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MICROFACIAL ANALYSIS AND ENVIRONMENTAL DEVELOPMENT OF THE DUWI (PHOSPHATE) FORMATION, QUSEIR-SAFAGA DISTRICT, EASTERN DESERT, EGYPT

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ABSTRACT

Microfacial analysis, based on six stratigraphic sections, were carried out to the Duwi (Phosphate) Formation at the coastal plain of Quseir-Safaga along the Red Sea coast. The study showed that the main rock types are: phosphorite, organic-rich shale, siliceous claystone, glauconitic sandstone, chert, dolomite, and oyster limestone. Detailed field and microfacial investigations of these rock types were done.

The paleogeographical distribution of the Duwi (Phosphate) Formation was found to be influenced by biological and chemical parameters which was necessary for the precipitation of calcium phosphates. Other factors controlling the areal extent include water depth, wave base and current velocity.

INTRODUCTION AND PREVIOUS WORK

The Duwi (Phosphate) Formation occurs as a thin widespread shallow marine sediments which were deposited in an east-west trending belt spanning the middle latitudes of Egypt. These rocks lie near the base of a transgressive marine sequence, which was deposited during Late Cretaceous time on the northern edge of the Arabo-African craton. The formation comprises a shallow marine heterogenous sediment which overlies the Variegated Shales and underlies the Dakhla Shales. The present study is restricted at the Duwi (Phosphate) Formation in the Quseir-Safaga district and along the Red Sea coast where these rocks are well exposed, and the six sections were taken (*Fig. 1* and *2*). The main task is to reconstruct the depositional history and environmental development of the Duwi (Phosphate) Formation.

BARRON and HUME (1902) studied the topography and structure of the central portion of the Eastern Desert including the Quseir-Safaga region. They considered the whole series of Esna Shales (Dakhla Shale, Chalk and Esna Shale of Said, 1962) as Eocene and they determined the unconformity between the Cretaceous and Eocene. BALL (1913) examined the Safaga district, around Um El-Huetat mines. He regarded the phosphate beds as Upper Cretaceous. HUME *et al.* (1920) studied the area between Quseir and Safaga. They regarded the phosphate beds as Campanian. BEADNELL (1924) dealt with the coastal plain of the Red Sea between Quseir and Wadi Ranga. The phosphate beds in the *Ostrea villie* limestones were given as Upper Senonian (Campanian) age. YOUSSEF (1957) described the stratigraphy of the Upper Cretaceous rocks in the Quseir area. A Campanian-Maastrichtian age was assigned to the Duwi (Phosphate) Formation, which confirmed by SAID (1962).

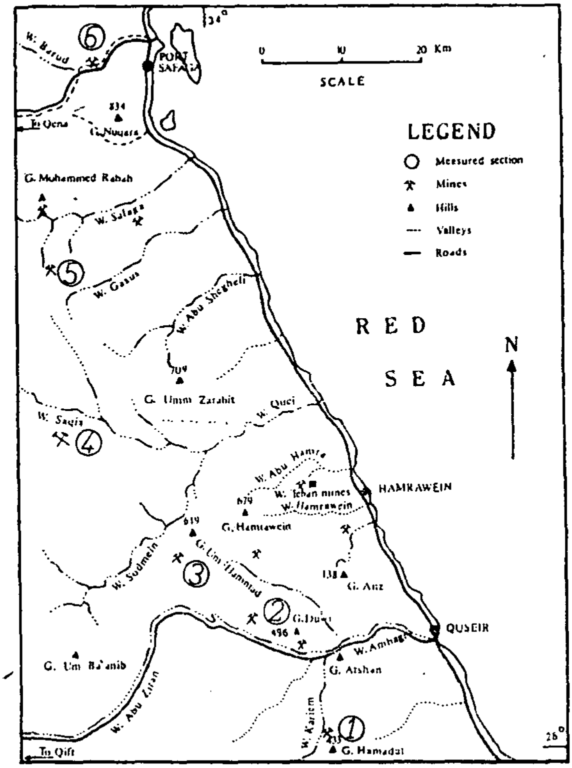


Fig. 1. Location map of the Quseir-Safaga district, Eastern Desert, Egypt
Stratigraphic sections:

1. Gebel Hamadat mine
2. Beida mine
3. Gebel Um Hamad mine
4. Wadi El-Saqia
5. Wassif mine
6. Wadi Barud

ABDEL RAZIK (1967) studied the stratigraphy of the sedimentary rocks in the area of Anz-Atshan-South Duwi region. He considered the Duwi (Phosphate) Formation as Maastrichtian age. ISSAWI *et al.* (1969) considered the Duwi (Phosphate) Formation to include all the phosphate beds which overlies the Quseir Variegated Shale and underlies the Dakhla Shale. The following fossils were identified: *Pecten farafrensis, Ostrea villei, Trigonoarca multidentata, Lucina dachlensis, Raudaireia drui, Libycoceras phosphaticus.* These faunal assemblage suggest Maastrichtian age, which conforms with the age assigned, to the Duwi (Phosphate) Formation in Safaga by EL-AKKAD and DARDIER (1966) and by AWAD (1964).

The beds of the Duwi (Phosphate) Formation were recently examined for micro- and nannofossils by MOHAMED (1982). Samples from the base contains the benthonic foraminifers *Ammodiscus mangusi* and *Lituola undulosa*, while, samples from the upper part of the formation contains the planktonic species *Pseudoguembelina costulata, Pseudoguembelina excolata, Heterohelix globulosa* and *Globotrun-*

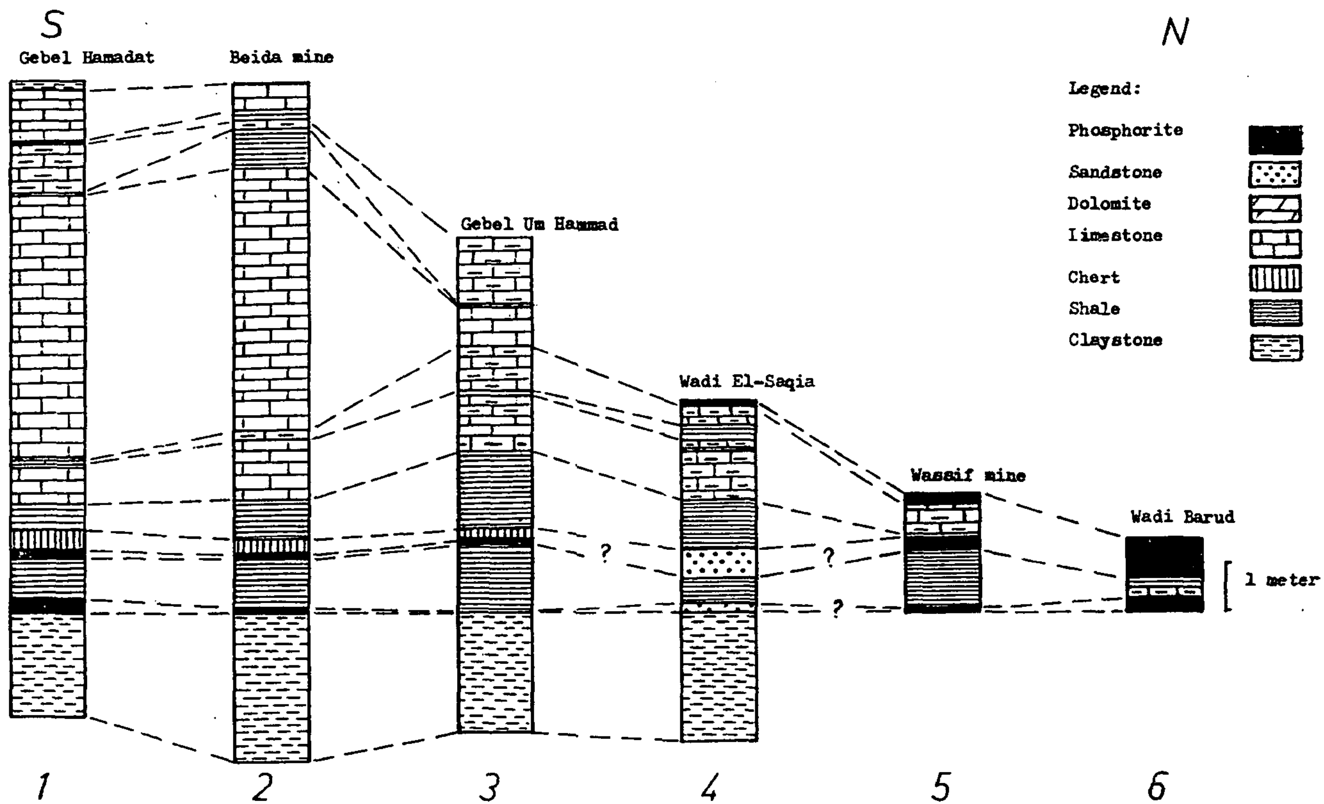


Fig. 2. Correlation chart of the studied sections of the Duwi (Phosphate) Formation, Quseir-Safaga district, Eastern Desert, Egypt

cana aegyptiaca. Herewith, the presence of the *Globotruncana aegyptiaca* zone is confirmed. This zone characterizes the top of the lower Maastrichtian. Furthermore, the nannoplankton zone *Quadrum trifidum* in association with *Micula staurophora* is present at the top of the formation. Therefore, the Duwi (Phosphate) Formation is considered of Campanian age in its lower part and of Maastrichtian age in its upper part, which conforms with the age assigned, to the Duwi (Phosphate) Formation in Quseir area, by YOUSSEF (1957), SAID (1962), WILLIAM and SHETA (1967, in ALLAM *et al.*, 1981: *Fig. 1*), and BARAKAT and EL-DAWOODY (1973).

MICROFACIAL ANALYSIS

The rocks of the Duwi (Phosphate) Formation include many varieties, e.g. phosphorite, organic-rich shale, siliceous claystone, glauconitic sandstone, chert, dolomite, and oyster-limestone. Field observations in the Quseir-Safaga district showed, that these rocks are lense shaped terminating both to the north and south, and thinning also to the east. The depositional environment deduced from lateral and vertical distribution of the facies could be either: a) an environment primarily controlled by hemipelagic deposition, or b) an environment favourable to the deposition of calcareous sediment. Hemipelagic environments are likely to be represented by shales and siliceous claystone, whereas limestone, dolomite, and marl facies are characteristic of environments dominated by calcareous deposition.

Siliceous claystone

The siliceous claystones are characteristically finely laminated or thinly bedded, predominantly siliceous fine-grained claystones which often contain scattered cryptocrystalline collophane intraclasts. The silica in these rock-types is usually present as microcrystalline cement. Other constituents include very fine silicate or carbonate grains together with some glauconite.

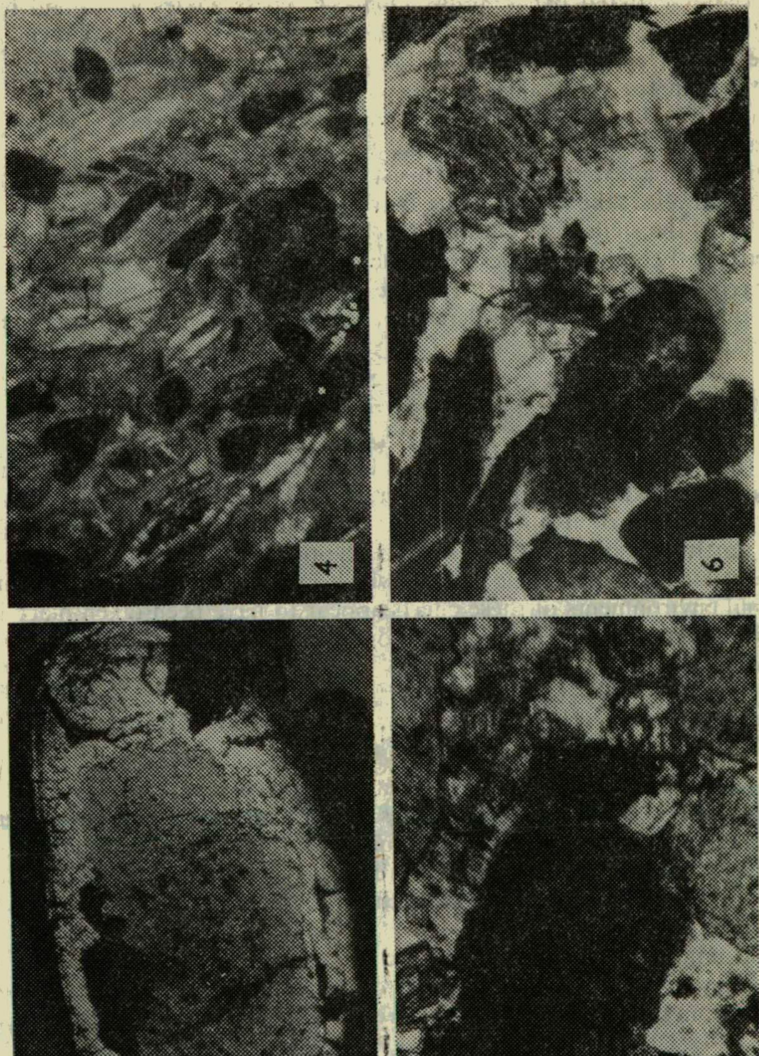
Study of the stratigraphic limits of the Duwi (Phosphate) Formation, revealed that the claystones are predominantly laterally confined to the exposures along Gebel Um Hammad, Gebel Duwi, and Gebel Hamadat. The siliceous claystones are generally confined to the base of the Duwi (Phosphate) Formation. These rocks appear to have been deposited within a relatively terrigenous free, low energy hemipelagic environment. The presence of glauconite and phosphate grains indicates that these rocks were probably deposited under a slightly reducing conditions.

Fig. 3. Photomicrograph of a polished section showing crystalline envelope of pyrite surrounding the pyrite grain, the core is formed of finely dispersed minute cryptocystalline pyrite. (reflected light, 6.3×30)

Fig. 4. Photomicrograph of thin section showing collophane grains and skeletal remains embedded in the ground mass (crossed nicols, 2.5×12.5)

Fig. 5. Photomicrograph of a thin section showing a collophane grain embedded in a ground mass totally composed of dolomite (crossed nicols, 2.5×12.5)

Fig. 6. Photomicrograph of a thin section showing collophane grains of different shapes, sizes, and structures (crossed nicols, 2.5×12.5)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Organic-rich shale

The shales are black to grey, finely laminated to thinly bedded, fissile, organic-rich, and containing some intercalated siltstones. The shales contain abundant fish fragments and scattered pyrite grains *(Fig. 3)*. These shales are found to contain small collophane nodules which have white to brown colour and form a shabby surface texture. The collophane grains *(Fig. 4)* reside either as scattered intraclasts that float within the groundmass or mixed with fish fragments and bone remains.

Within the Duwi (Phosphate) Formation, the organic-rich shale is laterally widespread throughout the investigated area, reaching maximum thickness along Gebel Um Hammad, thinning in southeast exposures, and disappearing to the north and south. However, the shales of the Duwi (Phosphate) Formation is lithologically very similar to the shale beds comprising the Variegated Shale, and that those units might actually be time-transgressive facies equivalents. The presence of organic-matter, pyrite, phosphate grains, and the general lack of bioturbation structures, indicates that these shales were deposited in a reducing, marginal marine or even shallow-marine environment.

Chert

The rock type consists of dark grey banded cherts, silicified fine-grained claystones, and silicified phosphorites. The remarkable feature of these rocks is the common occurrence of fissured bedding. The chert is widespread throughout all the areas north and south of Gebel Duwi. The presence of rock fragment intercalations is restricted in northern localities, which indicate high current velocities. The depositional environments of these cherts appear to have been taken place in conditions of low-energy hemipelagic deposition intermittenly disrupted by high-energy current activity.

Oyster limestone

This type of limestone consists of a heterogenous assemblages of faunal communities in which *Ostrea villie* predominantes. Oyster valves are unusually rugged. The limestone beds thin towards the east and northwest, but lacking in the north.

Actually, the oyster assemblages are largely restricted to the southwestern exposures, and it is apparently observed that the thick oyster beds are developed in southerly area.

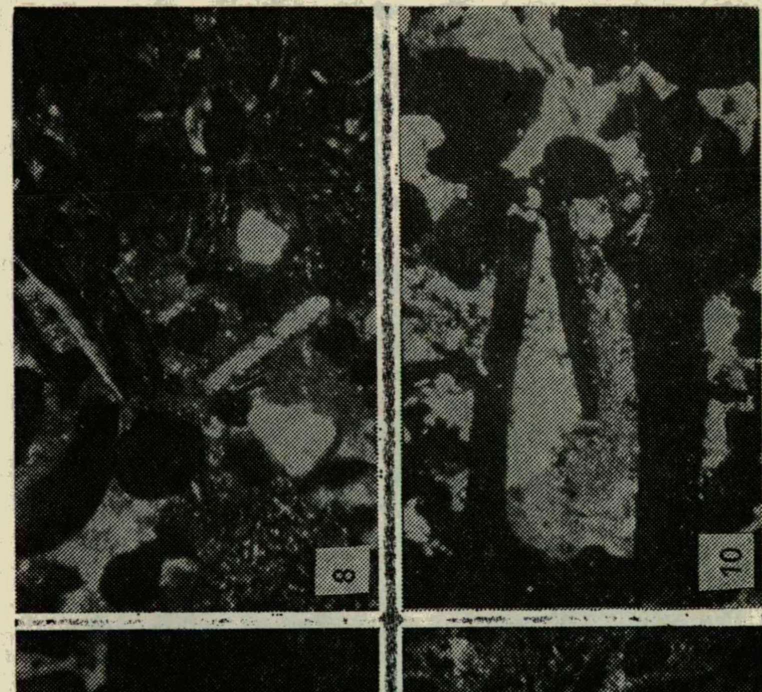
The accumulation of thick bioclastic remains forming the limestone of these deposits, together with the development of low-angle cross bedding, suggest that these faunal communities lived in a relatively high energy environment.

Fig. 7. Photomicrograph of a thin section showing coarse grained coprolite (crossed nicols, 2.5×12.5)

Fig. 8. Photomicrograph of thin section showing collophane grains and skeletal fragments embedded in the ground mass (crossed nicols, 2.5×12.5)

Fig. 9. Photomicrograph of a thin section showing fine crystalline calcite forming the ground mass (crossed nicols, 2.5×12.5)

Fig. 10. Photomicrograph of a thin section showing fine crystals of calcite enclosed in collophane (crossed nicols, 2.5×12.5)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Dolomite

This rock type is characterized by ochre-yellow colour and has a finely laminated appearance. Microscopic investigation reveals that these rocks consist of very fine crystalline dolomite rhombs *(Fig. 5)*. Regardless to the presence of several dolomite concretions found throughout the investigated area, the rocks of this type are found to be mainly restricted to southeastern localities. These dolomite are most probably formed by metasomatic replacement.

Glauconite sandstone

Although glauconitic sandstones appear to be widely dispersed throughout the upper part of the Variegated Shale, however, they are found to be of very limited occurrence within the Duwi (Phosphate) Formation. These rocks are mainly associated with black fissile shales. The glauconitic deposits are fine to medium-grained, well sorted, and consist of friable green galuconite-intraclast bearing quartz sandstones bound with a ferruginous cement. Observation of bedding surfaces has shown that they are characterized by a small scale ripple laminations indicating moderately high energy levels during deposition. The formation of glauconite requires slightly reducing conditions, weakly oxidizing and therefore may be linked to the upper- or lowermost levels of the oxygen-minimum zone.

Phosphorite

Particular attention was previously given to these phosphate bands by ALLAM *et al.* (1981, 1982 and 1983). The phosphorites are found to range from phosphatic fossiliferous pelmicrites to biosparites, i.e., phosphatic and carbonate allochemical constituents reside in a micrite matrix and/or a sparry cement *(Fig. 6, 7, 8, 9, 10* and *11)*. Siliceous and sometimes phosphatic cement was noticed. This rock type contains 30—60% collophane grains together with minor amounts of detrital quartz and/or feldspat grains. Phosphatic grains are primarily of skeletal, pelletal, or intraclast types. Skeletal grains include marine vertebrate bone fragments, fish teeth, and remains of phosphatized shell fragments. Intraclast types are commonly composed of pellets and fish remains bound by phosphatic cement. Pelletal grains range from silt to pebble size with subangular to well rounded shape. Ovoid-shaped grains

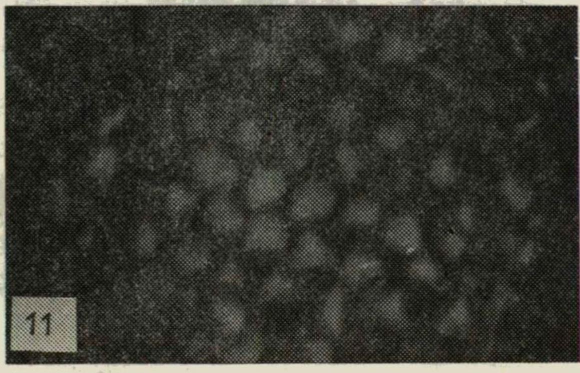

Fig. 11. Photomicrograph of a polished section showing an enlarged collophane grain containing an advanced stage of the globular pyrite network with organic material filling (reflected light, 6.3×30)

resemble phosphatized fecal pellets. Shallow scour-fill structures are common at the lower part and basal contacts and are commonly highly bioturbated. The phosphorite beds are widely distributed both laterally and vertically throughout the investigated area. They may range from few millimeters to few meters in thickness. Phosphorite deposits are usually intercalated with other rock types presented, but mainly associated with the siliceous claystones and organic-rich shales.

The phosphorite rocks of the Duwi (Phosphate) Formation are clastic sedimentary deposits that have probably accumulated through mechanical winnowing, reworking, and concentration of pre-existing phosphatic sediments. As previously mentioned siliceous claystones contain scattered phosphatic grains and skeletal fragments. These hemipelagic deposits represent a suitable source rocks from which the phosphorite beds were derived. Therefore, the relatively quiet, low-energy depositional environment of these hemipelagic sediments must have been interrupted from time to time by extensive high energy conditions. Such high-energy conditions seem to be attributed to wind- and wave-induced currents. Such currents can remove and rework the seafloor well below fair weather wave base. The fact that basal contacts of phosphorite beds are commonly highly bioturbated suggests that intermittent storm currents helped to oxygenate the anaerobic (or anoxic) bottom waters.

CONCLUSION

The study obviously indicate that the Duwi (Phosphate) Formation, in general has been mostly deposited in a marine environment. This marine environment is most probably poor in oxygen content. The deposition of the Duwi (Phosphate) Formation (phosphorite, siliceous claystone, and organic-rich shale) agrees with such conditions. However, the oyster limestone reflect the depositional settings isolated from such anaerobism. Such isolation must have been the result of either vertical or lateral distance from the oxygen-minimum-zone. Vertical effects could be attributable to such phenomenon as development of oyster reefs on topographic accumulations, whereas lateral isolation may be linked to a shore-ward development or reefal communities. Many differences exist between the general hydrologic, geographic, and tectonic environments associated with the recent phosphorite sea floor deposits and those of the Duwi (Phosphate) Formation. However, these modern deposits appear to be very similar to the siliceous claystone and shale facies associated with the origin of the Duwi (Phosphate) Formation phosphorites.

A highly generalized sequence of events leading to the formation of the Duwi (Phosphate) Formation phosphorite deposits can be summarized as follows: a) Nutrient-rich oxygenated waters are brought to the basin of deposition which resulted in high rates of biological productivity. These nutrient-rich waters may be associated with upwelling of bottom currents from the Tethyan seaway at the north during Late Cretaceous time. b) Large amounts of biogenic sedimentation in the form of diatoms, coprolites, and other organic remains. Biogenic debris settling within the oxygen-minimum-zone, is largely removed from the biochemical cycle. c) Oxidation of organic remains along the borders of the oxygen-minimum-zone due to sulphate reduction which mobilizes dissolved phosphate ions in pore waters. d) Collophane precipitation in anoxic sediments was most probably achieved, by: either rise in pH due to decomposition of organic matter, or deficiency of magnesium ion due to replacement of Fe^{3+} in clays of authigenic formation of dolomite and/or magnesium-rich silicates. e) These deposits are then winnowed and concentrated into phosphorite beds by currents generated during storm acitivities.

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