Sci. J. Fac. Sci., Menufiya Univ. Vol. XIII (1999) (91 - 109)

THE STRUCTURE AND FUNCTIONAL SIGNIFICANCE OF THE WALL OF SQUEEZED *Haplophragmoides excavatus* CUSHMAN & WATERS (AGGLUTINATED FORAMINIFERA)

By

Orabi H. Orabi

Geology department, Faculty of Science, Menoufia University

ABSTRACT

Haplophragmoides excavatus Cushman & Waters has undifferentiated organic cement morphotype connects particles at point of contact. The individual elements of the agglutinated grains of the septa are oriented, producing a fairly tight mosaic of larger fragments at the base and smaller fragments at the top. This phenomenon has not been previously recorded and may offer a clue to identify the direction of movement of this infaunal form.

Squeezed *Haplophragmoides excavatus* Cushman & Waters have been recorded at the Cretaceous/Tertiary boundary from the Lower Kharga Shale Member (Middle-Late Maastrichtian) of the Dakhla Formation (Western Desert of Egypt). This phenomenon may be due to the fact that agglutinated tests are weakly held together by organic material, or it may be caused by the cohesive nature of the claystone beds, which include these infaunal species.

INTRODUCTION

According to Loeblich & Tappan (1989) the systematic classification of foraminifera at the hierarchically highest level of the suborder is based on the chemical composition of their biogenic secretion and on their method of test constraction. According to these double criteria for the classification of suborders, it may opinion the

Textulariina should be split into only two super groups, both having the status of a suborder (Bender, 1989a). The basic criteria used for this division should be based on the composition of biogenic cement, either organic (1st suborder) or calcite (2nd suborder).

Due to the lack of information about the formation of an inner or outer organic layer, Loeblich & Tappan (1987) could not at the time evaluate these features. According to these authors, the inner organic layer characterizes superfamilies, families and subfamilies, but most frequently genera. Bronnimann & Whittaker (1988) established the suborder of Trochamminina, which is characterized by the presence of both an inner organic layer (IOL) and an outer organic layer (OOL).

Bender (*in* Kaminski *et al.*, 1995) argued that the inner organic layer, as a fundamental component of the agglutinated test of all organically and calcareous cementing species, characterizes the highest systematic category, the suborder. He mentioned that the presence or lack of an OOL could, according to the single or multilayered IOL structure, be of diagnostic value on family level.

The examination of microstructures of *Haplophragmoides excavatus* Cushman & Waters (Textulariina) extracted from Gabal Um El Ghanayim (Kharga Oasis, Western Desert of Egypt) (Fig. 1) has gained in importance; especially there is an apparent scarcity of basic information relating to the composition and the characteristics of the cement of this species.

Few authors have contributed important new data on microstructure analysis of arenaceous foraminifera. In the present work, these data have been compiled to draw systematic and phylogenetic conclusions. This paper presents an attempt to provide a well-founded basis for these reaching conclusions. Further, the scope of the present work is to know, the composition of biogenic cement of this species (either organic or calcite). Moreover, what is the type of the organic cement morphotype of this species, its mode of life and why most of the extracted *Haplophragmoides excavatus* species are squeezed?

Wall Structures

Agglutinated wall structures have been classified by Banner *et al.* (1991) into three groups: organo-agglutinated, those with an

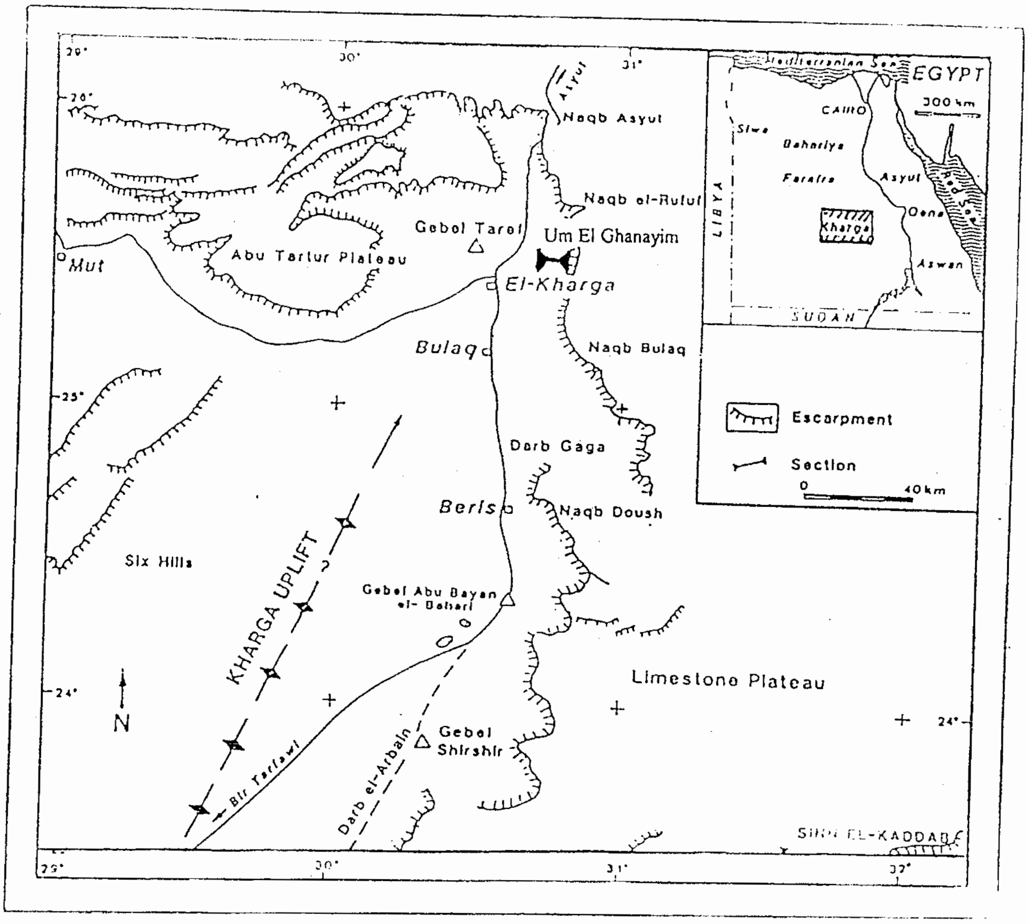


Fig.1: LOCATION MAP.

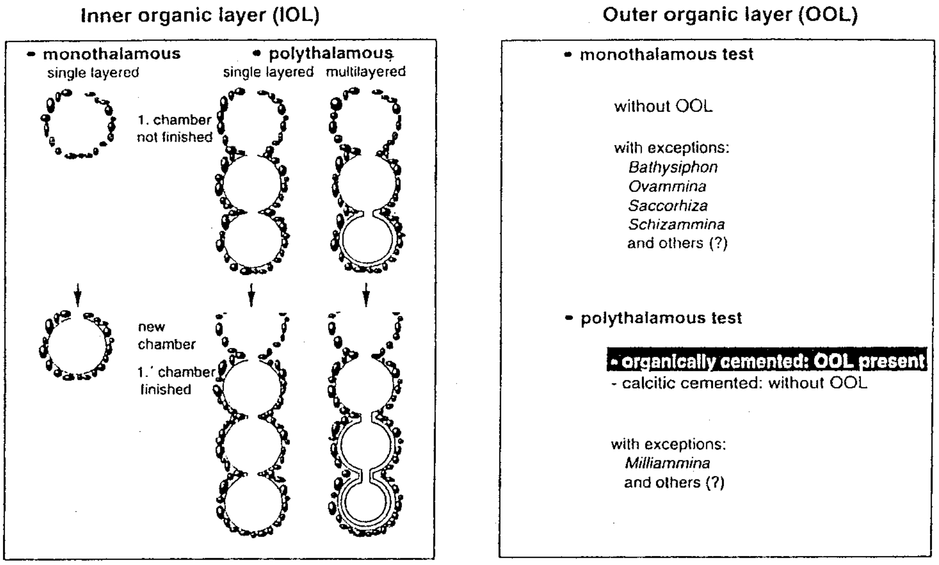


Fig. 2: Formation of organic layer (after Bender *in* Kaminski *et al.*, 1995)

Organic Cement	Modifications of cement microstructures
a) undifferentiated	• amount of organic substance
b) foam-like mass	• form of bubbles (regular at bubble contact, irregular at particle contact) • bubbles may be restricted to specific test areas
c) single strands	• disposition of strands (ordered, unordered, single, or combined in groups) • density of strands • length of strands • strands may be restricted to specific test areas
d) fibrous network	• width of the network • network may gradually change over to strands between grains <0.5 µm apart • network may be restricted to specific test areas
Calcitic Cement	• crystal sizes • disposition of crystals within bundles (bundle sizes, bundle forms) • disposition of bundles (ordered, unordered) • amount of bundles • unstructured, massive calcite deposits

Table 1: Modifications of cement microstructures (after Bender *in* Kaminski *et al.*, 1995)

organic cement only; ferro-agglutinated, those with additional ferric or other non-calcareous microgranular cements; and calc-agglutinated, those with additional calcareous cement.

Recently, Bender (*in* Kaminski *et al.*, 1995) argued that the fundamental structural characteristics of the Recent agglutinated foraminifera test are described and demonstrated into the following:

1) Organic layers, where the common feature of all agglutinated foraminifera is the formation of an inner organic layer (IOL), which is attached to the interior wall of the test. It has been shown that in a number of species a multilayered IOL develops during the entire interior of the test after the formation of each new chamber (Bender, 1989 a, b; 1992). This explains the thinly developed IOL in monothalamous species and decreasing IOL thickness towards younger chambers in some polythalamous species (Fig.2).

2) Cements, where the dominant examined species have organically-cemented tests, the remaining possess calcareous cement. The organically cementing species can further subdivided into four morphologically distinct groups according to cement morphotypes

a) Species attach particles only at the point of contact with morphologically undifferentiated cement.

b) Species use a foamy type of cement, the residual cement fragments cover the surface of the particles forming 120° angles, where they interest with each other.

c) Species use organic single strands, where the residual cement fragments project at a right angle away from the surface of the particle to connect different particles with each other (Strands)

d) Species use a network of strands. Some species use very close-meshed network cement in the proximal areas of the wall, especially in contact with the IOL, while in the distal wall area cement can be found only at inter-particles. (Table 1).

Material and Methods

Orabi (1995) recorded *Haplophragmoides excavatus* Cushman & Waters at the Cretaceous/Tertiary boundary. Specimens were provided from the Lower Kharga Shale Member (Middle-Late Maastrichtian) of Dakhla Formation of Gabal Um El Ghanayim (Kharga Oasis, Western Desert of Egypt) (Fig. 1).

The material itself is deposited in the collection of the Geology Department, Faculty of Science, Menoufia University (Pl.1, Figs.1-9). The identification of microstructures of this species is critically depending on the work of Bender (*in* Kaminski et al., 1995).

For all specimens, microstructure analysis was carried out on broken chamber walls. Scanning electron microscopy of Plymouth University (JEOL, JSM 5200) was conducted using at least ten tests of this species, which were coated with gold and examined at 25 kV.

Litho and Biostratigraphy

Lithostratigraphical subdivision of the Late Cretaceous to Early Tertiary in the Kharga Oasis (Um El Ghanayim section) is mainly based on the work of Awad and Ghobrial (1966) and recently Luger (1985, 1988) (Fig. 3).

Awad and Ghobrial (1966) introduced Lower Kharga Shale Member subdivision to designate a succession of claystones and shales containing agglutinated foraminifera. It reaches 36m thick in the studied area with no marked variation in lithological content. The top of this member includes genus *Ammoastuta* beside *Miliammina, Haplophragmoides* and *Trochammina* (Orabi, 1995).

Baris Oyster Mudstone Member of Awad and Ghobrial (1966) is underlain the Lower Kharga Shale Member and formed mainly of a number of fossiliferous marl and sandy limestone beds, intraformational conglomerate of phosphatic pebbles and mudstone beds. The marl layer contains foraminifera of the *Gansserina gansseri* Zone (Luger, 1985). This member is flooded with *Exogyra (Exogyra) overwegi* v. Buch embedded in sandy limestone bed of high carbonate content. Bir Abu Munqar Horizon of Barthel and Herrmann-Degen (1981) marks the top of the Lower Kharga Shale Member. This

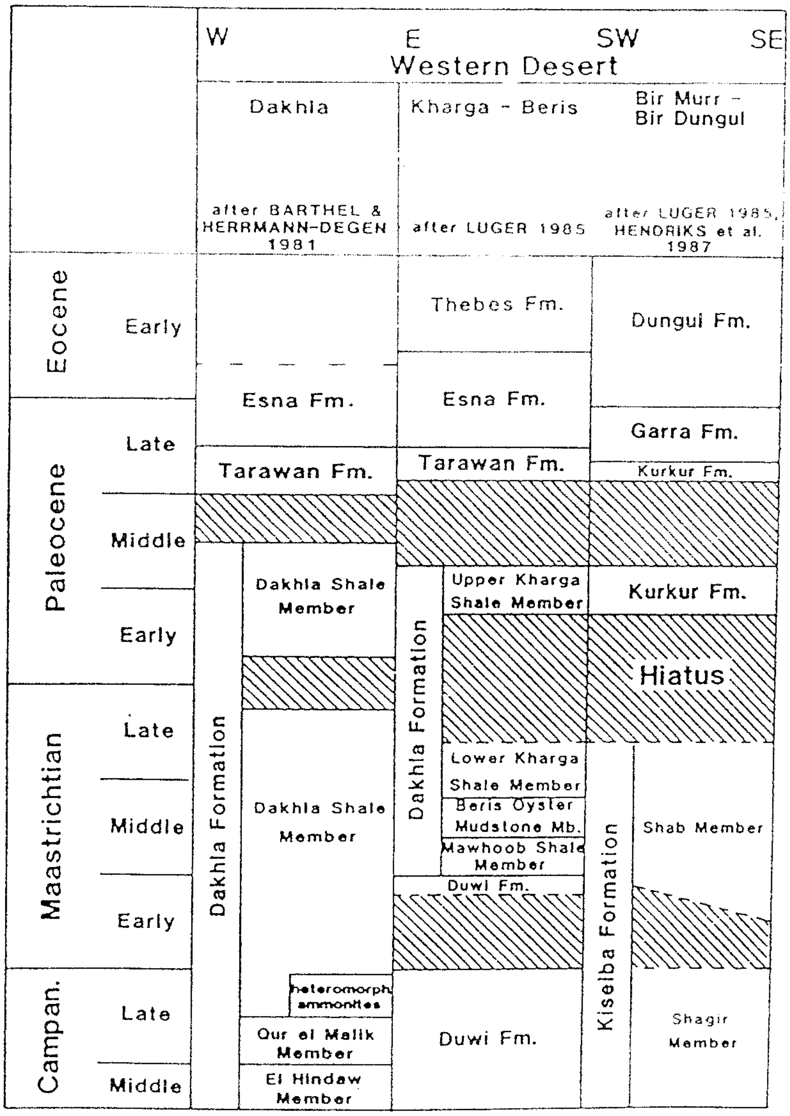


Fig. 3: Correlation of the Campanian-Early Eocene lithostratigraphic units in Western Desert (after Luger, 1988).

Orabi H. Orabi

horizon of phosphatic conglomerate layer was later raised to member rank by Luger (1985), where it separates the Lower Kharga Shale Member of Middle-Late Maastrichtian from the Upper Kharga Shale Member of Paleocene age. Barthel and Herrmann-Degen (1981) mention that in some cases the conglomerate layer of Bir Abu Munqar Member contains Late Maastrichtian planktonic foraminifera. This conglomerate bed marked an unconformity surface and represents a regressive episode at the Cretaceous/Tertiary boundary in the area under study.

RESULTS

The fundamental structural characteristics and functional significance of the wall of the *Haplophragmoides excavatus* species are described and demonstrated.

1- Organic layers

In the examined species of *Haplophragmoides excavatus,* a multilayered IOL develops during continuous test growth by lining of organic material, where no decrease in IOL thickness towards younger chambers is observed (Pl.2, Fig. 4, Pl. 4, Fig. 1).

Outer organic cement (OOL) of *Haplophragmoides excavatus* is likely to experience postmortem alteration. Using SEM techniques the presence of an OOL could not unambiguously be proven in *Haplophragmoides excavatus.* As the OOL can be very thinly developed, it may be necessary to utilize transmission electron microscope (TEM) studies in order to prove its existence.

According to Loeblich & Tappan (1987) the inner organic layer characterizes superfamily, family and subfamily but most frequently genera. Accordingly in the present study the multilayered structure of the IOL represents a characteristic feature probably on the level of family Haplophragmoididae.

The presence or lack of an OOL could be of diagnostic value on the family level, where the structure of the OOL has not yet been investigated in the TEM. The existence of a multilayered OOL in *Haplophragmoides excavatus* has not yet been observed.

The structure and functional significance of the wall ....

2- Cement

All studied *Haplophragmoides excavatus* species are attached particles only at the point of contact with morphologically undifferentiated cement. In the broken chamber walls voids created by removed particles clearly delineate the outline of cement substances (Pl. 2, Fig. 2; Pl. 3, Fig. 1).

Some of studied *Haplophragmoides excavatus* species are used organic strands. Single, regularly and densely spaced stands can be found within the chamber itself (Pl. 2, Fig. 6).

Loeblich & Tappan (1989) divided organically cementing species into three suborders (Astrorhizina, Haplophragmiina and Trochamminina), based upon the few organic cement microstructures. This classification must be rejected, because the cement microstructures do not allow further division into suborder. The determination of the organic cement morphotype is regarded as an important tool for the species concept and the definition of morphospecies. However, the definition of *Haplophragmoides excavatus* species depends upon its undifferentiated morphotype.

In the present study the outer surface of the studied species are characterized by random pores may be present as a result of diagenetic processes (Pl.3, Fig. 2)

3- Mode of Life

The wall structure of *Haplophragmoides excavatus* has inner organic sheets, and organic substance in the interior of the wall, which enveloped the agglutinated grains and binds them together (Pl. 2, Fig. 1&5). The agglutinant may be tightly packed.

The SEM photographs of the septa (Pl. 2, Fig. 3 & Pl. 3, Figs.1, 6) show the individual elements of the agglutinant to be oriented, producing a fairly tight mosaic of larger fragments at the base and smaller fragments at the top of this rounded planispiral forms. So, we can identify the direction of moving of this infaunal form (just the coarse grains present at the base of the test). Nagy (1992) mentioned that rounded planispiral form such as *Haplophragmoides* and *Cribrostomoides* are probably shallow infaunal forms moving and feeding just below the surface of the sediments.

Orabi H. Orabi

6- Squeezed Forms

About 32% of the total studied species of *Haplophragmoides excavatus* extracted from Lower Kharga Shale Member (K/T boundary) show squeezed inner organic layer (Pl. 4, Fig. 2) and squeezed chamber (Pl. 4, Fig.4). This phenomenon may be caused by the fact that agglutinated tests are weakly held together by organic material. Also, the organic matter is probably oxidized within the surface layer of sediment (Douglas *et al.*, 1980).

The abundance of benthic foraminifera in the Lower Kharga Shale Member can be caused by a slower sedimentation rate. Gradstein (1983) pointed out that an increase in the number of testes per unit volume of sediment could be cased by a slower sedimentation rate. So, surface productivity (organic carbon flux) is correlated with benthic foraminifera abundance (Herguera & Berger, 1991). The slower sedimentation and the cohesive nature of the claystone beds, which occupied the infaunal *Haplophragmoides excavatus,* beside the flexible of organic layer, all of these factors, may produce squeezed forms.

SUMMARY AND CONCLUSION

The knowledge of test structure and cement characteristics of *Haplophragmoides excavatus* during this study reveals the following:

1- The multilayered IOL develops during continuous test growth by organically lining, the outer organic cement OOL has not yet been observed. The presence of an OOL may occur immediately after death of the agglutinated foraminifera.

2- To identify *Haplophragmoides excavatus* species it is necessary to take into account the organically cementing morphogroups, where this species is characterized by undifferentiated cement morphotype (particles attached at the point of contact).

3- The septa of *Haplophragmoides excavatus* show the individual elements of the agglutinant to be oriented producing a fairly tight mosaic of larger fragments at the base and smaller fragments at the top. It can identify the direction of moving and feeding of this infaunal form below the surface of the sediments, whereas the coarse fragments present at the base of the test.

4- Squeezed *Haplophragmoides excavatus* species recorded at K/T boundary may be caused due to the agglutinated test are weakly held together by organic material, as well as the flexibility nature of organic layer may be affected by the cohesive properties of the claystone beds.

REFERENCES

Awad, G. A. & Ghobrial, M. G. (1966): Zonal stratigraphy of the Kharga Oasis. Geol. Survey. Paper 34, 77p. Cairo.

Banner, F. T., Simmons, M. D. & Whittaker, J.E. (1991): The Mesozoic Chrysalidinidae (Foraminifera, Textulariacea) of the Middle East: the Redmond (Aramco) taxa and their relatives. Bulletin of the British Museum (Natural History), Geology Ser., Vol. 47, No. 2, p. 101-152.

Barthel, K. W. & Herrmann-Degen, W. (1981): Late Cretaceous and Early Tertiary stratigraphy in the Great sand Sea and its SE margins (Farafra and Dakhla Oasis). SW Desert, Egypt. Mitt. Bayer. Staatsslg. Palaont. Hist. Geol., Vol. 21, p.141-182, Munchen.

Bender, H. (1989a): Gehauseaufbau, Gehausegenese und Biologie agglutinierter Foraminiferen (Sarcodina: Textulariina). Jahrbuch Geologische Bundesanstalt, Vol. 132, No. 2, p. 259-347, Vienna.

Bender, H. (1989b): Chamber formation and biomineralization in *Textularia candeiana* d' Orbigny. Program and abstracts of III. International Workshop on Agglutinated Foraminifera. IWAF III, 5, Tubingen 17-28 September 1989.

Bender, H. (1992): Chamber formation and biomineralization in *Textularia candeiana* d' Orbigny. (Sarcodina: Textulariina). Journal of Foraminiferal Research, Vol.22, No 3, p. 229-241.

Bronnimann, P. & Whittaker, J. E. (1988): The Trochamminacea of the Discovery Reports. A review of the Trochamminacea (Protozoa: Foraminiferida) described from South Atlantic and

Orabi H. Orabi

Antarctic waters by Heron-Allen (1932) and Earland (1933; 1934; 1936). British Museum (Natural History), p.1-152.

Douglas, R. G.; Liestman, J.; Walsh, C.; Blake, C. & Cotton, M. L. (1980): The transition from live to sediment assemblage in benthic foraminifera from the southern California borderland. In Field, M.; Bouma, A.; Colbum, I.; Douglas, R. C. & Ingle. J. (eds) Pacific Coast Paleogeography Symposium Pacific Section, Vol. 4, p. 256-280.

Gradstein, F. M. (1983): Paleoecology and stratigraphy of Jurassic abyssal foraminifera in the Blake-Bahama Basin, Deep Sea Drilling Project Site 534. In Sheridan, R. E., Gradstein, F. M. et al., Initial Reports of the Deep Sea Drilling Project, Vol. 76, p. 537-560.

Herguera, J. & Berger, W. H. (1991): Paleoproductivity from benthic foraminiferal abundance: Glacial to postglacial change in the west-equatorial Pacific. Geology, Vol. 19, p.1173-1176.

Kaminski, M. A.; Geroch, S. & Gasinski, M. A. (eds.) (1995): Proceedings of the fourth international workshop on agglutinated foraminifera, Krakow Poland, September 12-19,1993. Grzybowski Foundation Special Publication no.3, pp. 27-70.

Loeblich, A. R. & Tappan, H. (1987): Foraminiferal genera and their classification. 2 vol., 1182 p., Van Nostrand Reinhold Co., New York.

Loeblich, A. R. & Tappan, H. (1989): Implications of wall composition and structure in agglutinated Foraminifera. Journal of Paleontology, Vol. 36, p. 769-777.

Luger, P. (1985): Stratigraphie der marinen Oberkreide und des Alttertiars im sudwestlichen Obernil-Becken (SW-Agypten) unter besonderer Berucksichtigung der mikropalaontologie, Palokologie und Palaogeographie. Berliner geowiss. Abh. A, Vol. 63, p. 1-151, pls. 1-24, Berlin.

Luger, P. (1988): Campanian to Paleocene agglutinated foraminifera from freshwater influenced marginal marine (Deltaic) sediments of southern Egypt. Abh. Geol. Bundesanstalt, Vol. 41, p. 245-154, 2 pls, Wien.

Nagy, J. (1992): Environmental significance of foraminiferal morphogroups in Jurassic North Sea deltas. Palaeogeography, Palaeoclimatology, Palaeoecology, Vol. 95,p. 111-134.

Orabi, H. O. (1995): Biostratigraphy and paleoecology of the Campanian-Paleocene agglutinated foraminifera from Gabal Um El Ghanayim, Kharga Oasis, Egypt. Scientific Journal. Fac. Sci. Menoufia Univ., Vol. XI, p. 25-68.

Plate 1

All illustrations are scanning electron photomicrographs.
White scale bars on all figures equal 100µm.

All material based on specimens of *Haplophragmoides excavatus* Cushman & Waters from the Lower Kharga Shale Member of Gabal Um El Ghanayim, Kharga Oasis in the Western Desert of Egypt.

1,2- Figures show rounded planispiral forms

4 - Figure shows low squeezed form.

3,5- Figures show moderate squeezed forms.

6-9- Figures show high squeezed forms

PLATE 1

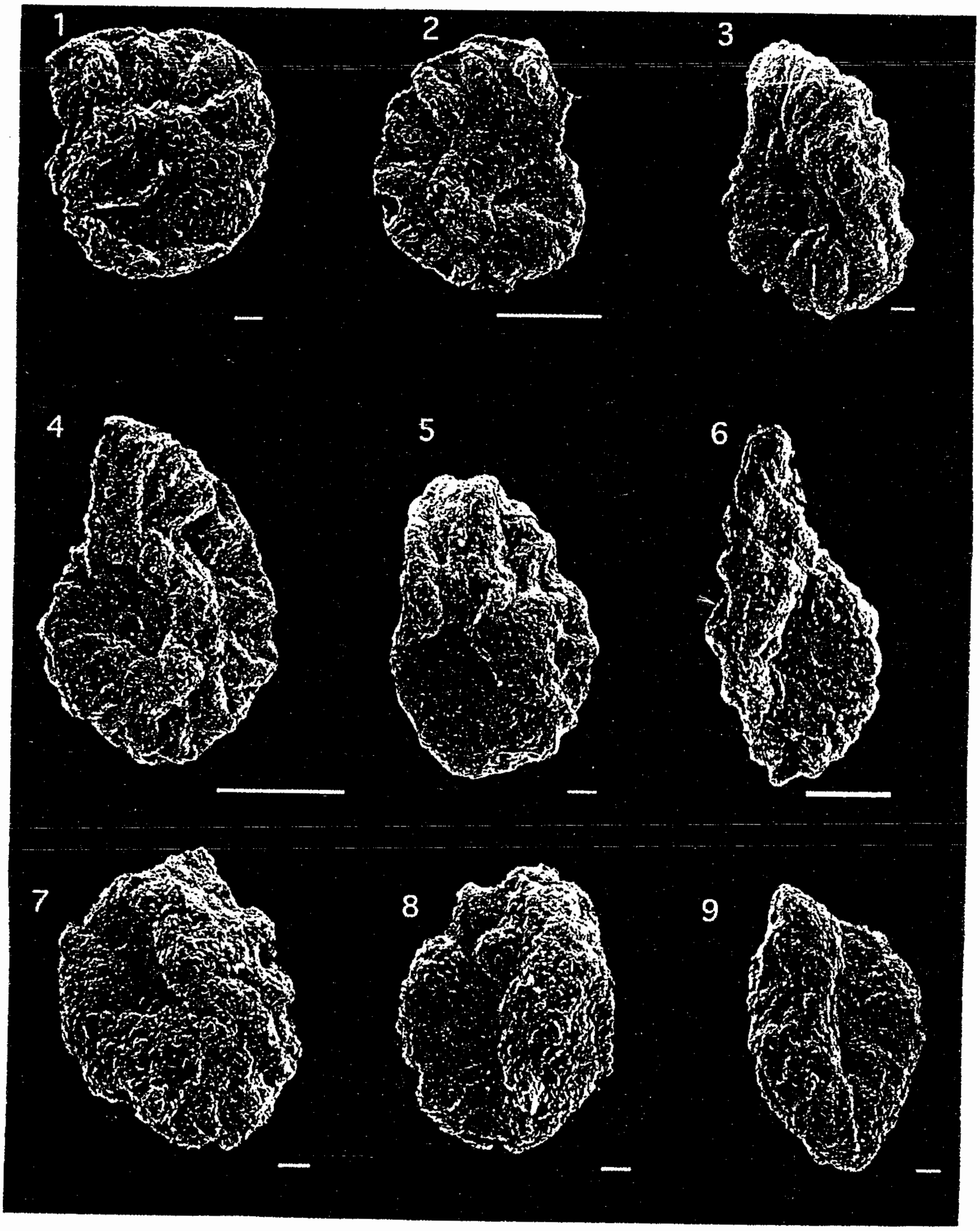


Plate 2

All illustrations are scanning electron photomicrographs.
White scale bars on all figures equal 100µm.

1- Test of fractured specimen. showing organic cement morphotype.

2- Broken chamber walls, voids created by removed particles clearly delineated the outline of cement substances.

3- Undifferentiated organic cement connects particles at the point of contact, the larger fragments at the base and smaller fragments at the top.

4- Multilayered inner organic layer (IOL) develops during continuous test growth by organically lining (notice no decreasing in IOL thickness towards young chamber).

5- The chamber is coated with an inner organic layer (enlargement of right side of figure 3).

6- Single stands may be restricted to specific test area within the chamber itself.

Plate 3

All illustrations are scanning electron photomicrographs.
White scale bars on all figures equal 100µm.

1- Quartz crystals connected by organic cement at the point of contact (enlargement of left side of Pl. 2, Fig. 3)

2- Wall structure showing random pores (enlargement of Fig. 3).

3- Surface of the wall consisting of densely packed quartz crystals.

4,5- Specimens fractured, showing organic cement morphotypes.

6- Undifferentiated organic cements particles at the point of contact (enlargement of Pl.2, Fig.3), notice larger fragments at the base.

PLARE 2

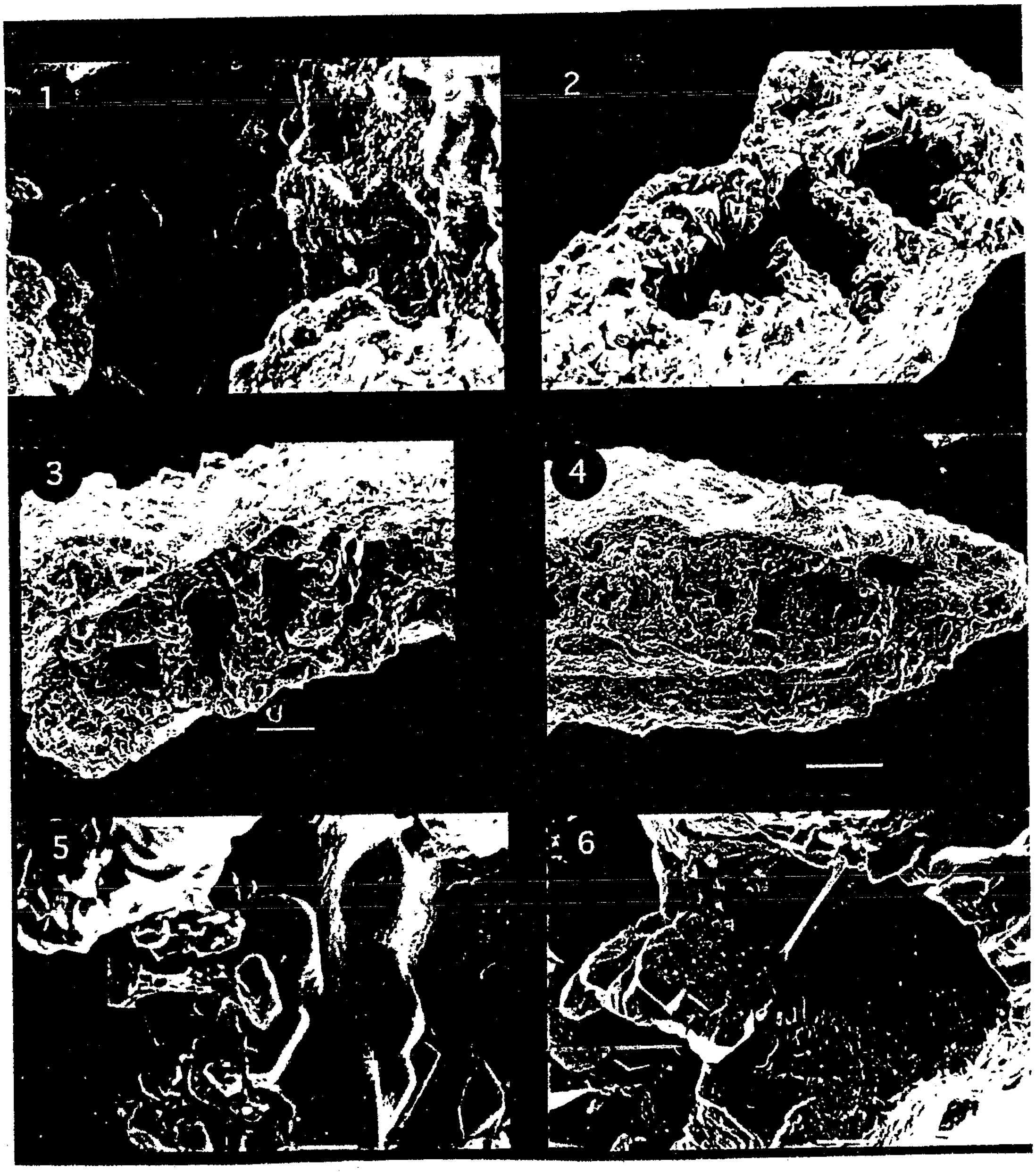


PLATE 3

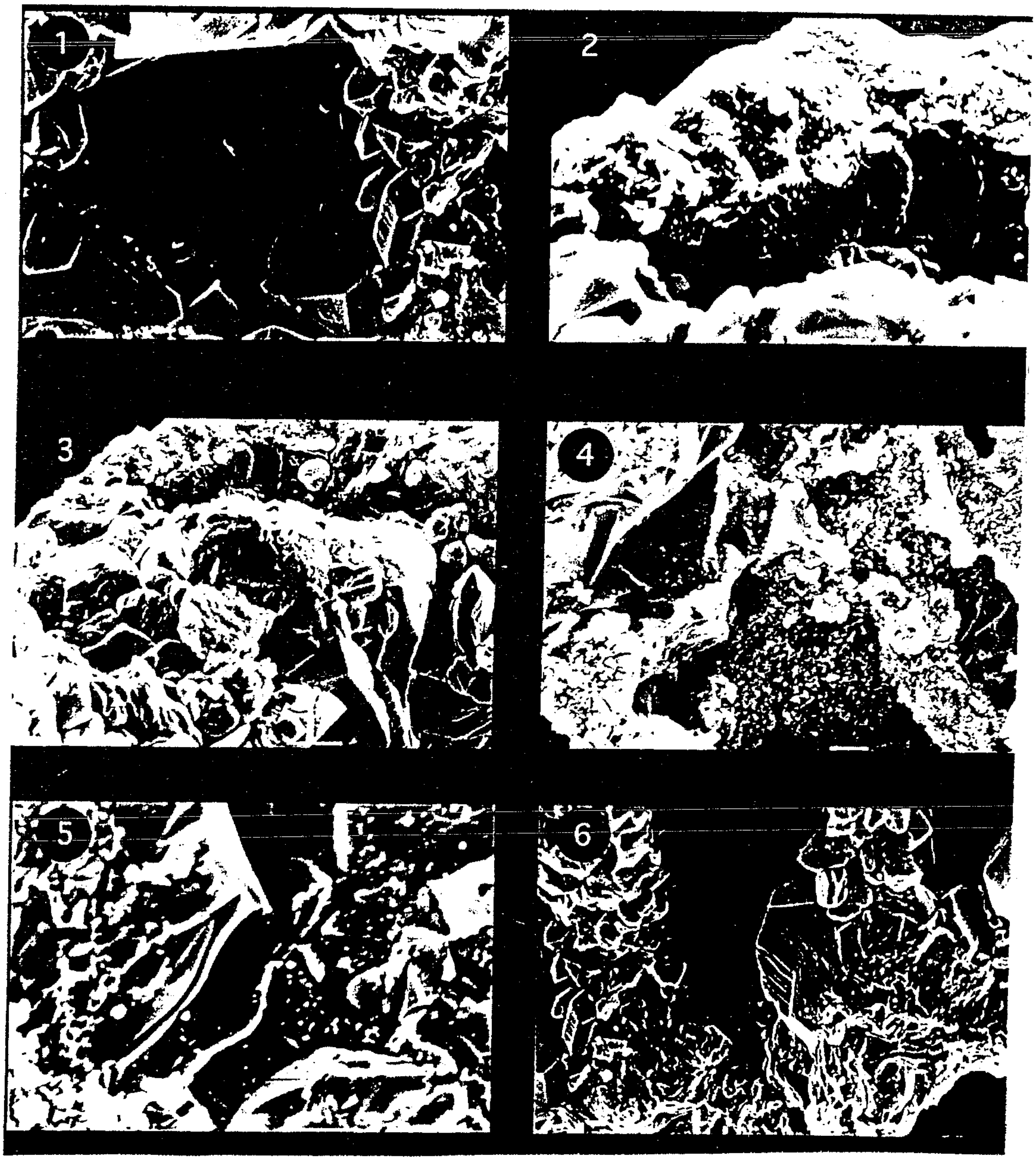


Plate 4

All illustrations are scanning electron photomicrographs.
White scale bars on all figures equal 100μm.

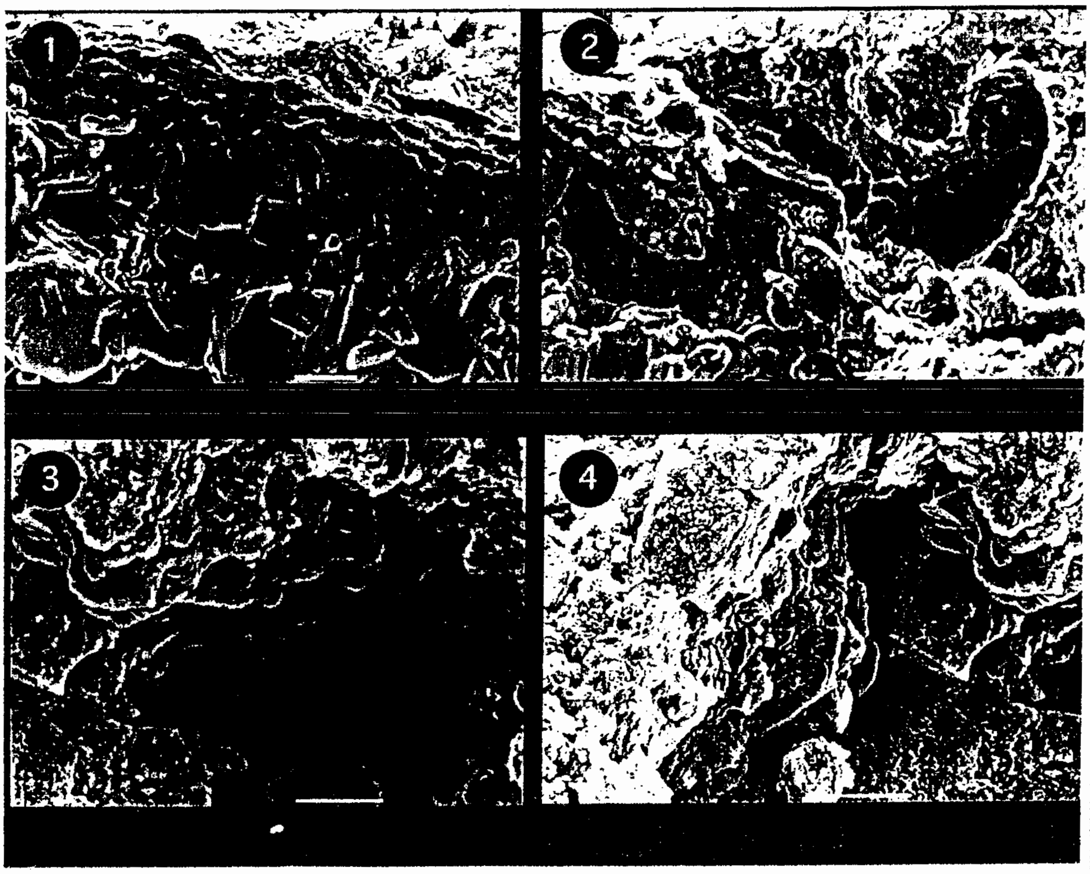
1- Multilayered IOL develops during continuous test growth by organically lining, enlargement of the boundary.

2- Squeezed inner organic layer.

3- Chamber is coated with an inner organic layer.

4- Squeezed chambers.

PLATE 4



التركيب والأهمية الوظيفية لجدار هابلوفراجميدس اكسكفاتس كوشمان & ووترز المنضغط (فورامنيفرا ملزنة)

عرابي حسين عرابي
قسم الجيولوجيا - كلية العلوم - جامعة المنوفية

من دراسة عضو طفلة الخارجة السفلى الذى يمثـل الحـد الفـاصل بيـن الطباشـيرى والباليوسين بمنطقة الواحات الخارجة (جبل أم الغنايم) وجد أنة يحتوى على نسبة لأيستهان بها من نوع هابلوفراجميدس اكسكفاتس ذو جدار منضغط بشكل لافت للنظر.

وقد قام الباحث بدراسة هذا الجنس ذو الجدار الملزن بعمل عدة قطاعات في هذا الجدار تم فحصها بواسطة الميكروسكوب الإلكتروني لتحديد المادة اللاحمة للحبيبات المكونة لهذا الجنس وبيئة الترسيب السائدة أثناء معيشته هذا علاوة على معرفة الأسباب التى أدت إلى انضغاط هـذا الجدار بالإضافة إلى معرفة طرق معيشة هذا الجنس الذى يقع عند الحد الفاصل بين الطباشـيرى والباليوسين.

وقد وجد حديثا أن هناك أربع أنماط مورفولوجية مختلفة تبعا للمادة اللاحمة يمكن عـن طريقها معرفة نوع الجنس والعائلة التى ينتمى أليها فمنها الغير متفرق والشبكى والرغـوى وذو الخيط الفردي وقد أوضح الباحث من خلال فحصـــة لصـور الميكروسـكوب الإلكـتروني أن هابلوفراجميدس اكسكفاتس ينتمى للنمط الغير متفرق مع وجود طبقة عضوية داخلية ذات سـمك ثابت أثناء نمو هذا النوع بينما يرجح الباحث عدم وجود الطبقة العضوية الخارجية ألي عوامـل التحلل فيما بعد الموت.

وقد اكتشف الباحث لأول مرة نظام ترتيب الحبيبات الخاصة بالحواجز التى تفصل بيـن الحجرات حيث وجد الباحث أن الحبيبات الخشنة توجد فى قاعدة هذا النوع موضوع الدراسـة بينما توجد الحبيبات الدقيقة لأعلى مما ساعد على تحديد المنطقة العلوية من السفلية واتجاه تحرك هذا النوع من خلال تتبع ترتيب الحبيبات الخاصة بالحواجز هذا مع التأكيد على اكتشاف هـذه الظاهرة الدقيقة لأول مرة.

ومن دراسة الزيادة العددية المتنوعة للأجناس الموجودة فى عضو طفلـة الخارجـة السفلى أمكن استنتاج معدل الترسيب خلال الحد الفاصل بين الطباشيرى والباليوسين والـذي يستدل منها على بطء معدل الترسيب فى هذه الفترة كما كان لوجود ظاهرة الجدران المنضغطـة لنوع هابلوفراجميدس اكسكفاتس تفسيرا واضحا على ضعف المادة اللاحمة علاوة على كونـها ذات طبيعة مرنة مما جعلها تتأثر بخاصية قوى الضغط التى تمتاز بها الصخور الطينية السائدة في عضو طفلة الخارجة السفلي.