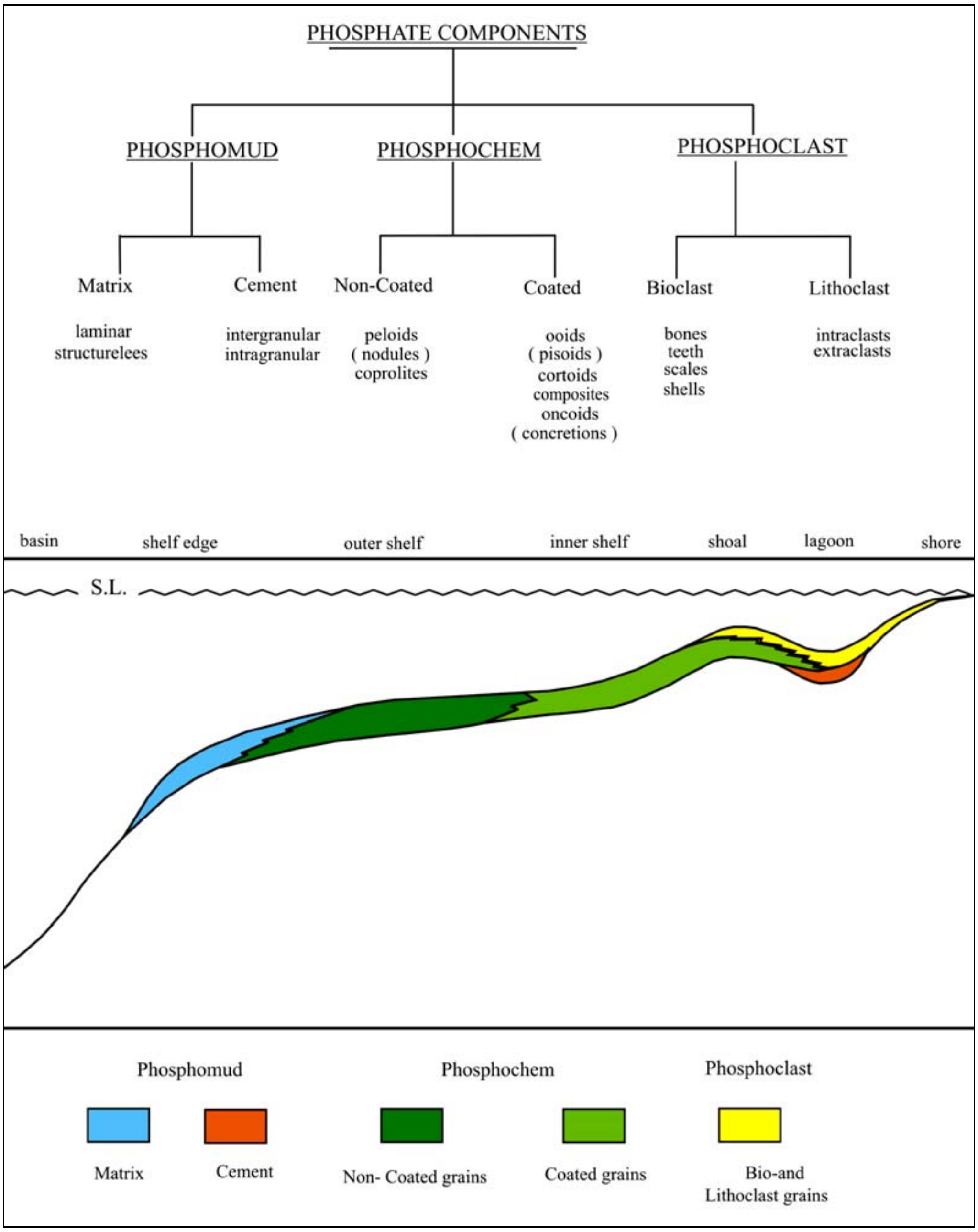

Fig.10: Classification and dominant occurrence of phosphate components in marine shelf environments

## CONCLUSION

The authors do not claim that the classification presented in this paper is perfect to identify phosphate components in phosphorites. However, based on the number of samples studied and the number of phosphate deposits in the East Mediterranean region covered by this study, it is possible to conclude that the suggested classification covers most of the variables and types of marine sedimentary phosphate components in this part of the Tethyan Phosphogenic Province. The suggested classification is easy to use, clear and precise in definition, useful as an environmental indicator of deposition and can be used in the field (major classes) as well as in the microscopic studies (detailed classes).

## ACKNOWLEDGMENS

Thanks are due to Miss. Zainab S. Haddu, Miss. Mariam A. Kaka and Mr. Ali Mahmoud for their help in typing and reproduction of the figures of this paper.

## REFERENCES

Aba-Hussain, A., 1987. Geochemical, petrographical and mineralogical study of Paleocene phosphatic units in Ga'ara –Akashat area. Ph.D. Thesis, University of Baghdad, 277pp.

Abed, A. and Fakhouri, K., 1990. Role of microbial processes in the genesis of Jordanian Upper Cretaceous phosphorite. In: A.J., Notholt and I., Jarvis (Eds.), Phosphorite Research and Development. Geol. Soc., London, special publication, No.52, p. 193 – 203.

Ahluwalia, A.D., 1988. Some alternative petrographic classification based on study of Tethyan (Lesser Himalayan) phosphorites. IGCP Project 156, Newsletter No.19, p. 24 – 25.

Akturk, A., 1979. Stratigraphy of the SE Turkey and correlations of phosphate deposits. MTA report, 16pp, (Ankara).

Al-Bassam, K., 1974. The mineralogy and geochemistry of the marine sedimentary phosphate deposits of Iraq and other areas in the Middle East. Ph.D. Thesis, University of Wales (UK), 360pp.

Al-Bassam, K., 1976. The mineralogy, geochemistry and genesis of the Akashat phosphorite deposit, Western Iraq, Jour. Geol. Soc. Iraq, Vol.9, p.1 – 33.

Al-Bassam, K., 1988. Geology and reserve estimation of the Swab phosphorite deposit, Western Desert. GEOSURV, int. rep. no. 1940.

Al-Bassam, K. and Al-Hashimi, H., 1982. Middle Eocene phosphorites in the Western Desert, Iraq. GEOSURV, int. rep. no. 1154.

Al-Bassam, K. and Hagopian, D., 1983. Lower Eocene phosphorites of the Western Desert, Iraq. Sediment. Geol., Vol.23, p. 295 – 316.

Al-Bassam, K., Aba-Hussain, A., Mohamed, I. and Al-Rawi, Y., 1988. Petrographic classification of phosphate components in phosphorites. A preliminary proposal for East Mediterranean deposits. IGCP Project 156, Newsletter No.19, p. 22 – 23.

Al-Bassam, K., Al-Haza'a, S. and Aba-Hussain, A., 2005. Microbial role in phosphogenesis: Evidence from Late Cretaceous – Early Tertiary phosphorites of Iraq. Iraqi Geol. Jour., Vol.34 – 38, p. 119 – 129.

Al-Dahan, A., 1977. Petrology and geochemistry of Upper Cretaceous phosphatic rocks from Western Desert, Iraq. M.Sc. Thesis, University of Baghdad, 217pp.

Al-Jaleel, H.S., 1983. Geochemistry and mineralogy of Lower Eocene phosphorites in the Western Desert area. M.Sc. Thesis, University of Baghdad, 147pp, (in Arabic).

Al-Maleh, K., 1974. Les phosphates Senoniens du Nord-Quest Syrien. C.R. Acad. Sc. Paris, Vol.278, p. 1003 – 1006.

Ames, L.L., 1959. The genesis of carbonate apatite. Econ. Geol., Vol.54, p. 829 – 841.

Balson, P.S., 1980. The origin and evolution of Tertiary phosphorites from Eastern England. Jour. Geol. Soc. London, Vol.137, p. 723 – 729.

Braithwaite, C.J.R., 1980. The petrology of oolitic phosphorites from Esprit (Aldabra), Western Indian Ocean. Philosophical Transactions of the Royal Soc. of London, Vol.288, p. 512 – 542.

Carozzi, A.V., 1960. Microscopic Sedimentary Petrography; Ch.8: Phosphatic Rocks, p. 373 – 403. John Wiley and Sons, N.Y.

Cook, P.J., 1972. Petrology and geochemistry of the phosphate deposits of northwest Queensland, Australia. Econ. Geol., Vol.67, p. 1193 – 1213.

Cook, P.J., 1976. Sedimentary phosphate deposits. In: K.H., Wolf (Ed.), Handbook of stratabound and stratiform ore deposits. Elsevier Publ. Co., Amsterdam, p. 505 – 535.

Cook, P.J., Shergold, J.H., Burnett, W.C. and Riggs, S.R., 1990. Phosphorite research: a historical overview. In: A.J.G., Notholt and I., Jarvis (Eds.), Phosphorite Research and Development. Geol. Soc. London, special publ. No.52, p. 1 – 22.

Dunham, R.J., 1962. Classification of carbonate rocks according to depositional texture. In: W.E., Ham (Ed.), classification of Carbonate Rocks. Am. Ass. Petrol. Geol. Mem. Jour. p. 108 – 121.

El-Shazly, E.M., El-Hazek, N.M. and El-Mahrouky, F.K., 1972. Mineralogical study on East Luxor rock phosphate as a basis for its technology. Transactions of the Arab Mining and Petroleum Association, ARE, Vol.27, p. 165 – 196.

Folk, R.L., 1959. Practical petrographic classification of limestones. AAPG Bull., Vol.43, p. 1 – 38.

Freas, D.H. and Riggs, S.R., 1968. Environments of phosphate deposition in the central Florida Phosphate district. University of Texas, Bureau of Economic Geology. Proc., 4th Forum on the Geology of Industrial Rocks, p. 117 – 128.

Ghanem, M., Zalata, A., Abd El- Razik, T., Mikhailov, I., Razraliaev, A. and Mirtov, Y., 1970. Stratigraphy of the phosphate-bearing Cretaceous and Paleocene sediments of the Nile Valley between Idfu and Qena. Studies on some mineral deposits of Egypt. UAR Geol. Surv., Article 7, p. 109 – 134.

Gulbrandsen, R.A., 1960. Petrology of the Meade Peek Phosphatic shale member of the Phosphoria Formation at Coal Canyon, Wyoming. Bull. U.S. Geol. Surv., V.1111-c, p. c71 – c146.

Gulli, I., 1989. Mineral prospecting and reserve estimation of Marbat phosphorite deposit, W. Desert. GEOSURV, int. rep. no. 1966.

Horton, A., Ivimey-Cook, H.C., Harrison, R.K. and Young, B.R., 1980. Phosphatic ooids in the Upper Liass (Lower Jurassic) of central England. Jour. Geol. Soc. London, Vol.137, p. 731 – 740.

Ilyin, A.V., Ratnikov, G.I. and Sergeeva, N.E., 1975. Petrographic type of layered phosphorites and their microstructure. Lithology and Mineral Resources, Vol.10, p. 85 – 94. Translated by: Plenum Publ. Corp.

Kazakov, A.V., 1937. The phosphorite facies and the genesis of phosphorite In: Geological Investigation of Agricultural Ores. Sci. Instit. Fertilizers and Insecto-Fungicides. Trans. No.142, p. 95 – 113.

Kennedy, W.J. and Garrison, R.E., 1975. Morphology and genesis of nodular phosphates in the Cenomanian glauconitic marl of south-east England. Lethaia, Vol.8, p. 339 – 360.

Kidder, D.L., 1985. Petrology and origin of phosphate nodules from the mid-continent Pennsylvanian epicontinental Sea. Jour. Sed. Pet., Vol.55, p. 809 – 816.

Lamboy, M., 1990. Microbial mediation in phosphogenesis: New data from the Cretaceous phosphatic chalks of northern France. In: A.J.G., Notholt and I., Jarvis (Eds.), Phosphorites Research and Development. Geological Soc. London, Special Publication, No.52, p. 157 – 167.

Lamboy, M. and Monty, C., 1987. Bacterial origin of phosphatized grains. Terra Gognita, Vol.7, p. 207.

Lucas, J. and Prevot, L., 1985. The synthesis of apatite by bacterial activity: Mechanism. Science Geologiques, Strasbourg, Memoire No.77, p. 83 – 92.

Mabie, C.P. and Hess, H.D., 1964. Petrographic study and classification of Western phosphate ores. U.S. Bureau of Mines. Report of Investigation, No.6468, p. 7 – 92.

Marshal, J.F. and Cook, P.J., 1980. Petrology of iron and phosphorite-rich nodules from the East Australian continental shelf. Jour. Geol. Soc. London, Vol.137, p. 765 – 771.

McClellan, G.H., 1980. Mineralogy of carbonate fluorapatite. Jour. Geol. Soc. London, Vol.137, p. 675 – 681.

Mohamed, I.Q., 1985. Petrology and geochemistry of Upper Cretaceous – Paleocene phosphatic rocks in the Rutba – $H_3$ area, Western Desert, Iraq. M. Sc. Thesis, University of Baghdad, 267pp.

Mohamed, I. and Jassim, R.Z., 1988. Geology and sedimentology of Nukhaib phosphate deposit, Western Iraq. GEOSURV, int. rep. no. 1768.

Notholt, A.J.G., 1985. Phosphorite resources in the Mediterranean (Tethyan) Phosphogenic Province: A progress report. Sci. Geol. Mem., No.77, p. 9 – 21 (Strasbourg, France).

O'Brien, G.W., Harris, J.R., Milnes, A.R. and Veeh, H.H., 1981. Bacterial origin of East Australian continental margin phosphorites. Nature, Vol.294, p. 442 – 444.

Pettijohn, F.J., 1957. Sedimentary Rocks. Harper and Row Publ., N.Y., 718pp.

Prevot, L. and Lukas, J., 1988. Phosphate petrography data base. IGCP Project 156, Newsletter, No.19, p. 20 – 21.

Purnachandra, R. and Nair, R.R., 1988. Microbial origin of the phosphorites of the western continental shelf of India. Marine geology, Vol.84, p. 105 – 110.

Riggs, S.R., 1979. A petrographic classification of sedimentary phosphorites. In: P.J., Cook and J.H., Shergold (Eds.), Proterozoic – Cambrian Phosphorites. IGCP, 156, 1st field workshop and Seminar, Canberra. National Library of Australia.

Slansky, M., 1979. Proposals for the nomenclature and classification of sedimentary phosphate rocks. In: P.J., Cook and J.H., Shergold (Eds.), Proterozoic – Cambrian Phosphorites. IGCP, 156, 1st field workshop and Seminar, Canberra. National Library of Australia.

Soudry, D. and Nathan, Y., 1980. Phosphate peloids from the Negev phosphorites. Jour. Geol. Soc. London, Vol.137, p. 749 – 755.

Soudry, D. and Champetier, Y., 1983. Microbial processes in the Negev phosphorites. Sedimentology, Vol.30, p. 411 – 423.

Southgate, P., 1986. Cambrian phosphocrete profiles, coated grains and microbial processes in phosphogenesis: Georgina Basin, Australia. Jour. Sed. Pet., Vol.56, p. 429 – 441.

Trueman, N.A., 1971. A petrological study of some sedimentary phosphorite deposits. Bull. Australian Mineral Development Laboratories. No.11, 65pp.

Zanin, Y., Letov, S.V., KrasiĺnikovaLetov, N.A. and Mirtov, Y.V., 1985. Phosphatized bacteria from Cretaceous phosphorites of European Platform and Paleocene phosphorites of Morocco. Sci. Geologiques, Memoir No.77, p. 79 – 81 (Strasbourg, France).