

משרד האנרגיה והתשתית



**DIATOMS AND FORAMINIFERS IN THE
'UBEIDIYA FORMATION
(JORDAN VALLEY) :
PALEO-ENVIRONMENTAL SIGNIFICANCE**

R. Siman-Tov, A. Almogi-Labin
and
E. Debard

The research of diatoms in the stratigraphy of Israel was initiated and significantly advanced by our late friend and colleague Dr. Aline Ehrlich, who passed away in 1991. To her memory this study is dedicated.

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(JORDAN VALLEY): PALEO-ENVIRONMENTAL SIGNIFICANCE**

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Report GSI27/93

Jerusalem

December, 1993

CONTENTS

	Page
Abstract	1
Introduction	1
Materials and Methods	3
Results	3
Section III	3
Section Ia	7
Discussion	10
Conclusions	12
Acknowledgements	13
References	13
List of Figures and Table	
Figure 1. Location map	2
Figure 2. Distribution chart of the microfossils in section III	4
Figure 3. Distribution chart of diatoms in section III	6
Figure 4. Distribution chart of the microfossils in section Ia	8
Figure 5. Distribution chart of diatoms in section Ia	9
Table 1. Correlation between the two studied sections	12
Plates 1-3	17-21

תקציר

בשני חתכים של תצורת עובדייה מגיל פלייסטוקן תחתון זהו 52 מינים של דיאטומיאות השייכים ל - 28 סוגים. מאספי הדיאטומיאות מעידים על תנודות במליחות במחזור האגמי התחתון, בין סביבות של מים מתוקים לסביבות מאוסליניות. תנאי מליחות אלו נתקבלו גם באמצעות קבוצות נוספות של מיקרו-מאובנים.

ABSTRACT

A total of 52 species of diatoms, belonging to 28 genera were identified in two sections of the Early Pleistocene 'Ubeidiya Formation. Several fluctuations of freshwater and mesosaline paleo-environments could be discerned within the lower limnic cycle. These fluctuations could be observed also in other microfaunal and microfloral groups.

INTRODUCTION

The 'Ubeidiya site located in the Jordan Valley (Coord. 2020/2330, Israeli grid) about 4 km south of Lake Kinneret (Fig. 1), was excavated between 1960-1974. It has yielded a rich vertebrate fauna, including scanty remains of *Homo erectus* and an Acheulean lithic industry, resembling that of the Olduvai site (Goren-Inbar, 1981; Tchernov, 1992; Bar-Yosef & Goren-Inbar, 1993).

The 'Ubeidiya Formation, younger than the 'Erq el-Ahmar Formation and older than the Naharayim Formation (Tchernov, 1987; Braun, 1992), dated at the Early Pleistocene about 1.4 My (Tchernov, 1987). The thickness of this formation is about 190 m (Picard & Baida, 1966) and it is exposed mainly in Tel 'Ubeidiya. This formation was deposited in a lacustrine-fluviatile environment. Four sedimentary cycles are distinguished (Picard & Baida, 1966): the lower limnic cycle (Li), the lower fluviatile cycle (Fi), the upper limnic cycle (Lu) and the upper fluviatile cycle (Fu).

Excavation has been renewed² in 1988 by a joint team of Claude
Bernard University, Lyon
1 and the Hebrew University, Jerusalem.

A very diversified association of mammals, birds, reptiles, amphibians, fish, molluscs, ostracodes and diatoms was found (Haas, 1966; Picard & Baida, 1966; Bar-Yosef & Tchernov, 1972; Tchernov, 1973, 1980, 1986).

The present study deals with diatoms and foraminifers of the lower limnic cycle (Li), selected sections of the lower fluviatile cycle (Fi), and the base of the upper limnic cycle (Lu).

This study continues the work begun by Dr. Aline Ehrlich on the diatoms of the 'Ubeidiya site, which was interrupted by her untimely death in 1991.

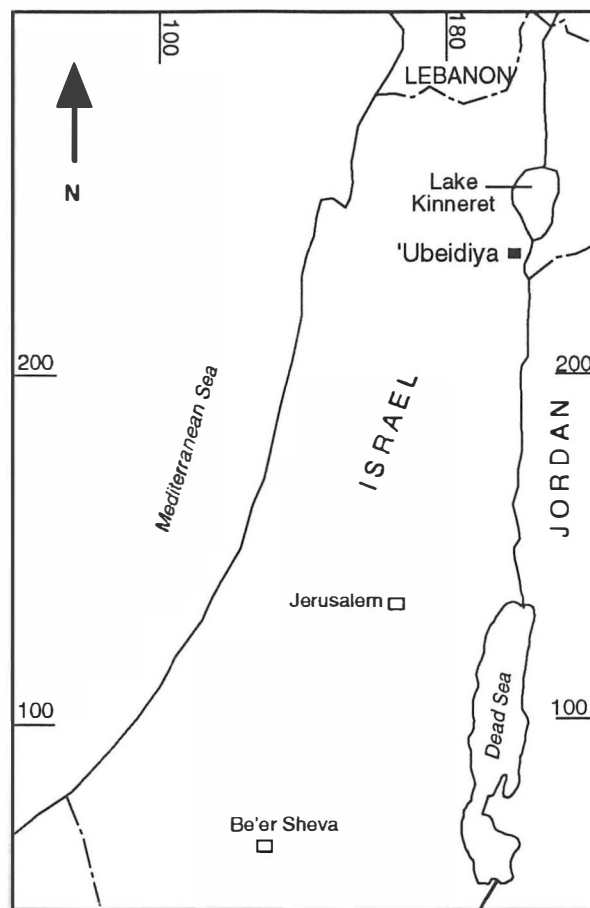


FIG. 1 LOCATION MAP

MATERIALS AND METHODS

Material was studied from two sections of the 'Ubeidiya excavation (terminology according to Picard & Baida, 1966; Debard and others, 1989). Twenty samples were taken from the lower part of section No. III (layers 5 - 20) and five samples from section No. Ia.

For the calcareous microfossil analysis, 50 g samples of dry sediment were washed through 63 μm sieve and dried.

For the diatom analysis 1 g of sediment was treated in a beaker of 200 ml with 10% HCl. After flushing to neutral pH, the residue was digested with 33% Hydrogen Peroxide for 30 minutes on a hot plate followed by 6 washings with distilled water. Finally, the residue was diluted in 150 ml of distilled water, 0.2 ml of this diluted suspension was drained on a slide and mounted in Naphrax mountant, and 0.2 ml was set on a stub for taking SEM microphotographs.

RESULTS

The examined residues contained diatoms, charophytes, foraminifers, ostracods, gastropods, fish teeth and bones. Results are summarized in the distribution charts (Figs. 2-3 for section III, and Figs. 4-5 for section Ia).

Section III

This section yielded a rich association of microfossils (Fig. 2). Diatoms occur within 7 samples of this section in layers 5-8 and 19-20. Charophytes (Pl. 11) occur in layers 6 and 8. Ostracods are the most prevalent among the microfauna, occurring almost in all samples except layer 12. Fish teeth and small bone fragments are present in all samples except those of layers 9 - 11. Gastropods occur within layers 6-8, 17 and 20. Foraminifers are present only within the upper part of layer 5. Reworked Paleogene foraminifers occur within layers 10-11, 13, 15-17 and 19.

Foraminifers

The number of foraminifer specimens in the examined samples is very small. A monospecific population of *Ammonia beccarii* (Linné) consists of dwarf specimens with a maximum diameter

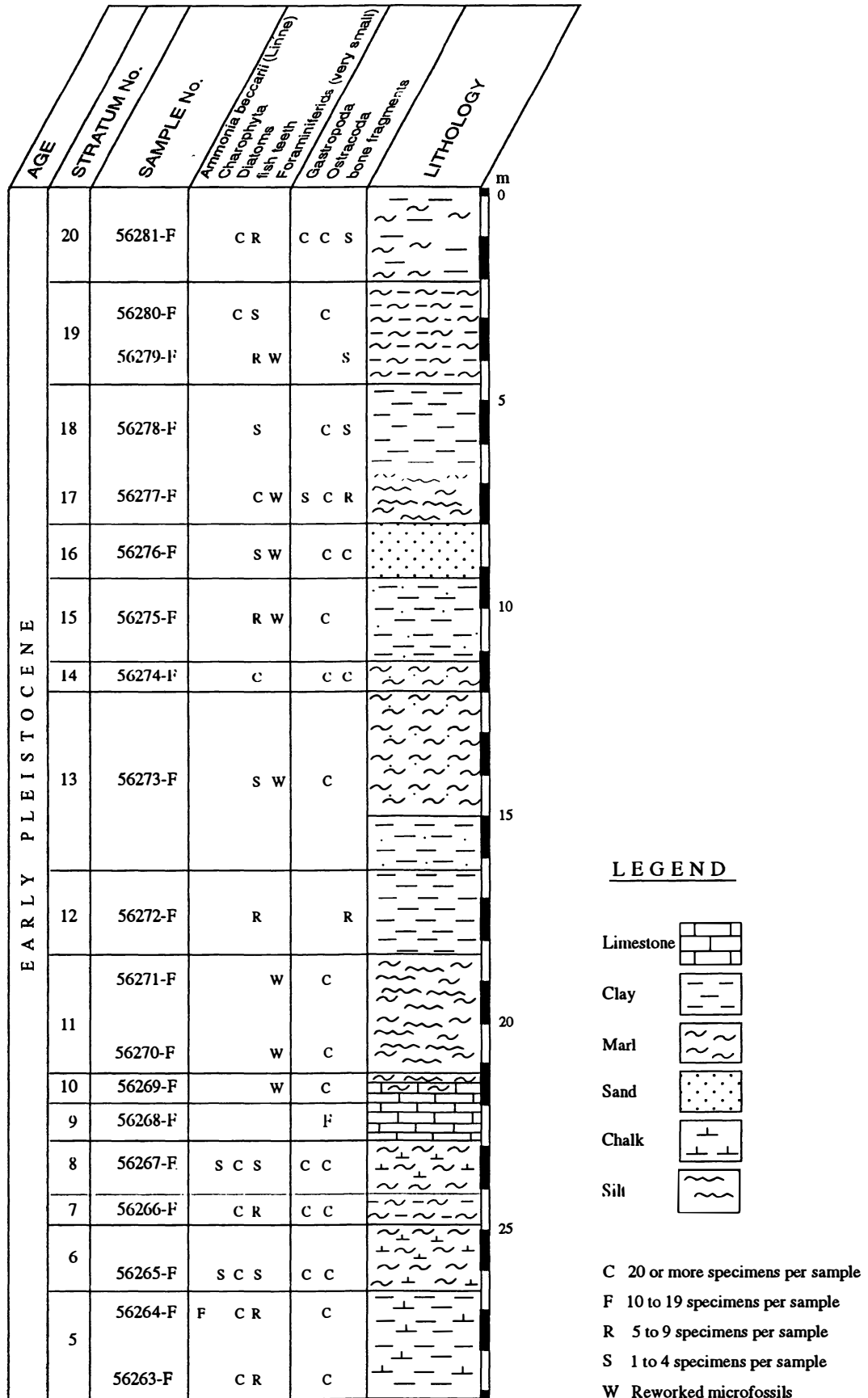


Figure 2. Distribution chart of the microfossils groups in section III.

ranging from 122 μm to 226 μm (average 173 μm). A few of them are *Ammonia beccarii tepida* (Pl. 3c) lacking an umbilical plug, while others resemble *Ammonia beccarii cf. parkinsoniana* (Pl. 3a-b) possessing an umbilical plug (Walton & Sloan, 1990).

Diatoms

The taxonomy of the diatoms and their ecological interpretation is based mainly on Ehrlich (in press), Gasse (1986), Krammer & Lange-Bertalot (1986, 1988, 1991a, 1991b) and Van Campo & Gasse (1993).

A total of 64 diatoms taxa were identified (Fig. 3) in section III. The diatom assemblages comprise pennate and centric forms, with the former more common. Most of the pennate forms are considered periphytic, the few centric species like *Ellerbeckia arenaria*, and probably *Cyclotella kuetzingiana* and *Cyclotella meneghiniana* are also periphytic. The low ratio of planktic/periphytic forms is considered to be indicative to shallow water depth.

Two assemblages are recognized in section III:

1. A well-diversified diatom assemblage (56 taxa), found within layers 6-8, consisting of well-preserved frustules with few fragmented frustules. A similar low diversity diatom flora (only 17 taxa) is present within layer 20 with mostly highly fragmented frustules. The common species in the assemblage are: *Achnanthes minutissima*, *Amphora ovalis*, *Caloneis silicula*, *Cocconeis placentula* (Pl. 1c), *Cymbella cymbiformis*, *Diploneis elliptica*, *Fragilaria brevistriata* (Pl. 1f), *F. construens* var. *venter* (Pl. 1e), *Ellerbeckia arenaria* (Pl. 1a), *Gomphonema clavatum* (Pl. 1d), *G. clevei*, *Nitzschia amphibia* (Pl. 1g-h), *Nitzschia denticula* (Pl. 1i) and *Synedra ulna*. All the above mentioned taxa are freshwater and alkaliphilous species. Very few euryhaline species, such as *Campylodiscus clypeus* (Pl. 1j), *C. levanderi* (Pl. 1k) and *Cyclotella meneghiniana* (Pl. 1b), which are known from oligosaline to mesosaline waters and even in higher salinities (Ehrlich, in press; Gasse, 1990; Gasse and others, 1987; Krammer & Lange-Bertalot, 1988 and 1991a; Pienitz and others, 1992), were found rarely in layers 6-8.

2. A low-diversity diatom assemblage composed of badly preserved specimens. These pennate periphytic species include: *Campylodiscus* sp. (Pl. 2a-c), *Surirella* cf. *capronii* (Pl. 2d-f), *S.* cf. *robusta* (Pl. 2g-i) and *S.* cf. *spiralis*. These taxa occur rather frequently in layers 5 and 19. Specimens are relatively large, 120-150 μm in diameter or 150-200 μm in length, and indicate preference for mesosaline waters.

No diatoms were found within layers 9 to 18.

Section Ia

An impoverished microfloral and microfaunal assemblage was found in this section (Fig 4). Diatoms are present only in layer 12 together with fish teeth and small bone fragments. Ostracods occur within layers 30-32 and 33. Foraminifers occur abundantly within layer 33.

Ostracod frequency is generally high in all the examined samples, except for layer 33 where foraminifers dominate.

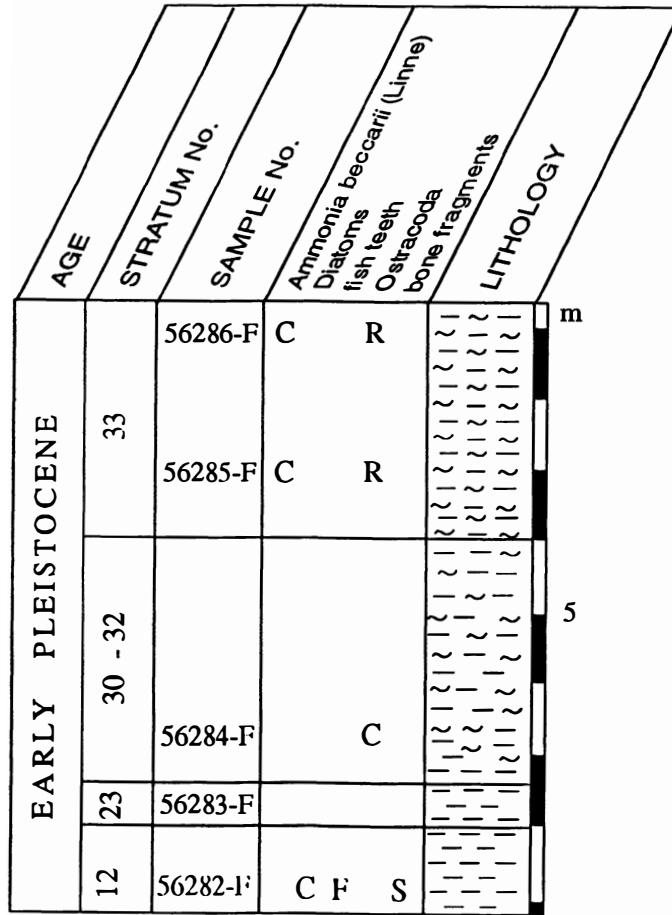
Foraminifers

Ammonia beccarii tepida is the only foraminifer present in the two samples of layer 33 (Pl. 3d-i). Maximum diameters of the specimens in this section range from 200-377 μm (average 290 μm).

Diatoms

Layer 12 yielded an assemblage relatively poor in diatoms (15 taxa), dominated by the periphytic forms and mostly fragmented. Twelve of these (Fig. 5) are taxa mentioned in assemblage 1 of section III (Fig. 3) as freshwater diatoms.

No microfossils were found within layer 23.



C 20 or more specimens per sample
 F 10 to 19 specimens per sample
 R 5 to 9 specimens per sample
 S 1 to 4 specimens per sample

Marl
 Clay

Figure 4. Distribution chart of microfossils in section Ia

DISCUSSION

The reconstruction of paleoenvironments at the 'Ubeidiya site was based mainly on detailed sedimentary, malacological and vertebrate analyses (Haas, 1966; Picard & Baida, 1966; Bar-Yosef & Tchernov, 1972; Tchernov, 1973, 1980, 1986). The microfossil assemblages add some insights to the paleoenvironments, which are summarized in Table 1.

Diatom assemblages are used as indicators of salinity, pH and water depth (Patrick & Reimer, 1966; Singer & Ehrlich, 1978; Ehrlich & Ortal, 1979; Fontes and others, 1985; Krammer & Lange-Bertalot, 1986, 1988, 1991a, 1991b; Gasse and others, 1987; Anderson & Renberg, 1992; Pienitz and others, 1992; Van Campo & Gasse, 1993 and Ehrlich in press). The diatom assemblages in the 'Ubeidiya sections represent two distinct paleoenvironments in the lake:

- 1) Fresh to oligosaline waters (salinity < 5 ‰) and shallow depth.
- 2) Mesosaline waters (salinity 5 ‰-30 ‰) and shallow depth.

Freshwater to oligosaline environments

The association of diatom assemblage 1 accompanied by freshwater gastropods, ostracods, fish teeth and sometimes also with oogonia of the Charophyta group (Soulié-Märsche, 1993) indicates a freshwater to oligosaline lake (salinity < 5 ‰). Two intervals of fresh to oligosaline salinities were recognized. The oldest low-salinity phase occurs at the deposition of layers 6-8 (section III). The younger low-salinity phase occurs during the deposition of layer 20 (section III) and layer 12 (section Ia). The predominance of periphytic forms denotes shallow water (Van Campo & Gasse, 1993).

Layer 12 (section Ia) is correlative to layer 20 (section III), agreeing with Bar-Yosef & Tchernov, 1972. The younger low-salinity phase contains freshwater assemblage 1 and is relatively poor in diatoms compared to the older low-salinity phase. The smaller species diversity of layer 20 could be due to growth conditions, or an effect of differential frustule preservation (enhanced dissolution or breakage).

Mesosaline environments

Diatom assemblage 2 accompanied by fish teeth, euryhaline ostracods and a monospecific population of foraminifers indicate a mesosaline environment (salinity 5 ‰-30 ‰). These associations are found within finely laminated sediments in two separate intervals. The first mesosaline phase was found at the base of the sequence in layer 5 (section III), the second mesosaline phase was recognized in the upper part of the lower limnic cycle (Li), in layer 19 (section III). Only a few large periphytic species are found in these layers, preserved as ferric oxide molds. Apparently bottom water conditions caused dissolution of all diatom material, leaving only the ferric fill of larger specimens.

Specimens of *Ammonia beccarii* occur only within the laminated layers (5 of section III and 33 of section Ia) of two distinct episodes (Figs. 2, 4). In both cases mesosaline conditions probably prevailed at the beginning of the limnic Li and Lu cycles.

The foraminifer *Ammonia beccarii* s.l. and the ostracod *Cyprideis torosa* are known from a wide range of salinities in the marine environment and also from inland aquatic environments. Living *Ammonia beccarii tepida* and *Cyprideis torosa* were found recently within an inland hypersaline pond in Israel (Almogi-Labin and others, 1992) and previously in other inland lakes (references in Almogi-Labin and others, 1992; Anadón, 1992). Although living *Ammonia* has been recorded within salinities from less than 1 ‰ to more than 90 ‰ (Walton & Sloan, 1990), the optimal salinity range for reproduction of *Ammonia beccarii* is limited to the 13 ‰-40 ‰ range (Bradshaw, 1957, 1961) with a preference of *Ammonia* forma *tepida* to brackish waters (Walton & Sloan 1990). The abundance of normal-size specimens (290 µm) of *Ammonia tepida* (compare to Bradshaw, 1961; Almogi-Labin and others, 1992) in layer 33 (section Ia), probably represent a mesosaline environment. The small numbers and the dwarfed specimens of *Ammonia beccarii tepida* and *A. beccarii* cf. *parkinsoniana* within layer 5 (section III), may suggest bottom water conditions, near the lowest salinities of their ecological tolerance.

During the long interval between layers 9-18 (section III), within the lower limnic cycle, no diatoms were recorded. At the same interval, almost all these layers contain reworked foraminifers. The occurrence of reworked foraminifers may point to periods of strong fluvial activity eroding foraminifers from Paleogene strata. Hence, the absence of diatoms can be related to increased water turbidity and deterioration in diatom growth conditions (Ehrlich &

Noël,1988). Alternatively,

bottom conditions may have been adverse to frustule preservation.

CONCLUSIONS

On the basis of diatom distribution we suggest placing the boundary between the lower limnic cycle and the lower fluviatile cycle at the top of layer 20 (section III) and layer 12 (section Ia), one layer higher compared to Picard & Baida (1966) and Bar-Yosef & Tchernov (1972). The modification is based on the interpretation that these layers still represent fresh to oligosaline lake conditions, i.e. an extension of the lower limnic cycle.

CYCLE	SECTION		PALEOECOLOGY	
	III	Ia		
Lu		33	Mesosaline	
Fi		30-32		
		23		
Li	e	20	12	Fresh to oligosaline
	d	19		Mesosaline
	c	9-18		Possible high turbidity and turbulence
	b	6-8		Fresh to oligosaline
	a	5		Mesosaline shallow
Base of the exposed 'Ubeidiya Formation				

Table 1. Correlation between the two studied sections, and paleoecology as determined by the diatoms and foraminifers.

Five distinct phases were recognized in the **lower limnic cycle** (Li) representing mainly salinity fluctuations (Table 1):

Mesosaline conditions at the base of the section (a) followed by freshwater to oligosaline conditions (b). High turbidity and turbulent conditions probably prevailed in the intermediate phase (c). Mesosaline conditions (d) returned, followed by freshwater to oligosaline conditions (e).

Almost no microfossils were found in the **lower fluviatile cycle** (layers 23, 30-32 section Ia).

The **upper limnic cycle** starts with mesosaline conditions (layer 33 section Ia).

ACKNOWLEDGEMENTS

This work was supported by the Aline Ehrlich Fund. We are indebted to I. Perath for editing the manuscript, to T. Beer for technical assistance, to M. Devorachek and Y. Levy for the SEM photographs and to N. Shragai and A. Pe'er for the figures.

REFERENCES

- Almogi-Labin A., Perelis-Grossovicz L. & M. Raab, 1992. Living *Ammonia* from a hypersaline inland pool, Dead Sea Area, Israel. - J. Foram. Res., 22 (3): 257-266.
- Anadón P., 1992. Composition of inland waters with marine-like fauna and inferences for a Miocene lake in Spain. - Palaeo., Palaeo., Palaeo., 99: 1-8.
- Anderson N. J. & I. Renberg, 1992. A palaeolimnological assessment of diatom production responses to lake acidification. - Environmental Pollution, 78: 113-119.
- Bar-Yosef O. & E. Tchernov, 1972. On the Palaeo-Ecological History of the Site of 'Ubeidiya. - The Israel Academy of Sciences and Humanities, Jerusalem, 35 p.
- Bar-Yosef O. & N. Goren-Inbar, 1993. The lithic assemblages of 'Ubeidiya, a lower palaeolithic

- site in the Jordan Valley. - Quedem, monographs of the Institute of Archaeology, Heb. Univ. Jerusalem, No. 34, 266 p.
- Bradshaw J. S., 1957. Laboratory studies on the rate of growth of the foraminifer "*Streblus beccarii* (Linné) var. *tepida* (Cushman)". - J. Paleontol., 31 (6): 1138-1147.
- Bradshaw J. S., 1961. Laboratory experiments on the ecology of foraminifera. - Contr. Cush. Found. Foram. Res., 12 (3): 87-105.
- Braun D., 1992. The Geology of the Afiqim Area. - M.Sc. thesis, Heb. Univ. Jerusalem, 93 p. (In Hebrew).
- Debard E., Bar-Yosef O., Chech M., Eisenmann V., Faure M., Guerin C., Libermann D. et E. Tchernov, 1989. Nouvelle mission archéologique et paléontologique d'Oubéidiyeh (Israël): premiers résultats. - Paléorient, 15 (1): 231-237.
- Ehrlich A. & D. Noël, 1988. Sedimentation patterns in the Pleistocene Lake Lisan, precursor of the Dead Sea: new data from nannofacies analysis and the diatom floras. - Cahiers de Micropaléontologie, 3 (3): 5-21.
- Ehrlich A. & R. Ortal, 1979. The influence of salinity on the benthic diatom communities of the lower Jordan River. - Nova Hedwigia, 64: 325-334.
- Ehrlich A. (in press). Inland diatom flora of Israel. - The Israel Academy of Sciences and Humanities, Jerusalem.
- Fontes J. C., Gasse F., Callot Y, Plaziat J. C., Carbonel P., Dupeuble P. A. & I. Kaczmarska, 1985. Freshwater to marine-like environments from Holocene Lakes in northern Sahara. - Nature, 317: 608-610.
- Gasse F., 1986. East African diatoms; taxonomy, ecological distribution. - Bibliotheca Diatomologica, Cramer Berlin, 11: 201 p.
- Gasse F., 1990. Tectonic and climatic controls on lake distribution and environments in Afar from Miocene to present. - B. J. Katz (ed), Lacustrine Basin Exploration; Case studies and modern analogs, AAPG Memoir 50: 19-41.
- Gasse F., Fontes J. C., Plaziat J. C., Carbonel P., Kaczmarska I., De Deckker, P., Soulié-Märsche I., Callot Y. & P. A. Dupeuble, 1987. Biological remains, Geochemistry and stable isotopes for the reconstruction of environmental and hydrological changes in the

- Holocene lakes from North Sahara. - *Palaeo.*, *Palaeo.*, *Palaeo.*, 60: 1-46.
- Goren-Inbar N., 1981. The lithic assemblages of the site of 'Ubeidiya, Jordan Valley. - Ph.D. Thesis, The Heb. Univ., Jerusalem, 203 p.
- Haas G., 1966. On the vertebrate fauna of the Lower Pleistocene site of 'Ubeidiya. - Israel Academy Sciences and Humanities, Jerusalem, 68 p.
- Krammer K. & H. Lange-Bertalot, 1986. Bacillariophyceae. Part I: Naviculaceae. - In: H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer (eds) *Susswasserflora von Mitteleuropa*. Gustav Fischer Verlag, Jena. 876 p.
- Krammer K. & H. Lange-Bertalot, 1988. Bacillariophyceae. Part II: Bacillariaceae, Epithemiaceae, Surirellaceae. - In: H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer (eds) *Susswasserflora von Mitteleuropa*. Gustav Fischer Verlag, Stuttgart. 596 p.
- Krammer K. & H. Lange-Bertalot, 1991a. Bacillariophyceae. Part III: Centrales, Fragilariaceae, Eunotiaceae. - In: H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer (eds) *Susswasserflora von Mitteleuropa*. Gustav Fischer Verlag, Stuttgart/Jena. 576 p.
- Krammer K. & H. Lange-Bertalot, 1991b. Bacillariophyceae. Part IV: Achnanthaceae. - In: H. Ettl, J. Gerloff, H. Heynig & D. Mollenhauer (eds) *Susswasserflora von Mitteleuropa*. Gustav Fischer Verlag, Stuttgart/Jena. 437 p.
- Patrick R. & C. W. Reimer, 1966. The diatoms of the United States. - *Monographs of the Academy of Natural Sciences of Philadelphia*, 13, (1-2).
- Picard L. & U. Baida, 1966. Geological report on the Lower Pleistocene Deposits of the 'Ubeidiya Excavations. - The Israel Academy of Sciences and Humanities, Jerusalem, 39 p.
- Pienitz R., Walker I. R., Zeeb B. A., Smol J. P. & P. R. Leavitt, 1992. Biomonitoring past salinity changes in an athalassic subarctic lake. - *Int. J. Salt Lake Res.*, 1 (2): 91-123.
- Singer A. & A. Ehrlich, 1978. Paleolimnology of a Late Pleistocene - Holocene crater lake from the Golan Heights, eastern Mediterranean. - *Journal of Sedimentary Petrology*, 48 (4): 1331-1340.
- Soulié-Märtsche I., 1993. Diversity of Quaternary aquatic environments in NE Africa as shown by fossil Charophytes. - Thorweihe & Schandelmeier (eds), *Geoscientific Research in*

Northeast Africa: 575-579.

Tchernov E., 1973. On the Pleistocene molluscs of the Jordan Valley. - Israel Academy of Sciences and Humanities, Jerusalem, 46 p.

Tchernov E., 1980. The Pleistocene birds of 'Ubeidiya, Jordan Valley. - Israel Academy of Sciences and Humanities, Jerusalem, 83 p.

Tchernov E., 1986. The Lower Pleistocene mammals of 'Ubeidiya (Jordan Valley). - Mémoires et Travaux du Centre de Recherche Français de Jérusalem, 5, Association Paléorient, Paris,

405 p.

Tchernov E., 1987. The age of the 'Ubeidiya Formation, an Early Pleistocene Hominid Site in the Jordan Valley, Israel. - Isr. J. Earth Sci., 36 (1-2): 3-30.

Tchernov E., 1992. The Afro-Arabian component in the Levantine mammalian fauna - a short biogeographical review. - Isr. Jour. of Zoology, 38: 155-192.

Van Campo E. & F. Gasse, 1993. Pollen and diatom-inferred climatic and hydrological changes in Sumxi Co Basin (Western Tibet) since 13,000 yr B.P. - Quaternary Research, 39: 300-313.

Walton R. & B. J. Sloan, 1990. The genus *Ammonia* Bruennich, 1772: Its geographic distribution and morphologic variability. - J. Foram. Res., 20 (2): 128-156.

PLATE 1. Diatoms and a Charophyte, of typical fresh to oligosaline conditions in section III
(SEM photomicrographs).

- a) *Ellerbeckia arenaria* (Moore) Crawford, 1988. Layer 8, sample No. 56267-F. Scale bar = 10 μm .
- b) *Cyclotella meneghiniana* Kützing, 1844. Layer 8, sample No. 56267-F. Scale bar = 5 μm .
- c) *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck, 1880-1885. Layer 7, sample No. 56266-F. Scale bar = 5 μm .
- d) *Gomphonema clavatum* Ehrenberg, 1832. Layer 7, sample No. 56266-F. Scale bar = 5 μm .
- e) *Fragilaria construens* var. *venter* (Ehrenberg) Grunow, 1881. Layer 6, sample No. 56265-F. Scale bar = 1 μm .
- f) *Fragilaria brevistriata* Grunow, 1885. Layer 6, sample No. 56265-F. Scale bar = 1 μm .
- g-h) *Nitzschia amphibia* Grunow, 1862. Layer 7, sample No. 56266-F. g) Scale bar = 5 μm .
h) Enlargement of a portion of the same valve. Scale bar = 1 μm .
- i) *Nitzschia denticula* Grunow, 1880. Layer 6, sample No. 56265-F. Scale bar = 10 μm .
- j) *Campylodiscus clypeus* Ehrenberg, 1840. Layer 8, sample No. 56267-F. Scale bar = 10 μm .
Resembles the specimen in Krammer & Lange-Bertalot, 1988 T-175(3).
- k) *Campylodiscus levanderi* Hustedt in Jarnefelt, 1925. Layer 8, sample No. 56267-F. Scale bar = 10 μm . Similar to the specimen in Krammer & Lange-Bertalot, 1988 T-181(6).
- l) A Charophyte oogonium. Layer 8, sample No. 56267-F. Scale bar = 100 μm .

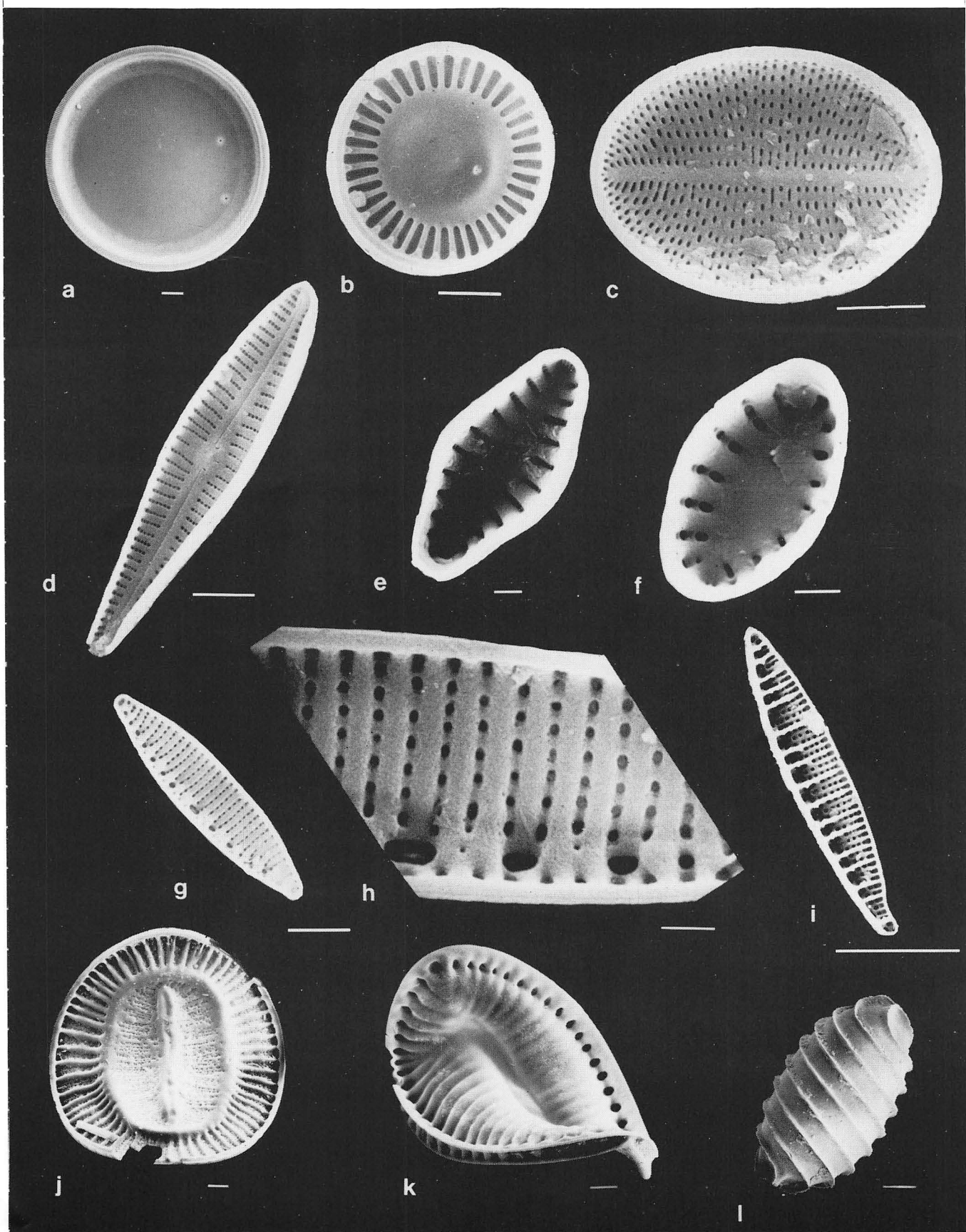


PLATE 1

PLATE 2. Diatoms typical of mesosaline environments in section III.

(SEM photomicrographs).

Scale bar = 10 μm (except g, where it represents 100 μm).

- a-c) *Campylodiscus* sp. a-b) Two specimens of layer 5, sample No. 56263-F. c) Layer III-19, sample No. 56280-F.
- d-f) *Surirella* cf. *capronii* Brébisson in Kitton, 1869. Layer 5. d) Sample No. 56264-F. e-f) Sample No. 56263-F.
- g-i) *Surirella* cf. *robusta* Ehrenberg, 1841. g) Layer 19, sample No. 56280-F. h-i) Layer 5, sample No. 56263-F.

PLATE 3. *Ammonia beccarii* s.l. of the mesosaline conditions.

(SEM photomicrographs).

- a-b) *Ammonia beccarii* (Linné, 1758) cf. *parkinsoniana*. Layer 5 section III, sample No. 56264-F. a) Spiral view, scale bar = 100 μm . b) Umbilical view, scale bar = 10 μm . Note the extremely small size of this form.
- c) *Ammonia beccarii* (Linné) *tepida* Cushman, 1926. Layer 5 section III, sample No. 556264-F. Spiral view, scale bar = 10 μm .
- d-i) *Ammonia beccarii* (Linné) *tepida* Cushman, 1926. Various specimens of layer 33 section Ia. d) spiral view, scale bar = 50 μm , sample No. 56286-F. e) Umbilical view, scale bar = 100 μm , sample No. 56285-F. f) Lateral view, scale bar = 100 μm , sample No. 56286-F. g) Spiral view, scale bar = 50 μm , sample No. 56286-F. h) Umbilical view, scale bar = 100 μm , sample No. 56285-F. i) Lateral view, scale bar = 100 μm , sample No. 56285-F.

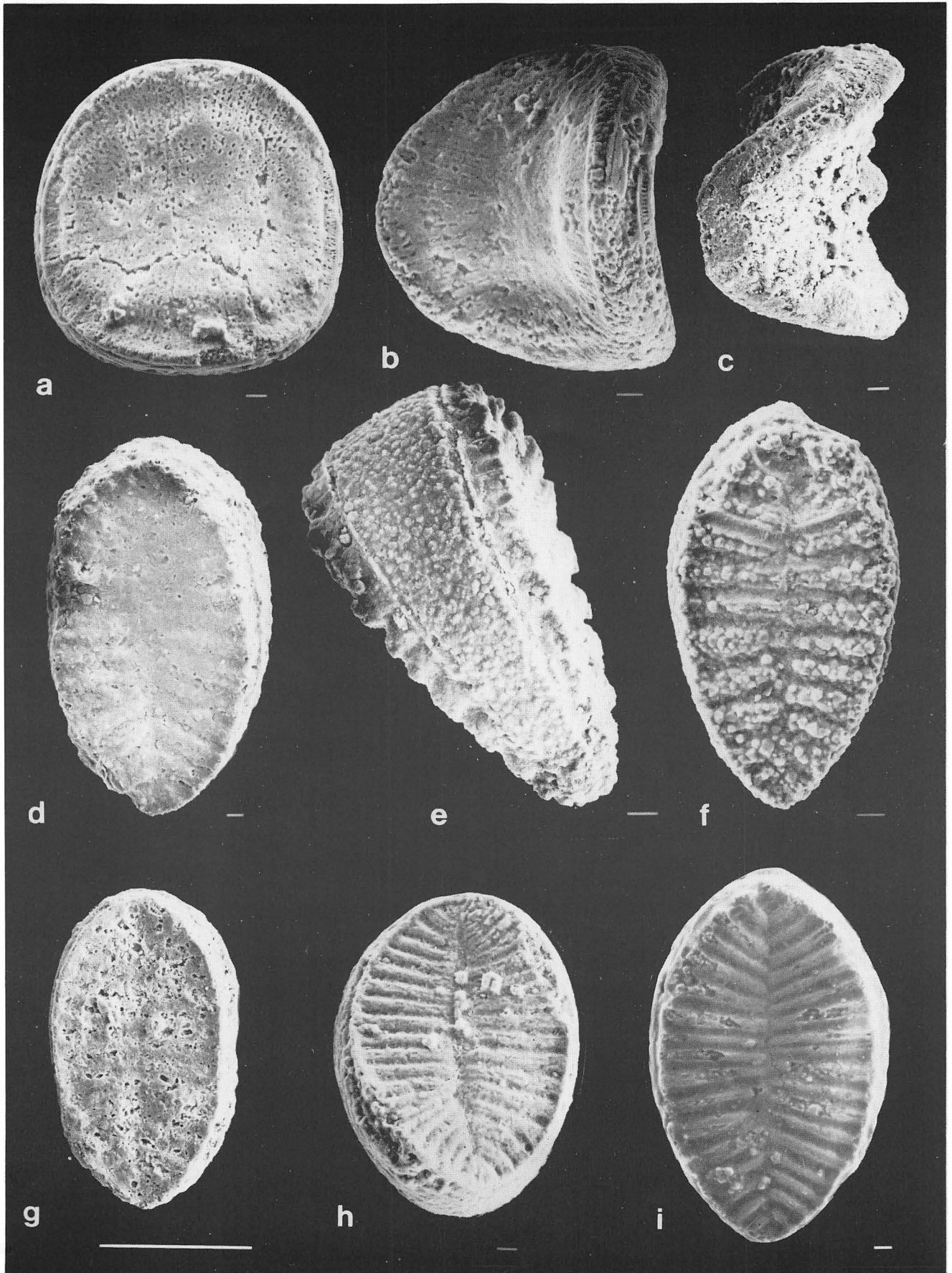


PLATE 2

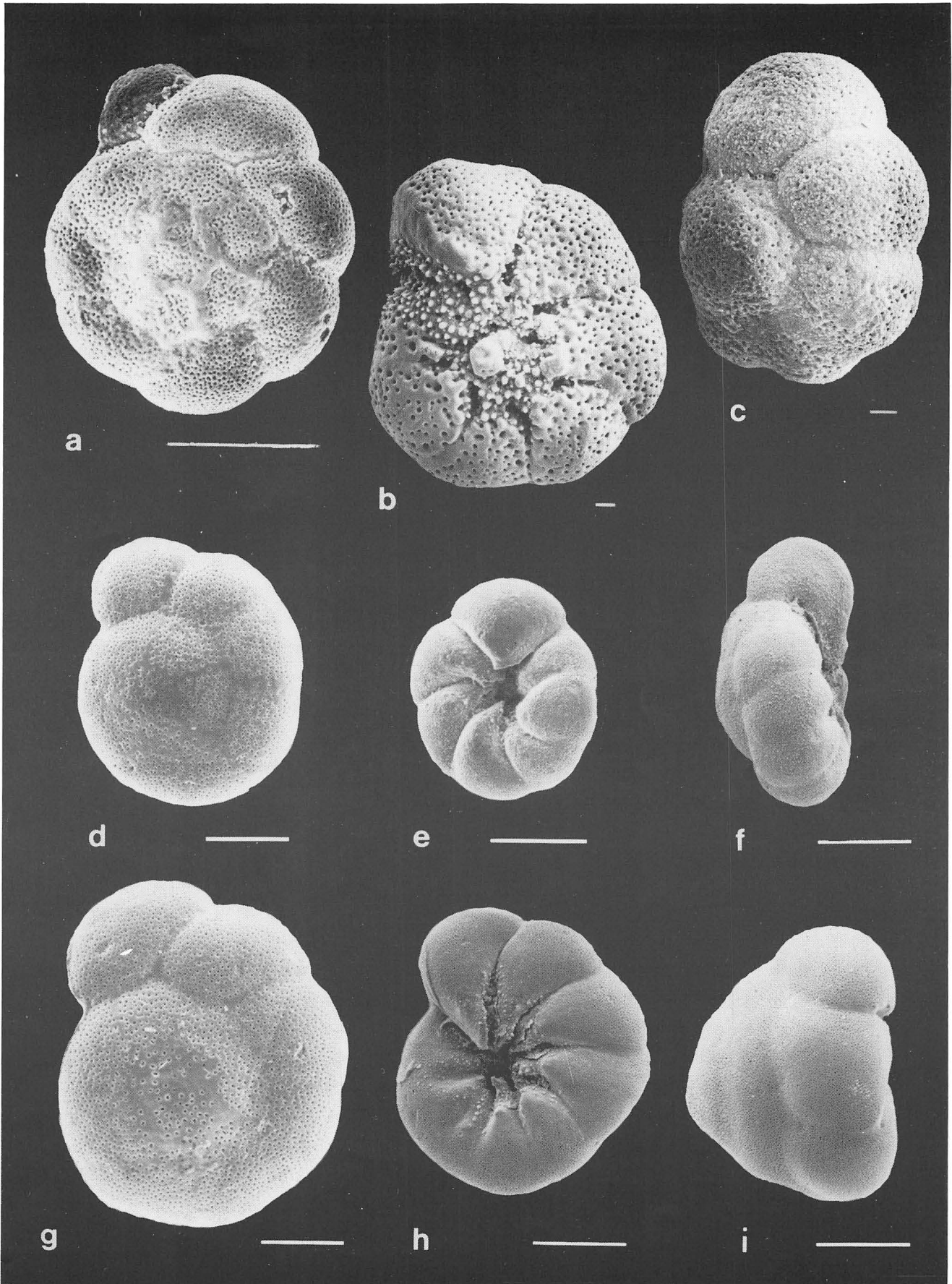


PLATE 3

