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Taxonomy and Paleoecology of marine benthic macrofossils of high-productivity settings, Upper Campanian Phosphate Member of Mishash Formation

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Abstract

The benthic (ground dwelling) macrofossils of the Phosphate Member of the Mishash Formation (Upper Cretaceous; Upper Campanian) in southeastern Israel reflect the ecological and sedimentological conditions under the marine high-productivity settings that prevailed in this region. The studied fossils are dominated by mollusks. Thirty eight bivalve species, 31 of gastropods and a scaphopod species were identified, as well as three serpulid species and calcified cheliped segments of a burrowing crustacean. Many of these species were recorded from the Middle East and North Africa. Some resemble North American taxa, and are temporarily identified as such because of the good paleogeographic connection along the Tethys Ocean based on ammonite species common to both Israel and the Western Interior of the Unites States. The species are described in systematic order with a short discussion and remarks on their distribution, ecological affinities, and their range in the Mishash Formation (range chart).

Introduction

The Mishash Formation in central and southern Israel (Fig. 1) was the object of numerous studies mainly because of the phosphate beds in the upper part of the formation (see Nathan et al., 1979). An understanding of the distribution of the economic beds involved geochemical and petrographic analyses with detailed studies of the diverse kinds of phosphatic particles that constitute the phosphorites (Soudry, 2000; Soudry and Nathan, 1980). These phosphatic beds occur mainly in the Phosphate Member above the Chert Member (Fig. 2). Both members consist of silicates (chert, porcelanite and silicified phosphorite), carbonate and phosphate. The Chert Member is dominated by chert and porcelanite, keeping this lithological aspect throughout the region with minor lateral thickness changes (Soudry et al., 1985). The Phosphate Member consists of organic-rich (preserved in fresh, subsurface samples) carbonate and phosphate in various proportions locally silicified, alternating with chert and porcelanite layers (Fig. 2). The member is divided into the lower Phosphatic Carbonate Unit, the middle Porcelanite Unit, and the upper Phosphorite Unit (Soudry et al., 1985), each dominated by the naming rock type (Fig. 2). However, lateral lithofacies changes toward the deeper part of the Nahal Ashosh (syncline) basin resulted in the recognition of a higher stratigraphic position of the base of the Porcelanite Unit compared to its position at Nahal Qazra (Soudry, 1983; Fig. 1). The lithologies comprising the Mishash Formation reflect a high P-Si-C content characteristic of high-productivity settings as the result of upwelling systems (Almogi-Labin et al., 1993). These regional oceanographic

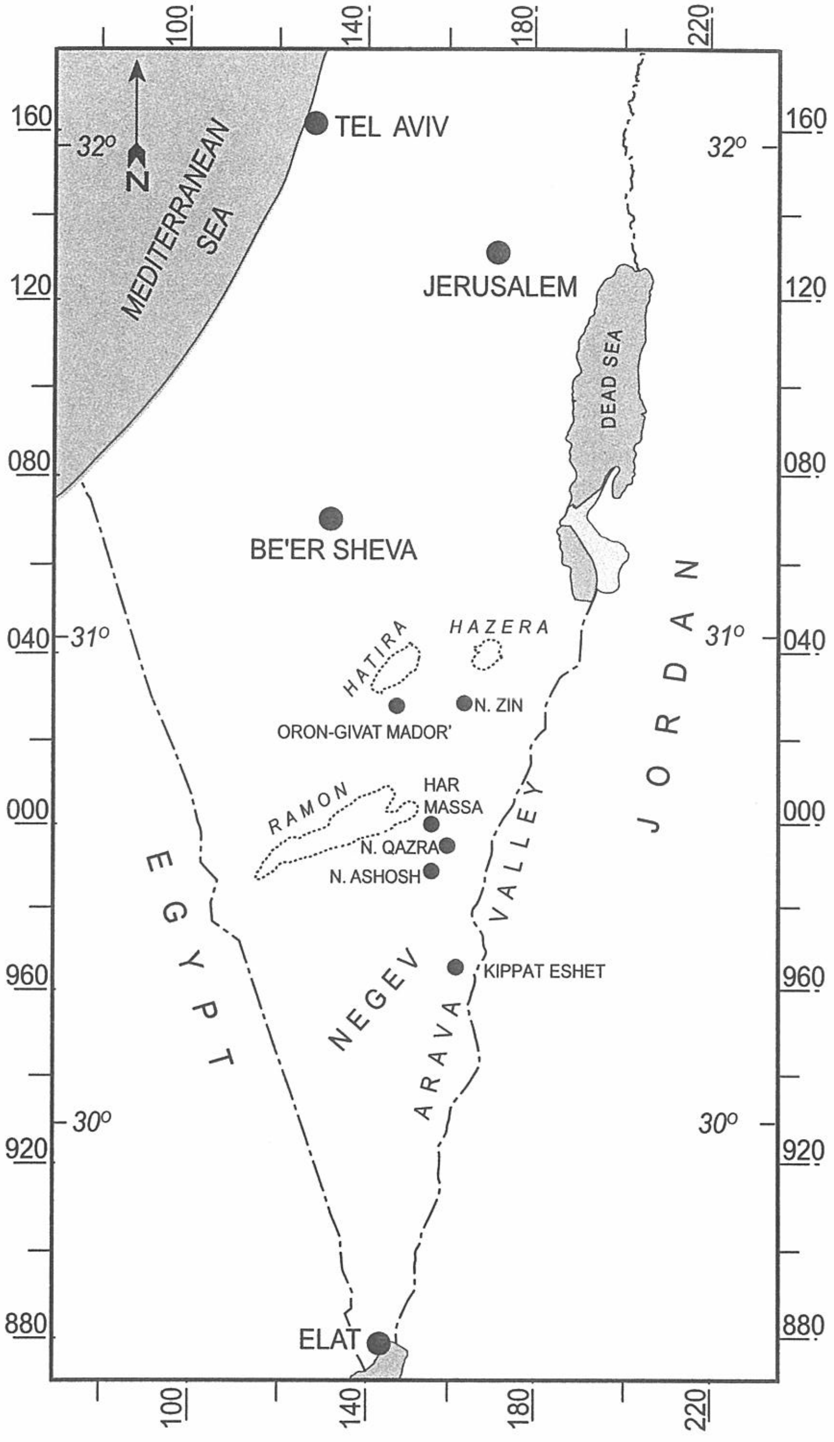

Fig.1. The macrofossils collecting sites in southern Israel.

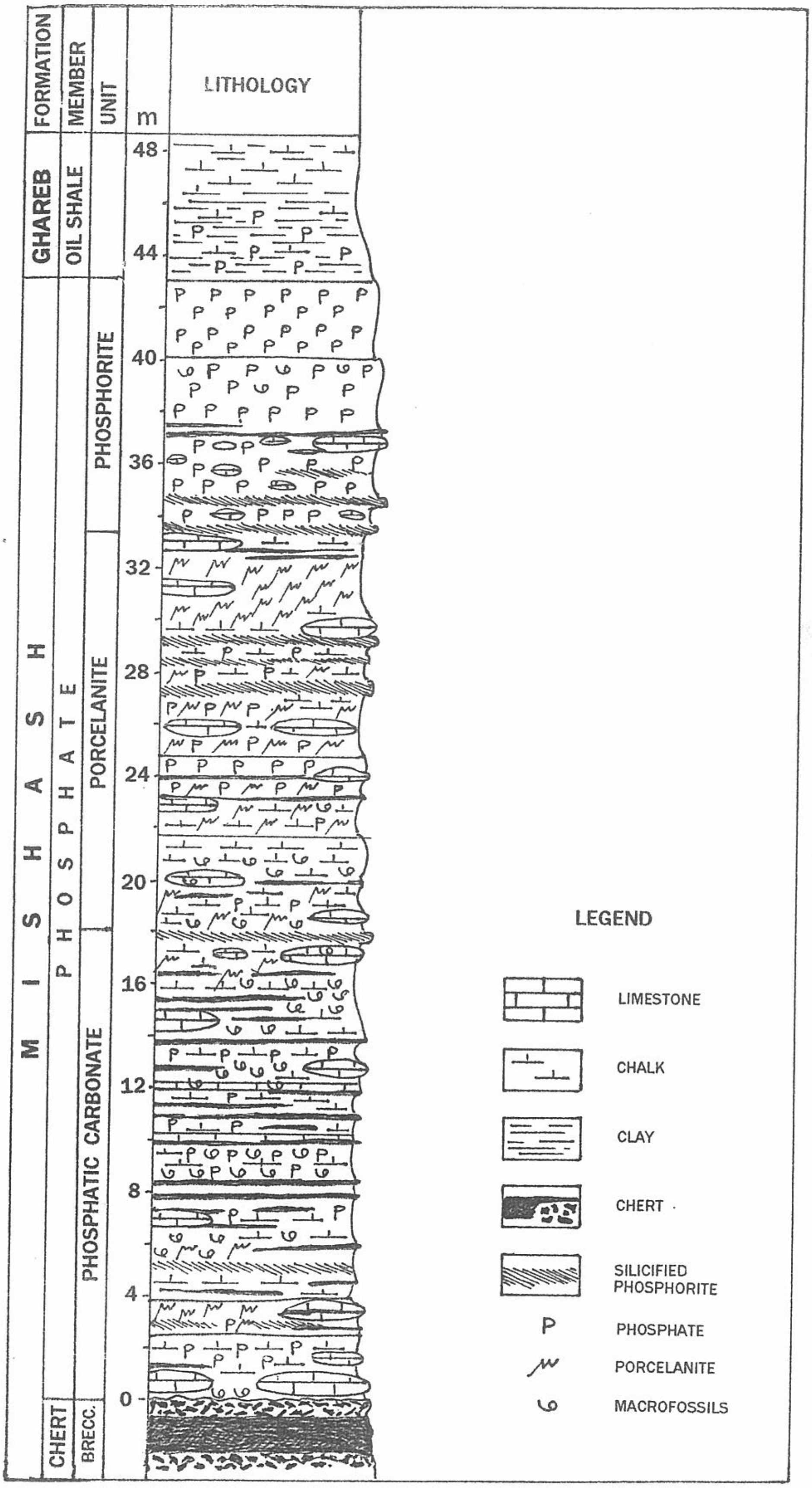

Fig. 2. The Phosphate Mbr. of the Mishash Fm. at the eastern entrance to Nahal Qazra

settings were superimposed on the local Syrian Arc folding system (Krenkel, 1924). The folding and some faulting affected the Phosphate Member as reflected by the profound lateral lithofacies and thickness changes up to its total absence on anticlinal flanks (Soudry et al., 1985). The gradually forming submarine paleostructure (hence paleobathymetry, water energy and rate of deposition) and the resulting complex sedimentary history were reconstructed in relation to the economic phosphorite fields (see in Nathan et al., 1979). During these studies diverse micro- and macrofaunal assemblages were observed, providing paleoecological data (Almogi-Labin et al., 1990; Reiss, 1962, 1988), as well as a detailed biostratigraphic framework based mainly on ammonites (Lewy, 2001). The rich assemblages of benthic macrofossils (mainly bivalves and gastropods) and trace-fossils (e.g., crustacean burrows) were recently studied as additional paleoecological and taphonomic indicators. They should improve the reconstruction of the ecological-sedimentological conditions on, and in the upper layer of the sediment in high-productivity settings under a variety of bathymetries and other chemical and physical oceanographic factors (Edelman-Furstenberg, in prep.).

The material studied

The macrofauna collected from the Phosphate Member during this study, as well as additional taxa from the member previously collected (mainly by Z. L.) in southern Israel, are listed in systematic order. The identification of the taxa is based on species described from Israel (mainly Lartet, 1877; Blanckenhorn, 1927, 1934; Chavan, 1947; Picard, 1930, and other cited references) and North Africa (e.g., Quaas, 1902; Pervinquière, 1912). Nevertheless some specimens are compared to North American taxa because of the good biogeographic connection along the Tethys Ocean between the Western Interior of the United States and Israel in Late Cretaceous times as evidence by ammonites (e.g., Lewy, 2001). In the absence of many of the old paleontological descriptions referred to in these publications the present study accepts the analyses and synonymy lists presented there with minor discussion. The systematic order of the bivalves is based on part N of the Treatise of Invertebrate Paleontology (Moore, 1969; Stenzel, 1971). However, the lack of a similar comprehensive systematic description of fossil gastropods required the compilation of a tentative and partial systematic scheme for the fossil gastropods. The references relating to the systematic order of the species, cites only the publication of the identified species, disregarding the authors of higher systematic ranks. The main study areas comprise Nahal Ashosh and Nahal Qazra-Har Omer (Fig. 1). Additional species found in the

Phosphate Member in other places (e.g., Kippat Eshet, Oron-Giv'at Mador, Nahal Zin; Fig. 1) are marked in the text and the range-chart (Table 1) by an asterisk. The rare occurrence of two rudist species (attached bivalves: *Durania farafrahensis* Douvillé and *Biradiolites* sp.) found at the uppermost part of the Phosphate Unit at Nahal Ashosh (Har Nishpe; Lewy, 1995) are mentioned herein though they are not characteristic to the benthic fauna of the Phosphate Member and represent local ecological conditions.

The aim of the study is to record the macrofossils of the Phosphate Member of the Mishash Formation, with paleontological remarks and photographs of most of the species. This follows the detailed documentation of the mollusks from the lowermost part of the Mishash Formation near the Mount of Olives (Jerusalem) by Chavan (1947, 1948). In the lack of several old paleontological publications the present study refers to the available best systematic analysis of each taxon without presenting a full synonymy list or discussing similarly looking species.

Mode of preservation

The fossilized conchs of the Mishash Formation occur as almost original calcitic shells of oysters, *Pinna* and inocerami species. Aragonitic shells altered to calcite, mostly without preserving the original microstructure. Some shells in limestone are partly silicified. A silicified phosphatic carbonate contains molluscan silicified internal mold while the aragonitic shells dissolved during diagenesis. Completely silicified conchs paving chert beds or in porcelanitic carbonate preserve the delicate external features, as well as part of the original micro-texture, mainly of the external and internal surfaces, whereas the inner part of the shell dissolved and recrystallized as chalcedony. Silicification must have proceeded rapidly from the outside of the shell inward while the organic framework of the microstructures remained in tact. Only the innermost part of the conch dissolved and recrystallized later. Shells of the ammonite *Baculites* reflect the pearl mother luster, preserved as silica in the microstructure of the original aragonitic nacreous inner layer.

Articulated bivalves are not only of deep and shallow burrowers, but also of the epifaunal *Nannonavis* and *Plicatula*. Thick shells are usually complete, articulated or disarticulated. Molluscan fragments are mainly of thin shells associated with a few complete specimens (articulated or disarticulated) of the same species. It seems that disarticulation and selective fragmentation of thin shells do not result from wave energy or sediment compaction but rather from the predation activity of crustaceans and some fish. *Cliona* borings occur on a few

Pycnodonte (reclining oysters) and perhaps also on *Plicatula* (cemented). A single ammonite conch is encrusted by serpulids. Otherwise most of the molluscan shells are not corroded, nor bored by epizoans, apart of naticid (predating gastropod) borings.

Paleoecological remarks

The general aspect of the molluscan fauna of the Phosphate Member of the Mishash Formation reflects adaptation to low-energy bottom settings as suggested by the associated beds of fine-grained, organic-rich carbonate and porcelanite. The common species are of small burrowing bivalves (nuculanids, lucinids, venerids, corbulids) and narrow-elongated gastropods such as *Turritella* and the small *Clathroscala* species, and small Naticidae. The quite common large and small aporrhaid (*Struthioptera* and *Drepanochilus*) species are characterized by the winged terminal aperture which prevents them from sinking into fine grained (low-energy) sediments. The largest gastropod of the genus *Volutomorpha*, which reaches a height of more than 25cm, has a very long and hence fragile siphonal canal and also must have lived under low-energy settings. The largest bivalve is *Sphaera*?, which is more than 10cm long, 9.5cm high and nearly 8cm the breadth of both valves. This large burrower occurs together with the large *Volutomorpha* and *Protocardia silicea* in shell beds with diverse molluscan species (15-20 species) in the upper part of the Phosphatic Carbonate Unit suggesting to represent the best-aerated and periodically agitated (winnowed) bottom conditions. Therefore, the taphonomic history of these assemblages reflect exhumation, intensive winnowing and some transportation, as has been demonstrated on the associated phosphorite beds (Soudry, 1983, 1987).

The more restricted low-energy bottom settings are reflected by beds with a low species-diversity to monospecific populations (e.g., the nuculanid *Mesosacella*, *Lucina* and *Parmicorbula*) that indicate low-oxygen conditions. The bivalves in these low-diversity assemblages are well-preserved and articulated *Lucina dachelensis* and *Mesocallista*? *rohlfsi* in phosphatic carbonate. Many extant lucinid species have chemoautotrophic endosymbionts in their gill, enabling them to thrive in low-oxygen settings where no other organism can live and nourish (e.g., Distel, 1998). This phenomenon among the Lucinidae, or another physiological adaptation can be applied to *Mesosacella*? *rohlfsi* (Veneridae) as well, because it exclusively appears in concentrations of articulated large specimens, or dominates the faunal assemblage in phosphatic sediments.

The reclining oyster *Pycnodonte vesicularis* tends to appear exclusively in argillaceous (mainly phosphatic) sediments. Rarely they occur with the other molluscan species. The oyster *Rastellum diluvianum* tends to concentrate in a layer, but many of the shells seem disarticulated and hence in an in-situ disturbed population.

A large conch of an ammonite, an inoceramid bivalve, or vertebrate remains are found enclosed in limestone concretions in a phosphatic-porcelanitic carbonate. These fossils are mainly of nektonic organisms (swimming at the upper part of the water column), or inoceramid bivalve that seem to tolerate low-oxygen bottom settings. The other rare mollusks found in concretions live under low-energy such as corbulid, lucinid and venerid bivalves. It was suggested that the decomposition of the organic matter (including the skeletal organic framework) results in localized chemical settings whereby calcium carbonate precipitates at the decomposition site and silica moves away and precipitates at the concretion median periphery (Sass and Kolodny, 1972). The formation of similar limestone concretions were explained in other ways as well, but all relate to local ion mobilization in restricted sedimentary settings.

Crustacean burrows occur at the top of calcareous beds. They are usually filled with phosphate or phosphatic carbonate that forms the overlying layer. The burrowing activity was carried out in a stabilized (firm) sediment, and the burrows were later filled by a different sediment than the surrounding substrate, suggesting transportation from elsewhere. Therefore, the burrowed level represents a sedimentary omission surface. Crustacean calcified cheliped (arm; *Protocallianassa*?) and leg segments were found together with phosphatic burrow fillings (*Thalassinoides*) near the top of the Mishash formation at Oron-Giv'at Mador. Burrow fillings in other regions did not yield any crustacean fragments.

Systematic description

Class BIVALVIA Linné, 1758
Order NUCULOIDA Dall, 1889
Superfamily NUCULACEA Gray, 1824
Family NUCULIDAE Gray, 1824
Genus *Nucula* Lamarck, 1799
Nucula crebrilineata Conrad, 1852
Fig. 1

Remarks: This rather small, shallow burrowing bivalve is described and discussed by Chavan (1947, p. 191). The species is usually rare, but can dominate a certain layer of restricted distribution (e.g., lower level of *Baculites palestinensis* Zone at Nahal Zin).

Family NUCULANIDAE Adams & Adams, 1858
Genus *Mesosaccella* Chavan 1946

Mesosacella grovei (Chavan, 1947) (=*larteti* Chavan, 1947)

Fig. 2a-c

Remarks: Chavan (1947) distinguished two new nuculanid species without pointing out the differences between them. Both have a similar outline and are nearly smooth with fine concentric growth-lines (cf. *grovei*; Chavan, 1947, pl. 4, fig. 17). Others bear fine concentric ribs in varying density (seeming to widen from the Lower Campanian upward) with growth-lines in between, especially in the early growth stage (cf. *larteti*; Chavan, 1947, pl. 4, fig. 23). The intra-populational variability of the collected material does not substantiate the differentiation between these morphotypes as described by Chavan (1947).

Mesosacella perdita (Conrad, 1852) was described from the lower part of the Mishash Formation near Jerusalem (Chavan, 1947). Its record from higher levels (Phosphate Mbr.) was not confirmed during the present study.

Subclass CRYPTODONTA Neumayer, 1884
Order SOLEMYOIDA Dall, 1889
Family SOLEMYIDAE Adams & Adams, 1857 (1840)
Genus *Solemya*, Lamarck, 1918
**Solemya* cf. *S. subplicata* (Meek & Hayden, 1856)

Fig. 3

Remarks: The single fragment from the Phosphorite Unit at Oron-Giv'at Mador is identified by the radiating microstructure (partly dissolved) of the thin, fragile shell.

Subcalss PTERIOMORPHIA Beurlen, 1944
Order ARCOIDA Stoliczka, 1871
Superfamily ARCACEA Lamarck, 1809
Family PARALLELODONTIDAE Dall, 1898
Genus *Grammatodon* Meek & Hayden 1861
Subgenus *Nannonavis* Stewart, 1930
Nannonavis parallelus (Conrad, 1852)

Fig. 4a-d

Remarks: The species is quite common and many specimens are articulated, with the right valve smaller than the left one. The specimens from various Campanian levels show intra-populational morphological variations of ribbing. Lower Campanian specimens are finely and densely ribbed. Middle and Upper Campanian specimens are more irregularly ribbed, with a weakly ribbed mid-lateral part and an up to smooth posterior part. However, this trend in morphological change seems gradual and cannot be divided at any level for the distinction of successive species.

Family GLYCYMERIDAE Newton, 1922
Subfamily ARCULLAEINAE Newell, 1969
Genus *Israelarca* nov. gen.
Israelarca elroni gen. & sp. nov.

Fig. 5a, b

Holotype: Largest, most complete specimen in the center of a slab (Fig. 5a), surrounded by more of its kind. M-7723 from Nahal Zin (1753/0365; collected by E. Elron).

Stratigraphic position: Upper Campanian Mishash Fm. (Phosphatic Carbonate Unit; lower part phosphatic layer at Nahal Ashosh; precise level of holotype in the unit is unknown).

Derivation of name: *Israelarca*, following *Peruarca*; and *elroni* in honor of the collector Ehud Elron.

Description: Moderately large (up to 58mm long), elliptical, equivalve, inequilateral valves with an opisthogyre beak. The hinge is slightly bent into a short anterior part with weakly arched, forward concave teeth, and a posterior, longer straight part with numerous inclined teeth (posterior end not preserved). Shell exterior with growth lines and a weakly angular flexure extending from the beak to the posterior-ventral end of the valve.

Remarks: The new genus resembles the Upper Cretaceous genus *Peruarca*, differing from the latter by a much more inequilateral (backward elongated) valves.

Occurrence: The precise level of the holotype in the Phosphatic Carbonate Unit is unknown. The species occurs in Nahal Ashosh at the base of the Unit. Similar valves occur at the top of the Chert Member (Mishash Fm.) in the Har Omer region, which their hidden hinge does not enable precise identification.

Order MYTILOIDA Férussac, 1822
Superfamily MYTILACEA Rafinesque, 1815
Family MYTILIDAE, Rafinesque, 1815
Subfamily MODIOLINAE Keen, 1958
Genus *Modiolus* Lamarck, 1799
**Modiolus* sp.
Fig. 6

Remarks: The single specimen from the Phosphorite Unit of Oron-Giv'at Mador is a young stage (small) of an articulated, smooth (growth lines only) *Modiolus.*

Superfamily PINNACEA Leach, 1819
Family PINNIDAE Leach, 1819
Genus *Pinna* Linné, 1758
Pinna sp.
Fig. 7

Remarks: The dorsal half of the shell bears radiating ribs, and the ventral half is ornamented by concentric growth-lies and folds, resembling the Aptian *P. robinaldina* d'Orbigny.

Order PTEROIDA Newell, 1965
Superfamily PTERIACEA Gray, 1847
Family INOCERAMIDAE Giebel, 1852

Remarks: Inoceramidae shells occur embedded in limestone concretions in the lower third of the Porcelanite Unit (mainly Nahal Qazra region) and in the fossiliferous beds in between bituminous phosphate of the Phosphorite Unit. Inoceramid shell prisms were observed in some other carbonate beds.

Genus *Cataceramus* Heinz, 1932
Cataceramus goldfussianus (d'Orbigny, 1847)
Fig. 8

Remarks: The material is fragmented and referred to this "classical" species on the basis of the smooth shell with concentric folds of a longer than high valve shape.

Genus *Trochoceramus* Heinz, 1932
Trochoceramus costaecus (Khalafova, 1966)
Fig. 9

Remarks: This Maastrichtian species from Russia was identified by Walaszczyk et al. (2002) among the Upper Campanian-Lower Maastrichtian inoceramids of Tercis (France). It is

characterized by radiating folds rather than by shell shape. Its distinction from *T. radiosus* (Quaas, 1902) is therefore obscure on incomplete material. Meantime the *Trochoceramus* fragments are referred to *T. costaecus.*

Superfamily PECTINACEA Rafinesque, 1815
Family PECTINIDAE Rafinesque, 1815
Genus *Chlamys* Röding, 1798
Subgenus *Aequipecten* Fischer, 1886
Aequipecten acuteplicatus (Alth, 1850)

Remarks: These pectinids first occurs in the uppermost part of the Phosphorite Unit correlative by ammonite zonation to the North American *Baculites reesidei* Zone, high in the Upper Campanian, ranging throughout the Maastrichtian Ghareb Formation.

Family PLICATULIDAE Watson, 1930
Genus *Plicatula* Lamarck, 1801
Plicatula batnensis Coquand, 1880
Fig. 10a-c

Remarks: The identification is based on Pervinquière (1912, p. 162, pl. 9 figs. 21 a-c). However, some specimens (Fig. 10c) are ornamented by more widely spaced ribs comparable to a Maastrichtian form attributed by Pervinquière (1912, Pl. 11, fig. 24) to *P. flattersi* Coquand 1862. The species is restricted to the upper part of the Phosphatic Carbonate Unit, where it is associated with a diverse assemblage of benthic and nektonic (ammonites) mollusks.

Suborder OSTREINA Férussac, 1822
Superfamily OSTREACEA Rafinesque, 1815
Family GRYPHAEIDAE Vyalov, 1936
Subfamily PYCNODONTEINAE Stenzel, 1959
Genus *Pycnodonte* Fischer de Waldheim, 1835
Subgenus *Phygraea* Vialov, 1936
Pycnodonte (*Phygraea*) *vesicularis* (Lamarck, 1806)

Remarks: This temporarily cemented and mainly reclining bivalve frequently comprises the exclusive species in marly or chalky beds, probably reflecting a soft ground, unstable and unfavorable for infaunal (burrowing) and other epifaunal organisms.

Family PALAEOLOPHIDAE Malchus, 1990
Genus *Rastellum* Faujas-Saint-Fond, ?1799 (1802)
Rastellum diluvianum (Linné, 1767)

Remarks: This species closely resembles *Hyotissotia semiplana* (J. de C. Sowerby, 1825), differing from the latter by lack of vesicular shell structure, which was not detected on our specimens. The species occurs in several localities concentrated in a phosphatic carbonate layer (middle Phosphatic Carbonate Unit), which may not be contemporaneous (e.g. Oron and Nahal Zin regions).

Family OSTREIDAE Rafinesque, 1815
Subfamily OSTREINAE Rafinesque, 1815
Genus *Ostrea* Linné, 1758
**Ostrea* sp.

Remarks: The single fragment is part of a highly diverse macrofaunal assemblage in the upper part of the Phosphatic Carbonate Unit of Kippat Eshet.

Subfamily LOPHINAE Vayalov, 1936
Genus *Lopha* Röding,1798
Subgenus *Actinostreon* Bayle, 1878
**Actinostreon sollieri* (Coquand, 1869)

Fig. 11

Description: The single, large (176mm of height), right valve has a sub-quadrate elongated shape. The external side is corroded, but shows the 'dichotomous', coarse angular ribs radiating from the beak, forming a zigzag-shaped commissure. These ribs curve sidewise on both posterior and anterior upper (dorsal) flanks of the shell and become finer and more densely spaced than the ribs on the main surface of the valve. The specimen looks like a gigantic '*Lopha*' *dichotoma* (Bayle, 1849).

Remarks: Malchus (1990) erected the genus *Oscillopha* based on the species *dichotoma* Bayle (1849). He followed Pervinquière (1929, p. 206) and included in this species the Campanian species *sollieri* (Coquand, 1869), whereby the typical Coniacian range extended to the Upper Campanian. It is temporarily preferred to distinguish this Upper Campanian species from the Coniacian one until more material will be found, as well as refer to the previous nomenclature as presented by Stenzel (1971).

Occurrence: The single, gigantic specimen was found in the Phosphate Member (by D. Soudry) on the southeastern flank of the Hatira anticline inclined toward the Oron syncline. The specimen preserves pelloidal phosphatic components and is supposed to originate from the lower part of the member. It may represent shallow marine settings, different from the more basin-ward environment near Giv'at Mador where most of the collecting was done.

Lopha? sp.

Fig. 12

Remarks: The fragment with angular coarse ribs found in the upper part of the Phosphatic Carbonate Unit of Nahal Qazra-Har Omer, may be part of *Rastellum diluvianum* known from this unit in other localities in a more flattened and finely ribbed shape.

Genus *Nicaisolopha* Vialov, 1936
**Nicaisolopha forgemolli* (Coquand, 1869)

Fig. 13

Description: The ribs radiating from the beak are rounded and tend to be of an irregular width. Like in *Actinostreon* the dorsal posterior and anterior ribs are narrower and more densely spaced than the ribs on the main surface of the right valve.

Occurrence: The species occurs in phosphate at the top of the Mishash Formation of the Oron-Giv'at Mador and Nahal Zin regions together with *P. vesicularis* and *Aequipecten acuteplicatus.*

Genus *Ambigostrea* Malchus 1990
Ambigostrea villei (Coquand, 1862)

Remarks: This species concentrates in a bed in the upper part of the Chert Member at Kippat Eshet and Nahal Ashosh and forms a lenticular body in the southern Arava Valley (Lifshitz et al., 1985). Similar bioherms occur beside intraformational faults (e.g. Porcelanite Unit) in southern Israel (Bartov and Steinitz, 1982). These bioherms comprise densely ribbed typical *villei* as well as coarsely ribbed valves of the species *forgemoli* Coquand, 1862, regarded by Malchus (1990) identical to *villei* Coquand of the same publication. Fragments of the coarsely ribbed morphotype are associated with *P. vesicularis* at the top of the formation.

Subclass HETERODONTA Neumayer, 1884
Order VENEROIDA Adams & Adams, 1856
Superfamily LUCINACEA Fleming, 1828
Family *LUCINIDAE* Fleming, 1828
Genus *Lucina* Bruguière, 1797
Lucina blanckenhorni Chavan, 1947

Fig. 14a-c

Remarks: The species is very common in the molluscan assemblages of the Mishash Formation, ranging throughout the Chert Member and the Phosphatic Carbonate Unit of the Phosphate Member. The concentric ribs of this species are irregular in strength and spacing comprising low-fine ribs in between more protruding ones. The height to length ratio (H/L) is 0.83-0.86, compared to the regularly and densely ribbed *Lucina dachelensis* with H/L 0.77-0.80.

Lucina dachelensis Wanner, 1902

Fig. 15

Remarks: This lucinid was referred by Blanckenhorn (1934) and A. Parnes (in Bentor and Vroman, 1960, p. 53) to *Lucina dachelensis* Wanner (1902). The species probably evolved from *L. blanckenhorni* through a rapid increase in size (mainly length) and a denser spacing of the concentric elevated ribs. It succeeds *L. blanckenhorni* in the overlying Porcelanite and Phosphorite units and dominates the benthic macrofauna in phosphatic sediments.

Lucina? sp.

Fig. 16a, b

Description: almost circular (slightly longer than high), equivalve, smooth (growth lines only) shell. The posterior margin is less rounded than the anterior one. The posterior part is demarcated from the main surface of the valve by a weak flexure extending from the beak to the posterior-ventral corner, where the curvature of the commissure changes between the venter and the posterior side. This pattern recalls a lucinid shape, though the structure of the hinge teeth is not known.

Remarks: The unidentified species is rare and occurs in 1-2 specimens in a few levels in the Phosphate Member.

Genus *Pterolucina* Chavan, 1942
Pterolucina? *subnumismalis* (D'Orbigny, 1850)

Fig. 17a, b

Description: Large (59mm long, more than 52mm high) lucinid with growth line and low, concentric fine ribs. Inner surface (on a mold; Fig. 17b) with a radiating sculpture. The species, as recognized in the present material, may belong to the genus *Pterolucina*.

Remarks: The species was described by Picard (1930, p. 529, pl. 21, fig. 22) from the Phosphorite Unit of the Judean Desert. It is quite rare, but ranges throughout the whole Phosphate Member.

Family FIMBRIIDAE Nicol, 1950
Genus *Sphaera* Sowerby, 1822
Sphaera? sp.

Fig. 18a, b

Description: Large (10.5cm long, 9-10.5cm high), globose (about 8cm breadth of articulated valves), nearly equivalve (in some specimens the right valve seems larger), smooth conch. Beaks

prosogyrous. Right valve with a massive frontal elongated (poorly preserved) tooth, a socket and a cyclodont tooth. Relics of the inner part of shell show a dense radial pattern.

Remarks: The inflated shape and the relics of the cardinal teeth resemble the genus *Sphaera*, which usually bears corrugated concentric ribs.

Superfamily CARDITACEA Fleming, 1820
Family CARDITIDAE, Fleming, 1828
Subfamily CARDITESINAE Chavan, 1969
Genus *Ludbrookia* Chavan, 1951
Ludbrookia? *barroneti* (Munier-Chalmas, 1881)
Fig. 19a-c

Description: Moderately sized (22mm long) subquadrate , equivalve, inequilateral shell, ornamented by strong ribs radiating from the eccentric (anterior) beak. The ribs bear blunt spines (echinate).

Remarks: The hinge dentition is not well preserved and the species may belong to *Venericardia.*

Superfamily CRASSATELLACEA Férussac, 1822
Family CRASSATELLIDAE Férussac, 1822
Genus *Crassatella* Lamarck, 1799
Subgenus *Landinia* Chavan, 1952
Landinia rothi (Fraas, 1867)
Fig. 20a-c

Remarks: The species is abundant in the upper part of the Phosphatic Carbonate Unit and hence a guide fossil for this part of the succession. Isolated lower and higher rare occurrences were observed as well.

Superfamily CARDIACEA Lamarck, 1809
Family CARDIIDAE Lamarck, 1809
Subfamily PROTOCARDIINAE Keen, 1951
Genus *Protocardia* von Beyrich, 1845
Protocardia silicea Blanckenhorn, 1934
Fig. 21a-c

Remarks: This local species defined by Blanckenhorn (1934, p. 245, pl. 13, figs. 133, 134) is characterized by the coarsening of ribbing and larger dimensions than in the widely distributed and long ranging *P. hillana* (Sowerby), which occurs at the lower part of the Mishash Formation (Middle Campanian). In contrast to other protocardiids, the posterior region of *P. silicea* is divided into an outer part with the typical radiating ribs and an inner protruding part with concentric growth folds only (Fig. 17a), comparable to the escutcheon.

Superfamily MACTRACEA Lamarck, 1809
Family MACTRIDAE Lamarck, 1809
Genus *Mactra* Linné 1767
*cf. *"Mactra"* sp.
Fig. 22

Description: A nearly complete external surface of right valve and a fragment of a smooth (growth lines only), triangular, thin shell. The beak is sub-central, slightly closer to the broad posterior side. The anterior-ventral part is demarcated from the main surface of the valve by a weak angular flexure, which occurs in many Mactridae.

Remarks: These two questionable representatives of the Mactridae were collected from the Phosphorite Unit of Oron-Giv'at Mador.

Superfamily TELLINACEA de Blainville, 1814
Family TELLINIDAE de Blainville, 1814
Genus *Tellina* Linné, 1758
**Tellina*? cf. *T. marcouti* (Coquand, 1862)
Fig. 23

Description: 30-33mm long and 21-23mm high, rather flattened, elliptical valves ornamented by concentric, fine lirae. The posterior side is demarcated from the main surface by an angular ridge and an angular posterior-ventral margin of the valve, characteristic of many tellinids.
Remarks: The species is quite common and articulated. It resembles *Tellina* sp. from the uppermost Campanian to Lower Maastrichtian of central Egypt (Quaas, 1902, pl. 25, figs. 5-6), and the Cenomanian-Coniacian *Lavignon marcouti* Coquand (in Pervinquière, 1912, pl.19, figs. 28a, b).

Superfamily ARCTICACEA Newton, 1891
Family ARCTICIDAE Newton, 1891
Genus *Veniella* Stoliczka, 1870
Veniella auressensis (Coquand, 1862)
Fig. 24

Remarks: The small populations of this species are variable in ribbing intensity and spacing, and Coquand's species should include *V. drui* (Munier-Chalmas, 1881) as a junior synonym. However, larger populations are needed to confirm this morphological variability and the resulting wide stratigraphic range of the species (at least Cenomanian-Maastrichtian; see Greco, 1917) .

Superfamily VENERACEA Rafinesque, 1815
Family VENERIDAE Rafinesque, 1815
Subfamily PITARINAE Stewart, 1930
Genus *Mesocallista* Cox 1952
Mesocallista andersoni Newton, 1909
Fig. 25a-c

Remarks: This is a moderately sized (about 2cm long) venerid with concentric, periodic, elevated, sharp ribs up to 1mm spacing at the mature stage. Lunule and escutcheon degenerated or missing.

Mesocallista? *rohlfsi* (Quaas, 1902)
Fig. 26a-c

Discussion: This is the largest venerid species ornamented with concentric lirae (strong growth lines). The rich material exhibits individual long (Fig. 26b) or short (Fig. 26c) length. Lunule and escutcheon are well developed, in contrast to *M. andersoni*; therefore the attribution of the species to *Mesosacella* is questionable.

Mesocallista sp.
Fig. 27

Remarks: This moderately sized (e.g., 28mm long) venerid bears widely spaced (2mm apart), concentric ribs by which it differs from the other venerids. Lunule and escutcheon degenerated (hardly discernible).

Subfamily MERETRICINAE Gray, 1847
Genus *Meretrix* Lamarck, 1799
Meretrix? *judaica* Picard, 1930
Fig. 28a, b

Remarks: The small species (up to 18mm long) has a well developed lunule and ornament of growth lines only, thus it is easily confused with small *M. rholfsi.* The main difference in the exterior shape is by the weak posterior-ventral sinusoidal curvature of the commissure

Order MYOIDA Stoliczka, 1870
Superfamily MYACEA Lamarck, 1809
Family CORBULIDAE Lamarck, 1818
Subfamily CORBULINAE Gray, 1823
Genus *Corbula* Bruguière, 1797
Subgenus *Flexicorbula* Chavan, 1947
Corbula (*Flexicorbula*) *vokesi* Chavan, 1947
Fig. 29

Remarks: This rare species first described from the lower part of the Mishash Formation (Chavan, 1947) is represented by two right valves from the lower and upper part of the Phosphatic Carbonate Unit of Nahal Qazra-Har Omer.

Subfamily CAESTOCORBULINAE Vokes, 1945
Genus *Caestocorbula* Vincent, 1910
Subgenus *Parmicorbula* Vokes 1944
Parmicorbula subelegans (Picard, 1930)
Fig. 30a, b

Remarks: This rather common species ranges throughout most of the Campanian of Israel associated with other Corbulidae of a much shorter range.

Superfamily HIPPURITACEA Gray, 1848
Family RADIOLITIDAE Gray, 1848
Subfamily BIRADIOLITINAE Douvillé, 1902
Biradiolites sp.
Fig. 31a, b

Remarks: This yet unidentified form is known from the Upper Campanian phosphate of top Mishash Formation at Nahal Ashosh and the Oron-Giv'at Mador region. It is associated with fragments of *Durania farafrahensis,* which ranges into the Upper Maastrichtian (Lewy, 1995).

Subfamily SAUVAGESIINAE Douvillé, 1908
Genus *Durania* Douvillé, 1908
Durania farafrahensis Douville, 1912

Remarks: The occurrence of this rudist in Israel was discussed by Lewy (1995).

Subclass ANOMALODESMATA Dall, 1889
Order PHOLADOMYOIDA Newell, 1965
Superfamily PHOLADOMYACEA Gray, 1847
Family PHOLADOMYIDAE, Gray, 1847
Genus *Pholadomya* G. B. Sowerby, 1823
Pholadomya sp.

Fig. 32

Description: Elongated shell (49mm long) with subparallel dorsal and ventral margins. The articulated bivalve is broadest at the anterior end, tapering backward. The mold preserves the irregular concentric growth lines crossed by a few, low radial ribs.

Remarks: The poorly preserved specimens resemble *Pholadomya pedernalis* Roemer from the Middle Cretaceous of Texas (Pervinquière, 1912) (Turonian-Coniacian of Israel). This deep burrowing species is represented by a nearly complete specimen from a limestone concretion in the lower part of the Porcelanite Unit at Har Omer, and a fragment from the Phosphorite Unit of Oron-Giv'at Mador (both specimens of articulated valves).

Class GASTROPODA Cuvier, 1797
Subclass PROSOBRANCHIA Milne Edwards, 1848
Order ARCHAEOGASTROPODA Thiele, 1925
Superfamily TROCHACEA Rafinesque, 1815
Family TROCHIDAE Rafinesque, 1815
Subfamily MARGARITINAE Stoliczka, 1868
Genus *Margarites* Gray, 1847
Subgenus *Periaulax* Cossmann, 1888
Margarites (*Periaulax*) sp.
Fig. 33a-c

Description: Small (D=1cm), low trochospiral gastropod with a deep umbilicus. Elevated growth-lines form with the fine spiral ribs form a finely tuberculated pattern on the ribs and a reticulated pattern in between them. A stronger spiral rib occurs the upper (adapical) part of the flank, three ones on the curved middle part of the flank, which form a tri-carinate periphery. The angular umbilical shoulder does not preserve the tuberculated edge that characterizes the subgenus.

Occurrence: The rare species is represented by a young specimen (Fig. 33a) from the Phosphatic Carbonate Unit of Nahal Qazra-Har Omer, and a larger one (Fig. 33b, c) from the top of the Porcelanite Unit of Oron-Giv'at Mador.

Family AMBERLEYIDAE Wenz, 1938
Genus *Eucyclomphalus* VonAmmon, 1892
Eucyclomphalus sp.
Fig. 34a-c

Description: Small (up to 1.5cm in height), trochospiral (apical angle 48^0), deep whorl sutures and a sharp, denticulated, median carina shaping the angular appearance of the flanks. Round to oval aperture. Lower surface with at least one concentric rib exposed at the level of the whorl sutures. A weaker concentric rib may occur in adult conchs in between the median carina and the suture. Several weak ribs may occur between the median carina and the carinate umbilical shoulder. The umbilicus is open and deep. The denticulation along the median carina are periodical mid-lateral thickenings of the shell that fade above and below on the flank as degenerated ribs.

Remarks: The species is common in the lower part of the Phosphatic Carbonate Unit of Kippat Eshet, quite rare at Nahal Qazra-Har Omer in this unit, and not yet detected at Nahal Ashosh.

Superfamily CERITHIACEA
Family TURRITELLIDAE Clark, 1851
Genus *Turritella* Lamarck, 1799
Turritella sexlineata Roemer, 1841

Fig. 35

Description: Large (over 4.5cm), apical angle 18^0. The turrifom conch is ornamented by concentric lirae and strong ribs, the lower two of which are the strongest and the earliest to form. With growth three additional concentric ribs appear at the upper half of the whorl flank. One or two secondary ribs intercalate the lower two "primary" ribs in adult conchs.

Remarks: These variably ribbed turritellids are regarded a single species according to Quaas (1902, p. 243, pl. 25, figs. 34-35).

Subgenus *Zaria* Gray, 1847

Turritella (*Zaria*) *seetzeni* Lartet, 1877

Fig. 36

Description: *Turritella* with apical angle of 20^0, a strong mid-flank carina and two weaker carinae on the lower half of the flank, the lower one of which is hidden under the preceding whorls at their sutures.

Remarks: Lartet (1977) described two species of *Turritella* from the Senonian of the Judean Desert. *T. seetzeni* is characterized by two caninae on the lower half of the exposed flank, while *T. reyi* has a single mid-flank carina only. Blanckenhorn (1927) collected similar turritellids in this region with additional faint spiral carinae. He suggested that they all represent the single species *T. reyi,* even though *T. seetzeni* has the priority. On the other hand Blanckenhorn (1927, p. 143) distinguished several subspecies (varieties) of *T. reyi* (*tricarinata, quadricarinata*) on the basis of additional weak spiral carinae. Such weak spiral, carina-like features are observed on the present material and regarded as defects in growth. Accordingly *T. seetzeni* and *T. reyi* are recognized.

Turritella (*Zaria*) *reyi* Lartet, 1877

Fig. 37

Description: *Turritella* with a growth angle of 20^0 and a strongly protruding mid-flank carina and a weaker basal (adapical) carina, upon which the succeeding whorls attach and hide.

Remarks: *T. seetzeni* and *T. reyi* range from the uppermost Santonian (?) throughout the Lower and Middle Campanian. A single turritellid of the species *seetzeni* was found at the lower part of the Upper Campanian (tri-fold partition).

Family MATHILDIDAE Cossmann, 1912

Genus *Mathilda* Semper, 1865

**Mathilda*? sp.

Fig. 38

Remarks: The single specimen is from the middle part of the Phosphatic Carbonate Unit at Kippat Eshet.

Family ARCHITECTONICIDAE Gray 1850

Genus *Eosolarium* Chavan, 1947

Eosolarium massei Chavan, 1947

Fig. 39a-c

Remarks: The species was defined from the lowermost part of the Mishash Formation (Chavan, 1947), and ranges higher throughout most of the Phosphatic Carbonate Unit.

Family EPITONIIDAE S.S. Berry, 1910

Genus *Striatocostatum* Sohl, 1964

Striatocostatum schweinfurthi (Quaas, 1902)

Fig. 40

Remarks: Quaas (1902, p. 241, pl. 25, fig. 33) described the new Maastrichtian *Scalaria schweifurthi* from Egypt, which seems to occur in the Phosphatic Carbonate Unit (Upper Campanian), being referred herein to the genus *Striatocostatum* (defined by Sohl, 1964, p. 317, from the Western Interior, USA).

Striatocostatum sp.

Fig. 41a, b

Remarks: The single specimen from the lower part of the Phosphatic Carbonate Unit of Nahal Ashosh is slightly deformed, characterized by a growth angle of 40^0, and ribs in the form of grouped lamellae as in *S. schweinfurthi* but in a more dense pattern.

Genus *Clathroscala* De Boury, 1889

Subgenus *Undiscala* Chavan, 1947

Undiscala goryi (Lartet, 1877)

Description: The flanks bear strong axial ribs superimposed by three finer spiral sharp ribs, which turn spinose on the axial ribs. The axial ribs extend up to the spire suture. There a spiral rib marks the end of the exposed flanks of the spire, whereas additional 3-6 finer ribs occur on the exposed adapical (lower) side of the last whorl.

Remarks: The species has a coarser and more spinose ornament than *U. vicina.*

Undiscala vicina Chavan, 1947

Remarks: The species differs from *U. goryi* by its finer ornament. The spire bears coarse axial ribs as in *U. goryi*. However, the spiral ribs are finer and more numerous, increasing in number with growth to about 14 on the flank (correlative to between successive sutures) of the adult stage, and additional 7-10 on the exposed adapical side of the last whorl.

Family CALYPTRAEIDAE Blainville, 1824

Genus *Calyptraea* Lamarck, 1799

Calyptraea bouei Pervinquière, 1912

Fig. 42

Remarks: The Maastrichtian Tunisian species was defined by Pervinquière (1912, p. 10, pl. 1, figs. 7, 8a-b, 9-11) and seems to comprise the Israeli Upper Campanian forms as well. Specimens occur in the upper part of the Phosphatic Carbonate Unit (Kippat Eshet and Nahal Qazra) and in the Phosphorite Unit (Oron-Giv'at Mador).

Family NATICIDAE Gray, 1840

Remarks: Chavan (1947) assigned the following two species to *Vanikoro*, which does not agree with the definition of this extant genus. Based on the sutural groove present in these species they are attributed to *Gyrodes*.

Genus *Gyrodes* Conrad 1860

Gyrodes asiatica (Blanckenhorn, 1927)

Fig. 43a, b

Description: This small (up to 16mm high) naticid is higher than it is broad, and has at the suture between successive whorls a groove bordered by a sharp, angular shoulder. Umbilicus open and deep. Smooth, with growth-lines only. Young growth stages may be confused with *Euspira judaica*, which lacks the sutural groove, and the flanks are rounded to the sutures.

Remarks: Chavan (1947, p. 152) refers to the synonymy of the species, distinguished by Blanckenhorn (1927, p. 132) as a variety of *Natica lyrata* Sowerby.

Gyrodes farafrensis (Wanner, 1902)

Fig. 44

Description: Broader than high, depressed, smooth naticid with a sutural groove and angular apical shoulder. Umbilicus open and deep.
Remarks: This Maastrichtian species is recognized by Chavan (1947) at the lower part of the Mishash Formation and ranges throughout the whole formation, increasing in dimensions toward the Phosphorite Unit (19mm broad).

Genus *Euspira* Agassiz (in Sowerby, 1812)

Euspira judaica (Blanckenhorn, 1927)

Fig. 45a, b

Description: Rather small (less than 1cm high), higher than broad naticid. The flanks are smooth (grow-lines only), and rounded from the deep suture, which lacks any sutural groove and sharp-angular shoulder as in the above described two *Gyrodes* species.
Remarks: According to Chavan (1947) the species includes *Natica paludinaeformis* Blanckenhorn (1927).

Family APORRHAIDAE Gray, 1850

Genus *Struthioptera* Finlay & Marwick, 1937

Struthioptera sp.

Fig. 46a-c

Description: High (over 9cm) conch with a spire of about 10 whorls of an apical angle of 30^0. The flanks appear gently rounded as the result of opisthocline, bullate ribs on the adapical (lower) two-third of the whorl. The bullate ribs change near the terminal aperture into tubercles, that further form an angular flexure like a rib. The apical area between this rib and the whorl suture becomes concave and smooth. The suture between the whorls are deep, especially in advanced growth stages due to an apical shoulder. The adapical part of the last whorl bears four spiral ribs, which in the preceding whorls are covered by the coiling. At maturity the whorl flank expands into a trapezoidal wing that thickens marginally and forms an upward (apically) pointing spine. Another spike forms as an adapical extension of the siphonal canal. These spikes, as well as much of the wing structure are fragile and rarely preserved.
Discussion: Zinsmeister (1977) described quite similar forms from Seymour Island (Antarctica) under the genus *Struthiopotera* (Finlay and Marwick, 1937), which is supposed to range from the Upper Cretaceous to the Upper Eocene of the southern hemisphere. This generic name is tentatively applied to the Israeli morphotype.
Remarks: In the lower part of the Mishash Formation occurs a densely ribbed form of a similar shape and size.

Genus *Drepanochilus* Meek, 1964

Drepanochilus sp. 1 (weakly ornamented)

Fig. 47a, b

Description: Moderately sized (about 3cm high) aporrhaid, spire of 7-8 whorls at a 30^0 growth angle. The terminal whorl forms a small wing structure, converging into an upward (apically) curved spike and an adapical, short rounded extension. The wing and its spikes are thickened into rib-like margins. The whorl of the young growth stage bear weak median bullate tubercles which fuse together into an angular flexure with degenerated nodes at the mature stage.

Adapically to this median flexure occurs another spiral rib, exposed on the last whorl and usually at the suture of the previous whorls. It is adapically associated with another weaker spiral rib.
Remarks: The generic name is based on the study of Sohl (1967).

Drepanochilus sp. 2 (small)

Fig. 48a-c

Description: This morphotype looks like a small (about 1.5cm high) variety of *Drepanochilus* sp. 1. The 6-7 whorl of the spire increase by an angle of 30^0 and has the same type of median bullate tubercles that fuse into a median flexure on the last whorl. There appear additional 1-2 weaker spiral ribs at the adapical end. The partially preserved wing shows the thickened margins and base of the short adapical spine and the laterally and slightly apically curving, short wing-spine.
Remarks: It cannot be ruled out that this morphotype may reflect *Drepanochilus* sp. 1 that reached maturity at earlier growth-stages than the older (lower levels) typical forms.

Superfamily BUCCINACEA Rafinesque, 1815

Family MELONGENIDAE

Genus *Deussenia* Stephenson, 1941

Deussenia sp. cf. *D. ripleyana* Harbison, 1945

Fig. 49

Description: A small specimen consists of a partly-preserved spire increasing by 42^0 and an incomplete aperture. Each whorl has a weak adapical shoulder and a concave upper band that expands and forms a rounded shoulder. From there the flanks converge into a siphonate, elongate aperture. The conch bears fine spiral lirae and periodic rather straight ribs parallel to the coiling axis that are weak on the concave band, strengthen on the shoulder and weaken again toward the adapical end. A larger specimen is not well-preserved but develops on the last whorl the ornament of the North American uppermost Campanian? –Maastrichtian species described and illustrated by Sohl (1964, p. 200, pl. 25, figs. 1, 2, 5-7, 11-13).
Remarks: The species occurs in the Phosphatic Carbonate Unit of Kippat Eshet and Nahal Qazra-Har Omer.

Family FASCIOLARIIDAE Gray, 1853

Genus *Serrifusus* Meek, 1876

**Serrifusus* sp. cf. *S. dakotensis* (Meek and Hayden, 1856)

Fig. 50

Description: Large (reconstructed conch about 7cm of height), about 45^0 growth angle of the spire and a siphonate aperture (incomplete). Each whorl has an upper (apical) concave band, which expands into an angular shoulder. The suture are hardly discernible because the upper part of the whorl is almost a continuation of the lower part of the preceding whorl. The angular shoulder bears strong clavate spines, which form the broadest periphery of the conch. Below (adapically) the flanks converge toward an angular flexure, up to which the whorls envelope the preceding ones of the spire. The siphonate (adapical) end is missing. The conch bears irregular, weak, fine spiral ribs and growth-lines.
Discussion: The seemingly continuous flexure between successive tuberculated shoulders that nearly eliminates the suture between adjacent whorls distinguishes the Israeli specimens from the North American species, in which the apical part of the whorls is less concave.
Remarks: The specimens are from the Upper Campanian uppermost part of the Porcelanite Unit and the overlying Phosphorite Unit of Oron-Giv'at Mador, a little older than the Lower Maastrichtian American specimens.

**Serrifusus*? sp.

Fig. 51a, b

Description: The two small (the largest reconstructed to 35mm high), specimens differ from the above described morphotype by a clear suture and an adjacent weak shoulder. This is followed by a concave band expanding toward the main (median) carina of each whorl of the spire. Adapically occurs a weaker spiral carina, up to which the whorls envelope the preceding adapical part of the conch. This carinate, angular flexure is followed adapically by 1-2 weaker spiral ribs visible on the last whorl only. Further adapically the flank converge to form the siphonate aperture. The conch bears weak spiral lirae and irregular growth folds and lines that serrate the two main carinae as if finely tuberculated.
Discussion: This morphotype differs from the above related taxon by the lack of coarse clavate spines and the weak upper (apical) shoulder near the suture of the whorls.
Remarks: The two specimens were associated with cf. *Serrifusus dakotensis* at Oron-Giv'at Mador.

Genus *Anomalofusus* Wade, 1916

Anomalofusus turris Chavan, 1947

Fig. 52a, b

Description: Small (about 22 mm high) conch, spire increases at a 30^0 growth angle. Elongated, siphonate aperture (differing from *A. vignali* Chavan). The flanks are rounded with a narrow apical band and a few strong orthocline, dense ribs, which their apical part may be prominent and give an impression of a stepwise spire. Fine spiral ribs cover the whole conch.
Remarks: Most of the specimens are from the middle of the Phosphatic Carbonate Unit of Kippat Eshet and a few from Nahal Qazra-Har Omer.

Genus *Graphidula* Stephenson, 1941

**Graphidula melanopsis* (Conrad, 1860)

Fig. 53a, b

Description: Rather large (over 3cm high) fusiform. The spire is almost evenly tapering because of the only weakly rounded flanks of the whorls. Aperture with a long siphonal canal. The ornament consists of gently opisthocline ribs of a faint mirrored S-shape, which is better visible on the last whorl. There the ribs weaken adapically and are missing on the siphonal part of the whorl. Fine, densely spaced spiral ribs cover the whole conch.
Discussion: The North American species described by Sohl (1964) is represented by a variety of morphotypes, which include the Israeli morphological variation

**Graphidula*? sp. cf. *G. nachtigali* (Quaas, 1902)

Fig. 54

Description: Rather large (over 3cm high) fusiform. The spire has an angle of 35^0, and the coiling is a little stepwise. The ornament consists of opisthocline low ribs that are superimposed by more pronounced spiral ribs together giving a reticulated pattern. The opistocline ribs weaken adapically on the last whorl and disappear on the siphonal extension where the spiral ribs become much finer and more densely spaced.
Discussion: Quaas (1902, p. 277, pl. 27, fig. 5a, b) described a new Lower Maastrichtian species as *Fusus nachtigali,* which seems to represent the Upper Campanian Israeli material.
Remarks: The species was found in the upper part of the Phosphorite Unit of Oron-Giv'at Mador.

Family CANCELLARIIDAE Gray, 1853

Genus *Caveola* Stephenson, 1941

**Caveola* sp. cf. *C. acuta* (Wade, 1926)

Fig. 55a, b

Description: Elongated fusiform, spire growth angle of 25^0, with last whorl nearly as high as the previous whorls. The elongated aperture has a shallow siphonal notch, which is strengthened by the thickening of the inner lip. Ornament of low, undulating ribs, as broad as their inter-space, discernible mainly on the upper part of the flank. Occasionally a rib thickens to a weak varix (usually at the mature aperture) superimposed by fine, densely-spaced grooves that form a dense spiral ribbons.

Remarks: Our single specimen has broader and more widely-spaced ribs than the mature form of *C. acuta acuta* (Wade) described by Sohl (1964, pl. 44, figs. 6-8).

Occurrence: Uppermost part of the Porcelanite Unit at Oron-Giv'at Mador.

Genus *Bonellitia* Jousseaume, 1887

Bonellitia scaberrima Chavan, 1947

Fig. 56

Description: This fusiform gastropod of medium size is characterized by its coarse ornament. Each whorl has an upper (apical) inclined shoulder forming a protruding angular carina, on which clavate-spinose tubercles are situated. These are superimposed on prosocline ribs, which project on the upper shoulder as low undulations. The exposed part of the whorls bears two additional spiral ribs; a middle one forming with the vertical ribs a median row of clavi, and a lower spiral rib just above the suture of coiling. This latter rib forms with the vertical ribs another set of spinose tubercles visible on the last whorl only. This adapical exposed part bears additional 2-3 spiral ribs, whereas the vertical ribs weaken or are missing there.

Remarks: This coarsely ornamented gastropod ranges from the base of the Mishash Formation into the Phosphatic Carbonate Unit (Kippat Eshet; rare at Har Omer-Nahal Qazra).

Family OLIVIDAE

Genus *Pseudoliva* Swainson, 1840

Pseudoliva libyca Quaas, 1902

Fig. 57a, b

Description: Large (up to 45mm high) inflated fusiform gastropod with a small spire of 76^0-80^0 growth angle. Each whorl has an apical nearly horizontal shoulder surrounded by the first strongest apical spiral rib. There emerge the nearly orthocline fold-like ribs, forming with the upper spiral rib low spinose tubercles that point upward, whereby the upper shoulder appears concave. The flanks are further ornamented by the orthocline ribs, which fade adapically and disappear on the adapical half of the flank. Spiral ribs cover the whole whorl, being superimposed on the vertical broader ribs. These spiral ribs are divided by a furrow into two sets.

Remarks: The Israeli specimens seem identical to the species described from the Lower Maastrichtian of Egypt (Quaas, 1902). The species is quite common at the upper part of the Phosphorite Unit of Oron-Giv'at Mador, and rare in the upper part of the Phosphatic Carbonate Unit at Har Omer-Nahal qazra.

Pseudoliva sp.

Fig. 58a, b

Description: Moderately high (20-27mm) fusiform, with a spiral growth angle of about 50^0. Each whorl has a narrow upper shoulder formed by the clavate upper end of the sharp orthocline ribs. These ribs extend adapically up to a strong spiral rib followed by a furrow, which separates

between two, differently ornamented parts of the whorl; an upper with orthocline ribs, and a lower with spiral ribs only. However, some well-preserved mature specimens exhibit 2-3 faint spiral ribs already above the furrow and the earlier disappearance of the orthocline ribs.
Discussion: This undefined *Pseudoliva* species differs from *P. libyca* by its slender-fusiform shape and sharp ribbing in a different direction in the upper and the lower part of the whorl.
Remarks: This form occurs in the Phosphatic Carbonate Unit of Kippat Eshet and Har Omer-Nahal Qazra.

cf. *Pseudoliva* sp.

Fig. 59

Description: The single incomplete specimen has a stepwise, low spire (83^0 apical angle) with deep sutures between the whorls. Each whorl has an apical (upper), angular, tuberculated shoulder, a slightly concave flank and a rounded adapical (lower) flexure at which the next whorl attaches. The conch is ornamented by low, widely spaced, nearly orthocline ribs, which form the tubercles and weak undulations on the apical shoulder. The ribs weaken on the siphonal extension, where secondary weak ribs appear in between the primaries. Narrow spiral ribs occur on the flanks (5-6 on the last whorl) and continue to appear in a weakening trend on the siphonal part (incomplete).
Discussion: The specimen resembles *Pseudoliva* in the stepwise low spire with deep sutures and the mode of ornament. It differs from *P. libyca* by its shorter whorl height and more angular adapical flexure, in contrast to the olive-shape (oval) of *P. oliva.*
Remarks: The single specimen is from the top of the Phosphatic Carbonate Unit at Nahal-Qazra.

Family VOLUTIDAE Rafinesque, 1815

Genus *Volutomorpha* Gabb, 1877

Volutomorpha sp. cf. *V. valida* Sohl, 1964

Fig. 60a-c

Description: Large (10-15cm high) fusiform conch with a spiral growth angle of 40^0, and a very long siphonal extension. The whorls have a median angular shoulder, with or without tubercles in a variable spacing, which may extend to the lower half of the flank in different intensities and length. Most of the conch is smooth, with growth-lines only.
Discussion: The Israeli material exhibits a wide variability in ornament intensity, quite similar to the North American *V. valida*, which seems to represent a variety with a degenerated ornament among the other described *Volutomorpha* species (Sohl, 1964). The single *Volutomorpha* from the base of the Mishash Formation (ca 80 Ma) has rather a rounded, weakly tuberculated median shoulder, and hence questionably belonging to the younger, quite long-ranging morphospecies (Phosphatic Carbonate Unit, 76 Ma, to Phosphorite Unit, 72.5 Ma).

Subclass OPISTHOBRANCHIA Milne-Edwards, 1848

Family ACTEONIDAE d'Orbigny, 1835

Genus *Tornalellaea* Conrad, 1860

**Tornatellaea gracilis* (Blanckenhorn, 1927)

Fig. 61a, b

Remarks: The species was described and illustrated by Chavan (1947) from the lower part of the Mishash Formation, ranging to its uppermost part (at least nearly 8 million years).

Family RINGICULIDAE Philippi, 1853

Genus *Ringicula* Deshayes, 1838

**Ringicula* (*Ringiculopsis*) *larteti* Chavan, 1947

Remarks: the species was described from the lower part of the Mishash Formation (Chavan, 1947) and found in the upper part of the Phosphorite Unit of Oron-Giv'at Mador.

Class SCAPHOPODA Bronn, 1862
Family DENTALIIDAE Gray, 1834
Genus *Dentalium* Linné, 1758
Subgenus *Antalis* H. & A. Adams, 1858
Dentalium (*Antalis*) *vixlineatum* Chavan, 1947

Remarks: The species originates from the lower part of the Mishash Formation and is found in the Phosphatic Carbonate Unit of Nahal Ashosh and Kippat Eshet.

ANNELIDA; POLYCHAETA; SERPULIDA
Family SERPULIDAE Rafinesque, 1815
Subfamily FILOGRANINAE Rioja, 1923
Genus *Cycloserpula* Parsch, 1956
Cycloserpula gordialis (Schlotheim, 1820)
Fig. 62

Desrcription: Straight and curved, cylindrical tubes 0.7-2.3mm in diameter encrusting an ammonite.
Remarks: The species is associated with loose, larger tubes of *Prolisepula,* both found in the upper fossiliferous part of the Phosphatic Carbonate Unit of Nahal Qazra-Har Omer.

Subfamily SERPULINAE MacLeay, 1840
Genus *Proliserpula* Regenhardt, 1961
Proliserpula ampullacea (J. de C. Sowerby, 1829)
Fig. 63

Remarks: This cylindrical serpulid tube reaches a diameter of 12mm. It occurs in the fossiliferous middle and upper part of the Phosphatic Carbonate Unit of Nahal Ashosh, basal part of the Porcelanite unit at Nahal Zin, and in the Phosphorite Unit of Oron-Giv'at Mador.

Genus *Hamulus* Morton, 1834
**Hamulus sexangularis* (Münster *in* Goldfuss, 1831)
Fig. 64

Remarks: This serpulid tube with 6 carinae was previously defined as *H. ingeni* Avnimelech (1941), but according to a revision by Radwańska (1996) should be assigned to *H. sexangularis.* The material from the Mishash Formation is from the middle of the Phosphatic Carbonate Unit of Kippat Eshet.

ARTHROPODA; CRUSTACEA; MALACOSTRACA; DECAPODA

Remarks: Only a few calcified segments of burrowing crustaceans were found with *Thalassinoides*-like burrow fillings in the upper part of the Phosphorite Unit of Oron-Giv'at Mador. They consist of segments of the palm (cheliped of *Protocallianassa*?; Fig. 65b) and a leg of another species (Fig. 65a). Crustacean activity is evident by intensively burrowed levels filled by phosphatic carbonate of the overlying sediment, and by the fragmented molluscan thin shells compared to complete thick shells, suggesting fragmentation through crustacean and fish predatory activity.

Conclusions

The list of the preliminary identified species of marine benthic macrofossils from the Phosphate Member of the Mishash Formation comprise 70 mollusks, three serpulids and segments of a burrowing crustacean. 57 mollusk species found in the study area consist of 33 bivalves, 23 gastropods and a scaphopod. Additional 5 bivalve and 8 gastropod species were found outside the study area, mainly in the uppermost part of the formation at Oron-Giv'at Mador. All the specimens collected are over half a centimeter long and suggest that smaller fossils embedded in the rock may have been overlooked. Most of the mollusk species lived in normal marine, low-energy settings. A few lucinid and venerid bivalves dominate the faunal assemblage in phosphatic carbonate, or limestone concretion in calcareous porcelanite, probably reflecting low-oxygen bottom conditions. Periodical high-energy conditions are evidenced by shell beds of varying thickness, reflecting agitation, winnowing, exhumation of articulated burrowing bivalves and some transport. The abundant fragments of thin bivalve shells and associated with well preserved thickly-shelled bivalves suggest the selective destructive activity of predating crustaceans (the burrowing ones are represented by burrows) and some fish.

Acknowledgements

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Table 1. Range-chart of benthic macrofossils of the Mishash Formation.

GENERA & SPECIES	CHERT MBR.	PHOSPHATE MBR.		
		PHOS. C.	POR.	PHOS.
Nucula crebrilineata Conrad, 1852	—	—		
Mesosacella grovei (Lartet, 1872)	—	—	—	—
Solemya sp. cf. *S. subplicata* (Meek & Hayden, 1856)				•
Nannonavis parallelus (Conrad, 1852)	—	—		
Israelarca elroni nov. gen. & sp.	?	•		
Modiolus sp.				•
Pinna sp.	—	—		—
Cataceramus goldfussianus (d'Orbigny, 1847)		—	— —	—
Trochoceramus costaecus (Khalafova, 1966)			•	—
Aequipecten acuteplicatus (Alth, 1850)				—
Plicatula batnensis Coquand, 1880		—		
Pycnodonte (*Phygraea*) *vesicularis* (Lamarck, 1806)	·····	—	···	···· —
Rastellum diluvianum (Linné, 1767)		•		
Ostrea sp.		•		
Lopha (*Actinostreon*) *sollieri* (Coquand, 1869)		?		
Nicaisolopha forgemolli (Coquand, 1869)				•
Lopha? sp.		•		
Ambigostrea villei (Coquand, 1862)	—			
Lucina blanckenhorni Chavan, 1947	—	—		
Lucina dachelensis Wanner, 1902			—	—
Lucina (?) sp.		—	—	•
Pterolucina(?) *subnumismalis* (d'Orbigny, 1850)		?—	—	—
Sphaera (?) sp.		—		
Ludbrookia barroneti (Munier-Chalmas, 1881)		—		
Landinia rothi (Fraas, 1867)	—	• —		?
Protocardia silicea Blanckenhorn, 1934		—	— —	—
*cf. *"Mactra"* sp.				•
Tellina (?) sp. cf. *T. marcouti* (Coquand, 1862)				—
Veniella drui (Munier-Chalmas, 1881)		— —		
Mesocallista andersoni Newton, 1909	—	—		
Mesocallista(?) *rohlfsi* (Quaas, 1902)		—	—	—
Meretrix judaica Picard, 1930	—	—		
Meretrix (?) sp.		—		
Corbula (*Flexicorbula*) *vokesi* Chavan, 1947	—	• •		
Parmicorbula subelegans (Picard, 1930)	—	—	—	—
Biradiolites sp.				•
Durania farafrahensis Douvillé, 1912				•
Pholadomya sp.			•	•
Margarites (*Periaulax*) sp.		•	—	
Eucyclomphalus sp.		—		
Turritella sexilineata Roemer, 1841		• —	—	
Turritella (*Zaria*) *seetzeni* Lartet, 1877	—	—	—	
Turritella (*Zaria*) *reyi* Lartet, 1877	—	—	?	
Mathilda (?) sp.		•		
Eosolarium massei Chavan, 1947	—	—		
Striatocostatum schweinfurthi (Quaas, 1902)		—	•	
Striatocostatum sp.		•		
Undiscala vicina Chavan, 1947	—	—		
Undiscala goryi (Lartet, 1877)	—	—		
Calyptraea bouei Pervinquière, 1912		—		—
Gyrodes asiatica (Blanckenhorn, 1927)	—	—	?	
Gyrodes farafrensis (Wanner, 1902)	—	—	—	—
Euspira judaica (Blanckenhorn, 1927)	—	— —	?	
Struthioptera sp.		—	—	—
Drepanochilus sp. 1 (weakly ornamented)		• —	—	
Drepanochilus sp. 2 (small)		—		—
Deussenia sp. cf. *D. repleyana* Harbison, 1945		•		
Serrifusus sp. cf. *S. dakotensis* (Meek and Hayden, 1856)		•	—	—
Serrifusus (?) sp.		•		
Anomalofusus turris Chavan, 1947	—	• •		
Graphidula melanopsis (Conrad, 1860)				•
Graphidula sp. cf. *G. nachtigali* (Quaas, 1902)				•
Caveola sp. cf. *C. acuta* (Wade, 1926)			—	
Bonellitia scaberrima Chavan, 1947	—	?		
Pseudoliva libyca Quaas, 1902		—		—
Pseudoliva sp.		•		
cf. *Pseudoliva* sp.		•		
Volutomorpha sp. cf. *V. valida* Sohl, 1964	?	• —	—	—
Tornatellaea gracilis (Blanckenhorn, 1927)	—	•		—
Ringicula (*Ringiculopsis*) *larteti* Chavan, 1947	—			—
Dentalium (*Antalis*) *vixlineatum* Chavan, 1947	—	— •		?
Cycloserpula gordialis (Schlotheim, 1820)		•		
Proliserpula ampullacea (J. de C. Sowerby, 1829)		—	—	—
Hamulus sexangularis (Münster, *in* Goldfuss, 1831)		•		

Table 2. Locality, stratigraphic position and catalogue number (GSI) of the samples.

Locality	Coord.	Unit	Catalogue No.
Nahal Ashosh	1585/9878	Phosphatic Carbonate	6349
	1567/9861		6350
	1567/9859	Phosphorite	6368
	1568/9858		6352
Nahal Qazra-Har Omer	1602/9943	Phosphatic Carbonate	6354, 6369
	1602/9948		6360
	1592/9936		6361
	1596/9947		6362
	1609/9944		6363
	1605/9951		6355
	1605/9951		6370
	1605/9945	Porcelanite	6359
	1583/9960		6371
	1587/9937		6372
	1605/9950		6357
	1602/9942		6356
Oron-Giv'at Mador	1443/0295	Porcelanite	6364
	1450/0303	Phosphorite	6365
Kippat Eshet (Menuha ridge)	1636/9697	Phosphatic Carbonate	6373, 6366
Nahal Zin	1628/0328	Phosphatic Carbonate	6375
	1638/0322	Porcelanite	6374

PLATES 1-5

All figure in natural size unless marked by adjacent scale bar.

Each taxon is accompanied (in brackets) by the code number of the collecting area, the code letter of stratigraphic unit, and the GSI sample number (old GSI No. M-).

1. Nahal Ashosh; 2. Nahal Qazra-Har Omer; 3. Oron-Giv'at Mador; 4. Kippat Eshet (Menuha ridge) A: Phosphatic Carbonate Unit; B: Porcelanite Unit; C: Phosphorite Unit.

EXPLANATION OF PLATE 1

Fig. 1. *Nucula crebrilineata* Conrad (2A; 6354)

Fig. 2. *Mesosacella grovei* (Lartet) a, c (3C; 63654), b (2A; 6354).

Fig. 3. *Solemya* sp. cf. *S. subplicata* (Meek & Hayden) (3C; 6365)

Fig. 4. *Nannonavis parallelus* (Conrad); a-c (4A; 6354), d (2A; 6354)

Fig. 5. *Israelarca elroni* nov. gen. & sp. a-b (Nahal Zin, coord. 1753/0365; A; M-7723)

Fig. 6. *Modiolus* sp. (3C; 6365)

Fig. 7. *Pinna* sp. (3C; 6365)

Fig. 8. *Cataceramus goldfussianus* (d'Orbigny) (2B; 6357)

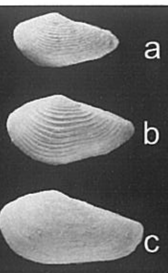
Fig. 9. *Trochoceramus costaecus* (Khalafova) (3C; 6365)

Fig. 10. *Plicatula batnensis* Coquand a-c (2A; 6350)

Fig. 11. *Lopha* (*Actinostreon*) *sollieri* (Coquand) (3A?; 6377); x 0.5

Fig. 12. *Lopha*? sp. (2A; 6363)

1



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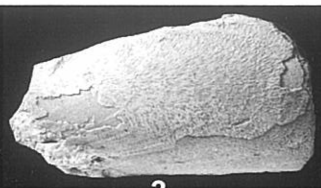

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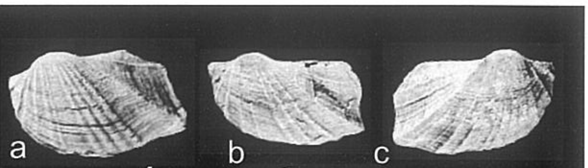

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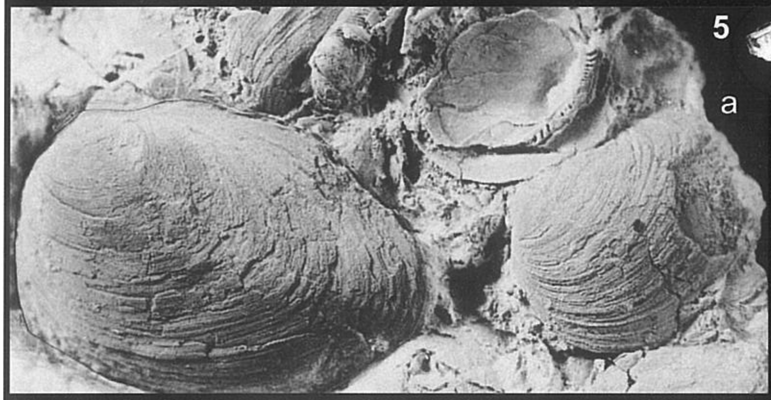

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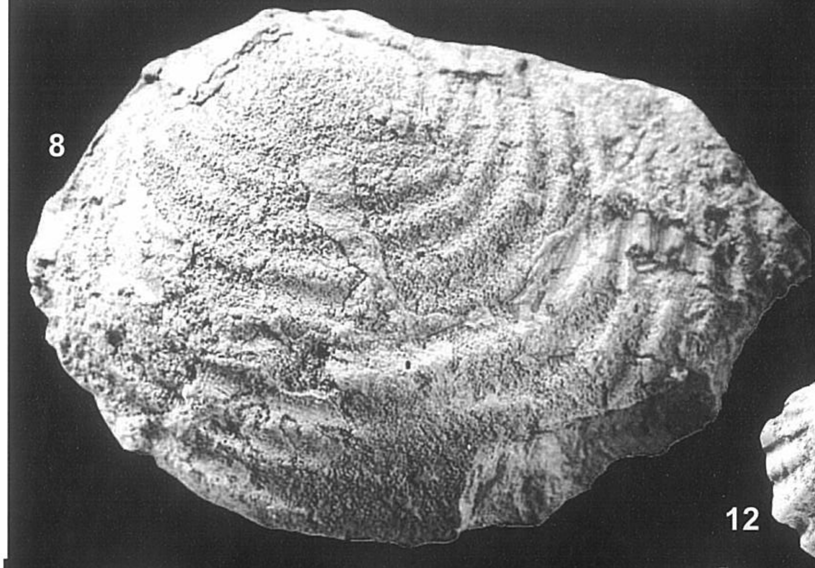

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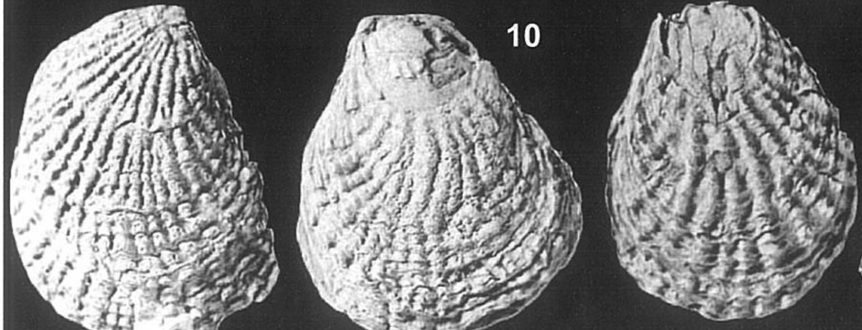
9

12



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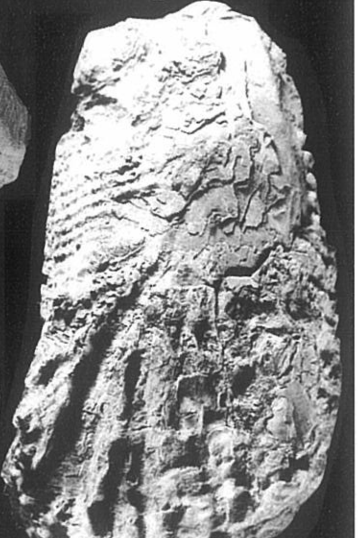
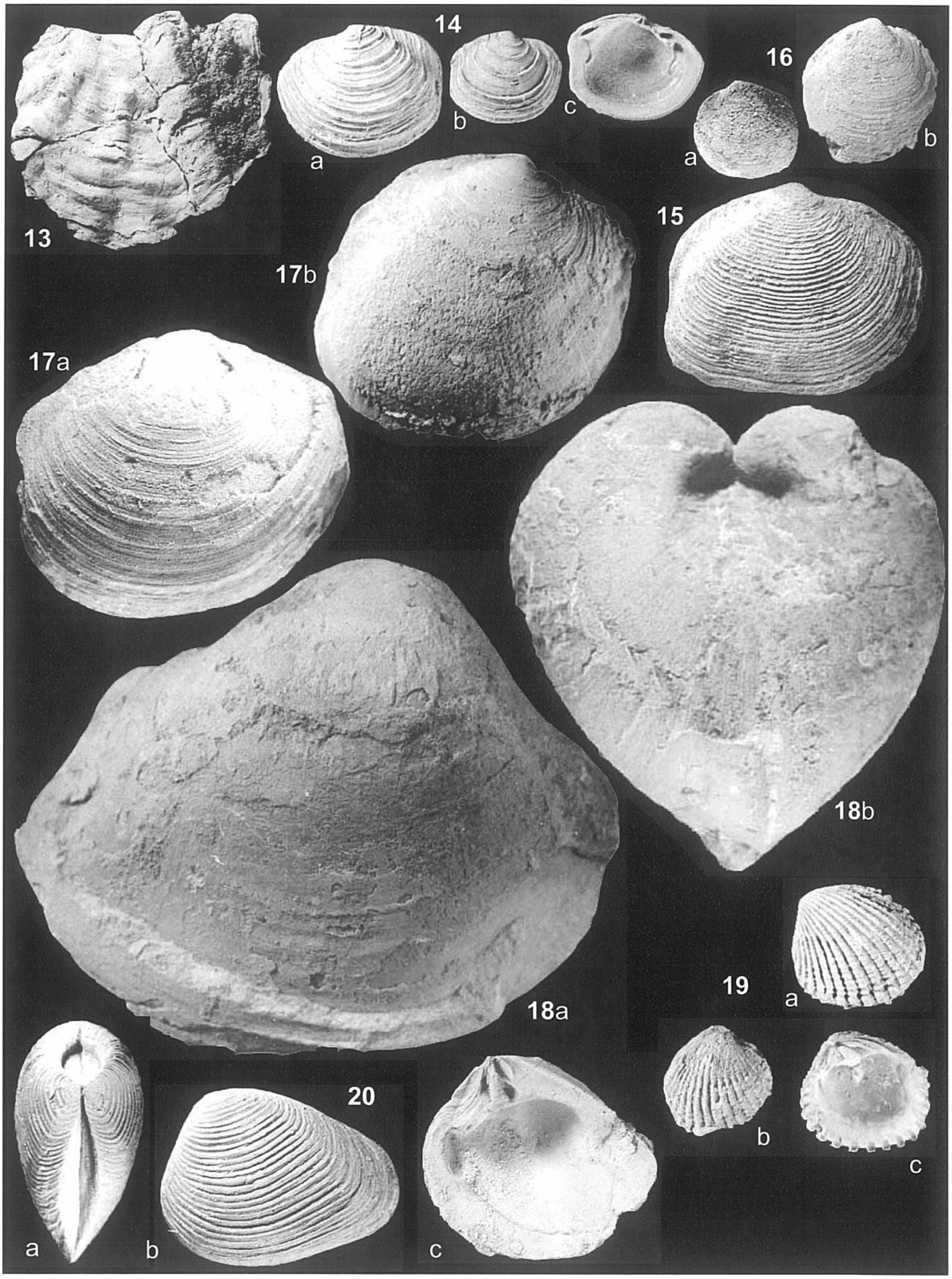


11

x0.5

EXPLANATION OF PLATE 2

Fig. 13. *Nicaisolopha forgemolli* (Coquand) (3C; 6380)
Fig. 14. *Lucina blanckenhorni* Chavan (2B; 6354)
Fig. 15. *Lucina dachelensis* Wanner (3c; 6365)
Fig. 16. *Lucina*? sp. a (2A; 6355), b (2C 6378)
Fig. 17. *Pterolucina*? *subnumismalis* (d'Orbigny) (3B; 6364)
Fig. 18. *Sphaera*? sp. a-b (2A; 6363)
Fig. 19. *Ludbrookia barroneti* (Munier-Chalmas) a-b (2A; 6355), c (2A; 6354)
Fig. 20. *Landinia rothi* (Fraas) (1A; 6350)


14
16
13
a
b
c
a
b
15
17b
17a
18b
18a
19
a
b
c
20
a
b
c

EXPLANATION OF PLATE 3

Fig. 21. *Protocardia silicea* Blanckenhorn a-c (2A; 6355)

Fig. 22. cf. *"Mactra"* sp. (3C; 6365)

Fig. 23. *Tellina* ? sp. cf. *T. marcouti* (Coquand) (3C; 6365)

Fig. 24. *Veniella drui* (Munier-Chalmas) (1A; 6349)

Fig. 25. *Mesocallista andersoni* Newton a-c (2a; 6354)

Fig. 26. *Mesocallista*? *rohlfsi* (Quaas) a (3C; 6365), b-c (2A; 6363)

Fig. 27. *Mesocallista* sp. (2A; 6355)

Fig. 28. *Meretrix judaica* Picard (2A; 6354)

Fig. 29. *Corbula* (*Flexicorbula*) *vokesi* Chavan (2A; 6363)

Fig. 30. *Parmicorbula subelegans* (Picard) a-b (2A; 6354)

Fig. 31. *Biradiolites* sp. a-b (1C; M-8078)

Fig. 32. *Pholadomya* sp. (2B; 6357)

Fig. 33. *Margarites* (*Periaulax*) sp. a (2A; 6363), b-c (3B; 6364)

Fig. 34. *Eucyclomphalus* sp. a-c (4A; 6366)

Fig. 35. *Turritella sexilineata* Roemer (2A; 6363)

Fig. 36. *Turritella* (*Zaria*) *seetzeni* Lartet (2A; 6354)

Fig. 37. *Turritella* (*Zaria*) *reyi* Lartet (2A; 6354)

Fig. 38. *Mathilda*? sp. (3C; 6365)

Fig. 39. *Eosolarium massei* Chavan a-c (2A; 6363)

Fig. 40. *Striatocostatum schweinfurthi* (Quaas) (2A; 6363)

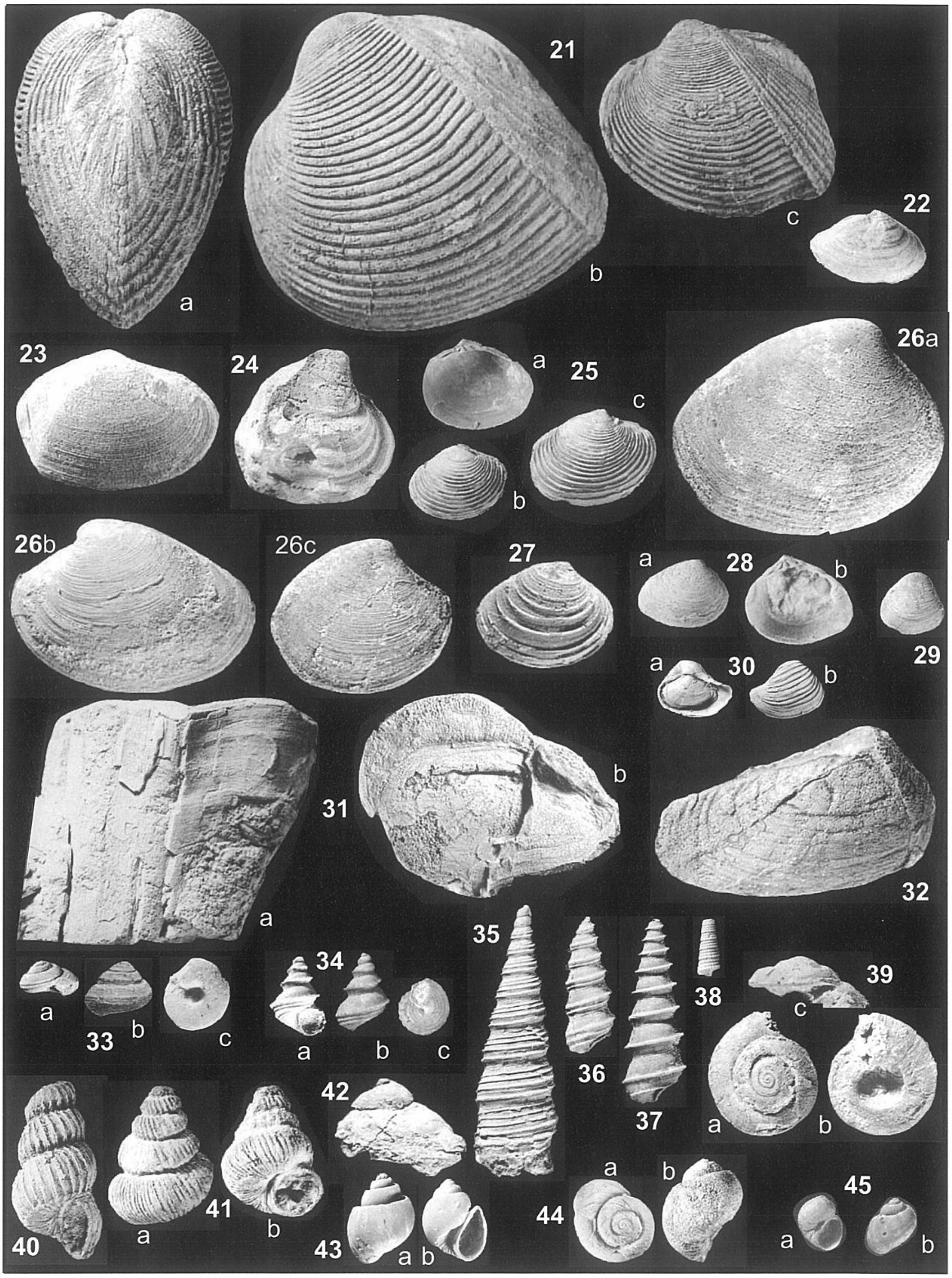
Fig. 41. *Striatocostatum* sp. a-b (2A; 6363)

Fig. 42. *Calyptraea bouei* Pervinquière (4A; 6366)

Fig. 43. *Gyrodes asiatica* (Blanckenhorn) a-b (2A; 6354)

Fig. 44. *Gyrodes farafrensis* (Wanner) a-b (3B; 6364)

Fig. 45. *Struthioptera* sp. a-b (3B; 6364), c (2A; 6354)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EXPLANATION OF PLATE 4

Fig. 46. *Drepanochilus* sp .1 a-b (2A; 6354)

Fig. 47. *Drepanochilus* sp. 2 a-b (3B; 6364)

Fig. 48. *Deussenia* sp. cf. *D. repleyana* Harbison (2A; 6363)

Fig. 49. *Serrifusus* sp. cf. *S. dakotensis* (Meek and Hayden) (3C; 6365)

Fig. 50. *Serrifusus*? sp. a-b (3C; 6365)

Fig. 51. *Anomalofusus turris* Chavan a (2A; 6355), b (4A; 6366)

Fig. 52. *Graphidula melanopsis* (Conrad) a (4A; 6366), b (3C; 6365)

Fig. 53. *Graphidula* sp. cf. *G. nachtigali* (Quaas) (3C; 6365)

Fig. 54. *Caveola* sp. cf. *C. acuta* (Wade) a-b (3B; 6364)

Fig. 55. *Bonellitia scaberrima* Chavan (4A; 6366)

Fig. 56. *Pseudoliva libyca* Quaas a-b (3C; 6365)

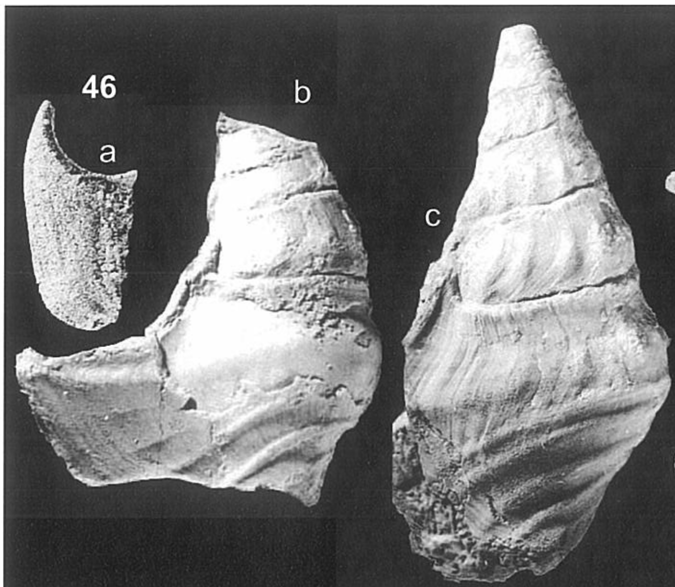
Fig. 57. *Pseudoliva* sp. a-b (2A; 6362)

Fig. 58. cf. *Pseudoliva* sp. (2A; 6362)

Fig. 59. *Volutomorpha* sp. cf. *V. valida* Sohl a (2A; 6355), b-c (3C; M-2798)

Fig. 60. *Tornatellaea gracilis* (Blanckenhorn) (3C; 6365)

Fig. 61. *Cycloserpula gordialis* (Schlotheim) (2A; 6361)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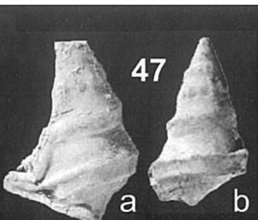
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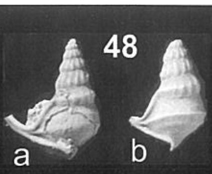
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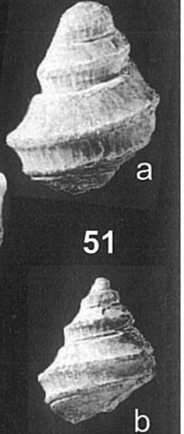
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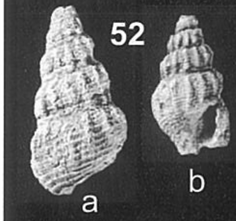
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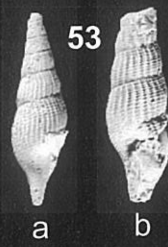
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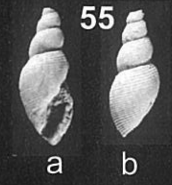
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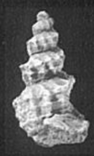
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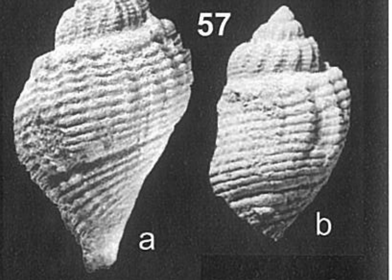
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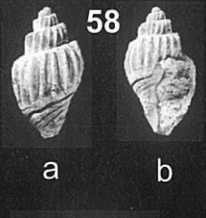
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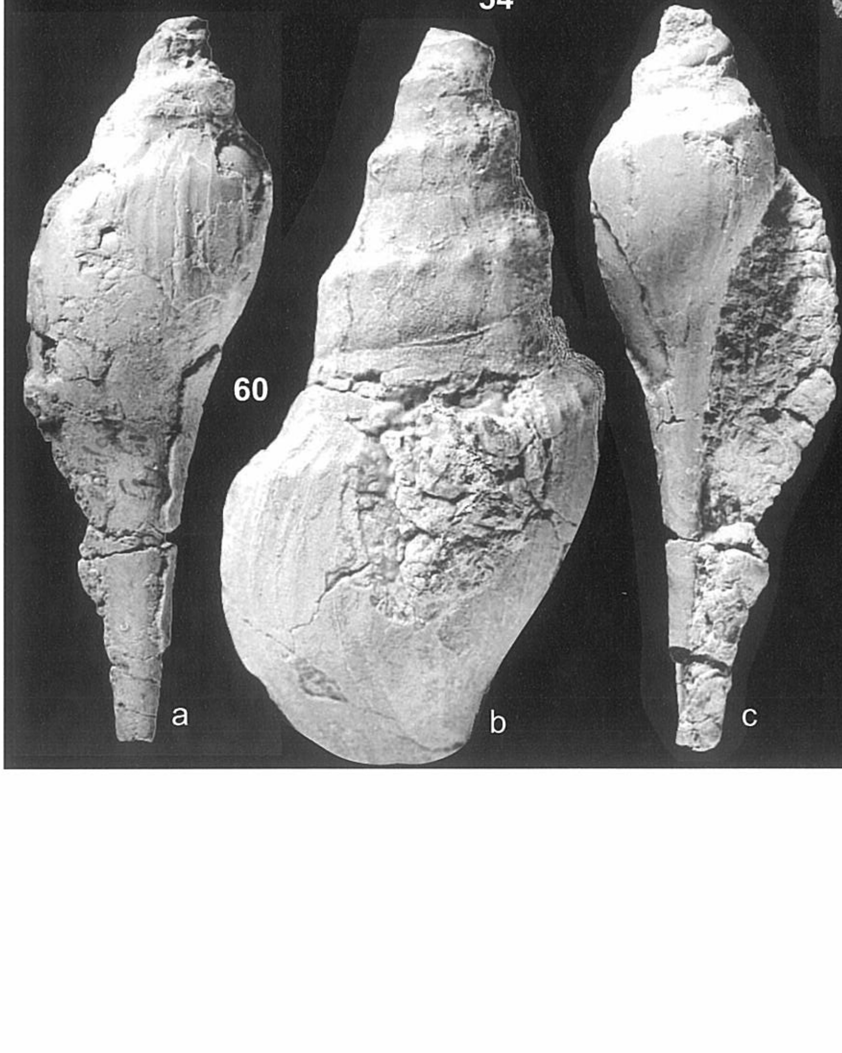
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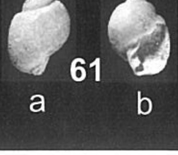
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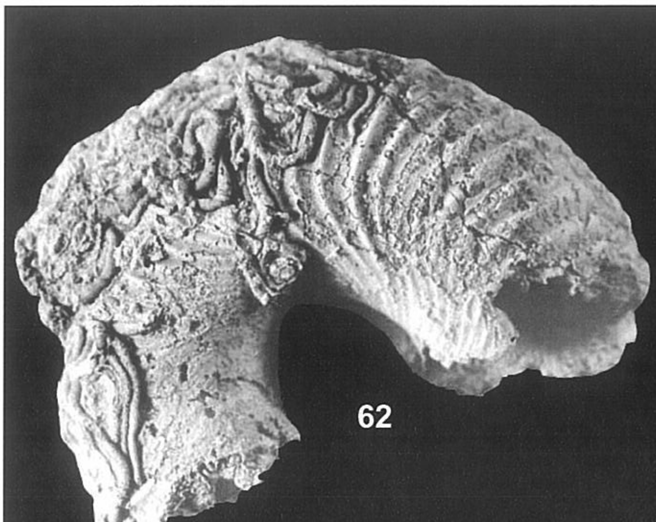
EXPLANATION OF PLATE 5

Fig. 62. *Proliserpula ampullacea* (J. de C. Sowerby) (1A; 6379)

Fig. 63. *Hamulus sexangularis* (Münster, *in* Goldfuss) (3C; 6365)

Fig. 64. Crustacean leg (a) and arm (b) segments (3C; 6381)



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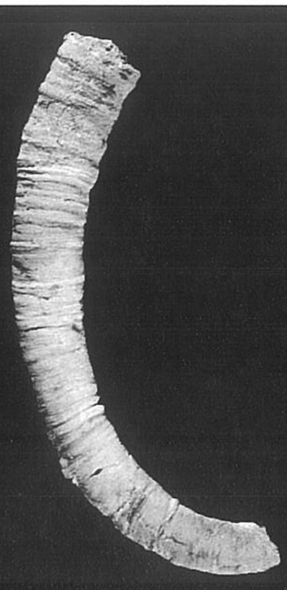

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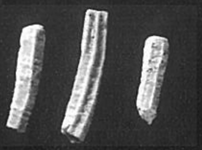

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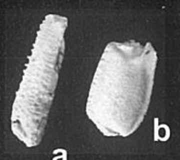

טקסונומיה ופלאואקולוגיה של מאובנים גדולים של בנתוס ימי בתנאים של פוריות גבוהה

פרט הפוספט של תצורת מישאש מגיל קמפן עליון

זאב לוי ויעל אדלמן-פורסטנברג
המכון הגאולוגי, ירושלים

תקציר

מאובנים גדולים של חסרי חוליות בנתוניים (שוכני קרקעית) מפרט הפוספט של תצורת מישאש (קרטיקון עליון, קמפן עליון) בדרום מזרח ישראל מורים על תנאי המחיה (פלאואקולוגיה) וההשקעה הקדומים תחת משטר של פוריות גבוהה, ששררה אז באותו אזור. מאסף המאובנים שנחקר נשלט על ידי רכיכות. הוגדרו שלושים ושמונה מינים של צדפות, 31 של חלזונות ומין של שן-הים, בנוסף לשלושה מינים של מחילות גיריות של תולעים ופרקי זרוע של סרטן נברן. רבים מהמינים תועדו מהמזרח התיכון וצפון אפריקה. כמה מהם דומים לצורות המוכרות מצפון אמריקה (ארה״ב) והוגדרו זמנית כמינים אלו בגלל הקשרים הביוגאוגרפיים הטובים ששררו אז לאורך דרומו של אוקיאנוס הטתיס, כפי שמעידים על כך מיני האמוניטים הזהים בישראל ובמערב התיכון של ארצות הברית של אמריקה. המינים מתוארים בסדר סיסטמטי-זואולוגי בליווי הערות ודיון קצר על תפוצתם הגאוגרפית והסטרטיגרפית בתצורת מישאש (מצורפת טבלת תפוצה), ואיפיון אקולוגי.

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16. **Abstract**

The benthic (ground dwelling) macrofossils of the Phosphate Member of the Mishash Formation (Upper Cretaceous; Upper Campanian) in southeastern Israel reflect the ecological and sedimentological conditions under the marine high-productivity settings that prevailed in this region. The studied fossils are dominated by mollusks. Thirty eight bivalve species, 31 of gastropods and a scaphopod species were identified, as well as three serpulid species and calcified cheliped segments of a burrowing crustacean. Many of these species were recorded from the Middle East and North Africa. Some resemble North American taxa, and are temporarily identified as such because of the good paleogeographic connection along the Tethys Ocean based on ammonite species common to both Israel and the Western Interior of the Unites States. The species are described in systematic order with a short discussion and remarks on their distribution, ecological affinities, and their range in the Mishash Formation (range chart).

17. Identifiers /keywords /Descriptors

Mishash Fm., Phosphate Mbr., Up. Campanian, southern Israel, benthic macrofossils, taxonomy, paleoecology.

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