Palaeoecology and taxonomy of the macrobenthic fauna from the Upper Cretaceous Ajlun Group, southern Jordan

Abstract. The Upper Cretaceous Ajlun Group (Cenomanian-Turonian) of southern/south-eastern Jordan has been analysed in 15 detailed sections with thicknesses between 40 m and 200 m. Taxonomic, palaeoecological, taphonomic, and sedimentological aspects were taken into account.

During the early Upper Cretaceous the study area was situated at the south-eastern margin of the Tethys Ocean, between the palaeo-shoreline in the south-east and an offshore carbonate platform in the west. Thus, the measured sections include a complete facies succession from terrestrial-dominated environments via marginal marine siliciclastics to an area of carbonate precipitation. So far, very little is known about the fauna and the depositional environment of the group, especially of the transitional marginal marine part. Also, in depth studies of the Cretaceous fauna of southern Jordan are very rare. Therefore, the benthic fauna of the area is described in an extensive taxonomic chapter. It consists of 117 taxa, 77 of which are bivalves, 22 gastropods, 9 echinoids, and 4 corals. The phyla Porifera, Bryozoa, and Brachiopoda are represented by 1 species each. Additionally, at least two species of decapod crustaceans were found. One bivalve species is new: *Anthonya jordanica* from Cenomanian claystones of the eastern study area.

41 quantitative samples of the benthic invertebrate fauna were grouped into nine associations and three assemblages by means of a Q-mode cluster analysis. These are described as remnants of former communities and their environments are discussed. Salinity and substrate consistency are assumed to have been the most important environmental parameters controlling the faunal distribution.

The overall palaeo-environment is discussed on the basis of sedimentological and palaeoecological results. It was primarily influenced by the morphology of the sea floor, sediment supply, and salinity of the sea water.

■ *Cretaceous, palaeoecology, cluster analysis, benthos, taxonomy, Jordan*

Zusammenfassung: Mit Hilfe von 15 detaillierten Profilen mit Mächtigkeiten zwischen 40 m und 200 m wird die oberkretazische Ajlun-Gruppe (Cenoman-Turon) im Süden/Südosten Jordaniens auf Fazies- und Faunenverteilung untersucht. Dabei wird besonderes Augenmerk auf Taxonomie, Paläoökologie, Taphonomie und Sedimentologie gelegt.

Während der frühen Oberkreide lag das Untersuchungsgebiet am Südostrand der Tethys, im Bereich zwischen Küstenlinie und einer vorgelagerten Karbonatplattform. Die Profile liefern einen kompletten Schnitt vom terrestrischen Ablagerungsraum im Südosten über stark siliziklastisch geprägte randlich marine Verhältnisse zu vollmarinen Bereichen mit Karbonatsedimentation. Insgesamt kann gerade der klastisch dominierte Übergangsbereich als bislang nahezu unbearbeitet gelten. Auch paläontologische Untersuchungen fehlen für dieses Zeitintervall bis auf wenige Ausnahmen nahezu völlig. Daher wurde zunächst in einem taxonomischen Teil eine Bestandsaufnahme der Fauna (mit Schwerpunkt auf Benthosorganismen) gemacht. Für das Arbeitsgebiet konnten 2 Ammonoideen und 117 Benthosarten bestimmt werden, die sich aus 77 Muschel-, 22 Schnecken-, 9 Seeigel- und 4 Korallentaxa, sowie je einen Vertreter der Schwämme, Bryozoen und Brachiopoden zusammensetzen. Zusätzlich wurden mindestens zwei neue Arten decapoder Krebse gefunden. Bei den Bivalven konnte die neue Art *Anthonya jordanica* sp. nov. aufgestellt werden. Der allgemein mäßige Erhaltungszustand der Fauna ließ die Aufstellung weiterer neuer Arten nicht zu, obwohl unter den in offener Nomenklatur geführten Taxa mit Sicherheit einige neue Arten sind.

Nach einer Fazies-Analyse der verschiedenen lithologischen Einheiten wurden mit Hilfe einer paläoökologischen Analyse neun Faunenassoziationen und drei Faunenvergesellschaftungen ausgeschieden. Diese statistischen Einheiten, überwiegend Überreste ehemaliger Lebensgemeinschaften, werden beschrieben und die sie bestimmenden Milieuparameter diskutiert. Die wichtigsten, limitierenden Faktoren, welche die Verteilung der Faunengemeinschaften entscheidend steuern, sind die Salinität und das Substrat.

Eine auf Faziesanalyse und Paläoökologie basierende Rekonstruktion des Ablagerungsraumes zeigt, dass dieser weitgehend von der Topographie des Meeresbodens, vom Sedimenteintrag und der Salinität des Meerwassers beeinflusst war.

■ *Kreide, Palökologie, Clusteranalyse, Benthos, Taxonomie, Jordanien*

Contents

Nuculidae GRAY, 1824

Nuculanidae ADAMS & ADAMS, 1858

Arcidae LAMARCK, 1809

Parallelodontidae Dall, 1898

Noetiidae STEWART, 1930

Glycymeridae NEWTON, 1922

Mytilidae RAFINESQUE, 1815

Bakevelliidae KING, 1850

Pectinidae RAFINESQUE, 1815

1 Introduction and aim of the study

The Upper Cretaceous Ajlun Group of southern Jordan contains a rich benthic fauna. A comprehensive study on these poorly to moderately well preserved macro-invertebrates does not exist so far. The last detailed accounts including, among some specimens from Israel and Syria, fossils from Jordan were published by BLANCKENHORN in 1925 and 1927. As in most of the studies concerning Cretaceous fossils from the southern/south-eastern Tethyan margin BLANCKENHORN concentrated on the calcareous invertebrates of the Upper Cretaceous platform carbonates, whereas the marginal marine, siliciclastic-influenced part of south-eastern Jordan was left out of consideration. This might have been due to the missing accessibility of the area during BLANCKENHORN´s field work. The only study of a Cenomanian fauna from siliciclastic sediments was published by SHALEM (1925) on the Motza clays and marls of Israel.

This study aims to fill this gap of palaeontological research in southern Jordan. A second study carried out by BAASKE (in prep.) concentrates on the geochemistry, sedimentology, and sequence stratigraphy of the same area.

The predominantly siliciclastic sediments exposed at the escarpment between Ras En Naqb and Batn El Ghoul yielded an characteristic, poorly known benthic fauna. Some new taxa such as the decapods will be described in a separate publication (FELDMANN & BERNDT, in prep.). In contrast, the north-western sections between Wadi Mousa and Ras En Naqb are dominated by a benthic fauna typical of the Cenomanian of the southern Tethyan margin, as described from Algeria, Tunisia, and Egypt. In this part of the study area, a typical Cenomanian carbonate platform fauna is documented.

Aim of this study is

- the precise recording of sections between At Taiyba in the north-west and Naqb Ataik in the east to obtain a detailed cross-section from marine via marginal marine to terrestrial environments;
- a biofacies analysis based on lithological, taphonomic and ecological criteria;
- a taxonomic documentation of the benthic macro-invertebrates from southern Jordan;
- a palaeoecological analysis of the statistically sampled macrobenthos and the discussion of its most important environmental parameters; and
- the reconstruction and interpretation of the depositional environment of the Ajlun Group in southern Jordan.

2 Previous studies

The history of palaeontological investigations of the Upper Cretaceous of the southern/south-eastern Tethyan margin started with an American expedition to explore the Dead Sea and the River Jordan in the first half of the 19th century. In an extensive report on that expedition, CONRAD (in LYNCH 1852) described and figured numerous Jurassic and Cretaceous fossils collected in Syria. In 1862 COQUAND published a comprehensive monograph of fossils from northern Algeria (Constantine area) which is dominated by Cretaceous macro-invertebrates. Many species, which occur in the marine sections of south-western Jordan, were described and figured for the first time by COQUAND. THOMAS & PERON (1885/1886) studied Cretaceous molluscs from Tunisia in detail. The species described by THOMAS & PERON show a great similarity with the material of

COQUAND. Another large monograph on Cretaceous benthic organisms from Tunisia was published by PERVINQUIÈRE in 1912. The main focus of his work were bivalves and gastropods. On the one hand, the similarity with the fauna described by COQUAND was ostensibly. On the other hand, he erected numerous new species. The first important palaeontological studies on the Cretaceous of Egypt were published by GRECO (1916/1917) and nearly at the same time by FOURTAU (1914/1917). At the beginning of the 20th Century the first German geologists (NOETLING, BÖHM, BLANCKENHORN) started to work in the region of Syria and the former Trans-Jordan. BLANCKENHORN dealt with the Cretaceous fauna from Syria and Trans-Jordan and published a monograph on the echinoids in 1925, in 1927 one on the gastropods, and in 1934 one on the bivalves. All these above mentioned palaeontological studies concentrated on fossils from the Cretaceous carbonate platform. Specimens from the siliciclastic marginal marine sediments of the southern Tethys were not included. The first studies including the area between Ras En Naqb and Batn El Ghoul were published by BENDER (1968) and BENDER & MÄDLER (1969) who took part in the German Geological Mission which started to work in Jordan in the 1960´s. BENDER & MÄDLER described a well preserved Cenomanian plant association from the Batn El Ghoul area.

Recent studies on the geology and palaeontology of southern Jordan were published by POWELL (1989) and in a series of papers of the Natural Resources Authority in Amman. For example, ABU SAAD & AL BASHISH (1996) described three sections of the Kurnub Sandstone Group from the escarpment between Ras En Naqb and Batn El Ghoul and correlated them with sections from Central and Northern Jordan. In 1999, the same authors published two sections of the Amman Silicified Limestone Formation from the afore-mentioned escarpment within the framework of a larger-scale study of the formation in Jordan.

MAKHLOUF et al. (1996) studied rocks of the Ajlun Group in Jordan. In this context, they described sections from the escarpment and Taiyba, respectivly, and discussed their correlation with strata from central and northern Jordan. In a study on the origin of nodular limestones from the Cenomanian of Jordan, ABED & SCHNEIDER (1979, 1982) also included information on this facies from Ras En Naqb.

KUSS (1992) traced the establishment and break up of Aptian – Paleocene carbonate platforms of north-eastern Egypt and southern Jordan.

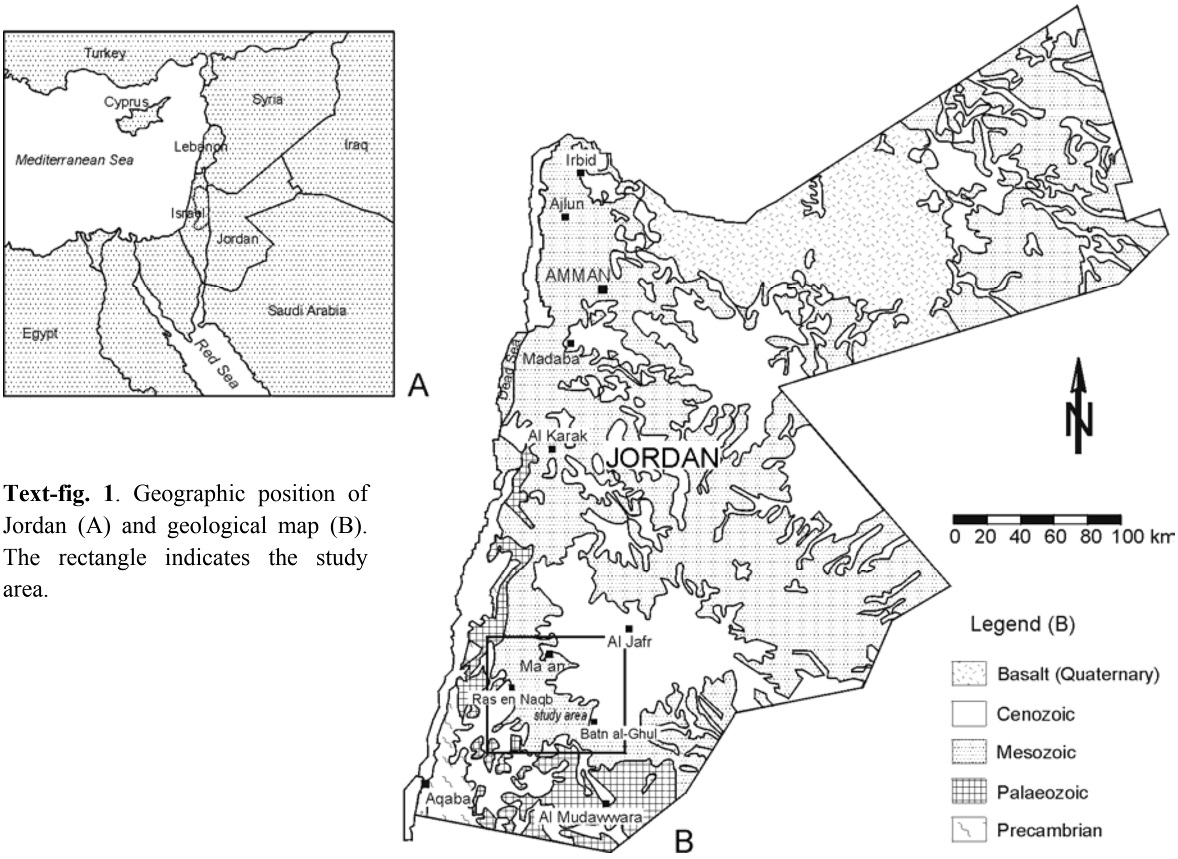
Additional information on the lithostratigraphy of Cretaceous rocks of southern Jordan is found in a series of geological maps (scale: 1:50.000) recently published by the Natural Resources Authority (e.g. RABBA 1991, IBRAHIM 1991).

Besides BENDER & MÄDLER (1969), KOCH (1968) mentioned fossils from the Cretaceous of southern Jordan and included material from Ras En Naqb in his study on Upper Cretaceous foraminifera of Jordan. In the context of their stratigraphic study, MAKHLOUF et al. (1996) figured also components of the benthic macrofauna (bivalves, gastropods, echinoids and corals).

Despite the studies mentioned above, very little details are available about the facies and biota of Upper Cretaceous rocks of southern Jordan.

3 Geological Framework

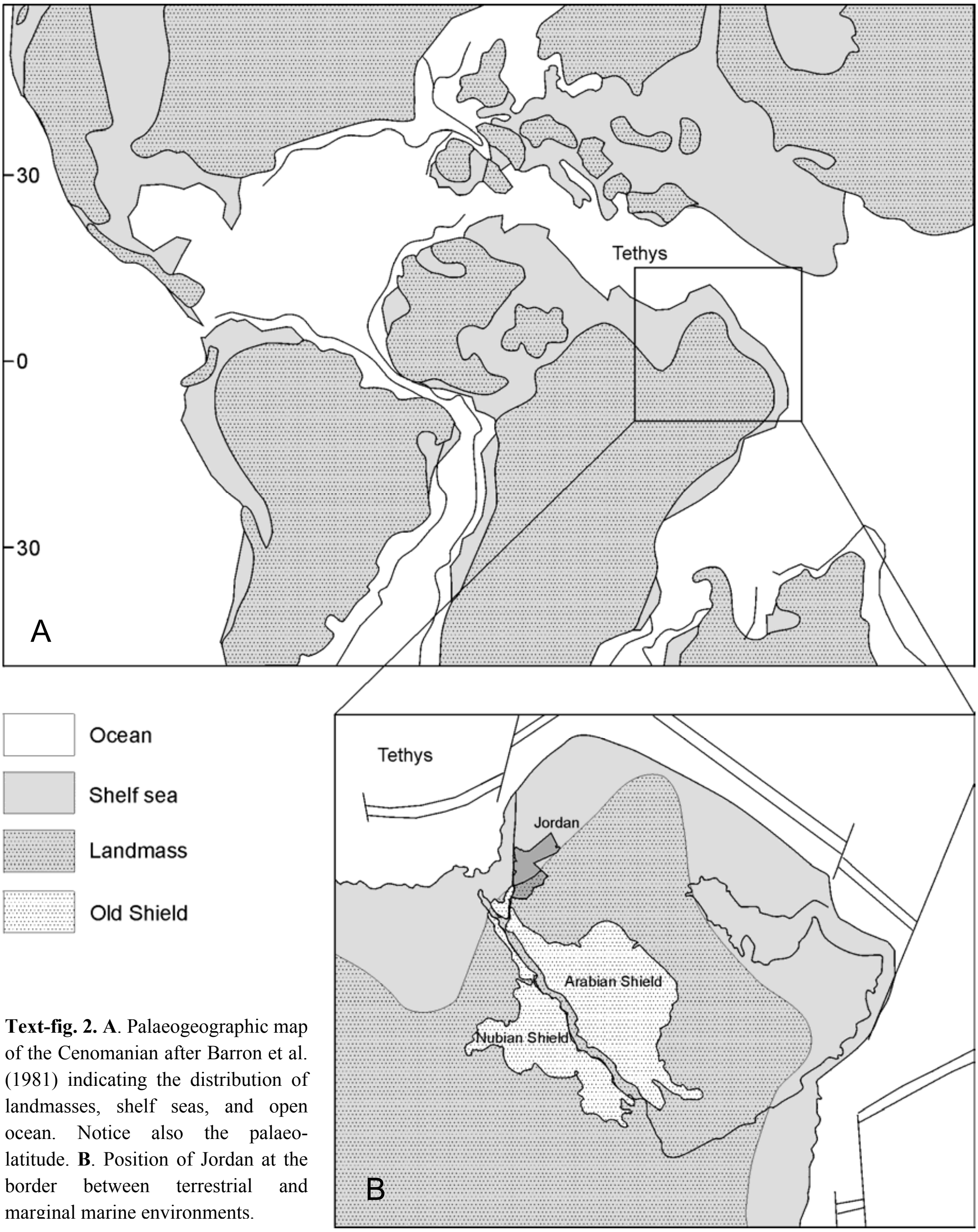
The country Jordan is part of the African-Arabian plate and provides rocks from almost all geologic epochs of earth history. The oldest rocks can be found in the south and south-east (Aqaba area, Wadi Ram) where metamorphic Proterozoic gneisses and schists are unconformably overlain by Cambrian sandstones. Nearly the whole Palaeozoic exhibits a siliciclastic development. In the study area Lower Cretaceous sediments of the Kurnub Group overlie Palaeozoic sandstones of the Ordovician/Silurian Khrayim Group, which include the Dubaidib and the Mudawwara Formation, as a result of pre Permo-Triassic and pre Cretaceous SE-tilting and erosion. Mesozoic rocks are usually limited to the Cretaceous, but a few outcrops of Triassic and Jurassic sediments can be studied along the Jordan rift valley and northern Jordan (e.g., COX 1924, 1932, BENDER 1974, BANDEL & KHOURY 1981, BANDEL & WAKSMUNDZKI 1985, MAKHLOUF et al. 1996). Cretaceous sediments which cover large parts of the country form the bulk of Mesozoic rocks. Tertiary rocks are represented by Paleocene and Eocene chalk, marls, cherts, and basalts. A geologic overview is shown in Text-fig. 1.



Text-fig. 1. Geographic position of Jordan (A) and geological map (B). The rectangle indicates the study area.

3.1 Palaeogeographic setting and evolution of Jordan during the Cretaceous

In Mesozoic times Jordan was situated at the southern margin of the Tethys Ocean (Text-fig. 2). Sedimentation was controlled by the configuration of the Tethys to the north and north-west and the movement of the Arabo-Nubian shield and its cover-rocks in the south (POWELL 1989). During the Early Cretaceous, the shoreline mostly run off northern Jordan, trending NE-SW. Only a few smaller transgressions reached the northern part of Jordan which resulted in thin marginal marine intercalations (BENDER 1974, ABED 1982a). In central and southern Jordan, the Lower Cretaceous Kurnub Group exhibits thick exclusively continental, mostly fluvial deposits. In the course of a worldwide transgression at the end of the Albian or beginning of the Cenomanian large parts of Jordan were flooded by waters of the Tethys Ocean. A carbonate platform was established during the Cenomanian which extended over large parts of northern Africa, Israel, Syria, and Lebanon. In Jordan, relics of this platform are represented by the Naur Formation, which is exposed with its typical facies of partly sandy, nodular limestones and vuggy dolomites in the west and north-west of the study area.

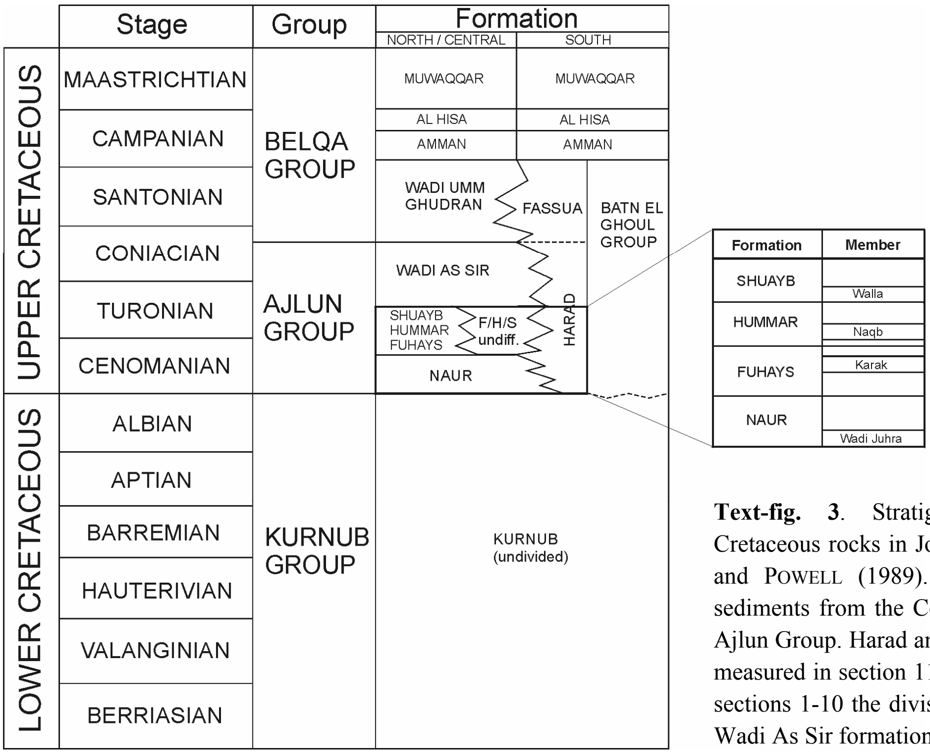


Text-fig. 2. A. Palaeogeographic map of the Cenomanian after Barron et al. (1981) indicating the distribution of landmasses, shelf seas, and open ocean. Notice also the palaeo-latitude. **B**. Position of Jordan at the border between terrestrial and marginal marine environments.

In the east of the working area a marginal marine siliciclastic succession was deposited. As a result of eustasy and local subsidence, the sea level fluctuated over the predominantly shallow water platform during the Cenomanian and Turonian (POWELL 1989) which led to cyclic sedimentation of limestones and marls in northern and central Jordan and to a variety of sedimentary rocks in the marginal marine regions of south-western Jordan. The eastern working area was characterised by depositional environments such as coastal plain, lagoonal, beach and shoreface, tidal flat, and marsh facies. With the end of the Turonian, a phase of non-deposition or uplift and erosion, respectively, began and lasted until the Late Coniacian or Early Santonian (POWELL 1989). In some basins with a high local subsidence (parts of central Jordan, Negev, and north Sinai (LEWY 1975)) carbonate platform growth continued. At the end of the Coniacian or beginning of the Santonian, an extensive transgression followed that flooded Jordan and partly reached Saudi Arabia in the south-east. The Wadi Umm Ghudran Formation (Santonian-Campanian) which consists of chalk, silicified limestones, limestones, marls, and dolomite in Central Jordan and of marginally marine siliciclastics with peat horizons and sandy dolomites in the study area (MOHS 2001) represents variable environments. The Campanian sea was characterised by high concentrations of organic material in a broad shallow water zone associated with oyster bioherms which led to the accumulation of phosphate deposits (POWELL 1989). They are exploited in central and southern Jordan. The sea deepened again during the Maastrichtian which resulted in the local deposition of anoxic marls. Pelagic sedimentation is widespread in Jordan and continued across the Cretaceous/Tertiary boundary. A regressive phase starting in the Eocene resulted in the deposition of nummulitic limestones and brackish gypsiferous marls (BENDER 1974). In the following, the sea retreated to the approximate position of the Mediterranean coastline (POWELL 1989).

3.2 Stratigraphy

The Cretaceous sedimentary succession of Jordan has been subdivided into three lithostratigraphic units which are the Kurnub Group, the Ajlun Group, and the Belqa group (QUENNELL 1951, BURDON 1959, POWELL 1989). According to the International Stratigraphic Guide (SALVADOR 1994) the additional information on lithofacies which were used in some group and formation names by many authors, are not used in this work (for example, Kurnub Sandstone Group, now Kurnub Group; Naur Limestone Formation, now Naur Formation etc.).



Text-fig. 3. Stratigraphic framework of Cretaceous rocks in Jordan after MASRI (1963) and POWELL (1989). This work deals with sediments from the Cenomanian and Turonian Ajlun Group. Harad and Fassua formation were measured in section 11 and more to the east. In sections 1-10 the division into Naur, FHS, and Wadi As Sir formations was possible.

3.2.1 The Kurnub Group

The Kurnub Group includes the Kurnub Formation (undivided), a siliciclastic succession characterised by large-scale trough- and planar-crossbedded sandstones, which are gravelly in places and contain intercalations of silt and clay. It represents predominantly fluvial to marginally marine environments. Sediments of the Kurnub Group are mostly reworked Palaeozoic deposits of the Arabo-Nubian shield. Deposits of the Kurnub Group decrease in thickness from 290 m in northern Jordan (Wadi Gamason) to 45 m in southern Jordan (ABU SAAD & AL BASHISH 1996). The few marine intercalations in northern Jordan are developed as sandy dolomites, dolomitic limestones and claystones (WETZEL & MORTON 1959, Parker 1970, BENDER 1974, ABED 1982, POWELL 1989). They contain the ammonite *Knemiceras* sp., that indicates an Aptian-Albian age (WETZEL & MORTON 1959).

The Kurnub Formation was measured completely in four sections along the escarpment between Ras En Naqb and Batn El Ghoul (Text-fig. 13). The thickness at Ras En Naqb (5) is about 58 m (Text-fig. 15), at section 9 about 31m. East of Batn El Ghoul a clear distinction between the Lower Cretaceous Kurnub Formation and overlying Upper Cretaceous deposits is very difficult because both units are developed as siliciclastics. At the microwave section (10) the boundary was placed at the horizon with the first marine evidence (bivalves, marine trace fossils) which overlies terrestrial sandstones exhibiting palaeosoils with rootlets and fluvial deposits (thickness at least 11.5 m, base not exposed).

3.2.2 The Ajlun Group

The mostly marine Ajlun Group overlies disconformably the Lower Cretaceous Kurnub Group throughout most of Jordan. Like the Kurnub Group this unit reaches ist highest thickness in northern Jordan where 363 m were measured by MAKHLOUF et al. (1996). At Ras En Naqb the thickness of the Ajlun Group is about 144 m. Shallow marine limestones, dolomites and marls intertongue towards the southeast with marine and fluvial siliciclastics. This siliciclastic equivalent of the Ajlun group is called Batn El Ghoul Group (Text-fig. 3).

The Ajlun Group was subdivided into five lithological formations (MASRI 1963, PARKER 1970). The Naur Formation (derived from the small village Na´ur 20km west of Amman) represents the basal formation of the Ajlun Group. It starts with an intercalation of marginal marine shales and sandstones, the Wadi Juhra Member (POWELL 1989) or Transition Zone, which is the result of a transgression of the Tethys Ocean from the north and northwest. The boundary between the Kurnub Group and the Ajlun Group is diachronous as it marks the change from terrestrial to marine environments. The age of this transgression is often stated as Albian to early Cenomanian (e.g., WETZEL & MORTON 1959, BASHA 1978, DILLEY 1985) based on benthic foraminifera and ostracoda. For the escarpment between Ras En Naqb and Batn El Ghoul no exact age determination was available due to the lack of characteristic microfossils (diagenetic solution of calcareous material, see also chapter 7.5). New findings of the forminifera *Thomasinella punica* and the ammonite *Schloenbachia* sp. in sections 7 and 8 (Text-fig. 13) allow an age determination as Cenomanian for the Wadi Juhra Member at the escarpment. It indicates at least temporarily euhaline conditions during the first highstand of the initial advance of the sea, in contrast to brackish conditions proposed by POWELL (1989). The overlying limestones and dolomites reflect the establishment of a carbonate platform in the course of a rising sea level. This platform extended over large parts of the southern Tethyan margin, e.g. northern Africa, Israel, Syria, and Lebanon. In the study area, the prominent cliff of the Naur Formation can be traced from At Taiyba (1) in the northwest to section 7 in the middle of the escarpment. More to the east the carbonates laterally pass into marginal marine sand- and claystones (sections 8, 9, and 10) and terrestrial siliciclastics (sections 11-15) of the Batn El Ghoul Group. Most of the Naur limestones and dolomites of the working area represent fine-grained inner shelf to lagoonal carbonates (chapter 6.4). Algal micrites (bindstones) reflect an oscillating, shallow seafloor. A special facies of the Naur cliff is exposed in section 4, where it consists of cross-bedded peloidal grainstones (Text-fig. 12E, F). They represent zones of higher water energy in a shallow shoal or slope setting. This facies has not been described up to now.

The outer shelf edge of the Cenomanian platform was situated in Israel (Judea Group; e.g., KAFRI 1972), where rudist-coral bioherms were recorded by BEIN (1974). Sediments from the Talme Yafe Group, which follows the Judea Group westwards represent slope and deeper water basins in Israel (BEIN & WEILER 1976). The present-day Mediterranean coast corresponds approximately with the line separating the shelf from the basin.

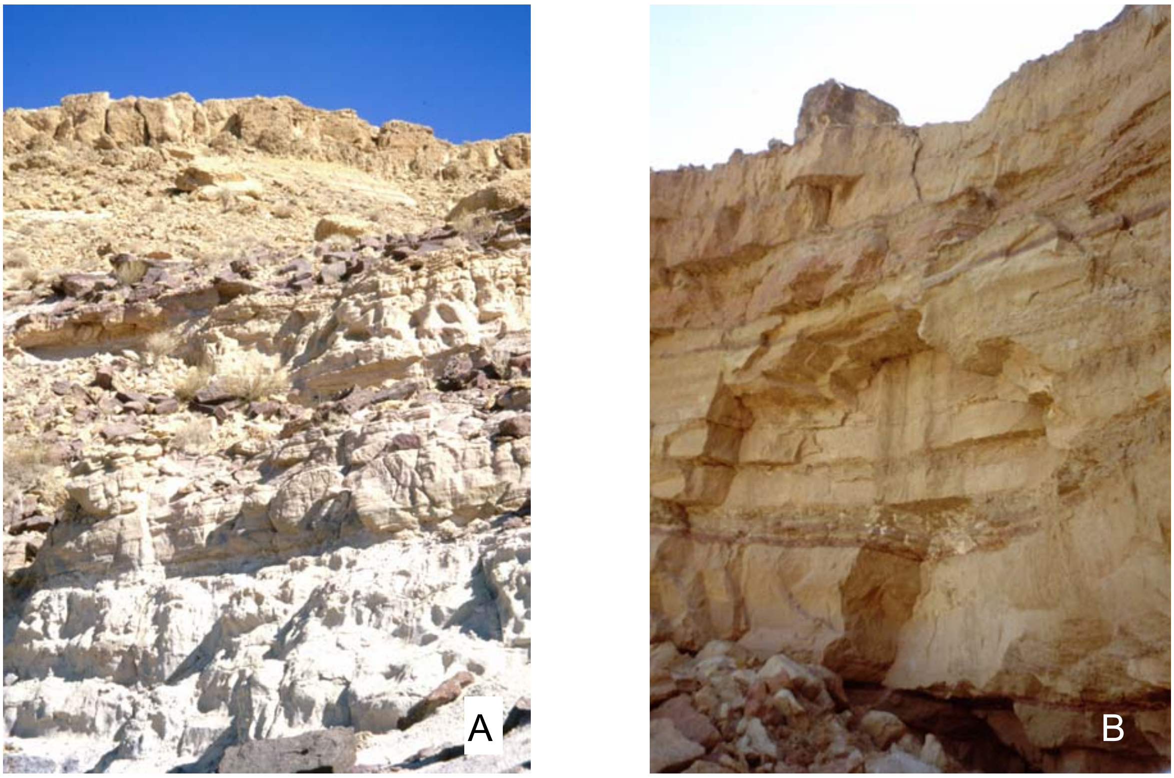
The prominent limestones of the Naur Formation are overlain by massive greyish-green marls and claystones of the basal Fuhays/Hummar/Shuayb (FHS) formations (undifferentiated) in the western sections. They reflect a deepening of the water column and the maximum rise of sea level. *Neolobites vibrayeanus* points to an early Upper Cenomanian age. This far-reaching transgression can be traced up to section 11 in the east, where it is represented by a heavily bioturbated marine sandstone bed containing *Rhizocorallium*.

The clear distinction between the Fuhays, Hummar, and Shuayb formations, which is typically for north and north-central Jordan, is not possible in the south because the Hummar Limestone is not developed. In northern Jordan, the Fuhays Formation consists of thick units of marlstones with interbedded thin, highly fossiliferous limestones. In central Jordan a thick prominent limestone bed (Karak Limestone) is developed, which thins towards north and south. In the study area, the southernmost extension of the Karak Member was found at At Taiyba (section 1). Locally, mappable limestone beds occur in the western sections of the Ras En Naqb area, the Naqb Member and the dolomite bed (maybe equivalent to the Wala Limestone of central Jordan) (Text-fig. 7A).

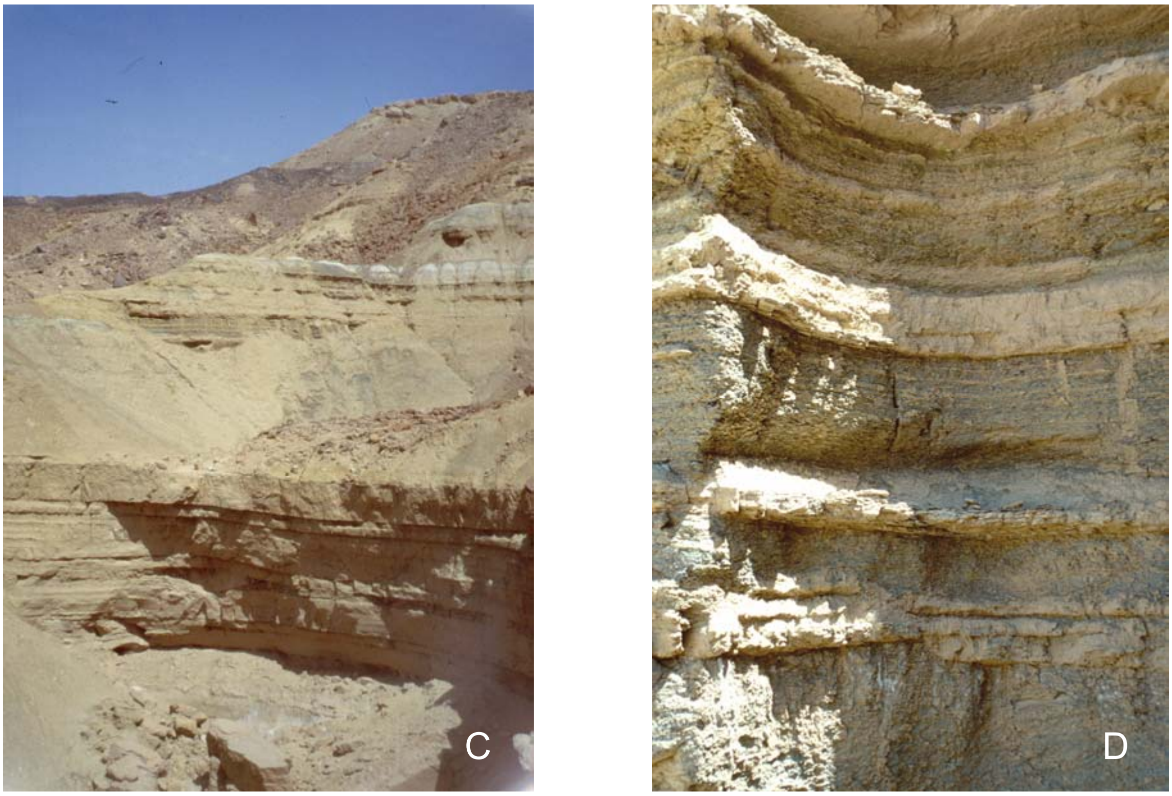
The Hummar Formation of northern Jordan consists of grey limestones, dolomitic limestones and dolomites (POWELL 1989). It is best exposed in the Amman area (e.g., Wadi Esh Shita, Wadi Shuayb). POWELL (1989) proposed a slight uplift of northern Jordan and warm, shallow water for the deposition of this limestone unit, while a deeper water, gently subsiding basin existed in central and south-central Jordan.

Drowning of the carbonate platform of the Hummar Formation resulted in sedimentation of deeper-water silts and calcareous muds in northern Jordan (POWELL 1989). A prominent limestone unit, the Wala Member, is intercalated in northern and central Jordan (Text-fig. 7A), consisting of nodular, highly fossiliferous wackestones with Lower Turonian ammonites (FREUND & RAAB 1962).

In the course of a subsequent sea level drop dolomites as well as lagoonal mudstones and gypsum were deposited. They are typical of the Shuayb Formation of central Jordan. ABED & EL HIYARI (1986) proposed shallow evaporating lagoons or supratidal sabkhas as depositional environments. This shallowing process is probably the result of tectonic uplift of the hinterland (Arabic-Nubian shield) (POWELL 1989). Indications of these movements can be also found in the study area, where an abrupt facies change from marginal marine sandstones and dolomites of the



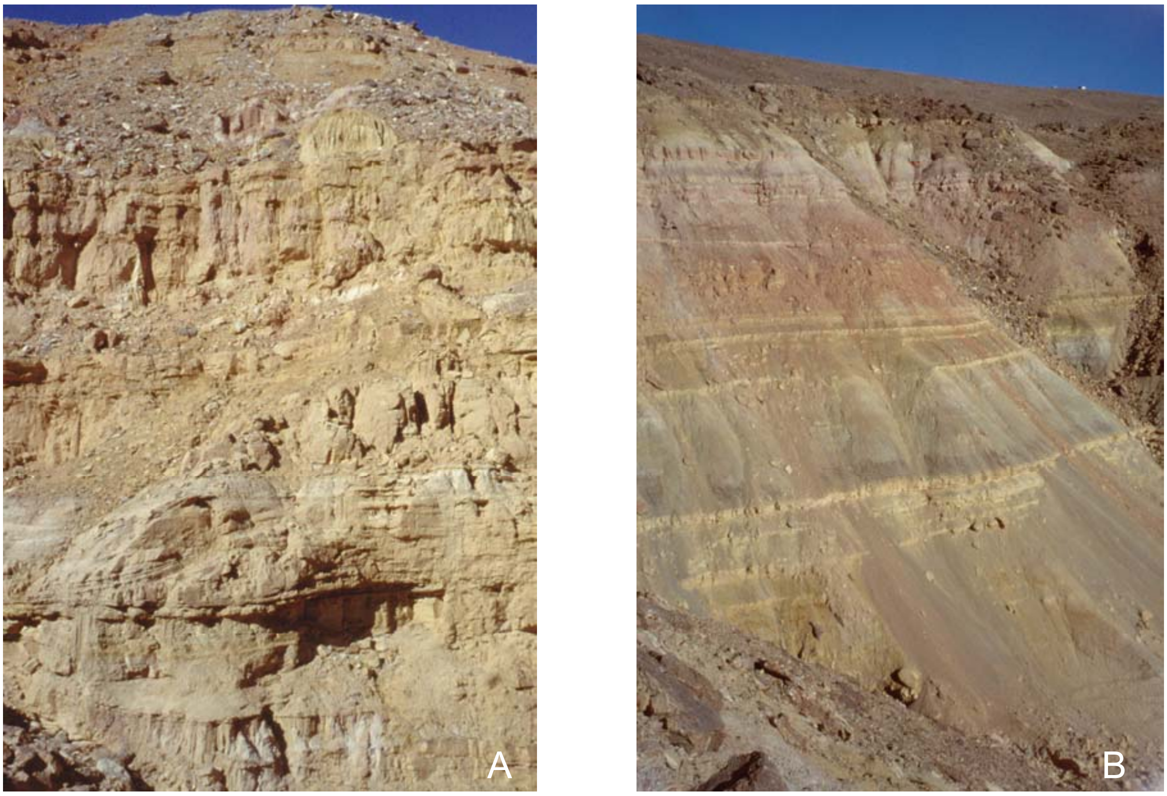
Text-fig. 4. **A**. Succession of Kurnub and Naur formations of section 5. The white sandatones with iron-impregnated crusts belong to the Lower Cretaceous Kurnub Formation. The medium part is covered and forms a gentle slope which is typical of the Wadi Juhra Member. It consists of marginal marine sand- and claystones. In the upper part , the cliff-forming limestones and dolomites of the Upper Naur Formation are seen.. **B**. The Wadi Juhra Member (Transition Zone) is well exposed at section 8. The sand-layers increase in thickness eastwards.



C. Wadi Juhra Member, Naur cliff and basal FHS Formation at section 9. The lower and middle FHS Formation is characterised by the high number of claystone units. They are visible in **D** which shows claystones from the FHS of section 9.

Text-fig 5. A. The Naur cliff consists of limestones and vuggy dolomites which are the result of the establishment of a carbonate platform during the Cenomanian. In the front the slope of the Wadi Juhra Member is visible. Section 3.

Text-fig. 5. **B**. Intercalation of claystones and sandstones of the Wadi Juhra Member and Naur limestones at the top of the cliff at section 9. The Wadi Juhra Member marks the first advance of the Tethys Ocean across the mainland.



Text-fig. 6. **A**. Lowstand deposits of the Turonian Wadi As Sir Formation consisting of thick channels of cross-bedded sandstones. Section 8. **B**. Marginal marine succession of the Coniacian/Santonian Umm Ghudran Formation. Main deposits are claystones, dolomites and sandstones (see also MOHS 2001).

early Wadi As Sir Formation to thick units of fluvial channels and overbank sediments can be noticed especially in the eastern part of the escarpment (sections 7-11; Text-fig. 13).

Another transgression of the Tethys Ocean into the study area is documented by thick units of shallow marine dolomites which form prominent cliffs in the higher part of the western sections. They represent the south-eastern margin of a new carbonate platform, the main relics of which are well exposed in northern and central Jordan. The type locality (Wadi As Sir) is located about 15km west of Amman. In the study area, the Wadi As Sir Formation consists of a basal marine unit, a thick medium part with fluvial, cross-bedded sandstones, and an upper marine unit with dolomites and marginal marine claystones. Along the escarpment the facies change of the two marine units to marginal marine and terrestrial sediments in the east is very clear. These two transgressions reached section 10 (Batn El Ghoul area), but the sea did not advance as far as during the basal Late Cenomanian (Text-fig. 7B). The basal marine unit is disconformably overlain by a thick package of fluvial channel sandstones, which are thinning north-westwards. These most probably mid-Turonian lowstand deposits are also recorded from southern Sinai (BAUER 2002). They might reflect tectonic processes which lead to an uplift of the hinterland. The upper marine horizon of the Wadi As Sir Formation consists of heavily bioturbated, dolomitic or carbonaceous sandstones and marginally marine claystones at the base (transgressive phase) and micritic dolostones and algal laminites at the top. Chert nodules are very common in the uppermost layers. Fossils are very rare in the Wadi As Sir Formation of the study area.

The Wadi As Sir Formation contains deposits of a wide, shallow carbonate platform that extended over a large area from near the present Mediterranean coastline to south-eastern Jordan (POWELL 1989). In northern Jordan it consists of thick limestone sequences with rudistid biostromes, bioclastic wacke- and packstones and foraminiferal limestones. The sea floor was subdivided into local shoals and basins which led to different lithofacies units on the Turonian platform.

The siliciclastic equivalent of the Ajlun Group in the south-east of Jordan is called Batn El Ghoul Group. The Batn El Ghoul Group was subdivided (PARKER 1970) into the lower Harad Formation and the Upper Fassua Formation which most probably belongs to the Belqa Group.

The top of the Wadi As Sir Formation marks the boundary between the Ajlun Group and the Belqa Group.

3.2.3 The Belqa Group

The 600 m (north) to 175 m (south-east) thick Belqa Group reflects a change in the configuration of the margins of the southern Tethys (POWELL 1989). The broad carbonate platform with local highs in the Turonian was replaced by an extensive low-gradient ramp (SASS & BEIN 1982, FLEXER et al. 1986) over which the sea transgressed far to the east and south-east, reaching Saudi-Arabia and Egypt. The sediments of the Belqa Group contain chalk, marls, cherts and phosphorites. In northern and central Jordan the boundary between the Ajlun and Belqa groups is marked by a depositional hiatus, which is hardly visible in the study area. Here, pelagic sediments start higher in the section, the basal part being dominated by marginally marine siliciclastics (MOHS 2001). In recent studies the Belqa Group was subdivided into six formations starting with the Umm Ghudran Formation at the base.

The Late Coniacian-Santonian Wadi Umm Ghudran Formation consists of pelagic chalk, dolomites and sandstones in northern and central Jordan, depending on the palaeorelief of the sea floor. The thickness ranges from 32 m at Waqf As Suwwan to 87 m at Wadi Mujib (POWELL 1989). The chalk facies is well developed in the Mujib area (Mujib Member, basal Wadi Ghudran Formation) and in the Dhiban area (Dhiban chalk, Upper Umm Ghudran Formation). These two chalk units are separated by a thick package of sandstone in the north, the Tafila Member. A time-equivalent deposit in south-central Jordan is the Alia Member, a thick large-scale cross-stratified sandstone unit. These two siliciclastic members may reflect a renewed uplift of the hinterland (POWELL 1989). At the escarpment between Ras En Naqb and Batn El Ghoul, the Umm Ghudran Formation (thickness 62-80 m) documents marginal marine paralic conditions. The dominating sediments are bituminous claystones, cross-stratified sandstones and dolomitic siltstones. At the base peat horizons are developed (MOHS 2001). In the south-east, at Batn El Ghoul and east of it, the Fassua Formation might be the stratigraphic equivalent of the Umm Ghudran Formation. The former overlies the Harad Formation without a significant unconformity but the change from red terrestrial sandstones and clays to green marginal marine claystones is distinctly traceable.

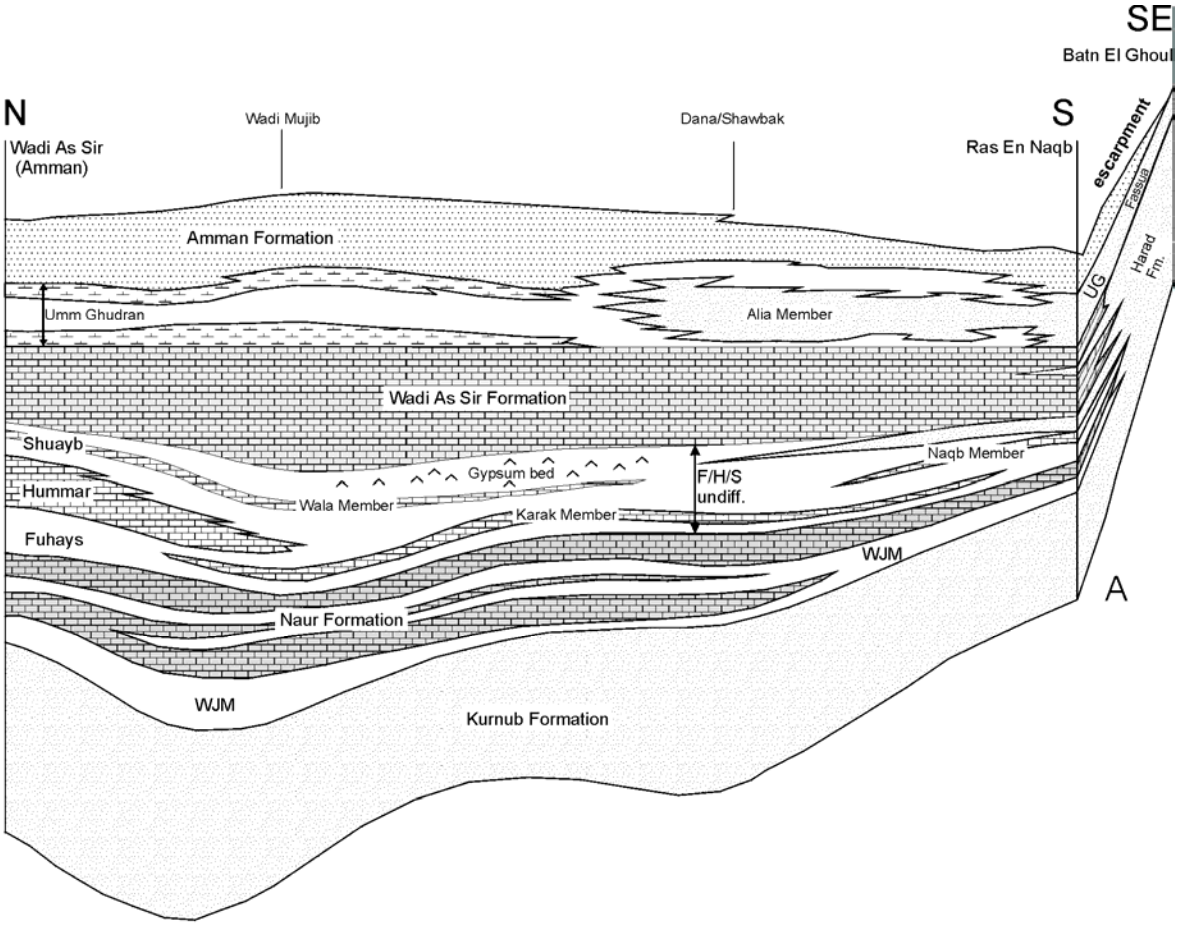
The Campanian Amman Formation (Amman Silicified Limestone Formation) represents the next shallowing phase in the Upper Cretaceous of Jordan (POWELL 1989). The characteristic sediments are thick, brecciated, sometimes laminated cherts, associated with chalky marls and chalk. The thickness of the Amman Formation changes from 64 m in the north (Irbid area) to 42 m at Ras En Naqb (ABU SAAD & AL BASHISH 1999). Because of its massive dark weathering chert beds forming a small cliff, the formation can easily be traced from northern to southern Jordan. In the south-east the siliciclastic influx increases towards the former coastline. The depositional environment was a shallow mid-shelf setting. POWELL (1989) proposed a water depth of about 10-

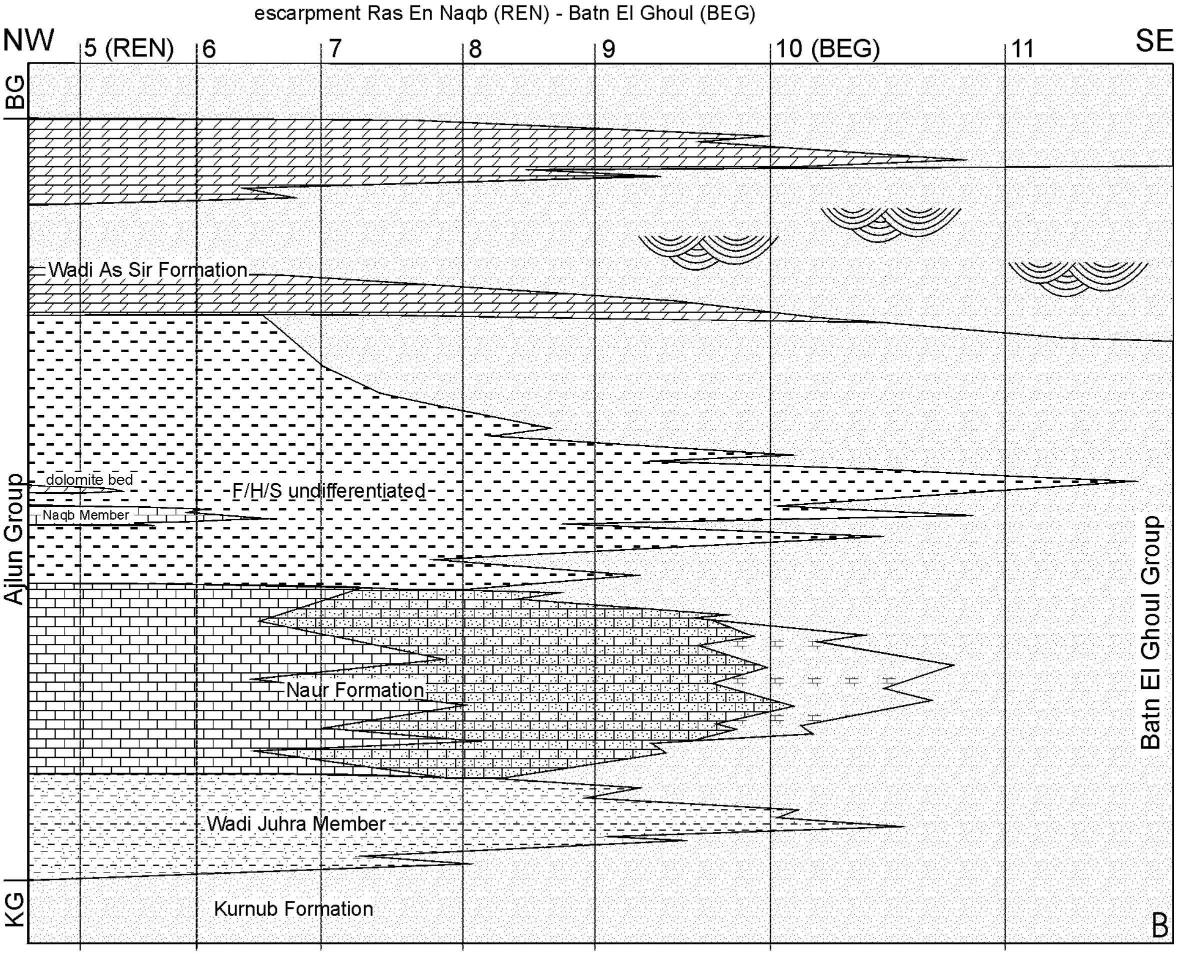
20 m. Benthic organisms are very rare in most of the beds, which might indicate lowered oxygen values at the sea floor. Intercalated horizons with concentrations of oysters, bivalves, gastropods and burrows might suggest periodic oxygenation of the sea floor (Powell 1989). Characteristic features are thick oyster banks (“Coquina”) which occur throughout most of Jordan in the Amman Formation, and indicate local highs and sea level lowstands. In the study area, especially in the Batn El Ghoul region, the base of the Amman Formation is characterised by a several decimetre-thick, red sandstone bed with common shark teeth and bone fragments. Here, a marginal marine environment is documented.

The overlying uppermost Campanian Al Hisa Formation (Al Hisa Phosphorite Formation), a lithologically rather heterogenous unit, is part of the Jordanian phosphorite belt which runs NNW-SSW in central Jordan (Powell 1989). It consists of chert, marl, phosphorites, and oyster-rich limestones. The thickness decreases from 63 m at Wadi Mujib to 22 m at Ras En Naqb and 12 m at Zakimet Al Hasah. The depositional environment can be described as a broad shallow shelf with high organic productivity. Oceanic upwelling might have produced a nutrient-rich sea water. Powell (1989) proposed a stratified water column responsible for the contrast between oyster-rich areas and unfossiliferous areas, which were deposited in deeper layers. Most of the phosphorite consists of fish teeth and bone fragments. At the top of the Al Hisa Formation a transgressive trend and a return to fully marine circulation is recorded by ammonite-rich limestones.

The Muwaqqar Formation (Muwaqqar Chalk Marl Formation) represents the uppermost unit of the Cretaceous. It ranges from the Maastrichtian to the Palaeocene (e.g., Heimbach 1962, Bender 1974). Main facies of this formation are chalky marls, marls, and limestones. A major sea level rise is documented, which led to pelagic deeper water sedimentation on a broad shelf (Powell 1989). The water depth was greatest along the rift margins, rich benthic faunas in central Jordan indicating slightly shallower conditions. Deeper water basins were developed at Jafr, Wadi Bustani, Azraq, and the Yarmouk river (Powell 1989) where bituminous marl and chalk were deposited. At the top of the formation, a shallowing trend is recorded by bioturbated glauconitic, phosphatic marls.

Text-fig. 7. **A**. The distribution of lithostratigraphical units (Formations) throughout Jordan after Powell (1989). Most of the formations were established from localities in the north. The correlation to the siliciclastic influenced environments in the south is often difficult. **B**. Distribution of formations along the escarpment Ras En Naqb-Batn El Ghoul with the help of the detailed measured sections from this work. For localities of sections see Text-fig. 13.


SE
Batn El Ghoul
N
Wadi As Sir
(Amman)
Wadi Mujib
Dana/Shawbak
S
Ras En Naqb
escarpment
Fassua
Harad Fm.
UG
Amman Formation
Umm Ghudran
Alia Member
Wadi As Sir Formation
Shuayb
Hummar
Fuhays
Gypsum bed
Wala Member
Karak Member
F/H/S undiff.
Naqb Member
WJM
Naur Formation
WJM
Kurnub Formation
A


escarpment Ras En Naqb (REN) - Batn El Ghoul (BEG)
NW
5 (REN)
6
7
8
9
10 (BEG)
11
SE
BG
Wadi As Sir Formation
Ajlun Group
dolomite bed
Naqb Member
F/H/S undifferentiated
Naur Formation
Wadi Juhra Member
KG
Kurnub Formation
Batn El Ghoul Group
B

4 Facies associations in the Upper Cretaceous of southern Jordan

4.1 Coastal plain facies association

Fluvial channel facies

Thick units up to 25 m of fine, medium, and coarse sand characterise the sedimentary succession of the Kurnub Formation of all sections, the Harad Formation in the east, and the upper part of the FHS Formation. The sands are poorly to moderately indurated, well sorted, predominantly white to yellowish and show medium- to large-scale planar and trough cross bedding. Gravel commonly occurs at the base of graded foresets. Deep red and purple iron concretions up to 10 cm in diameter and fragments of fossil wood are a characteristic feature of the Kurnub Sandstone Formation. These units are often composed of several channel structures. These channels are overlain by yellowish grey to grey claystone layers with a thickness of up to 0.5 m. They are well stratified, sometimes laminated and contain abundant plant debris. Most of them pinch out laterally as it is characteristic of clay lenses in fluvial systems.

Interpretation: These deposits document large braided river systems with intercalated overbank sediments which represent river highstands. They are often associated with colour-mottled horizons of the marsh facies.

Fluvial-dominated coastal plain facies

Characterised by thick units of alternating sands and clays, this facies exhibits ripple-bedded sands as well as horizontal, planar and trough cross-bedded sands. The sands are mostly fine-grained and contain a high amount of silt and clay. Often, they are incised into the underlying claystone units which are massive and sometimes colour-mottled. Fauna is very rare in this facies, as are plant remains and bioturbation. The fluvial-dominated coastal plain facies was mainly found in the Upper Cretaceous Harad Formation of the eastern sections, but also in the equivalent upper FHS Formation of the middle part of the escarpment.

Marsh facies

Sediments representing marsh facies are poorly sorted silty fine- to medium-grained sands or sandy silts that typically exhibit pedogenic structures. Colour-mottling, iron concretions and rare rootlets indicate soil-forming processes. Bioturbation is very common. Although marsh deposits have been examined only insufficiently up to now, the interpretation of the before mentioned units is likely because of the characteristic sedimentary structures and the stratigraphic context. Their occurrence is limited to the middle and upper part of the Harad Formation in the Batn El Ghoul area.

4.2 Marginal marine facies associations

Estuarine facies

Interbedded thin fine-grained sandstone and claystone units containing a typically brachyhaline fauna (*Crassostrea* sp. – decapod sp. B assemblage, chapter 8.6) most probably document a small estuary. The yellowish grey to brown sandstones are characterised by erosional bases and horizontal lamination, the claystones are massive and rarely bioturbated. This facies has been found in the upper part of the FHS Formation of section 9.

Tidal flat facies

Sediments interpreted as representing a tidal flat environment show interbedding of thin layers of well sorted, fine- or medium-grained sand and silty clay which are characterised by ripple-lamination or wavy lamination and common bioturbation. The clay layers contain fragments of fossil wood. Tidal processes such as the nearly equal alternation of bed-load and suspension-load deposition cause rapid alternations of grain sizes (e.g., DALRYMPLE 1992). Deposits of tidal flats have been found in the upper part of the FHS Formation of sections 6-9, and repeatedly in the Harad Formation of sections 10 and 11.

Text-fig. 8. Facies associations of the Ajlun Group of southern Jordan. A. Mottled sady siltstones with remains of roots from the uppermost FHS Formation of section 6, interpreted as marsh facies, B. Sandstone with ripple marks from shoreface/beach environments (section 9), C. Iron-impregnated sandstones heavily bioturbated by *Rhizocorallium jenense* from lower shoreface settings of section 10, undersurface view, D. Claystones from euhaline lagoonal environments (FHS Formation, section5).

Beach and shoreface facies

Well sorted fine- to medium-grained sands and poorly indurated sandstones with low-angle as well as steep planar cross bedding and thick structureless sand units are interpreted as deposits of beach and upper shoreface environments. The colours of these sands range from yellowish white to brownish yellow. A few shark teeth (*Carcharoides* sp.) and rare small internal moulds of bivalves could be observed. Low angle planar cross-bedding may be correlated with the zone of wave swash, whereas steep planar cross bedding is interpreted as caused by longshore currents. They indicate a high energy nearshore environment. Beach and upper shoreface sediments accumulated during deposition of the FHS and Wadi As Sir formations, and in the Harad and Fassua formations.

Shoreface sediments are characterised by sand/sandstone units which show mainly low angle planar cross bedding and medium- to large scale trough cross-bedding. Rare flaser bedding and steep planar cross-bedding as well as horizontal bedding with thin intercalated clay/silt layers could be recognised. These yellowish brown, red or grey commonly bioturbated claystone/siltstone beds contain a few body fossils, only some shark teeth, and very poorly preserved internal moulds of oysters. Occasionally, the sandy foresets are graded and exhibit gravel or coarse sand stringers at the base. Well preserved trace fossils include *Thalassinoides* and *Rhizocorallium*. A marginal marine environment with fluctuating water energy and euhaline conditions is documented. Aragonitic fossils and even the thick calcitic shells of oysters have been dissolved during diagenesis. In contrast to the benthic fauna in pure claystones which is preserved as composite moulds the porosity in sandy bioturbated clays was higher and the destruction of fossil material happened earlier and faster. Deposition in a well oxygenated shoreface environment with normal marine salinities is proposed.

Sediments of the shoreface can be found in the FHS, Wadi As Sir, and Harad formations.

Lagoonal facies

a. Brackish facies

Massive or indistinctly stratified grey and greenish grey clay units with thicknesses between 0.1 and 8 m are characteristic elements of the sedimentary succession of the Wadi Juhra Member (basal Naur Formation) as well as the FHS undifferentiated and the Wadi As Sir formations. The most common fossils are small corbulid bivalves, sometimes as monotypic shell concentrations, sometimes associated with nuculids, oysters, small trochiform gastropods, lingulid brachiopods and decapod fragments. Small pellet-filled horizontal and oblique burrows occur. One unit is dominated by *Eomiodon*. The Wadi Juhra Member as well as some horizons of the FHS undifferentiated contain sandy agglutinating foraminifera of the genus *Thomasinella*. In other horizons well preserved plant fossils such as *Sideroxytophylum* and *Weichselia* have been recognised together with very small and rare shallow infaunal (*Cerastoderma*-like) bivalves and corroborate a near-shore setting. The fine-grained sediment, the impoverished and small-sized benthic fauna, the occurrence of certain species known to be able to live in salinity-reduced environments, and the absence of stenohaline species indicate deposition in a low energy regime under brackish conditions in a protected part of the shallow shelf, most probably a brackish lagoon.

b. Euhaline facies

The Cenomanian Wadi Juhra Member and the Upper Cenomanian FHS Formation contain a few massive to indistinctly laminated, sometimes heavily bioturbated claystone horizons with a rich fauna that includes stenohaline species such as ammonites and burrowing echinoids as well as deep

infaunal bivalves (*Pholadomya*). These layers occur as single beds in siliciclastic successions and also between thicker clay units that mainly represent brackish conditions. Short periods of fully marine and well oxygenated environments in restricted shelf areas with a low water energy are documented. The substrate was rather soft indicated by small gastropods and a dominance of infauna. All shell material was dissolved during diagenesis.
These units are interpreted as relicts of euhaline lagoons.

4.3 Transitional facies associations

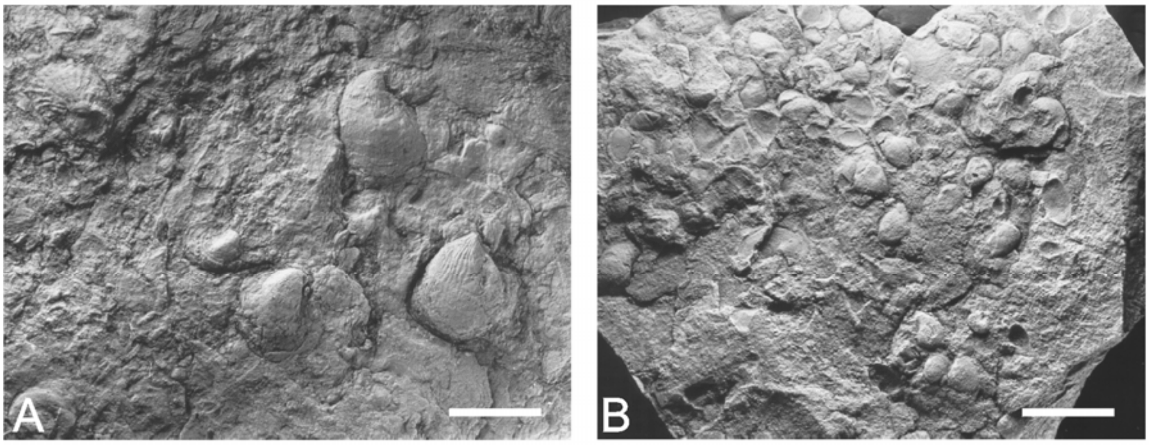
Marlstones and sandy dolomites/limestones are typical sedimentary rocks of the Naur Formation as well as the lower part of the FHS Formation. They form a transitional zone between the siliciclastic marginal marine environments in the east and south-east and the carbonate platform in the west and north-west.

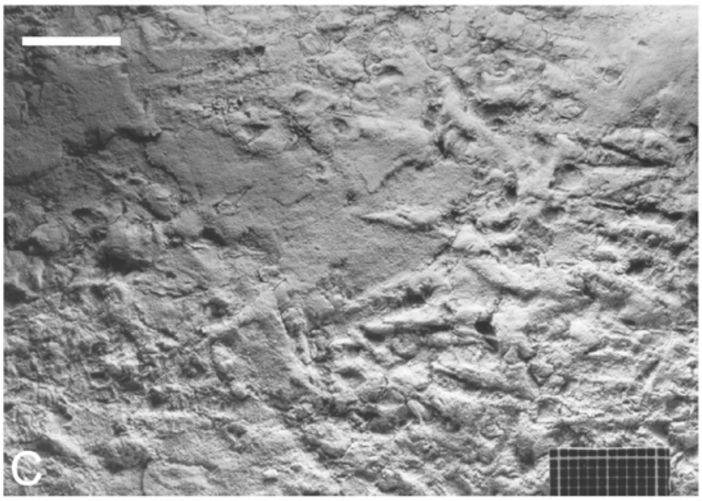
Oyster-rich marlstone facies

Dark-grey to greenish-grey, moderately bioturbated marlstones with abundant oysters are the dominant facies of the lower FHS Formation of the western sections. These oysters (*Ilymatogyra*, *Laevigyra*, *Costagyra*, *Ceratostreon*) occur mostly in situ and in shell preservation. Minor faunal elements are irregular echinoids (*Mecaster*) and internal moulds of large gastropods (*Nerinea*). In certain levels of the Ras En Naqb area, corals of the genera *Meandraraea* and *Astraeofungia* preserved in growth position have been found in marlstones of the lower FHS Formation. The marlstone units are up to 12 m thick and contain 3-5 layers of shell concentrations consisting of oysters or *Plicatula*.
The siliciclastic part of the sediment indicates a nearshore setting with, at times, a high terrigeneous input. The rather fine-grained sediment implies deposition under low water energy, most likely below normal wave base in slightly restricted parts of the shallow shelf. The substrate was, however, firm enough to support the thick-shelled free-living oysters. Large oysters, corals and infaunal echinoids indicate normal marine conditions. The shell concentrations with thicknesses between 5 and 20 cm are interpreted as results of storm events producing sorting but little fragmentation.

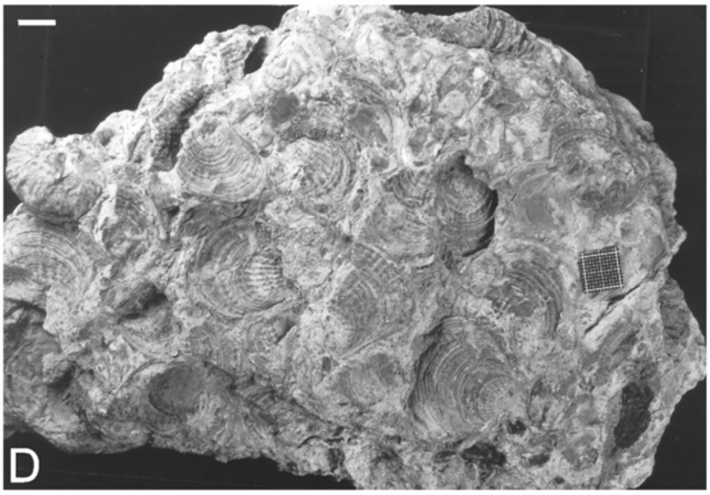
Sandy dolomitic bindstone facies

At the base of the calcareous Naur cliff in the north-western sections, which overlies the Wadi Juhra Member, dolomitic bindstones occur. In some layers, they contain angular to subangular quartz grains in a micritic matrix. Charateristic features are the occurrence of chert nodules in some layers as well as an impoverished macrofauna which consists of *Neithea*, *Exogyra* and internal moulds of rudists in less laminated parts. In thin-sections, the irregular stratified texture, rarely associated with a fenestral fabric, is clearly visible. Microbial and algal mats took part in constructing these rocks. Additional components are small fragmented shells and filaments as well as rare miliolid foraminifera.

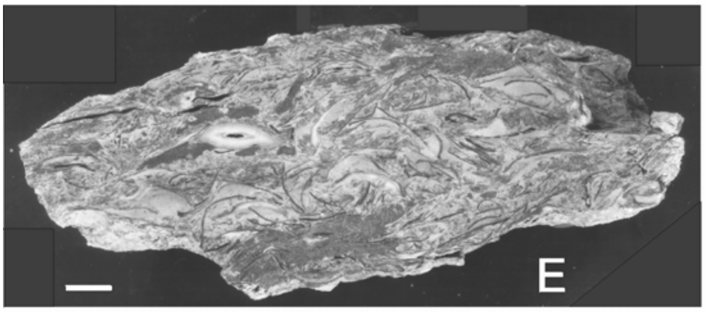




Text-fig. 9. Different types of brackish claystones deposited in lagoonal environments (A-C), and shell concentrations (D-E). All scales = 1cm. **A**. Sandy claystone with composite moulds of *Rhynchostreon mermeti* in growth position (undersurface view) from the Batn El Ghoul section (10). **B.** Nearly monospecific shell concentration of corbulid bivalves, lower FHS Formation of section 9. **C**. Concentration of small turriform gastropods from claystones of section 10 (FHS Formation).



D. Nearly monospecific shell concentration consisting of *Plicatula fourneli* and very rare *Ilymatogyra africana* forma *crassa* (upper left side) from Dilagha (section 2). These layers, or beds with *Ilymatogyra africana* forma *typica* and *Curvostrea* cf. *rouvillei* are very typical features of the marly developed lower FHS Formation of the western sections. They indicate storm events in an euhaline lagoonal environment.



E. Cross-section of a storm layer found within oyster-rich marlstones of Ras En Naqb. Main components are fragmented valves of *Curvostrea* cf. *rouvillei* and *Ilymatogyra africana*. Lower FHS Formation.

This dolomitic bindstone facies documents a very shallow depositional system in a restricted part of the carbonate ramp setting where the water energy was fairly low. Water depth might have been a few centimetres to one metre. The occasional fenestral fabrics indicate emergence. The laminated dolomites and the occurrence of only a few macrofossils might point to a restricted (hypersaline) lagoonal system. Times of higher water energy, for example storm events, are documented in the sandy layers which were subsequently overgrown by microbial mats.

Sandy grain- to rudstone facies

In the middle and upper parts of the Naur Formation of the Ras En Naqb area impure limestones occur, which show a very inhomogeneous microfacies. Marly and siliciclastic layers interfinger with grainstones and rudstones laterally. Some layers are graded and change upwards into packstones. The macrofauna includes fragments of bivalves, oysters, and bryozoans. In thin-sections rare foraminifera and peloids as well as coated grains and oncoids were identified. Parts of the rocks are strongly recrystallised.

The fragmented macrofossils and the variable microfacies components indicate a depositional environment with fairly high water energy, as do the individual sediment packeges that build up the units. These sediments were deposited above normal wave base, most probably at the margin or slopes of carbonate platforms. Terrigeneous influx is documented by the fairly high proportion of siliciclastics.

4.4 Carbonate platform facies association

Foraminiferal, partly laminated mud- to wackestone facies

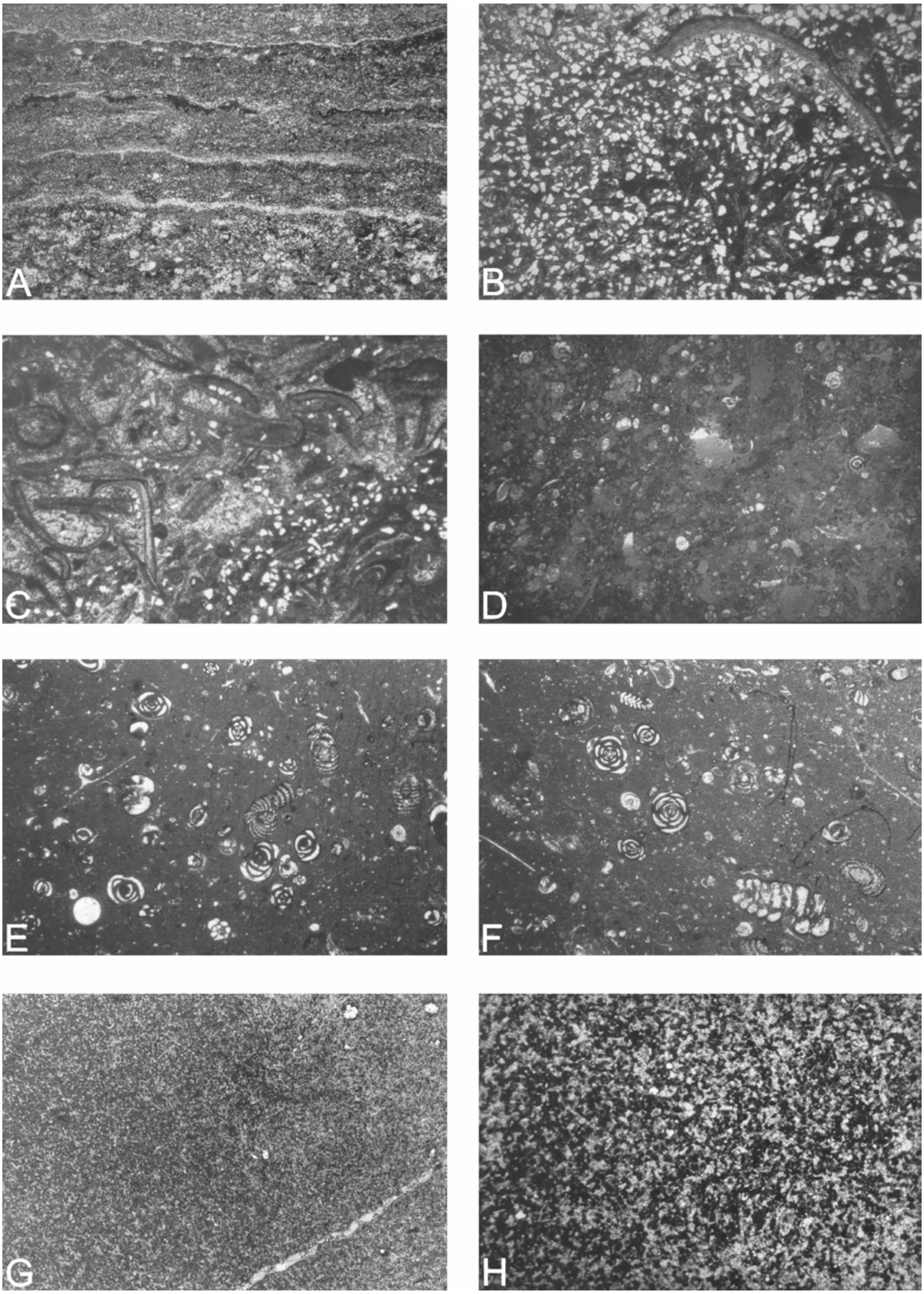
A very common facies in all western sections with a well developed calcareous Naur Formation are fine-grained foraminiferal limestones. In outcrops beds are nodular or well bedded. Main components are textulariid, rotaliid and miliolid foraminifera. Additional elements are small fragments of bryozoans, bivalves, gastropods, and dasycladaceans as well as rare peloids and encrusted lumps. The micritic matrix is partly bound by cyanophyceens (porostromate algae). Later dolomitization processes are documented by tiny idiomorphic dolomite crystals.

Open platform areas behind the outer platform margin, probably a shelf lagoon, are supposed to be the depositional environment of these limestones. It is characterised by low water energy and low sedimentation rates. Rotaliid foraminifera are pelagic forms and were transported into this depositional system.

Peloidal wackestone facies

A similar environment is recorded by several layers of peloidal wackestones which have been observed in the upper part of the Naur Formation of the Ras En Naqb area. They contain mostly well rounded fecal pellets and partly angular pelletoids (small micritic fragments) in a strongly recrystallised matrix. Other microfacies components include grapestones and cortoids among rare benthic textulariid foraminifera and small recrystallised shell fragments. The macrofauna consists of rare epifaunal echinoids.

These sediments accumulated in an open lagoon or bay behind the outer platform margin. They document low water energy and deposition below normal wave base.



Text-fig. 10. Microfacies types of the transitional facies association (**A**-**C**) and the carbonate platform facies association (**D**-**H**). **A**. Sandy dolomitic bindstone from the Naur Formation of Dilagha (section 2), **B**. Sandy grain- to rudstone from the Naur Formation of Ras En Naqb (section 5), **C**. Sandy rudstone from the Naur Formation of Ras En Naqb, **D**. Foraminiferal mud- to wackestone from the Naur Formation of Ras En Naqb, **E**, **F**. Foraminiferal wackestones from the Naur Formation of section 3, **G**, **H**. Peloidal wackestones from the Naur Limestone of Ras En Naqb. All thin-sections x10, except **G** (x4).

Bioclastic wacke- to packstone facies

A very common facies of the Taiyba, Dilagha and Ras en Naqb sections, especially in the upper parts of the Naur Formation, are wacke- to packstones. They are dolomitized in certain layers, with well developed zonar euhedral dolomite crystals. The micritic matrix is partly washed out and recrystallised. Angular to subangular quartz grains occur in some areas. The main components are fragments of oysters, rudists and other bivalves, echinoderms, calcareous algae, gastropods, and corals. Furthermore, calcispheres, peloids, textulariid (occasionally encrusted) foraminifera and rare grapestones occur. The macrofauna consists mainly of oysters, internal moulds of rudists (*Radiolites*), echinoids, and rare bryozoans. Their arrangement (not in growth position, but mostly not fragmented) indicates in most cases only limited transport.

The depositional environment of these sediments was a relatively shallow part of the carbonate platform with an open water circulation just below the fair-weather wave base. Open marine conditions are indicated by rudists, bryozoans, and echinoids. Fragmented elements of the fauna, sandy streaks, and the partly washed-out matrix record times of higher water energy possibly caused by storm events.

Foraminiferal packstone facies

This facies was found in the upper Naur and the lower FHS formations of the western sections. The components are a rich fauna of foraminifera (*Chrysalidina*, miliolid forms), peloids, fragments of calcareous algae, and small shell fragments. The macrofauna consists mainly of oysters and shallow infaunal bivalves.

These sediments represent an open shelf lagoon with a normal water circulation. Algae indicate a position within the photic zone.

Grainstone facies

Two main facies of grainstones were observed which are typical of the Upper Naur Formation of section 4 of the Ras en Naqb area. In addition, they occur also in the FHS Formation of section 3. They include biopelsparites and pelsparites.

a. Biopelsparites

Poorly sorted, loose-packed bioclastic limestones dominate the lower part of a 6 m thick grainstone unit of section 4. They are characterised by abundant, rather big subangular bioclasts and smaller peloids. The main components are fragmented gastropods, bivalves, oysters, calcareous algae, and echinoids. All of them, exept the echinoderm fragments, exhibit micritic crusts (minimicrite) which indicate activities of microboring organisms. Additionally, subrounded peloids and rare angular to subangular lithoclasts were found.

These sediments were deposited under continuous fairly high water energy conditions, which is indicated by the sparitic matrix and the fragmented bioclasts. The depositional environment was the shallow shelf above the normal wave base, more precise, margins of carbonate bars with regular reworking of sediment and continuous winnowing of fine material.

b. Pelsparites

Pelsparites occur in the upper Naur Formation of section 4 where they form a dominant limestone cliff. Beds up to 35 cm thick with erosional bases are cross-bedded and wedge out laterally. This facies has not been found in any other section.

The main components of these moderately sorted, densely packed limestones are peloids formed by intense micritization or derived from fecal pellets. The peloids are distinctly smaller than in facies (a) and subrounded to rounded in shape. Bioclasts are very rare and include foraminifera, gastropods, bivalves, oysters, and echinoderms. A few very rare, subrounded lithoclasts were observed.

The sparitic matrix, cross-bedding, and erosional bed contacts indicate a similar environment as reported in (a). It was situated at the margins of shoals.

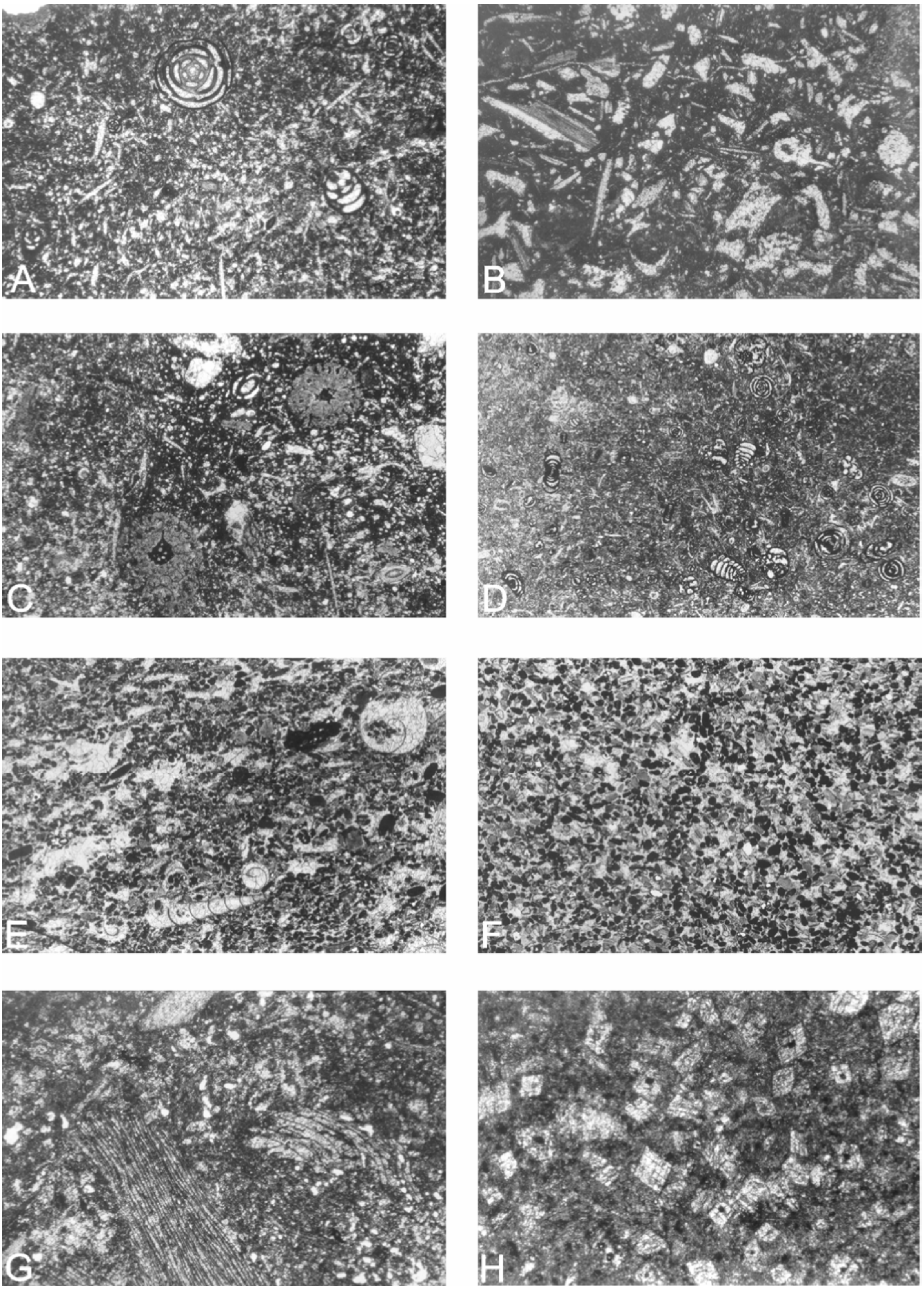
Text-fig. 11. Cross-bedded grainstones (pelsparites, biopelsparites) forming the upper part of the Naur cliff at section 4. They are interpreted as high energy sediments.

Rud- to floatstone facies

Coarse-grained limestones of this facies have been found rarely in the study area. They occur in the basal Naur Formation of Ras En Naqb (section 5) where they form a massive 3.5 m thick unit.

These rocks contain Numerous large fragments of oysters as well as internal moulds of rudists, gastropods, and bivalves. Furthermore, echinoids and small byrozoans have been found. The microfacies is characterised by bimodal sorting which indicates a mixing of components formed in different depositional environments: on the one hand small subrounded to rounded peloids, encrusted lithoclasts, and oncoids in a micritic matrix, on the other hand large angular fragments of oysters, bivalves, and echinoderms. Partly, these rocks are strongly dolomitised and show idiomorph dolomite crystals.

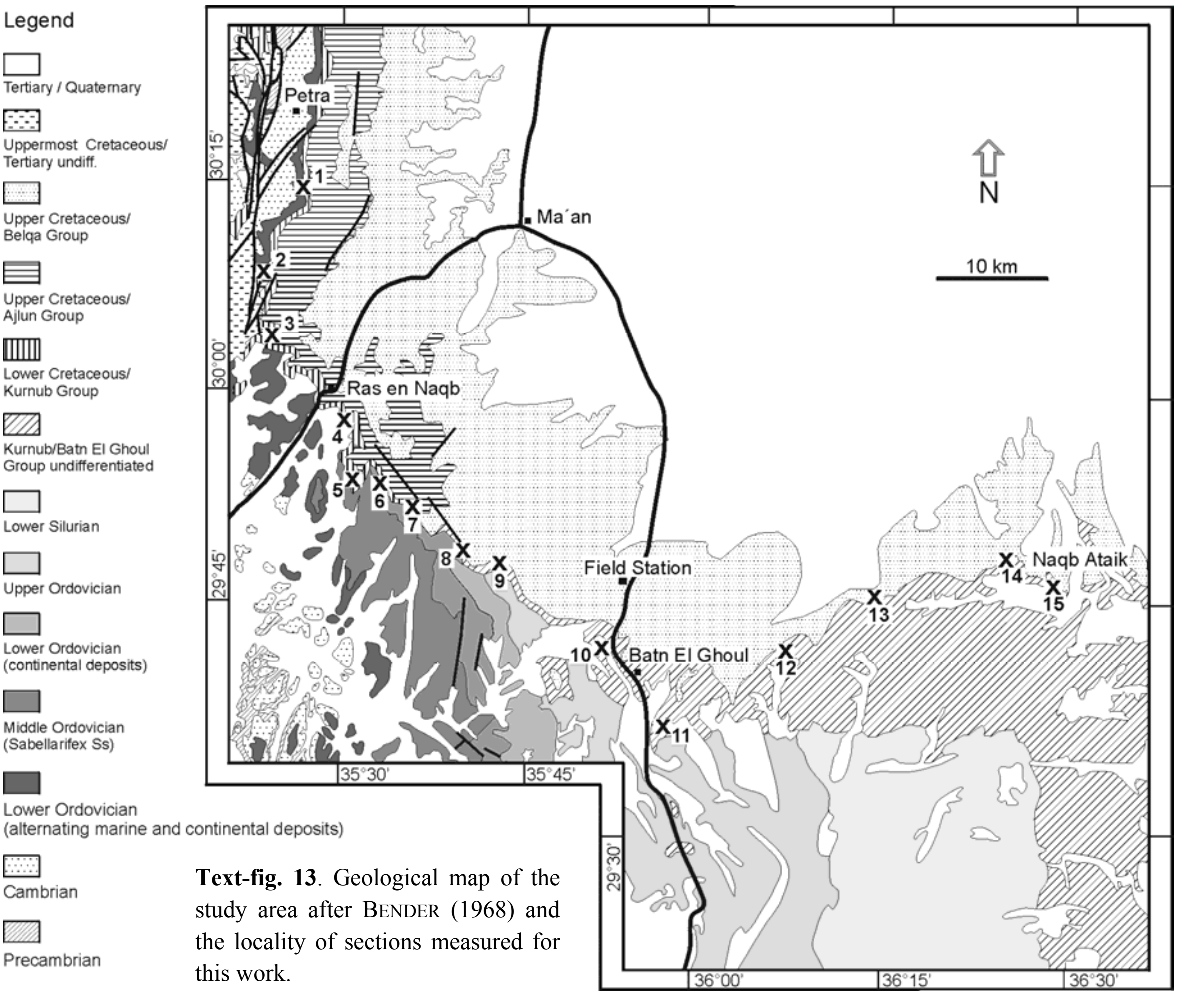
These sediments were deposited in shallow marine environments with agitated water conditions, possibly in shoal areas. The finer material including encrusted lithoclasts and oncoids, originated in a more quiet water environment.



Text-fig. 12. Microfacies types of the carbonate platform facies assiation. **A**. Bioclastic wacke- to packstone with miliolid foraminifera from the Naur Formation of section 4, x4. **B**. Bioclastic wacke- to packstone from the basal Naur Formation of section 3, x10. **C**. Bioclastic wacke- to packstone with remains of calcareous algae from the Naur Formation of section 4, x4. **D**. Foraminiferal packstone with *Chrysalidina* and Miliolida from the Naur Formation of section 3, x4. **E**. Bioclastic grainstone (biopelsparite) from the Naur Formation of section 4, x4. **F**. Grainstone (pelsparite) from the Naur Formation of section 4, x4. **G**. Rud- to floatstone with oyster fragments from the Naur Formation of Ras en Naqb (section 5), x4. **H**. Dolomitised part of the same sample showing well developed dolomite crystals, x50.

5 Sections

15 sections were measured in the Cretaceous of southern Jordan. The north-western sections (1-4) document only the Naur Formation and the basal part of the FHS undifferentiated due to extensive faulting in this area. The Cenomanian Wadi Juhra Member was covered in all cases by a large amount of debris from the overlying units. Nevertheless, in section 4 it was possible to measure the thickness of this member (8.4 m). Along the escarpment between Ras En Naqb and Batn El Ghoul six sections exhibiting the complete succession of the Ajlun Group have been measured in detail (sections 5-10). Additionally, the Lower Cretaceous Kurnub Formation has been studied in detail in sections 5, 6, and 9. East of Batn El Ghoul, section 11 exhibits a complete succession from the Lower Cretaceous to the Amman Formation of the Belqa Group. More to the east, the sections are characterised by thick continental deposits consisting of fluvial sandstones and colour-mottled palaeosoils. Here, marine horizons are limited to the Coniacian-Santonian Fassua Formation and the overlying Campanian Amman Formation, while in section 11 an additional marine unit is developed in the Ajlun Group. It is thought to be the easternmost expression of the maximum flooding zone of the *Neolobites* highstand (see also Text-fig. 19). In the following, four particular sections with overall significance are shown starting with the northernmost one (1), continuing with sections 5, 9, and 11. Generally, the marine units decrease in thickness from north-west to south-east, where the coastline was located. A correlation of the laterally strongly changing units is rather difficult, especially in the east.



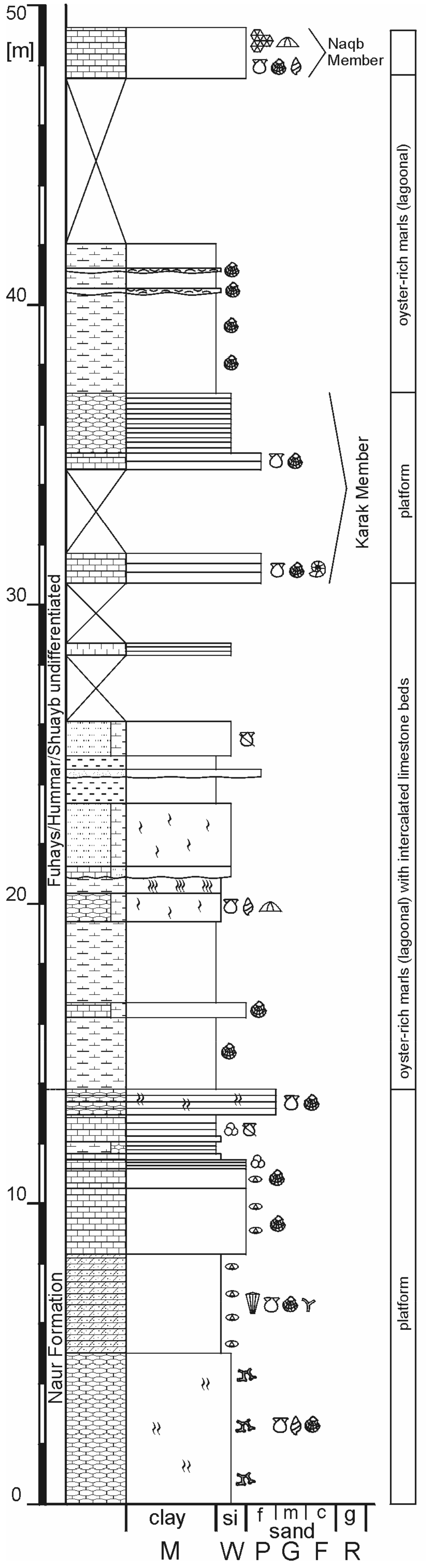
Text-fig. 13. Geological map of the study area after BENDER (1968) and the locality of sections measured for this work.

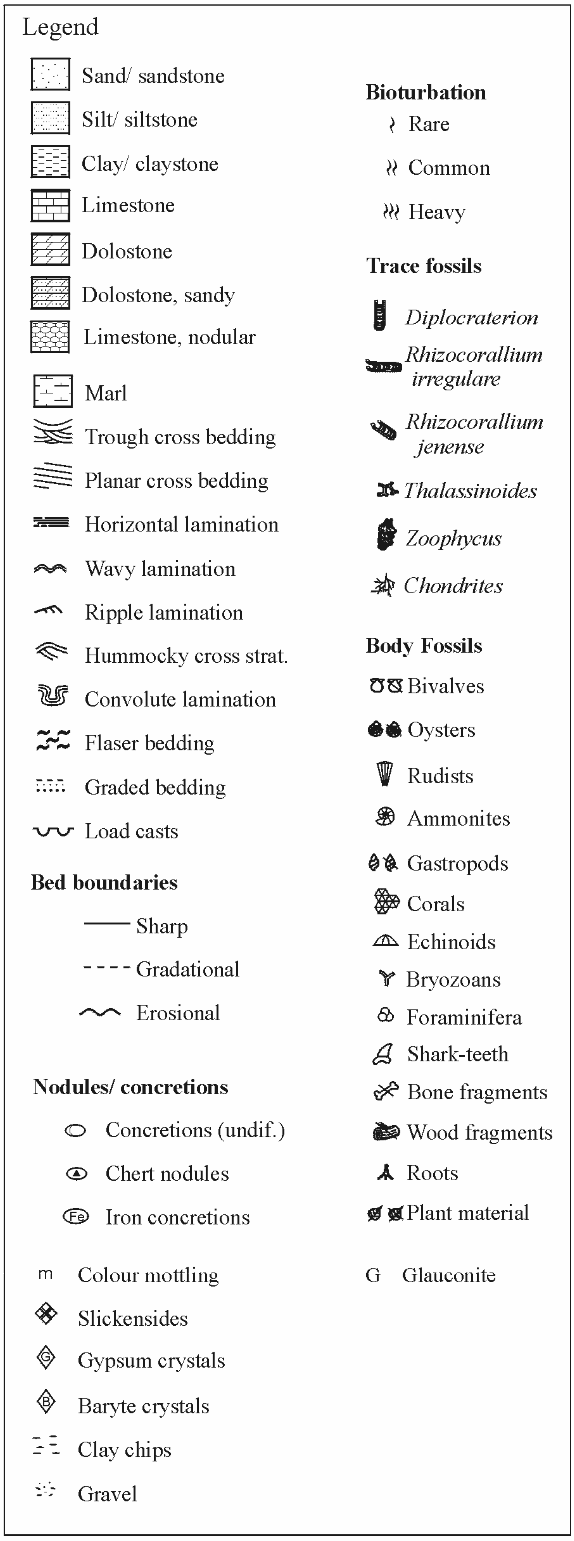
The sections were measured in decimetre scale. Where possible, covered sediments were dug out to get all information. All layers were examined for lithology, sedimentary structures, colour, fossil content, taphonomic features, ichnofacies, contact to the underlying unit, and lateral changes. Samples of fossils were taken wherever possible. All measured sections which are not presented in this chapter and their exact locality can be found in the appendix.

5.1 Section 1 (At Taiyba)

Section 1 (Text-fig. 14) is located at the old village At Taiyba, about 8 km south of Petra. The exact position is N 30° 14’ 21.5’’ E 035° 27’ 17.1’’(Text-fig. 13), the total thickness about 49 m. At this locality, the basal Naur Formation (Wadi Juhra Member) is not exposed. The overlying limestones and dolomites form a prominent cliff with a thickness of 13.8 m. Sediments of the Naur cliff are generally characterised by small grain sizes. The lowermost 5 m of this cliff consist of moderately bioturbated (*Thalassinoides* isp.), nodular peloidal wackestones with remains of oysters, gastropods and bivalves. The small grain size indicates a quiet water environment (open lagoon, see chapter 6.4). This unit is overlain by 3.3 m of sandy, vuggy dolomites which exhibit about 10 to 12 bands of chert nodules with a length of 5 to 25 cm. Fossils include internal moulds of rudists and bivalves, remains of oyster shells, and bryozoans. The relatively high amount of sand points to a high influx of terrestrial sediments and a slightly raised water energy. The sea level was probably low during that time, or the erosion of the hinterland was extensive. The following unit consists of 2.8 m of bioclastic wacke- to packstones with oysters and layers of chert nodules. Two beds can be distinguished. The increased grain size indicates shallow conditions with an open water circulation, the fragmentation of the fauna and concentrations of oysters point to occasionally higher water energy (chapter. 6.4). The overlying, partly laminated 1.6 m thick limestone beds (mud- to wackestones) are characterised by very small grain sizes and abundant benthic foraminifera (*Chrysalidina*, *Nezzazzata*, *Praealveolina*). They document very low water energy conditions of a shelf lagoon behind the outer platform margin. The top of the Naur Formation is formed by four beds of very nodular pack- to grainstones which are rich in foraminifera. The macrobenthos consists of bivalves (*Neithea*) and concentrations of oysters. The relatively large grain size and thick-shelled oysters point to a shallow, agitated water environment with an open circulation.

The overlying Fuhays/Hummar/Shuayb (FHS) Formation (undifferentiated) is characterised in the field by gentle, mostly covered slopes consisting of silt and marlstones and intercalated limestone beds or units, respectively. At the At Taiyba section, the FHS undifferentiated starts with about 6.75 m of impure, sometimes bioturbated marlstones, which rarely contain oysters preserved in growth position. At 2.4 m a marly wacke- to packstone with abundant oysters is intercalated. At 5.3 m a 1 m thick, fossiliferous, nodular, marly limestone unit occurs. The macrobenthos includes gastropods, bivalves, and echinoids. The top of this unit is marked by 60 cm of strongly bioturbated marlstone. This part of the section reflects a shallow quiet water environment with a moderate siliciclastic input from the mainland. The enriched fossil content in the two limestone beds may point to reduced sedimentation rates (slight condensation) in the course of decreased terrestrial input. The next unit (about 5.2 m) is characterised by a high amount of terrigenous sediments. It consists of marly limestones, sand-, silt-, and claystones. The base appears to be erosional. Bioturbation is very rare. Fossils were only found in one bed in form of fragmented bivalves. This clastic-dominated part of the lower FHS Formation is developed in all western sections from 1 to 7 and is interpreted as lowstand deposit of the basal *Neolobites*-depositional sequence. The rapidly





Text-fig. 14. Section 1 was measured close to the old village of At Taiyba. It is situated in the north-western part of the study area. The lower part of the Naur Formation (Wadi Juhra Member) is not exposed. The Naur cliff consists of nodular limestones and dolomites with layers of chert nodules. The overlying FHS Formation is characterised by thick units of marls and intercalated fossiliferous limestones.

changing grain size and the high amount of siliciclastics point to a marginal marine nearshore setting as depositional environment. The upper part of the At Taiyba section is dominated by pale green to greyish marlstones with intercalated limestone beds of different thicknesses. Often the marls are covered, but the gentle slopes indicate the lithology. The first limestone bed (60 cm thick) appears at 2.20 m. It contains foraminifera and fragmented bivalves. The overlying 2 m are not exposed but most probably marlstones. The unit continues with a prominent 1 m thick layer of highly fossiliferous packstone. It is interpreted as the basal part of the very southern expression of the Karak Member (see also chapter 3.2.2 and Text-fig. 18). The fauna includes predominantly *Neolobites vibrayeanus*, *Angulithes mermeti*, *Pholadomya vignesi*, *Aphrodina dutrugei*, *Paraesa* sp., and *Exogyra olisiponensis*. The ammonites indicate a lower Upper Cenomanian age. At this level the first sample of section 1 was taken (1-3B) for palaeoecologic analysis (see chapter 8.5.1: *Aphrodina dutrugei – Paraesa* sp. association). The following 2.8 m are covered. 2.5 m of fossiliferous wacke- to packstones, partly nodular, represent the upper part of the Karak Member. The overlying 10.5 m consist of dark grey to greenish marlstones which are characterised by oysters (*Ilymatogyra africana*, *Exogyra olisiponensis*) in life position and intercalated tempestite layers with oyster concentrations. This facies (chapter 6.3: oyster-rich marlstone facies) of the Lower FHS Formation has been found in sections 1-6. The marlstone facies is followed again by a prominent limestone bed of about 2 m thickness. This highly fossiliferous wackestone is interpreted as the northern expression of the Naqb Member (Text-fig. 18). It contains bivalves, oysters, large gastropods, echinoids, and in situ biostromal thickets of colonial corals (*Astraeofungia*, *Meandraraea*). Two samples of the macrobenthos were taken from this limestone bed (1-5, 1-5A). The Naqb Member (POWELL 1989) can be traced in the study area from section 1 to section 6. It documents well oxygenated, normal marine platform conditions with open water circulation. The lower medium part of the FHS Formation documents a deepening period and drowning of the Naur platform. The maximum transgression was reached in the zone of *Neolobites vibrayeanus*; equivalent marginal marine deposits can be traced up to section 11, far to the east. The intercalated limestone beds represent phases of reduced siliciclastic input from the hinterland.

5.2 Section 5 (Ras En Naqb area)

Section 5 is located about 9 km south-east of the village Ras En Naqb at the main road from Ma´an to Aqaba. The exact coordinates are N 29° 55’ 42.4’’ E 035° 33’ 52.2’’. At this locality, the complete Lower Cretaceous Kurnub Group and the Upper Cretaceous Ajlun Group as well as lower parts of the Belqa Group are exposed. The total thickness of this section from the base of the Kurnub Formation to the top of the Wadi As Sir Formation is 198 m. Deposits of the Lower Cretaceous overlie Palaeozoic sandstones of the Ordovician with a slight angular unconformity. The boundary is sometimes difficult to recognize because of the similar lithology. However, sandstones of the Palaeozoic are slightly more indurated and exhibit typical trace fossils (pipe rocks, “Sabellarifex sandstone” of BENDER 1974).

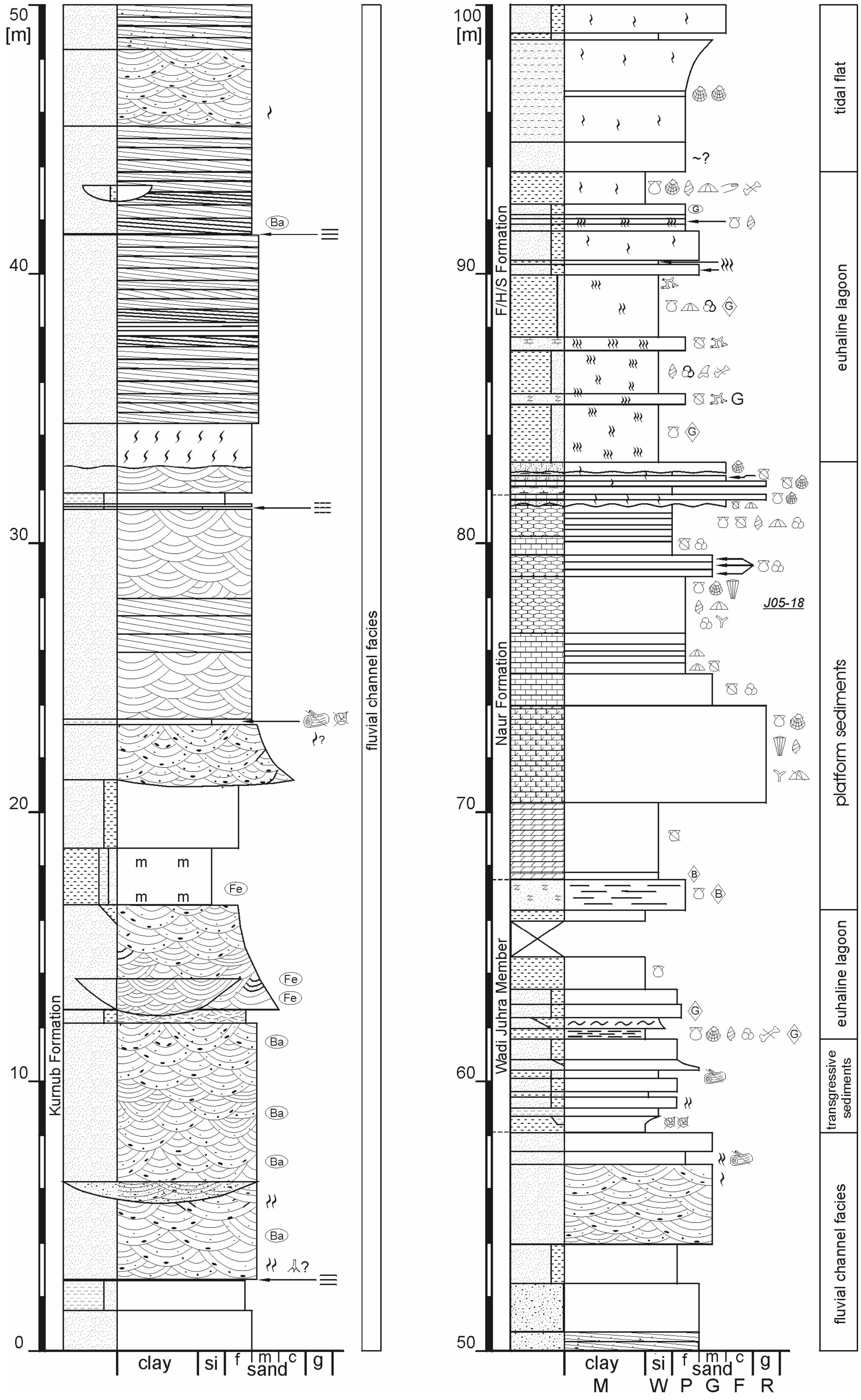
The Kurnub Formation reaches a thickness of 58 m at this locality. This thickness differs drastically from the measurement of ABU SAAD & AL BASHISH (1996) who give a figure of 92 m for the Ras En Naqb area. The Lower Cretaceous succession consists of massive units of trough and planar cross-bedded sandstones and a few intercalated clay horizons. The lower part (about 16 m) is dominated by medium- to large-scale trough cross-bedded sandstones with graded foresets.

Gravel layers occur at the base of troughs. Channel structures have been found in the whole sequence. These sediments reflect terrestrial conditions and are interpreted as deposits of large braided river systems. As a peculiarity, baryte concretions in form of desert roses are frequent in this part of the section. Iron concretions and remains of roots were found. This unit is overlaid by a 2 m thick package of colour-mottled sandy claystone containing iron concretions. It is interpreted as the relict of a soil horizon. A layer of 2.2 m of clayey sandstone follows. The overlying prominent unit (12 m) is characterised by thick beds of medium- to large scale cross-bedded, rarely planar cross-bedded sandstones and intercalated thin layers of fine siliciclastic material. At the base of the Kurnub Formation, a fluvial channel facies prevails. The fine-grained horizons are laminated and sometimes contain plant fragments. They are the remains of overbank sediments. It is followed by an about 2 m thick layer of sandstone with a bioturbated texture. The bioturbation was most probably caused by roots and is no indication of marine conditions. The next 16 m of section 5 are dominated by planar cross-bedded fine- to medium-grained sandstones. Single beds range in thickness from 1.5 m to 6.5 m. Subordinately, trough cross-bedding occurs. Overbank deposits are limited to one horizon of laminated claystone in the lower half of the unit. The topmost 8m of the Kurnub Formation consist nonuniformly of fine- and medium-grained sandstones, partly with a slight clay content, partly trough cross-bedded. Altogether, the facies of the Kurnub Formation of section 5 supports the environmental interpretation of POWELL (1989) who suggested a system of braided and low sinuosity rivers in a coastal plain setting.

The Naur Formation starts with the Wadi Juhra Member which is 9.5 m thick at this locality. It is characterised by an intercalation of thin layers of sand, silt, and claystones. The single beds range in thickness from 0.1 to 1 m. The whole unit had to be excavated. Indications of a marginal marine depositional environment are marine bioturbation and tiny body fossils which were found especially in the claystones. They include mostly poorly preserved bivalves, oysters, gastropods, bone fragments, and agglutinated foraminifera (*Thomasinella*), but they were too rare to be sampled for the statistical analysis. Conceivable environments of deposition are shallow, fully marine or brackish lagoons, but the small size of the fauna might indicate reduced salinities. The Wadi Juhra Member represents the first advance of the Tethys Ocean on the hinterland in the course of the Cenomanian transgression. As in section 1, the limestones and dolomites of the upper Naur Formation form a prominent cliff which reaches a thickness of about 15 m. It consists of dolomites and dolomitic float- to rudstones at the base (6.5 m). Less dolomitized parts contain a rich benthic fauna (rudists, bivalves, oysters, echinoids, bryozoans) that is moderately preserved and often fragmented. These sediments document agitated water conditions of shoals or slopes of the open platform (chapter 6.4). The following unit consists of fine- to medium-grained, mostly thin-bedded limestones. They include wackestones, packstones, and grainstones. Remains of benthic foraminifera and macrobenthic organisms are very common. Sample 5-18 (see also dendrogram, chapter 8.3) was taken at this part of the section. The fine-grained limestones and the composition of the fauna point to a shallow, quiet water lagoonal system with euhaline conditions. The absence of ammonites supports this assumption. Grainstones might indicate shoal or platform areas. The topmost 2 m of the Naur Formation consist of several beds of mixed siliciclastic-calcareous sediments. They include rather coarse-grained sandy limestones and marls. Erosional bases and large grain size of some layers indicate high water energy. The whole unit is bioturbated. The base of the overlying FHS Formation (61 m in total) is characterised by thick moderately to highly bioturbated claystone packages which are separated by slightly carbonaceous sandstone beds. The thickness of this unit is about 11 m. Fossils include euhaline echinoids and *Thalassinoides* among small gastropods, bivalves, and vertebrate remains in some layers. The claystones document quiet lagoonal conditions of a restricted part of the shallow shelf. The intercalated, highly bioturbated sandstone beds might indicate barrier systems or shoals. This change to siliciclastic sedimentation reflects most probably a falling sea level and a return to marginally marine environments, similar to the conditions of the Wadi Juhra Member. The increasing terrestrial input reached its maximum in the overlying unit that represents the lowest sea level of the basal FHS Formation. About 6 m in thickness, it consists of medium- to coarse-grained sandstones with a coarsening-upward trend. Very thin claystone layers are intercalated. Body fossils are very rare in this part of the section. Only some poorly preserved oysters were found. The whole part of the section is rarely bioturbated. The unit can be correlated to the lowstand period of the lower FHS Formation of section 5 (chapter 4.2). Within the next unit (32 m) the sea level rose again and reached its maximum with the deposition of the Naqb Member. The sequence starts with about 13 m of massive claystones, which are separated by layers of oyster concentrations. Even slightly thicker, these storm beds can easily be correlated with those in section 1 which occur in nearly the same stratigraphic context. The ecological analysis of two samples (5-36, 5-37; chapters 8.5, 8.6) taken from claystones of the basal part of this unit points to repeatedly changing marine and slightly brackish conditions. Furthermore, the depositional environment was characterised by a soft substrate. This transgressive period resulted in a sea level highstand in the medium part of the unit where limestones and euhaline claystones were deposited. It is interpreted as the maximum flooding zone of the lower Upper Cenomanian (*Neolobites* sequence). Echinoids and in situ corals verify full marine conditions. Oyster storm beds occur as in the basal part of the unit. Two samples (5-45, 5-46) were taken from euhaline claystones of this middle part of the unit. The topmost 8 m of the sequence document a regressive period which resulted in the deposition of lowstand sediments of the overlying unit. The terrestrial influx increased and fine- to medium grained, clayey sandstones and shales predominate. In contrast to the highly fossiliferous highstand deposits, the upper part of the unit contains only a very monotonous benthic macrofauna dominated by oysters (*Exogyra*, *Curvostrea*). Several layers of glauconitic sandstones indicate shallow marine conditions. The topmost 12 m of the FHS Formation consist of sandstone packages, which reach up to 3 m in thickness, and intercalated impure claystones. The sandstones exhibit medium- to large-scale trough cross-bedding. The claystones are mottled and interpreted as palaeosoils. Fossils are absent in this part of the unit. The return to coastal plain deposits or fluvial channel facies, respectively, is due to a very low sea level at the end of the FHS Formation.

The overlying Wadi As Sir Formation can be divided into three parts according to their lithology or environment of deposition, respectively. The lower 16 m of the formation contain marine to marginal marine sediments, the middle part is dominated by sandstones of the coastal plain, and the upper part is again clearly of marine origin. This division can also be seen in the Ras En Naqb section measured by MAKHLOUF et al. (1996), but no description or interpretation was made in that work. At the base of the Wadi As Sir Formation the sea returned after the lowstand of the Upper FHS Formation. In a transitional phase marginally marine silt and sandstones were deposited. They contain small bivalves, oysters, gastropods and vertebrate remains. The ongoing transgression resulted in the deposition of calcareous sediments. They include algal laminites, fine-grained dolostones, sandy dolomites and dolomitic sandstones. In Central Jordan, the base of the Wadi As Sir Formation is marked by the development of a new carbonate platform (POWELL 1989).

The dolomites in this part of section 5 are interpreted as the southernmost expression of this platform. Algal laminites indicate a very shallow environment. The middle Wadi As Sir Formation is dominated by massive and medium-scale trough cross-bedded sandstones, impure claystones, and palaeosoils. This lowstand facies is very typical of the sections along the escarpment.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Kurnub Formation
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F/H/S Formation
Naur Formation
Wadi Juhra Member
~?
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G
G
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B
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J05-18
tidal flat
euhaline lagoon
platform sediments
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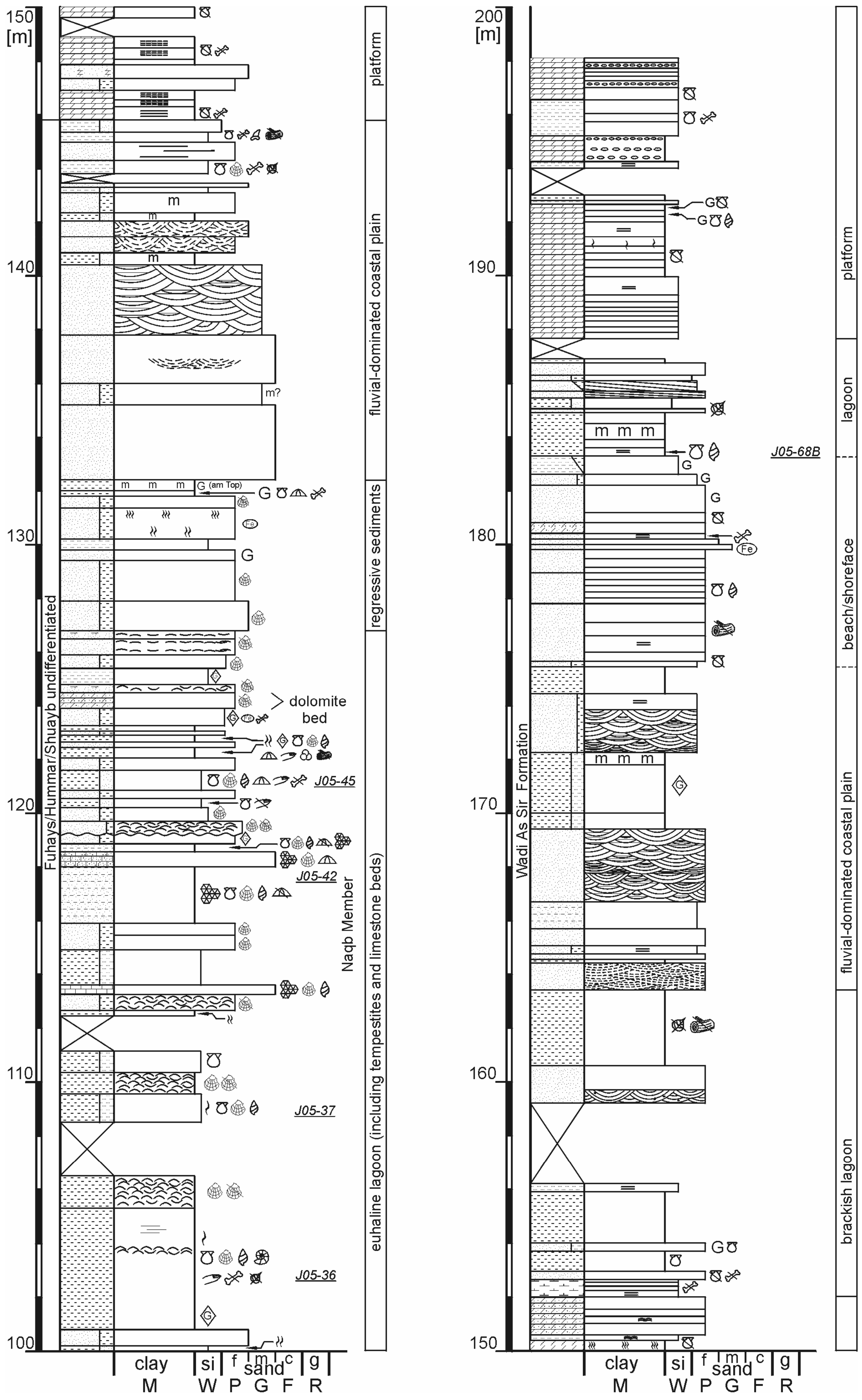
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dolomite bed
J05-45
J05-42
J05-37
J05-36
Fuhays/Hummar/Shuayb undifferentiated
Naqb Member
platform
fluvial-dominated coastal plain
regressive sediments
euhaline lagoon (including tempestites and limestone beds)
clay
si
f m c
sand
g
M W P G F R
200
[m]
190
180
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160
150
G
G
m m m
G
G
G
Fe
m m m
G
J05-68B
Wadi As Sir Formation
platform
lagoon
beach/shoreface
fluvial-dominated coastal plain
brackish lagoon
clay
si
f m c
sand
g
M W P G F R

It thickens eastwards and reaches a thickness of more than 40 m at Batn El Ghoul. Distinct erosional bases are developed in the eastern part of the escarpment. These prominent fluvial deposits might be correlated to the mid-Turonian sea level drop, which was described from southern Sinai (BAUER 2002) and which might have been due to a tectonically induced uplift of the hinterland (chapter 3.1, 5).

The upper 24 m of the Wadi As Sir Formation are again characterised by marine sediments. A transitional zone is developed at the base, containing sandstones with bivalves, gastropods and wood fragments. Glauconite was found in three layers. A claystone package at the top of this transitional part was rich in corbulid bivalves (sample 5-68B). It documents a brackish environment (chapter 8.5.4: *Brachidontes* aff. *fulpensis* – *Parmicorbula*? cf. *tapuchii* association). With the continuously rising sea level the carbonate platform was re-established and a succession of 10 m of calcareous sediments was deposited. Algal laminites point to a shallow setting. Fossils are rare due to strong dolomitization. The top of the Ajlun Group is characterised by several layers of chert nodules.

5.3 Section 9

Section 9 is located at the eastern part of the escarpment between Wad Rabigh and Wadi Arada on the Jibal Al Batra sheet. The precise position is N 29° 48'' 52.0'', E 035° 43'' 15.0''. The measured section includes the upper part of the Kurnub Formation and the complete Ajlun Group (Naur, FHS, and Wadi As Sir formations). The overlying Umm Ghudran Formation, basal part of the Belqa Group, was measured and examined in detail by MOHS (2001). In summary, it has to be stated that calcareous sediments diminish strongly compared to section 5. Due to a setting closer to the coastline, the terrestrial influx was distinctly higher in section 5. Altogether, the section reflects several changes from marginal marine to terrestrial deposits. Only at the top of the Wadi As Sir Formation relicts of a carbonate platform are preserved.

The section starts with the upper 25 m of the Kurnub Formation. They can be divided into three units, beginning with a 2 m thick bed of medium- to coarse-grained, trough cross-bedded sandstone. It is characterised by gravel at the base of graded foresets. The overlying unit (19 m) consists predominantly of impure siltstones and clayey sandstones. The single layers range in thickness from 0.2 to 6 m. They are colour-mottled and show remains of bioturbation. Subordinately, two beds exhibit relicts of small-scale trough cross-bedding. The topmost 4 m of the Kurnub Formation consists of three beds of planar and trough cross-bedded medium- to coarse sandstones. Like in all sections of the study area with a well defined Kurnub Formation, it documents a coastal plain environment with several fluvial channels and intercalated mottled horizons interpreted as the result of soil-forming processes.

The eastwards thinning of marine units along the escarpment concerns predominantly the overlying Naur Formation. The Wadi Juhra Member is only 5 m in thickness at section 9, the upper part of the formation reaches 6 m. The basal 5 m of the Naur Formation consists of an intercalation of marginal marine claystones and heavily bioturbated sandstones. In the lowermost claystone bed echinoids were found and indicate euhaline conditions. Other benthic elements include

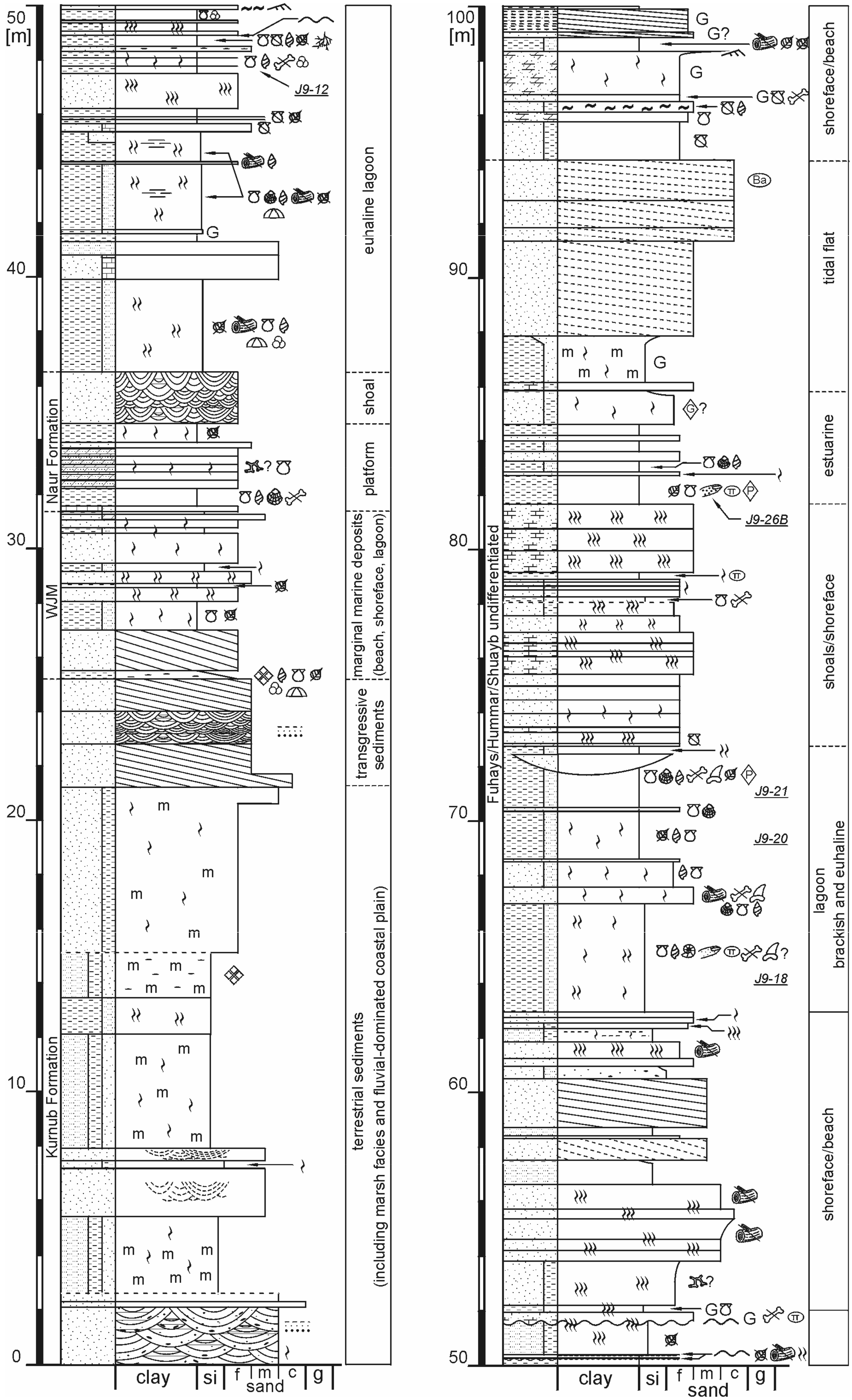
Text-fig. 15. Section 5 is located about 5km south-east of Ras En Naqb. Here, the complete succession from the Kurnub Formation to the top of the Wadi As Sir Formation is exposed. Position of quantitative samples is indicated by the numbers on the right-hand side of the columns.

agglutinating foraminifera, tiny bivalves, and gastropods. Additionally, strong bioturbation points to a marine setting. The upper part of the Naur Formation forms only a small cliff in section 9. It consists of sandy limestones, dolomites, marine clay, and sandstones. *Thalassinoides*, bivalves, and oysters indicate marine conditions. The impure calcareous sediments might reflect the south-easternmost extension of the Naur platform.

The overlying FHS Formation is only slightly thinner than in section 5. Its thickness is 58.5 m at this locality. Five quantitative samples of the macrobenthic fauna were taken in this part of the section. It starts with a 15 m thick unit dominated by mostly massive greenish-grey claystones which are highly fossiliferous. Echinoids indicate at least occasionally fully marine conditions. Rare ocurrences of *Chondrites* might point to reduced oxygen in deeper layers of fine-grained sediments. Sand and siltstone beds of 0.2 to 1 m thickness are intercalated. The coastline was located very close-by during that time which is indicated by abundant wood and plant fragments. The basal part of the FHS Formation represents marginal marine, restricted environments. Sand units might represent small bars of occasionally increased water energy. The regressive trend following the deposition of the Naur cliff in section 1 and 5 can be correlated with this unit. The middle part of the FHS Formation represents the *Neolobites* sequence, which has been already described from section 1 and 5. The lower unit of this sequence consists of about 11 m of heavily bioturbated sandstones of differing grain size. Coarsening-upward trends are visible. The lowermost layer exhibits an erosional unconformity which might have extended to parts of the lowstand deposits which occur in this stratigraphical position in sections 1 and 5.

Glauconite, bivalves, and *Thalassinoides* point to marine conditions. Fossil wood indicates the close position of the mainland. A deepening of the depositional environment is documented by massive, partly fossiliferous claystones which form the middle part (10 m) of the formation. They are interpreted as the maximum flooding zone of the *Neolobites* sequence. Apart from *Neolobites*, bivalves, gastropods, decapods, and vertebrate remains were found. In the upper clay layers of this part of the formation a regressive trend is discernable. The ecological analysis suggests brackish environments for the samples 9-20 and 9-21 (chapter 8.5.4). The regressive trend continues into the overlying sediments, which consist of heavily bioturbated, partly calcareous sandstones (9 m). They contain poorly preserved bivalves and bone fragments. Another brackish benthic community (9-26B) was sampled from siltstones of the following unit, which is characterised by an intercalation of shales and sandstones. Marginal marine conditions are documented by tiny bivalves, oysters, and gastropods. Glauconite was found in one bed. The ongoing regression resulted in the deposition of planar cross-stratified medium- to coarse sand which forms the uppermost 6 m of the FHS Formation. These lowstand deposits can be correlated with those of the topmost FHS Formation of section 5.

The Wadi As Sir Formation starts again with marine sediments which reflect the transgressive phase that has already been described for section 5. In section 9, the marine event resulted in only 7 m of argillaceous and dolomitic sandstones and clay layers, whereas in section 5, a thickness of 16 m was measured. Indications of marine conditions are glauconite, bivalves, and gastropods. One layer of dolomitic sandstone exhibits slight bioturbation. The following 44 m are characterised by thick beds of trough cross-bedded sandstones of a fluvial channel facies. The grain size ranges from fine to coarse. Thin layers of laminated claystones are intercalated. They contain plant material and are interpreted as overbank sediments. Fossil wood was found in the sandstones. The deposition of this thick unit of fluvial sandstones might be the result of a tectonic uplift of the hinterland which resulted in erosion of Palaeozoic deposits. These sediments are correlated with the mid-Turonian sea level fall.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J9-12
G
Naur Formation
WJM
Kurnub Formation
euhaline lagoon
shoal
platform
marginal marine deposits
(beach, shoreface, lagoon)
transgressive
sediments
terrestrial sediments
(including marsh facies and fluvial-dominated coastal plain)
m
clay
si
f
m
c
sand
g
100
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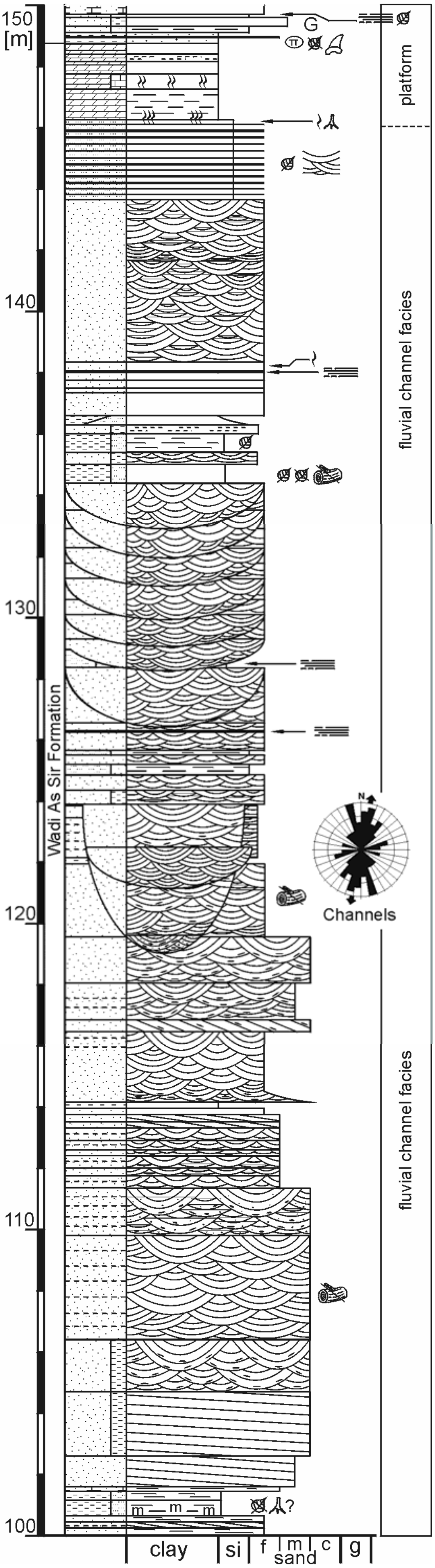
90
80
70
60
50
G
G?
Ba
J9-26B
J9-21
J9-20
J9-18
Fuhays/Hummar/Shuayb undifferentiated
shoreface/beach
tidal flat
estuarine
shoals/shoreface
lagoon
brackish and euhaline
shoreface/beach

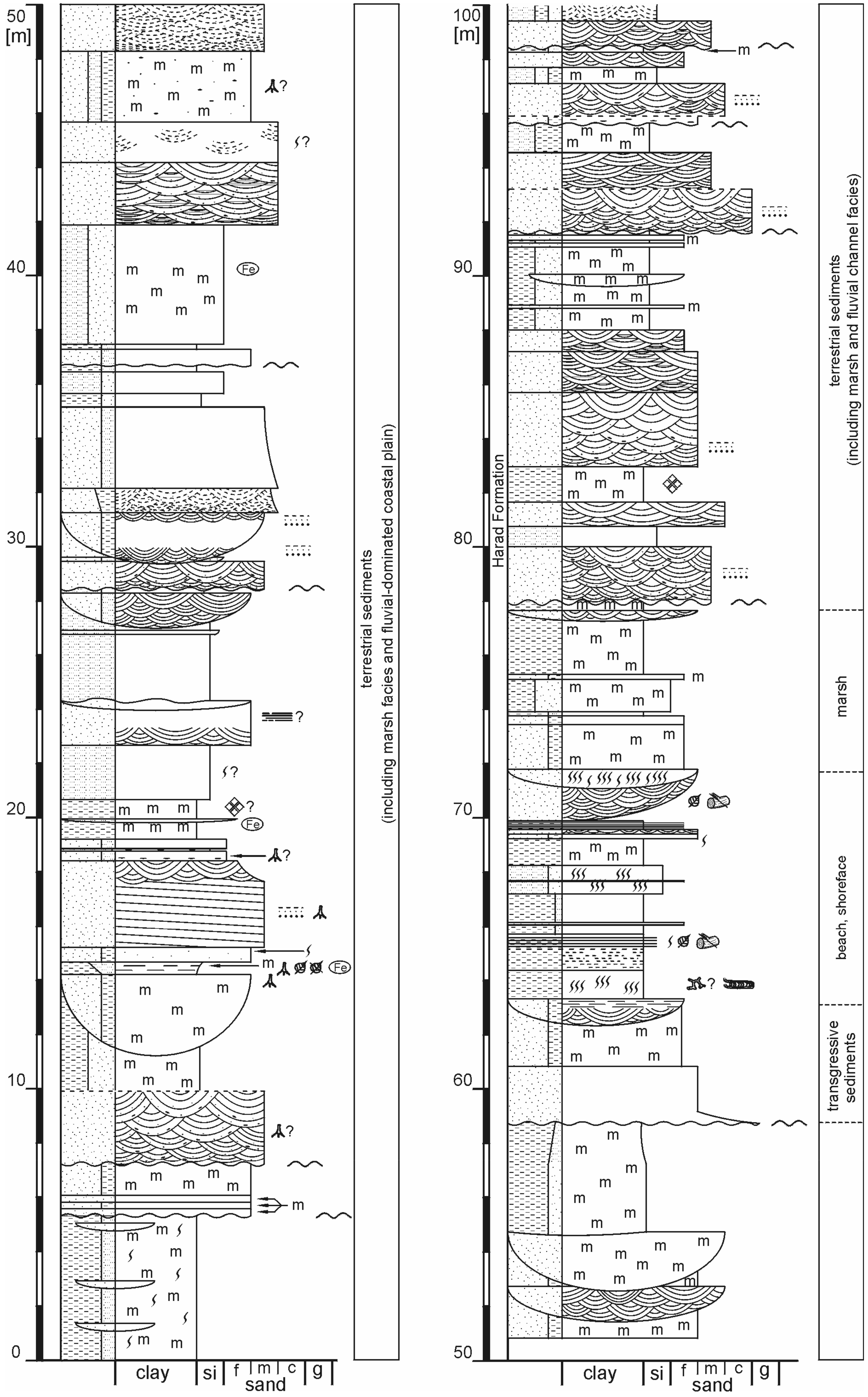


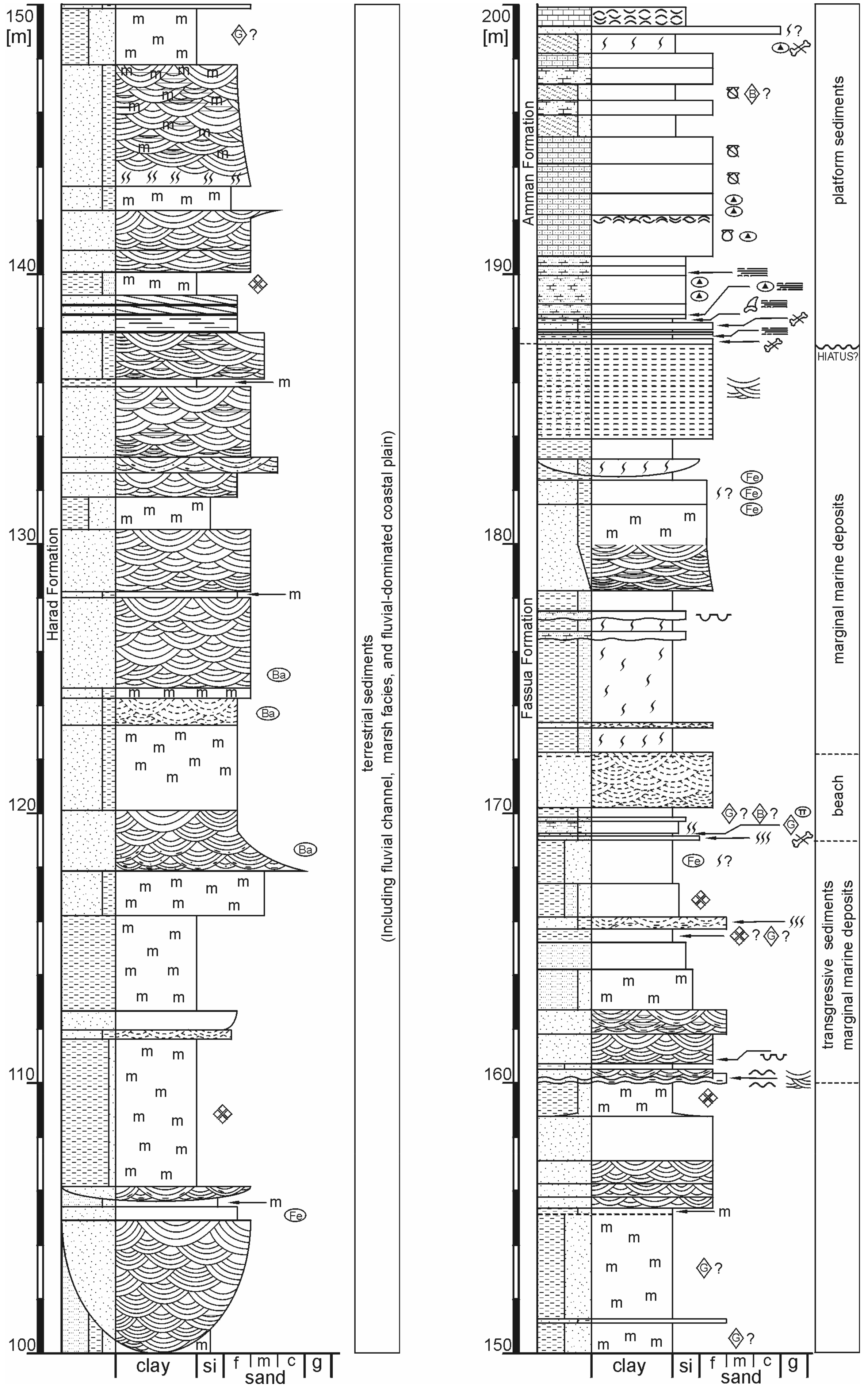
The uppermost 6 m of the Wadi As Sir Formation point to a return of the sea. They consist of dolomites and calcareous sandstones. Bioturbation and glauconite indicate marine conditions. The top of the formation is characterised by four beds of small-scale trough cross-bedded, calcareous sandstones. Chert nodules, typical of the topmost Wadi As Sir Formation, were absent at this locality.

5.4 Section 11

Section 11 is the easternmost section in which evidence of marine environments was found. The marine sediments are limited to a 5 m thick zone in the middle part of the Harad Formation, which is the very marginal marine to terrestrial equivalent of the Naur, FHS and basal Wadi As Sir formations (chapter 3.2.2). Section 11 is located about 25 km south-east of section 9, east of the main road from Ma´an to Mudawwara. Its exact position is N 29 36’ 32.0’’, E035 57’ 39.6’’ at the southern slope of an isolated hill. The section starts with a 63 m thick succession of terrestrial sediments, containing predominantly trough and planar cross-bedded sandstones and colour-mottled impure claystones. Coarse-grained, trough cross-bedded channels are common. Subordinately, massive siltstone beds with a thickness of 2 to 3 m occur. In several layers rootlets and iron concretions were found. The fine-grained siliciclastics are often mottled and indicate soil-forming processes. The dominant colours of the deposits of this basal unit are red and light grey. These sediments are interpreted as the eastern terrestrial equivalents of the upper Kurnub Formation, the Naur Formation, and the basal FHS Formation. The depositional environment was an extensive, rather flat coastal plain with braided and low sinuosity rivers.

Text-fig. 16. Section 9, located at the eastern part of the escarpment beween Ras En Naqb and Batn El Ghoul. Calcareaous sediments are mostly replaced by siliciclastics. The section starts in the Lower Cretaceous Kurnub Formation and ceases at the top of the Wadi As Sir Formation.


50 [m]
40
30
20
10
0
terrestrial sediments (including marsh facies and fluvial-dominated coastal plain)
clay
si
f
m
c
g
sand
100 [m]
90
80
70
60
50
Harad Formation
terrestrial sediments (including marsh and fluvial channel facies)
marsh
beach, shoreface
transgressive sediments
m
Fe
?


150
[m]
140
130
120
110
100
Harad Formation
terrestrial sediments
(Including fluvial channel, marsh facies, and fluvial-dominated coastal plain)
m
G ?
Ba
Fe
clay
si
f
m
c
sand
g
200
[m]
190
180
170
160
150
Amman Formation
Fassua Formation
platform sediments
HIATUS?
marginal marine deposits
beach
transgressive sediments
marginal marine deposits
B ?
Fe
G ?
B ?
? G ?

The following part of the section is interpreted as the easternmost expression of the maximum flooding zone of the *Neolobites* sequence. It consists of heavily bioturbated claystones, and sandy siltstones. The single layers range in thickness from 0.1 to 1 m. Thin intercalations of fine-grained sandstones occur. They are mostly developed as iron-impregnated crusts which contain an excellently preserved ichnofauna including *Rhizocorallium irregulare* and *Thalassinoides* isp. Some claystones contain fossil wood and plant fragments. The overlying unit (36 m) is characterised by the return of terrestrial conditions. The facies is similar to the lower part of the section but trough cross-bedded sandstones become more common. This part of the section is dominated by intercalations of thick, partly channel-forming, trough cross-bedded sandstone beds and colour-mottled fine-grained palaeosoils. It is equivalent to the uppermost part of the FHS and large parts of the Wadi As Sir formations. A distinct erosional contact at 78 m might be correlated with the middle part of the Wadi As Sir Formation which is characterised by the sudden occurrence of fluvial deposits in sections 5-10. The overlying unit consists predominantly of thick, colour-mottled claystone and clayey sandstone packages. The thickness of this part of the section is about 17 m, the single beds range from 0.2 to 5.5 m. Colour mottling and slickensides are thought to be indications of soil forming processes. The depositional environment was a fluvial-dominated coastal plain. Monotonous trough cross-bedded sandstones follow in the overlying unit (37 m). Fine-grained and colour-mottled sediments are intercalated. Towards the top fine-grained silt and claystone beds increase in thickness and frequency. The top is marked by an erosional base of the overlying unit. This horizon can be taken as the boundary between the Ajlun Group and the Belqa Group (in the east, the boundary between the Harad and Fassua formations can be correlated with the contact between the Wadi As Sir and Umm Ghudran formations in the west). The Fassua Formation reaches a thickness of about 28 m in section 11. It consists of a terrestrial-dominated lower part and a marine-influenced upper part. The predominant colour of the formation is light-green to grey which distinguishes it easily from the underlying Harad Formation. Indicators of a (marginal) marine environment are heavy bioturbation of some layers and bone fragments. While the base of the Fassua Formation is rather uncertain in section 11, the top is well defined. The overlying Amman Formation starts with red, phosphatic sands which are rich in shark teeth and other vertebrate remains. A transgressive phase started at the beginning of the Amman Formation which resulted in the deposition of calcareous sandstones with chert and bioclastic limestones at the base. These limestones are not as strongly silicified as in the western sections.

Text-fig. 17. Section 11 is dominated by terrestrial sediments. Fluvial sandstones and intercalated claystones form the bulk of the succession. A 5m thick horizon in the middle of the section represents the maximum flooding of the sea towards the south-east during the Cenomanian.

5.5 Correlation

Text-fig. 18 shows a correlation of the formations in sections 1-11 used by the recent Jordanian Mapping Project. Additionally, Table 1 summarises the thicknesses of these formations in the study area. The division of the Ajlun Group into Naur, FHS, and Wadi As Sir formations is possible from section 1 to section 10, more to the east they are combined in the Batn El Ghoul Group. Generally speaking, the thicknesses of the marine-dominated units decrease eastwards, whereas the terrestrial units increase in thickness in the same direction. For example, the Naur Formation changes from 25 m in section 5 to 10 m in section 10. The cliff-forming limestones of the upper Naur Formation reach 14 m at At Taiyba, at Batn El Ghoul this cliff is only 3.5 m thick. The cliff reaches the highest thickness at Ras En Naqb (section 4).

The limestones of the Karak Member of the lower FHS Formation can be traced in sections 1 to 3, more to the south-east they pinch out (Text-fig. 18). The Naqb Member was found in sections 1 to 5 with the highest thickness (about 6 m) at Ras En Naqb.

It is quite obvious that the terrestrial influx increases strongly to the east in all formations.

Table 1. Thickness of the formations (in meter) between At Tayba (1) and Batn El Ghoul (10). See also Text-fig. 18.

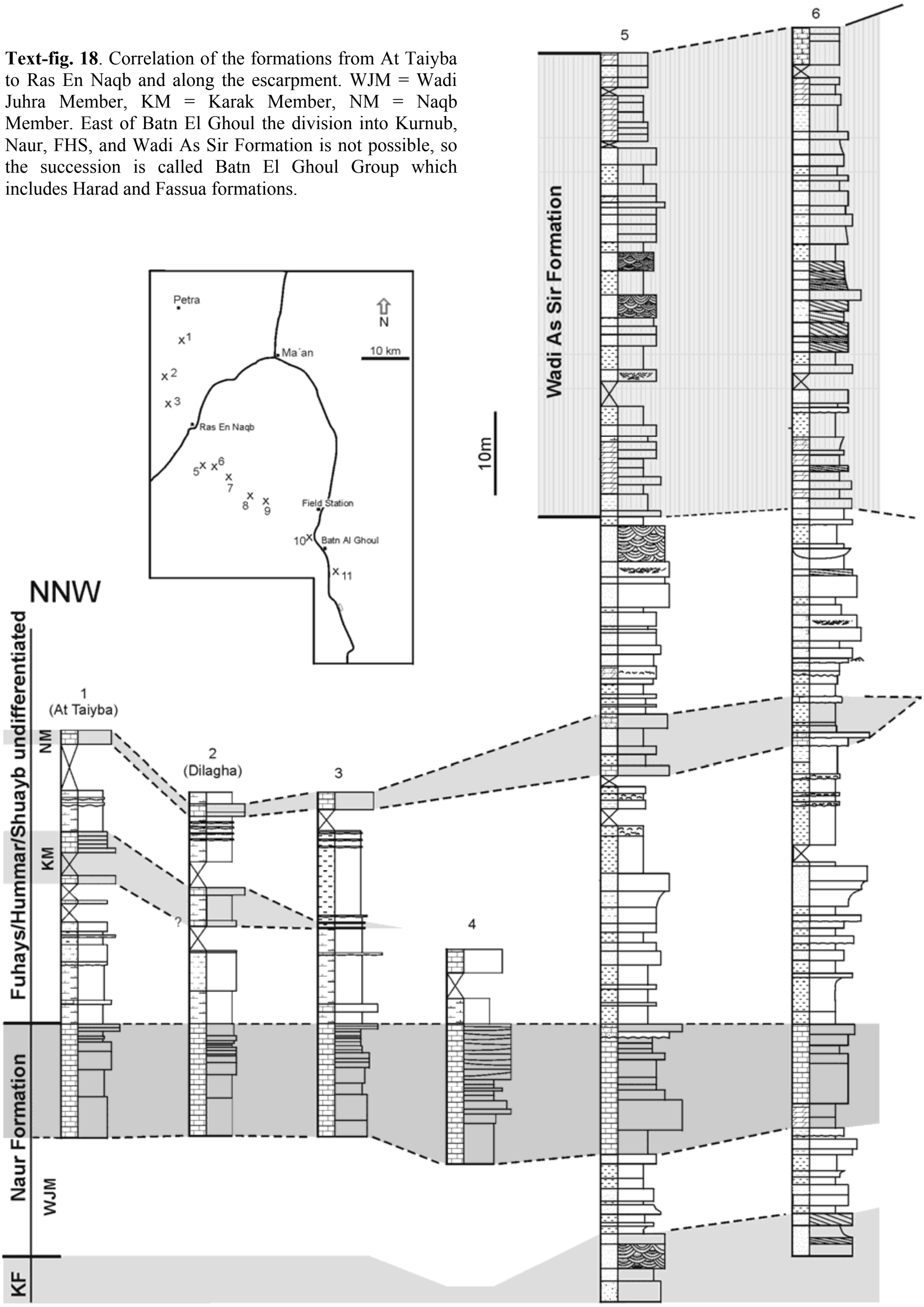
	1	2	3	4	5	6	7	8	9	10
Kurnub Formation					58	49				
Naur Formation (complete)					25	21	16.5	14.5	11	10
Wadi Juhra Member					9.5	9	6.5	8	6	~4.5
Naur Cliff	14	13.5	13.5	16	15.5	12	10	6.5	5	~3.5
F/H/S undifferentiated					61	59	56	49	57.5	61
Wadi As Sir Formation					54	59.5	71	≥51	58	~78

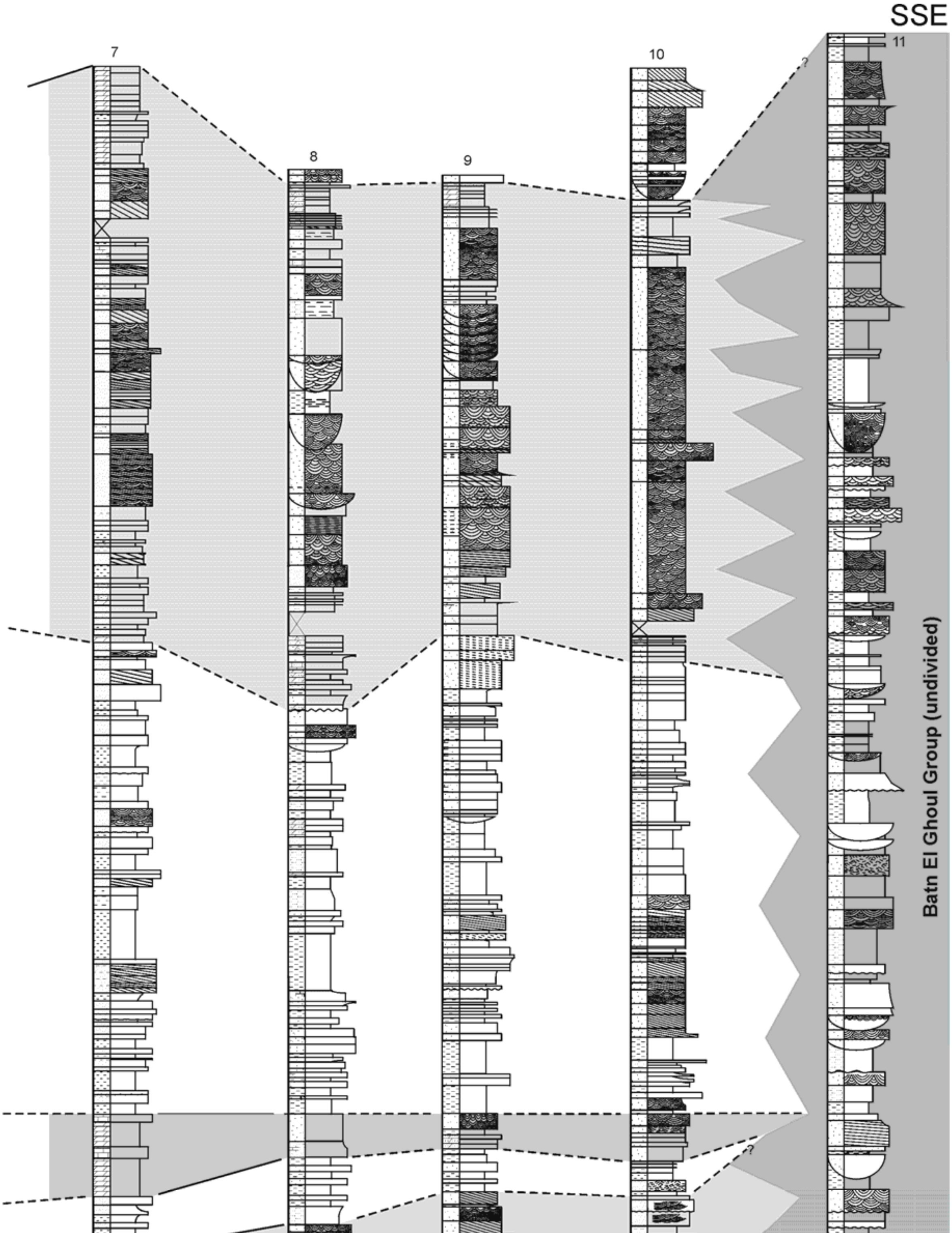
5.6 Biostratigraphic remarks

Relevant index fossils are rare in the study area. The time of the initial transgression of the sea in the Cretaceous is often given as Albian-Cenomanian for northern and central Jordan (POWELL 1989, BASHA 1978, DILLEY 1985). Rare findings of *Schloenbachia* sp. and agglutinated *Thomasinella* sp. in the basal Naur Formation (Wadi Juhra Member) of sections 7 and 8 point to a Cenomanian age of the transgression in southern Jordan. They evidence the diachronous character of the basal Naur Formation. *Neolobites vibrayeanus* and abundant *Costagyra olisiponensis* in the middle part of the overlying FHS Formation indicate an Upper Cenomanian age. *Neolobites* was found in sections 1 to 9 and marks the maximum flooding zone of the Upper Cenomanian sequence.

The Cenomanian/Turonian boundary is located within the upper part of the FHS Formation. The Wala Member marks the base of the Turonian in northern and central Jordan. This member is not developed in the south. Here, the Cenomanian-Turonian boundary is indicated by the disappearance of the oyster *Costagyra olisiponensis*. As this disappearance coincides with a change in lithofacies from highstand to lowstand deposits, the boundary can not be placed at a distinct bed. A hiatus, as proposed by BAUER (2002) for the Cenomanian-Turonian boundary of the Sinai, is not verifiable for the study area. The top of the sedimentary succession is devoid of relevant index fossils.

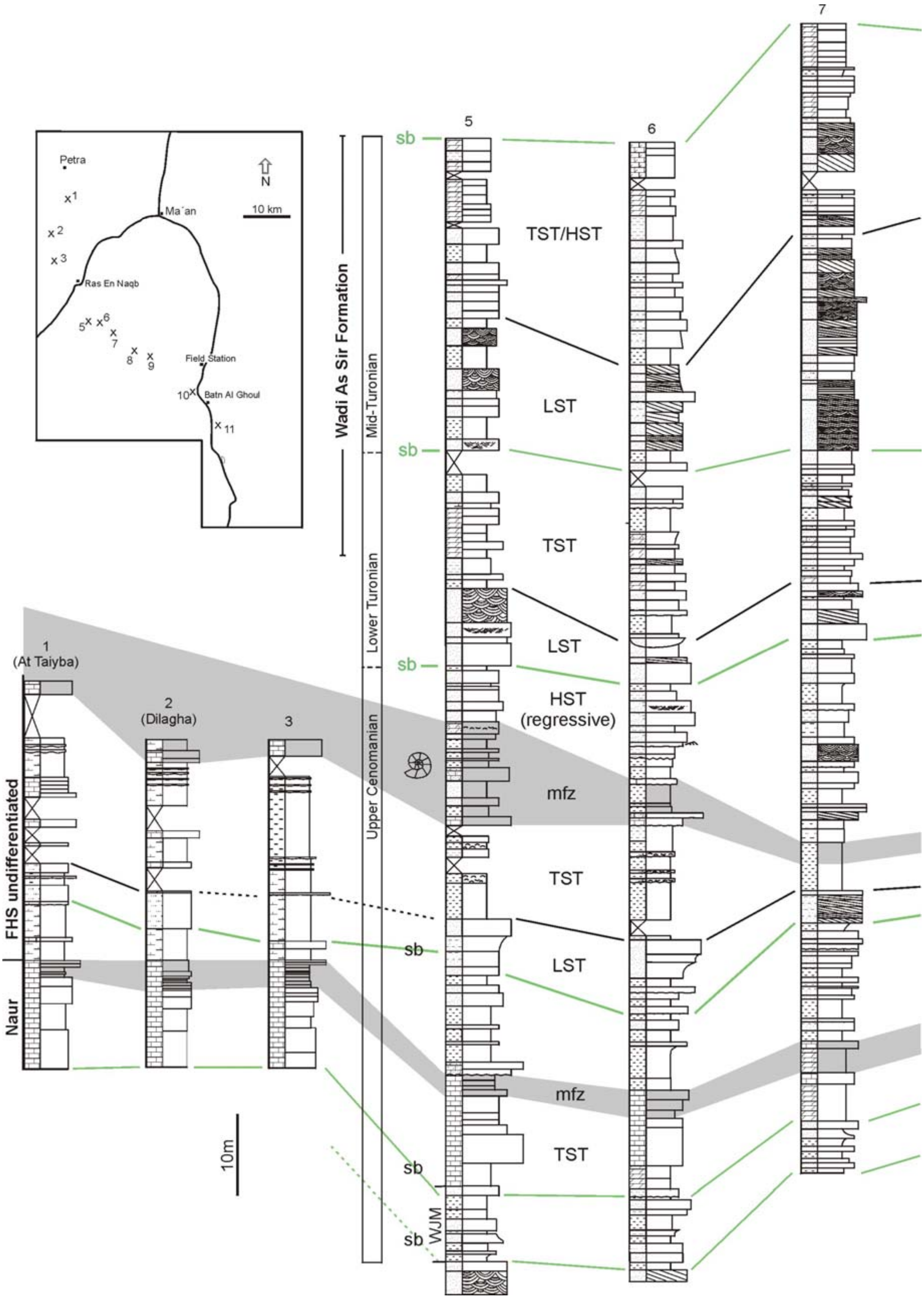
Text-fig. 18. Correlation of the formations from At Taiyba to Ras En Naqb and along the escarpment. WJM = Wadi Juhra Member, KM = Karak Member, NM = Naqb Member. East of Batn El Ghoul the division into Kurnub, Naur, FHS, and Wadi As Sir Formation is not possible, so the succession is called Batn El Ghoul Group which includes Harad and Fassua formations.

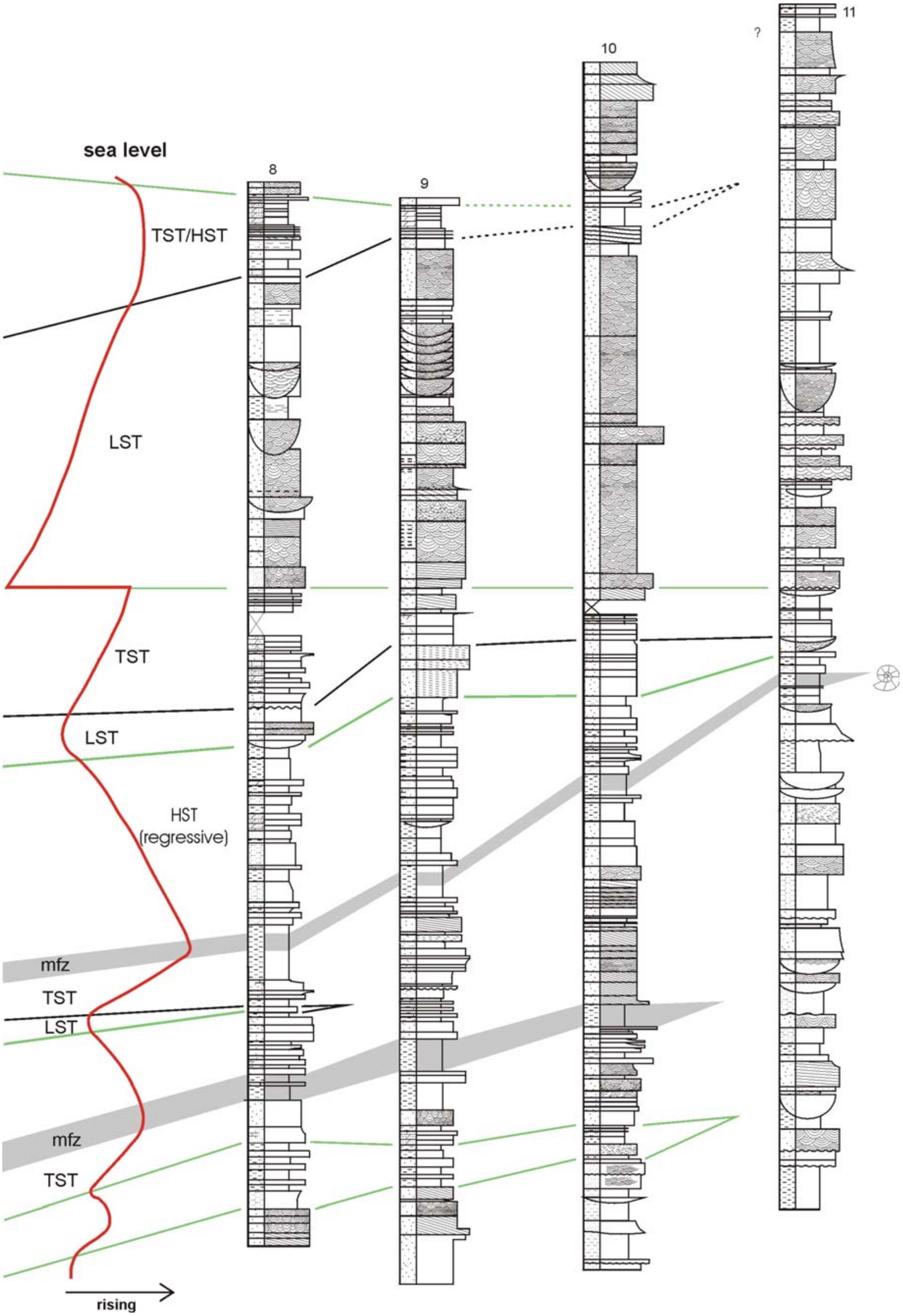



SSE
7
8
9
10
11
?
?
Batn El Ghoul Group (undivided)

6 Sequence stratigraphy and sea level fluctuations

At least four depositional sequences are documented in the Upper Cretaceous Ajlun Group of southern Jordan. Text-fig. 19 represents an overview on the development of the sequences along the escarpment between Ras En Naqb and Batn El Ghoul. Additionally, the resulting relative sea





Text-fig. 19. Sequence stratigraphic model for the Cenomanian/Turonian of southern Jordan. LST= lowstand systems tract, TST = transgressive systems tract, mfz = maximum flooding zone, HST = highstand systems tract, sb = sequence boundary. The red line indicates sea level changes.

level curve is illustrated. A comprehensive and detailed sequence stratigraphic examination will be published by BAASKE (in prep.).

The first sequence corresponds to the Wadi Juhra Member of the lower Naur Formation. It documents the first advance of the sea across the Lower Cretaceous mainland from the north-west. Following a transgressive phase at the base of the member, the medium part exhibits claystones with ammonites of the genus *Schloenbachia* (sections 6 and 7) which represent a Cenomanian age. Echinoids in sections 8 and 9 also indicate euhaline conditions. These horizons reflect the maximum flooding zone of the first sequence. In the upper Wadi Juhra Member a slight regressive trend is visible. The sea level rose again at the beginning of the upper Naur Formation. The dimension of this transgression was distinctly larger than that of the first cycle. In the western sections sediments of the offshore carbonate platform were deposited. The maximum sea level was reached at the top of the Naur cliff which consists of foraminiferal limestones with a rich benthic fauna in the west. The corresponding deposits in the east (Batn El Ghoul area) are heavily bioturbated sandstones and shales with a marine fauna. The basal FHS Formation reflects a regressive trend with marlstones in the west and marginal marine claystones in the east.

The third sequence starts with lowstand deposits which can be traced from section 1 to 8. More to the east, they were most probably eroded. The LST of the lower FHS Formation consists of siltstones and thin intercalated sandstones in the north-west, in the area of Ras En Naqb it is formed by sandstones and shales. More to the east, they are replaced by cross-bedded sandstones (section 7). These Mid- to Upper Cenomanian lowstand deposits can probably be correlated with the CenSin6 lowstands reported from southern Sinai by BAUER (2002, p. 69).

The following transgressive part (TST) consists predominantly of marlstones in the north-west and of claystones along the escarpment. Brackish faunas in the basal units indicate a restricted open marine circulation. Open marine conditions are documented in the maximum flooding zone (MFZ) of this sequence which is represented by fossiliferous limestones in the west (Karak and Naqb Member) and euhaline claystones in the middle and eastern part of the escarpment. Ammonites of the genus *Neolobites* indicate a Late Cenomanian age for this maximum transgression. The sea advanced far to the east, even in section 11, this MFZ is evidenced by heavily bioturbated sandstones including *Rhizocorallium jenense*. The following highstand reveals a regressive trend. Open marine organisms occur only sporadically. Horizons with glauconite are very common. Sandstone intercalations increase in abundance and thickness. The disappearence of *Costagyra olisiponensis* might indicate the Cenomanian-Turonian boundary. The regressive trend reaches its maximum with the lowstand deposits of the next sequence which most probably corresponds to the Shuayb Formation of northern and central Jordan. This LST can be traced from Ras En Naqb to Batn El Ghoul and even more to the east. The sediments consist of fluvial planar and trough cross-bedded sandstones and thin intercalated claystones. Occasionally roots and palaeosoils occur, indicating a very low sea level during that time (Early Turonian). The sandstones of this LST are overlain by dolomites in the west and dolomitic sandstones in the east which reflect a renewed transgression. These marine deposits mark the base of the Wadi As Sir Formation which is most probably Turonian in age (POWELL 1989). Fossils indicate euhaline conditions but they are few and poorly preserved. The TST of the basal Wadi As Sir Formation is cut by a thick erosional sandstone unit. They are predominantly trough cross-bedded and form large channel structures representing fluvial conditions. The low sea level results in the deposition of thinner units of fluvial sediments even in the Ras En Naqb area. Tectonically induced uplift of the hinterland in addition to a world wide low sea level in the middle Turonian might be reflected here. Lowstand deposits of a mid-Turonian age were also reported by BAUER (2002) from southern Sinai (Gebel Arabah and

Gebel Safariat). This siliciclastic unit above the TuSin 1 sequence boundary (BAUER 2002: p. 121, fig. 10) between limestones and dolomites, might be correlated with the southern Jordan deposits. The top of the Wadi As Sir Formation again consists of dolomites and dolomitic sandstones. Algal laminites are common and indicate shallow marine conditions. The succession of the Ajlun Group ends with these transgressive highstand deposits.

7 Faunal composition and preservation

7.1 Nekton

Representatives of the relatively rare nekton are two species of ammonites and one nautilid species and several remains of selachian and pycnodont fishes.

Cephalopods:
Schloenbachia sp.
Neolobites vibrayeanus (D´ORBIGNY, 1841)
Angulithes mermeti (COQUAND, 1862)

Angulithes only occurs in the western (euhaline) sections, usually together with *Neolobites vibrayeanus* in highly fossiliferous horizons of the FHS formation (see also the *Aphrodina dutrugei* - *Paraesa* sp. association; chapter 8.5.1). *Neolobites* was also found in claystones of the sections 5, 6, 7, and 9.

Ammonites and nautilids are preserved as internal moulds in limestones, *Neolobites* as compressed internal and composite moulds in claystones (Plate 13, Figs. 2-5).

Fishes are represented by teeth, scales and bone fragments which occur in claystones and marginal marine sandstones of the FHS and Wadi As Sir formations and the Harad and Fassua formations, respectively. Several teeth of *Carcharoides* sp. and one jawbone with circular smooth teeth of a pycnodont fish could be identified.

7.2 Benthos

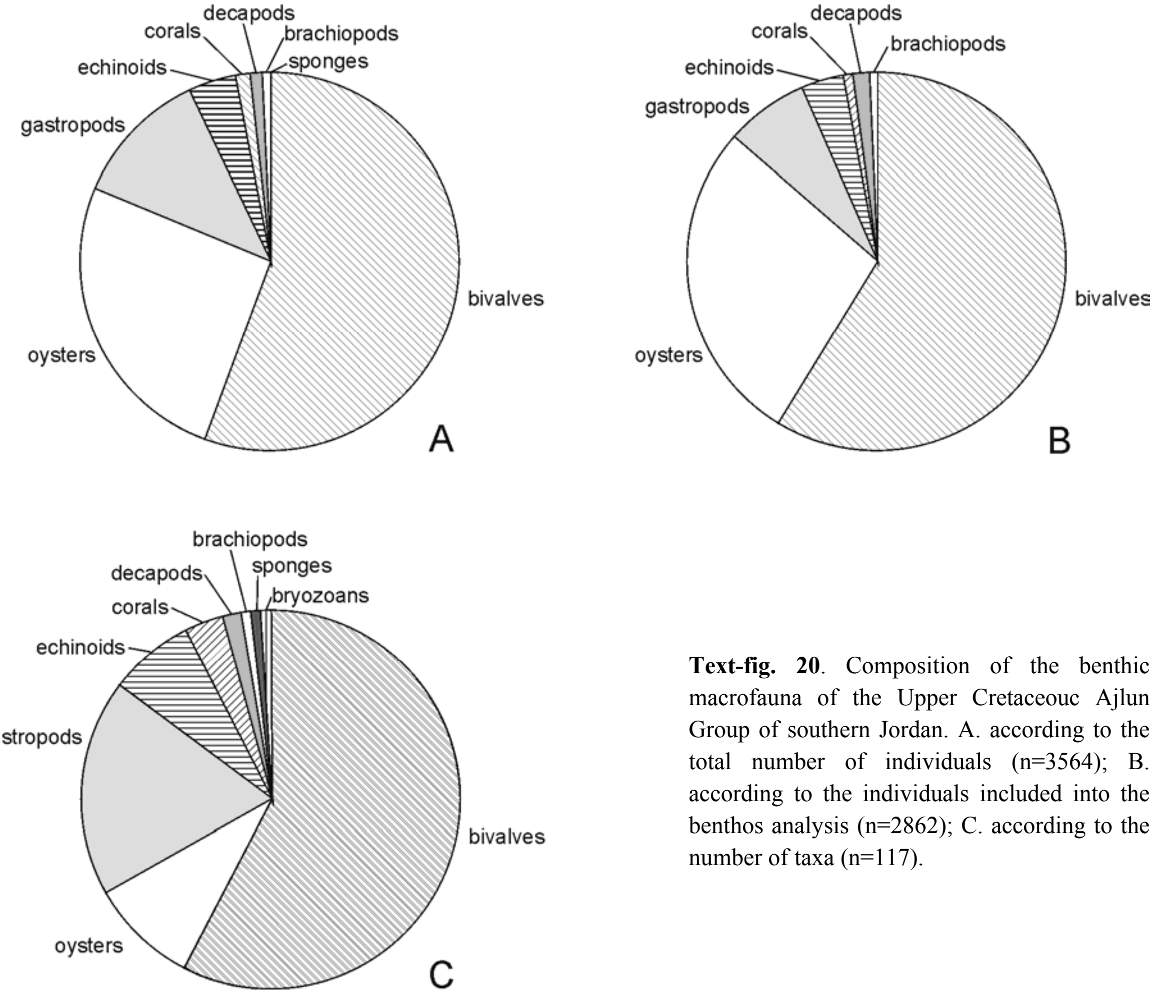
The collected benthic fauna consists of altogether 3564 individuals 2476 of which were included in the benthos analysis. The remaining 1088 individuals could not be included because they were not sampled horizontally. The 2476 individuals belong to 117 species which are distributed as follows:

Bivalves: 1678 individuals and 77 species, 12 of which are oysters (798 individuals)
Gastropods: 205 individuals and 22 species
Echinoids: 105 individuals and 9 species
Corals: 22 individuals and 4 species
Decapods: 36 individuals and at least 2 species
Brachiopods: 18 individuals and 1 species
Sponges: 1 individual and 1 species

Remains of small the branching bryozoan *Graysonia*?, which are common in certain layers of the Naur Limestone formation were not included in the benthos analysis.

According to life habits, 52.5% of the species lived infaunally (58 species were shallow infaunal, 5 species deep infaunal), 52.5% lived epifaunally. The life habit of at least three species of gastropods could not be reconstructed. According to the feeding mode, 9.1% (11 species) were substrate/deposit-feeders (nuculid bivalves, infaunal echinoids), 65.8% suspension-feeders, 3.3% microcarnivores (corals), 4.2% predators (naticid, olivid and turritellid gastropods). For 15.8 % of the species the feeding mode is uncertain. The decapod crustaceans are thought to have been scavengers or deposit-feeders. All benthic species from the Upper Cretaceous of southern Jordan are listed in chapter 7.6 including information on their life habit and feeding mode. The autecological data are taken from previous palaeoecological and ecological studies (STANLEY 1970, 1972, FÜRSICH 1977, 1980, 1982, 1984, FÜRSICH & KIRKLAND 1986, FÜRSICH & WERNER 1986, FÜRSICH et al. 2001, ABERHAN 1992, WIGNALL 1990, HOLZAPFEL 1998). Most of these studies concern Jurassic species. However, after detailed comparison with Cretaceous species, fairly precise statements for most of the taxa were possible. In the case of the gastropods the available data are very incomplete so that autecological data from Recent relatives of the same families were used (KEEN 1958). This concerned the families Strombidae, Olividae and Turritellidae.

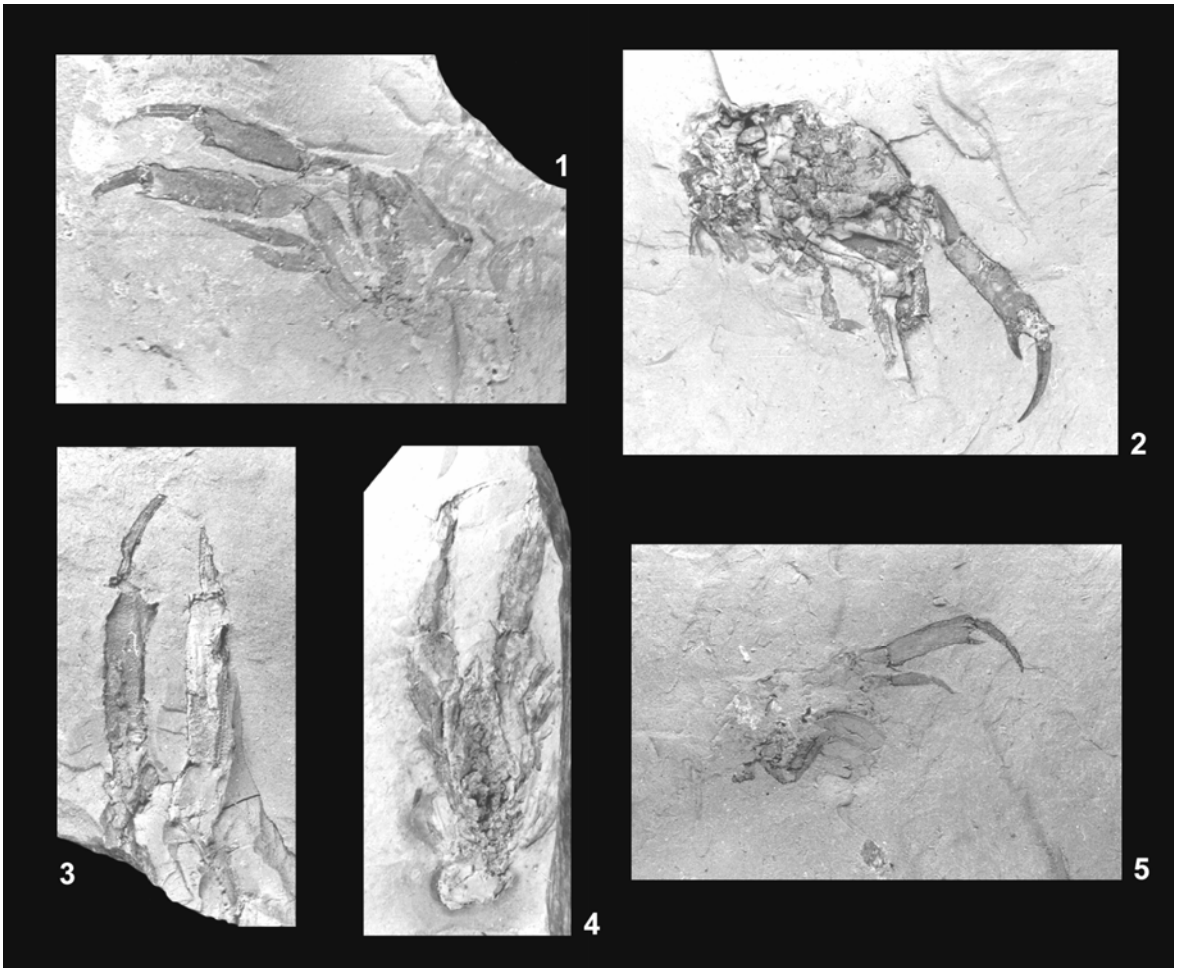
The composition of the benthic macrofauna of southern Jordan is shown in Text-fig. 20.



Text-fig. 20. Composition of the benthic macrofauna of the Upper Cretaceouc Ajlun Group of southern Jordan. A. according to the total number of individuals (n=3564); B. according to the individuals included into the benthos analysis (n=2862); C. according to the number of taxa (n=117).

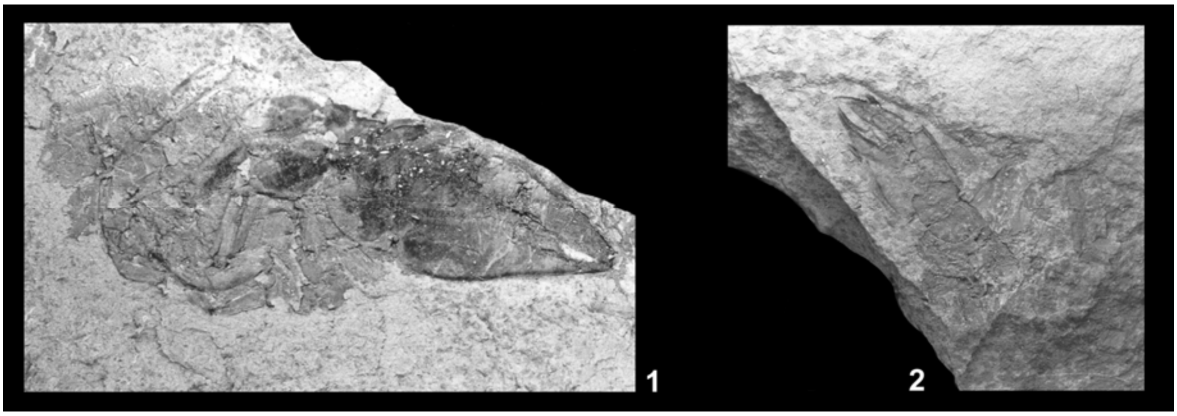
The following benthic species are not described in the taxonomic part of this work:
Decapod sp. A and **Decapod sp. B** (Text-fig. 21, B), *Enaulo* sp. (sponge), *Astraeofungia* sp., *Meandrarea* sp., *Columnocoenia*? sp., *Aspidiscus cristatus* (corals; Plate 12, Figs. 5-10), "*Lingula*" sp. (brachiopod; Plate 13, Figs. 7-8), *Graysonia*? sp. (bryozoan, Plate 13, Fig. 6).

Decapod sp. A is characterised by its small size in contrast to decapod sp. B. It shows a pseudochelate first pereiopod, while the rest of the pereiopods are smaller and neither pseudochelate nor chelate (R. FELDMANN written comm. 2002). Possibly it belongs to the genus *Glyphaea* or *Mecochirus*. Specimens of decapod sp. A have been found in Upper Cenomanian claystones of sections 5-9. Most of the specimens are preserved articulated, some of them in their burrows, which points to a catastrophic/rapid burial of the community.



Text-fig. 21. **A**. Some specimens of decapod sp. A, probably belonging to the family Glyphaeidae. All of them come from claystones of the Upper Cenomanian FHS Formation. **1**, **2**, and **3** from section 7, **4** from section 9, and **5** from section 8. All specimens x2.5.

Decapod sp. B is distinctly larger and is characterised by large pereiopods with well developed chelae. It occurs in impure siltstones of section 9, associated with abundant "*Lingula*" sp. (*Brachidontes* sp. – *Parmicorbula*? cf. *tapuchii* association; chapter 8.5.1). Maybe it belongs to the superfamily Thalassinoidea.



Text-fig. 21. **B**. Decapod sp. B (x2) from siltstones of the upper FHS Formation of section 9. Together with "*Lingula*" sp., these decapods form the trophic nucleus of assemblage III (see chapter 8.6).

7.3 Microfauna

Due to diagenetic dissolution of aragonitic and (partly) calcitic shell material microfauna is very rare in siliciclastic and marly layers. The relatively large agglutinating foraminifer *Thomasinella punica* SCHLUMBERGER is the only representative of benthic microfossils in the eastern sections. It was found in claystones of the Cenomanian Wadi Juhra Member and Cenomanian Harad and FHS formations.

In contrast, calcareous benthic foraminifera are very common in limestones of the Naur and basal FHS formations of the western sections. They include *Praealveolina*, *Chrysalidina*, *Nezzazzata*, and representatives of the families Miliolidae and Textulariidae. Comprehensive studies on Mid-Cretaceous foraminifera were published by SCHROEDER & NEUMANN (1985).

7.4 Ichnofauna

The following trace fossils have been observed in the Upper Cretaceous of southern Jordan:
Rhizocorallium irregulare MAYER, 1954
Rhizocorallium jenense ZENKER, 1836
Diplocraterion parallelum TORELL, 1870
Thalassinoides isp.
Zoophycos? isp.
Tomaculum? isp.
Burrows of decapods and infaunal echinoids.

The most common trace fossils are *Thalassinoides* isp. in limestone and marlstone beds of the western sections and *Rhizocorallium jenense* (Text-fig. 8C) in marginal marine sandstones in the east. A 20cm thick, iron-impregnated sandstone bed in sections 10 and 11 has been totally bioturbated by *Rhizocorallium*. In section 11, these traces are the only marine indicators that were found in the whole Harad Formation. In sections more to the east marine evidence of marine conditions is absent.

Because of the lack of body fossils in sandstones, especially in the east, trace fossils are often the only indicators of marginal marine environments.

7.5 Preservational and taphonomic aspects

Upper Cretaceous faunal elements from limestone beds of the western euhaline sections are usually preserved as calcareous internal moulds, especially shallow and deep infaunal bivalves. Primarily calcitic infaunal and epifaunal echinoids as well as epifaunal, thick-shelled oysters and plicatulid bivalves occur in shell preservation. Oysters often exhibit borings produced by sponges and gastropods. Gastropods are mostly complete except large fragile nerineids, and preserved as internal moulds. Corals are always strongly recrystallised.

Most infaunal bivalves of these limestones indicate only a very limited transport: they are mostly articulated and not fragmented, but possibly due to intense bioturbation, which can be observed in most of these layers (nodular limestones), not in growth position. Fragmentation ratios are higher among the epifauna; reclining and cementing oysters are often found disarticulated. Epifaunal echinoids are occasionally fragmented. This phenomenon can easily be explained by episodic higher current velocities (storms) at the sea floor which only affected the unprotected epifauna.

Thick marlstone units found in the western sections represent times of low energy and increased terrigenous input, so that reclining oysters (mostly *Ilymatogyra africana* "*typica*") often occur articulated and in growth position. Irregular echinoids are not fragmented. Intercalated thin shell concentrations with erosional base consisting of disarticulated epifauna (*Plicatula, Ilymatogyra*, Text-fig. 9D) are the result of higher water energy.

The preservational conditions are different in the marginal marine siliciclastic regime of the eastern sections. The few fossils found in sandstones such as rare bivalves and gastropods occur as poorly preserved internal moulds. Shell material was dissolved very early during diagenesis due to the high pore volume. In contrast, the fine-grained sediments exhibit a well preserved benthic macrofauna. All benthic elements, even thick-shelled oysters (*Rhynchostreon*) and plicatulid bivalves, are preserved as composite moulds, except the phosphatic lingulids. Infaunal bivalves occur articulated and in growth position as well as disarticulated in thin shell concentrations on bedding planes. Components of these shell concentrations occasionally are distinctly current aligned (Text-fig. 9C). Deep infaunal bivalves and rare infaunal echinoids representing euhaline conditions were mostly found slightly compressed and in situ. Some fragmented irregular echinoids are most probably victims of predatory organisms such as decapods or snails. Epifaunal echinoids are totally absent from the eastern sections, which can be explained most likely by the soft substrate.

In certain claystone horizons, decapod crustaceans occur compressed, but mostly articulated, and sometimes within their burrows. This kind of preservation indicates catastrophic or at least rapid burial possibly in connection with storm events.

Table 2. List of the benthic macrofauna of the Upper Cretaceous Ajlun Group of Sothern Jordan with autecological data on the taxa. Life habit: SI – shallow infaunal, DI – deep infaunal. IB (semi-)infaunal byssate, EB – epifaunal byssate, EC- epifaunal cemented, EF – epifaunal free-living, reclining, EM – epifaunal mobile. Feeding mode: D – deposit feeding, S – suspension feeding, H – herbivorous, O-omnivorous, C – carnivorous, MC – microcarnivorous, Sc – scavenger.

7.6 Autecology of the benthic fauna

	Life habit	**Feeding mode**
Bivalves		
• Nuculidae		
Nucula (*Nucula*) sp.	SI	D
• Nuculanidae		
Nuculana aff. *perdita*	SI	D
Mesosaccella cf. *subacuta*	SI	D
Mesosaccella sp.	SI	D
• Arcidae		
Barbatia (*Barbatia*) sp.	EB	S
• Parallelodontidae		
Nemodon? sp.	EB	S
Nemodon (*Pleurogrammatodon*) sp.	EB	S
• Noetiidae		
Noetia (*Icanopsis*?) sp.	?SI	S
• Glycymeridae		
Trigonarca? *diceras*	?SI	S
• Mytilidae		
Brachidontes (*Brachidontes*) aff. *fulpensis*	EB	S
Musculus (*Musculus*) sp.	IB	S
Inoperna cf. *transjordanica*	IB	S
Modiolus (*Modiolus*?) sp.	IB	S
• Bakevelliidae		
Phelopteria cf. *dalli*	EB	S
Phelopteria sp.	EB	S
Pseudoptera sp.	EB	S
• Pectinidae		
Camptonectes (*Camptonectes*) aff. *curvatus*	EB	S
Camptonectes (*Camptonectes*) sp.	EB	S
Neithea (*Neithea*) *shawi*	EF	S
Neithea (*Neitheops*) *syriaca*	EF	S
• Plicatulidae		
Plicatula (*Plicatula*) *auressensis*	EC/EF	S
Plicatula (*Plicatula*) *fourneli*	EC/EF	S
• Limidae		
Plagiostoma tithense	EB	S
Plagiostoma sp.	EB	S
• Gryphaeidae		
Amphidonte (*Ceratostreon*) *flabellatum*	EC	S
Ilymatogyra (*Afrogyra*) *afrinaca*	EC	S
Laevigyra dhontae	EC/?EF	S
Rhynchostreon mermeti	EC/EF	S
Rhynchostreon sp.	EC/EF	S
Exogyra (*Exogyra*) *italica*	EF	S
Exogyra (*Costagyra*) *olisiponensis*	EC/EF	S
Pycnodonte vesiculosum	EC	S
• Ostreidae		
Crassostrea sp.	EC/EF	S

	Life habit	**Feeding mode**
Curvostrea cf. *rouvillei*	EC/EF	S
Curvostrea sp.	EC/EF	S
Ambigostrea cf. *dominici*	EC	S
• Trigoniidae		
Trigonia cf. *ethra*	SI	S
Trigonia sp.	SI	S
• Lucinidae		
Lucina sp.	DI	?S
• Carditidae		
carditid bivalve sp. A	SI	S
carditid bivalve sp. B	SI	S
• Astartidae		
Opis? sp.	EF	S
• Crassatellidae		
"*Crassatella*" sp.	SI	S
Anthonya dayi	SI	S
Anthonya jordanica	SI	S
• Cardiidae		
Granocardium (*Granocardium*) *productum*	SI	S
Granocardium (*Granocardium*) cf. *desvauxi*	SI	S
Granocardium (*Granocardium*) cf. *carolinum*	SI	S
Trachycardium? *mermeti*	SI	S
Protocardia (*Protocardia*) cf. *judaica*	SI	S
Protocardia (*Protocardia*) *coquandi*	SI	S
• Tellinidae		
Geltena? cf. *mactraeformis*	DI	D
"*Tellina*" sp.	DI	D
Linearia (*Linearia*) sp.	DI	D
• Arcticidae		
Arctica cordata	SI	S
Arctica? sp.	SI	S
Schedotrapezium? *acclivis*	SI	S
Veniella? *trapezoidalis*	SI	S
Venilicardia? cf. *cordiformis*	SI	S
• Neomiodontidae		
Eomiodon libanoticus	SI	S
• Veneridae		
Aphrodina (*Aphrodina*) *dutrugei*	SI	S
"*Dosinia*" *delettrei*	SI	S
"*Dosinia*" sp.	SI	S
Paraesa sp. aff. *Venus reynesi*	SI	S
• Corbulidae		
"*Corbula*" sp.	SI	S
Corbulomima? cf. *aligera*	?SI	S
Caestocorbula? aff. *tapuchii*	SI	S
Caestocorbula (*Parmicorbula*) *eretzisraelensis*	SI	S

	Life habit	Feeding mode
• Requieniidae		
cf. *Toucasia matheroni*	EF	S
• Radiolitidae		
"*Radiolites*" sp.	EC	S
• Family uncertain		
Heterodont bivalve sp. A	SI	S
Heterodont bivalve sp. B	SI	S
Heterodont bivalve sp. C	SI	S
Heterodont bivalve sp. D	SI	S
Heterodont bivalve sp. E	SI	S
• Pholadomyidae		
Pholadomya (*Procardia*) *vignesi*	DI	S
Pholadomya (*Pholadomya*) cf. *pedernalis*	DI	S
Pholadomya? sp.	DI	S
• Laternulidae		
Cercomya? *jettei*	DI	S
Gastropods		
• Trochidae		
Calliomphalus orientalis	SI	?H/D
• Neritopsidae		
Neritopsis (*Neritopsis*) sp.	EM	?H
• Purpurinidae Zittel, 1895		
Coronatica cf. *ornata*	?SI/EM	C
• Potamididae		
Pyrazus cf. *valeriae*	EM	?H
• Turritellidae		
"Turritella" amotzi	SI	S
• Strombidae		
"*Strombus*" *incertus*	EM	H/D
• Aporrhaidae		
"*Aporrhais*" *turriculoides*	SI	S
• Naticidae		
Tylostoma globosum	SI	C
Tylostoma cossoni	SI	C
• Columbellinidae		
Columbellina fusiformis	EM	?C
Pterodonta deffisi	EM	?C/O
Pterodonta cf. *subinflata*	EM	?
Pterodonticeras germeri	?EM	?
• Olividae		
aff. *Pseudoliva* cf. *ambigua*	SI	C
• Architectonicidae		
Torinia (*Climacopoma*) *animi*	EM	?H/O
• Nerineidae		
"*Nerinea*" *gemmifera*	SI	S

	Life habit	**Feeding mode**
“*Nerinea*“ *pauli*	SI	S
“*Nerinea*“ *subaequalis*	SI	S
• Acteonidae		
Globiconcha rotundata	EM	?
• unidentifiable gastropods		
Gastropod sp. A	?SI	?S
Gastropod sp. B	EM	?
Gastropod sp. C	EM	?H
Brachiopods		
• Lingulidae		
“*Lingula*“ sp.	SI	S
Sponges		
Enaulo sp.	EC	S
Corals		
• Fungidae		
Astraeofungia sp.	EC/EF	MC
Meandraraea sp.	EC	MC
Columnocoenia? sp.	EC	MC
Aspidiscus cristatus	EF	MC
Bryozoans		
Graysonia? sp.	E	S
Echinoderms		
• Hemicidaridae		
Heterodiadema libycum	EM	?H/C
• Pseudodiadematidae		
Tetragramma variolare	EM	?H/C
• Arbaciidae		
Goniopygus menardi	EM	?H/C
• Family uncertain		
Micropedina olisiponensis	EM	?H/C
• Holectypidae		
Coenholectypus larteti	SI	D
• Archiaciidae		
Archiacia sp.	SI	D
• Hemiasteridae		
Hemiaster (*Hemiaster*) *syriacus*	SI	D
Hemiaster (*Mecaster*) *batnensis*	SI	D
Hemiaster (*Mecaster*) cf. *luynesi*	SI	D
Hemiaster (*Mecaster*) sp.	IM	D
Decapods		
• Glyphaeidae?		
Decapod sp. A	SI/EM	Sc/C?
• Callianassidae		
Decapod sp. B	SI/EM	Sc/C?

7.7 Effects of time-averaging, transport, and selective preservation

Fossil associations and assemblages are only relics of former communities and always impoverished compared to the former diversity. Quantitative studies showed that only 30% of all shelly fauna is preserved (JOHNSON 1964, STAFF & POWELL 1988). Reasons for this phenomenon are for example selective solution (e.g. of aragonite) as well as biologic and physical erosion.

Effects of transport can be both enriching or impoverishing the fauna. High energy transport caused by storm events might result in destruction of certain taxa or current sorting, but most probably in decreasing the number of species. In southern Jordan, this effect can be observed in the *Plicatula*/*Ilymatogyra* storm layers of the basal FHS Formation. These allochthonous taphocoenoses can not be included in the palaeoecological analysis.

Through transport communities from different environments can become mixed. This results in an enriched number of taxa. In favourable cases, i.e. in cases of distinctly different environments, the faunal composition might give away such composite assemblages. However, to recognize mixing of similar communities might be not possible. Low rates of sedimentation, compaction, and intensive bioturbation can also lead to a somewhat distorted picture concerning former benthic communities. The effect of decreased net sedimentation, which might be expressed by a higher shell density, could result in mixing of more than one community in a single horizon or sample unit. This might result in a higher species diversity. According to FÜRSICH & ABERHAN (1990) **time-averaging** can be an advantage concerning the interpretation of fossil communities: Although short-term changes might not be recognizable, long-term trends might be documented more clearly.

8 Palaeoecology

8.1 Introduction and definitions

In the last decades numerous studies demonstrated that palaeoecologic methods are a useful tool for reconstructing depositional environments. In addition to sedimentological analyses palaeoecology can achieve reliable results, if used correctly. With the help of palaeoecological methods statements about environmental parameters are possible, which are difficult to reconstruct with classic sedimentological methods, for example concerning oxygen values, palaeo-salinity, and water temperature. The occurrence of single taxa or groups of organisms may already indicate certain environments (e.g., echinoderms or ammonites indicate fully marine conditions). However, the best results are obtained by the analysis of fossil (benthic) communities.

The modern concept of palaeo-communities goes back to the classical studies of the first half of the last century (PETERSEN 1913, 1915; THORSON 1933, 1957). In these studies, communities were defined by characteristic species which dominate in a particular environment for a certain time interval.

As in ecological studies palaeoecology attempts to uncover the different interactions between organisms and their physical environment. The dominating environmental parameters determine the composition of a community, as well as their relative abundance in the community, but they also influence the single specimens. For example, size, shape, and thickness of shells are very closely related to environmental parameters such as water energy and salinity.

A major task of the palaeoecology is the reconstruction of depositional environments with the help of statistical samples from well defined horizons. A very important aspect is the identification of palaeo-communities; communities, which existed in the geologic past evidenced by fossils or traces (KAUFFMAN & SCOTT 1976).

A decisive disadvantage of palaeoecology in contrast to recent ecology are the short comings of the fossil record. According to JOHNSON (1964), on average only 30% of shelly macrofauna is preserved. According to SCHOPF (1978) on averadge 40% of intertidal faunal elements are preserved, preferentially including herbivore and suspension-feeding organisms. Shells consisting of aragonite exhibit a lower preservation potential than calcitic shells. Animals without skeleton are generally not at all preserved. Therefore, the usefullness of palaeosynecological studies was criticized in several papers (e.g., HOFFMANN 1979, 1982).

Including trace fossils into the analysis might increase the value of the preserved fauna indirectly, but not decisively. Therefore, distortion of the original faunal composition is the rule.

There are additional arguments that make palaeoecological analyses difficult and might even lead to wrong results if not recognised. Sedimentological and biological processes such as transport or bioturbation might cause mixing of faunas of different environments. Faunal condensation due to low rates of sedimentation causes mixing of communities from different time intervals. An extensive discussion of this factor so-called time averaging was published by FÜRSICH & ABERHAN (1990). They pointed out that time-averaged communities might reflect environmental and depositional parameters of longer time intervals, whereas short time trends are mostly destroyed. Prerequisite for meaningful interpretations in these cases is the recognition of time-averaging.

Despite all those limitations, palaeosynecological approach gained in importance over the last years, because of the meaningful results that can be achieved (e.g., FÜRSICH 1981, 1982, 1984, FÜRSICH & WERNER 1986, FÜRSICH et al. 2001, ABERHAN 1992, GAHR 2002).

This study follows the palaeoecological definitions introduced by FÜRSICH (1984). Benthic associations are relicts of authochtonous, repeatedly occurring communities, which were largely unaffected by diagenesis and taphonomic distortion. In contrast, an assemblage occurs mostly only once and might exhibit indications of transport, faunal mixing and diagenetic distortion.

8.2 Methods

In the study area, 15 sections were measured layer-by-layer. The individual beds were examined for lithology, sedimentological structures, nature of contacts,, fossil content (including trace fossils), and taphonomis features. Fossils were sampled from specific horizons. Where possible, 100 or more specimens were sampled to obtain a statistically usable sample size. Unfortunately, the sections especially in the eastern part of the escarpment lack faunas that could be used for statistical purposes. Altogether, only a few horizons yielded a sufficient number of specimens. Faunas of marlstones of the western sections were weathered out so that sampling from specific horizons was difficult. In order to minimize faunal mixing, the marlstone slopes were divided into several parts, each 1-3m thick, and sampled accordingly. In the laboratory, the fossils were prepared mechanically. Claystone samples were dissolved with diluted hydrogen peroxide and sieved through a 100 µm sieve. Unfortunately, calcareous microfauna was totally absent from all samples, only some layers yielded some agglutinating foraminifera (*Thomasinella*). After identification of the fauna, the specimens of each taxon in a sample were counted. Left valves, right valves and articulated specimens were counted separately. The final number of individuals of a species was calculated by adding to the number of articulated specimens the number of left or right valves, whichever was larger. This method (Minimum Number of Individuals, MNI) was introduced by GILINSKY & BENNINGTON (1994). It is based on the assumption that every sampled left valve belongs to a sampled right valve. A list of relative abundances was constructed for each quantitative sample. Samples with a number of specimen smaller than 40 were excluded from the analysis. Additionally, very rare species were removed from the matrix. This was necessary to prevent absence of species to be a criterion in comparing samples. 41 out of 66 samples of macrobenthos were included in the cluster analysis, which was carried out using SPSS for Windows.

8.3 Cluster analysis

Theoretical principles of the Q-mode cluster analysis have recently been described by GAHR (2002). Aim of this method within the framework of palaeoecology is to compare samples and to group them according to their similarity. Therefore, the occurrence and relative abundance of species is compared, and samples with a similar composition are combined into clusters.

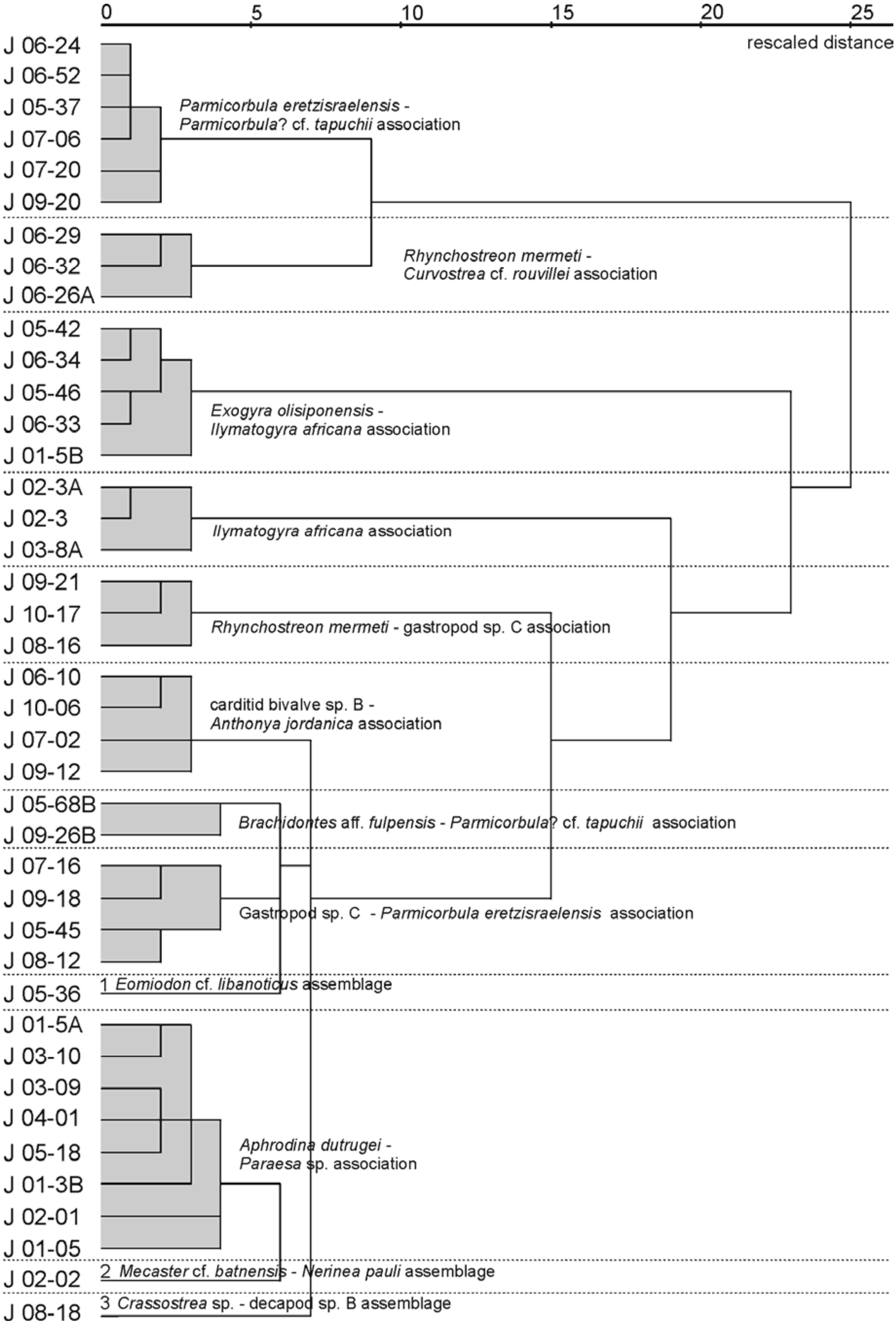
This computer-based method has been widely used for palaeoecological analysis in the last years (ETTER 1990, HEINZE 1991, ABERHAN 1992, FÜRSICH et al. 1995, FÜRSICH et al. 2001, GAHR 2002). For the calculation, the agglomerative method after WARD turned out to be the one which resulted in the most homogenous and clearest clusters. The results have been compared with other methods such as the "single linkage" and the "nearest neighbour" method. For the distance scale the squared euclidian distance was chosen.

The resulting dendrogram is shown in Text-fig. 22. The 41 statistical samples were grouped into nine associations and three assemblages which are described and discussed in chapter 8.5.

8.4 Diversity

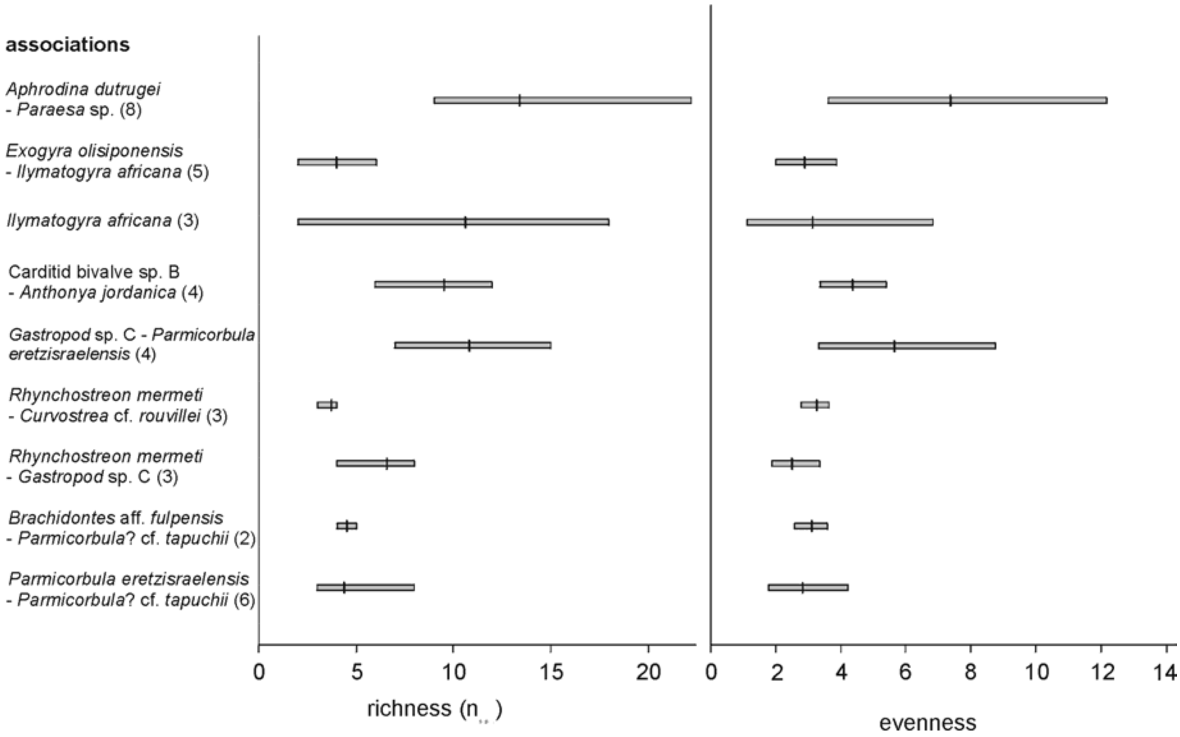
The diversity of a community or association allows statements on the stability of environmental parameters (SANDERS 1968, FÜRSICH 1981, STAFF & POWELL 1988). In general, low diversity values indicate a certain amount of environmental stress, whereas high species diversity points to stable and, in this case, normal marine conditions. Three methods for determining the diversity of the associations are used here.

The **species richness** of an association includes the number of its taxa. For that the minimum and maximum values of the samples of an association are given as well as the mean of all samples that belong to an association. Values of species richness are influenced by sample size. This means that small samples naturally contain less species than large samples (sample size effect, see KOCH 1987).



Text-fig. 22. Dendrogram of a Q mode cluster analysis of statistical samples from the Upper Cretaceous Ajlun Group of southern Jordan based on the Ward method. The samples were grouped into nine associations and three assemblages.

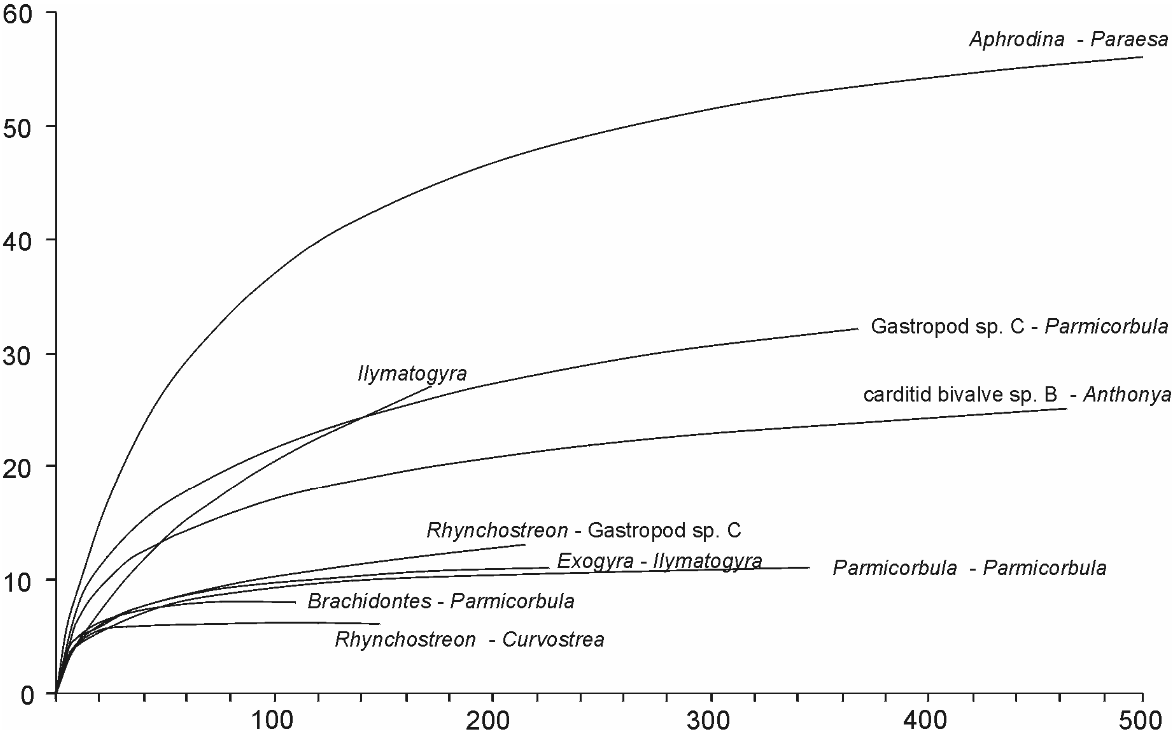
To compare samples of different size (i.e., with different numbers of individuals) the **rarefaction analysis** turned out to be a meaningful tool in palaeoecological studies. It results in data which allow a graphical comparison of the different associations. Strongly ascending curves represent phases of sampling with a high probability to find new species. In contrast, graphs that leveled off indicate that the probability to find new species is fairly low. Thus for the benthic analysis, associations with a flattened rarefaction curve are more suitable. Associations with a steep curve point to incomplete sampling. The rarefaction analysis was carried out using the program PAST (HAMMER et al. 2001).



Text-fig. 23. Range and mean values of species richness and evenness of the macrobenthic associations from the Cretaceous of southern Jordan. Number of samples in parentheses.

The dominance of one or more taxa in an association are characterised by the **evenness** values. A low value for evenness indicates strong dominance of a particular species. Like in the case of the species richness, minimum and maximum values and the mean are given. Evenness was calculated as $E = 1/\Sigma p_i^2$ (MACARTHUR 1972), whereby p_i is the relative frequency of the i-th species.

Diversity values based on evenness allow more reliable statements, because it is not as much affected by sample size as are values of species richness.



Text-fig. 24. Rarefaction plots of the benthic associations using PAST (HAMMER et al. 2001). Assemblages are less significant and therefore not included.

8.5 Benthic associations in the Upper Cretaceous of southern Jordan

A q-mode cluster analysis of the 42 statistical samples resulted in nine benthic associations and three assemblages which are described in the following.

8.5.1 Euhaline carbonate platform associations

(A) *Aphrodina dutrugei – Paraesa* sp. association

Eight samples with 498 individuals and 56 species have been grouped in this association. The trophic nucleus consists of 25 species dominated by the small shallow infaunal bivalves *Aphrodina dutrugei* and *Paraesa* sp. (together 20.6%). Five species of oysters (*Ilymatogyra africana* (forma *typica*), *Ilymatogyra africana* (forma *crassa*), *Ceratostreon flabellatum*, *Curvostrea* cf. *rouvillei*, *Rhynchostreon mermeti*, *Exogyra olisiponensis*; together 18.6%) belong to the trophic nucleus. Other important benthic organisms are the epifaunal rudistid bivalve cf. *Toucasia matheroni* (5.2%) and the deep infaunal *Pholadomya* (*Procardia*) *vignesi* (4.2%). Large gastropods (*Nerinea pauli*, "*Strombus*" *incertus*) are characteristic benthic elements. Bivalves dominate the association with 79.7%, gastropods represent 12.3% and echinoids 8.0%. With respect to the life habit, epifaunal (50.8%) and infaunal organisms (49.2%) are nearly equally abundant. With respect to the feeding habits, suspension-feeders prevail strongly (79.7%). The feeding mode of the gastropods and regular echinoids is difficult to determine. Possible is a detritus-feeding, omnivorous or herbivorous feeding mode for the gastropods, a microcarnivorous or herbivorous-grazing mode for the epifaunal echinoids. The infaunal irregular echinoids (4%) were most probably deposit-feeders.

The species richness varies strongly from 9 to 22 (mean 13.4), evenness from 3.6 to 12.1 (mean 7.3).

Nearly all infaunal bivalves are preserved as internal moulds of articulated specimens. Epifaunal oysters and Plicatulidae occur single-valved as well as articulated and are generally preserved with their shell. Echinoids are mostly well preserved, especially the infaunal specimens. All gastropods are preserved as internal moulds. Most of the large high trochiform shells of the nerineid gastropods are broken into fragments of 1 to 4 cm length.

Neolobites vibrayeanus and *Angulithes mermeti* represent the nektic organisms in this association.

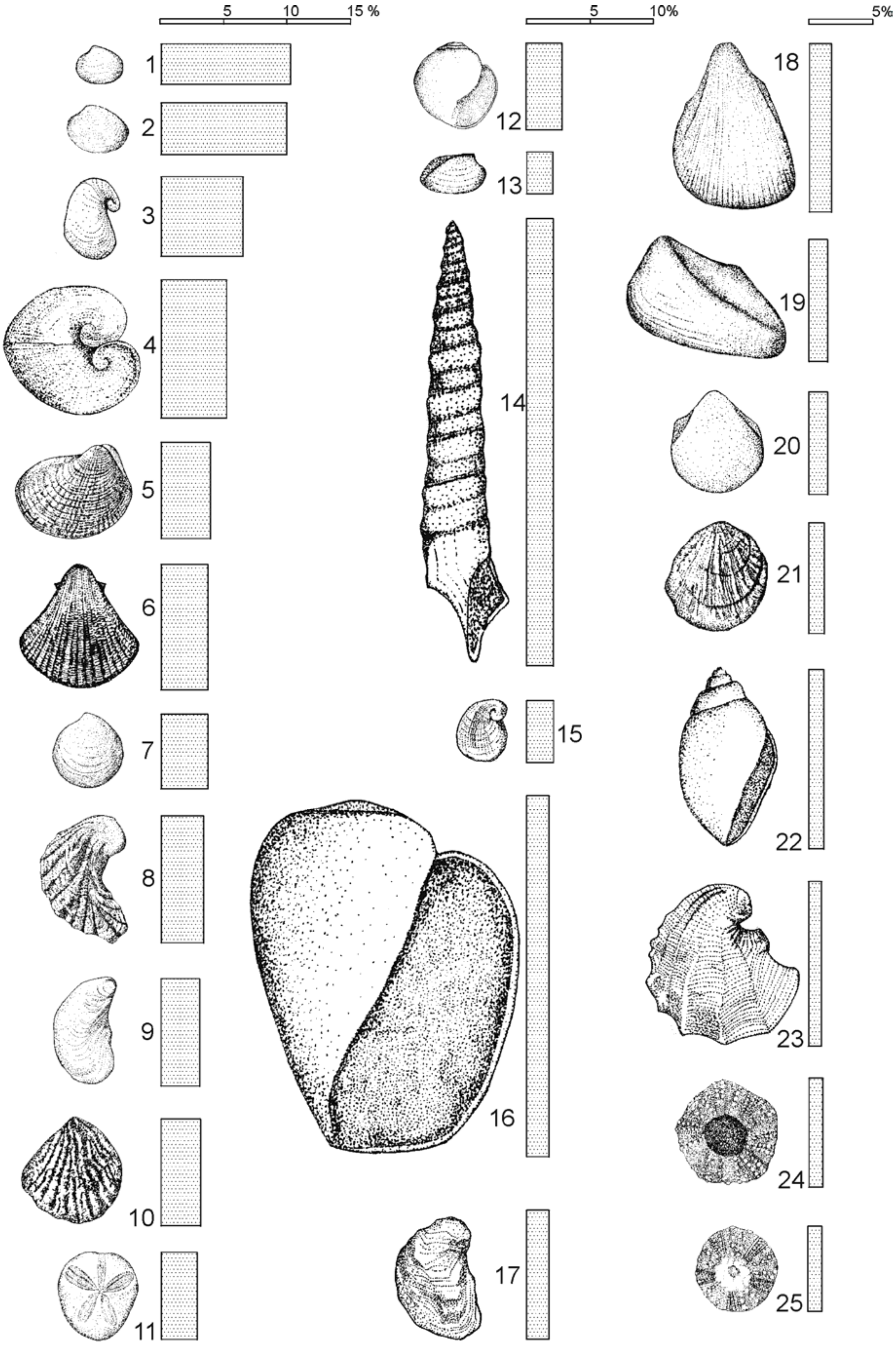
The *Aphrodina dutrugei – Paraesa* sp. association is limited to calcareous rocks and is found mostly in bioclastic wackestones, wacke- to packstones and (poorly washed) packstones in Cenomanian strata of the western sections (At Taiyba, Dilagha, Ras en Naqb). Some of these beds appear nodular owing to moderate to heavy bioturbation by crustaceans (*Thalassinoides*).

Discussion. The high diversity and evenness values of the *Aphrodina dutrugei – Paraesa* sp. association as well as the abundance of echinoids and ammonites as stenohaline groups indicate euhaline conditions in a carbonate platform setting. The fine-grained sediment and low degree of fragmentation of the shells indicate a moderate to low water energy level, below the fair weather wave base. Poorly washed packstones indicate occasional winnowing of fine material. The dominance of shallow infauna as well as the occurrence of infaunal echinoids and deep infaunal bivalves point to well oxygenated sea floor sediments. Large (heavy) gastropods and *Thalassinoides* burrows indicate a certain stability of the substrate. The low percentage of infaunal detritus feeders might be due to low concentrations of particulate organic matter within the sediment.

The epibenthos consists exclusively of conspicuously thick-shelled organisms (oysters, Plicatulidae, gastropods) which might be an adaptation to ward off predators such as echinoids, some gastropods, and ammonites. Thin-shelled heterodont bivalves (*Paraesa*, *Aphrodina*, *Dosinia*) are invariably infaunal suspension-feeders, this way being protected from predators.

The *Aphrodina dutrugei – Paraesa* sp. association with its high species richness and evenness was subject to a low degree of environmental stress and is the relic of a fully marine platform community.

Text-fig. 25. Trophic nucleus of the *Aphrodina dutrugei – Paraesa sp*. association. 1. *Aphrodina dutrugei*, 2. *Paraesa* sp., 3. *Afrogyra africana „typica“*, 4. cf. *Toucasia matheroni*, 5. *Pholadomya vignesi*, 6. *Neithea shawi*, 7. “*Dosinia*“ *delettrei*, 8. *Ceratostreon flabellatum*, 9. *Curvostrea* cf. *rouvillei*, 10. *Plicatula auressensis*, 11. *Mecaster* cf. *luynesi*, 12. *Globiconcha rotundata*, 13. ?*Schedotrapezium acclivis*, 14. *Nerinea pauli*, 15. *Rhynchostreon mermeti*, 16. “*Strombus*“ *incertus*, 17. *Afrogyra africana „crassa*“, 18. *Trachycardium mermeti*, 19. *Trigonarca*? *diceras*, 20. *Granocardium carolinum*, 21. *Plicatula fourneli*, 22. *Pterodonta deffisi*, 23. *Costagyra olisiponensis*, 24. *Tetragramma variolare*, 25. *Goniopygus menardi*. The length of the bars indicates relatively abundance, the height is a rough estimate of the relative size of the taxa.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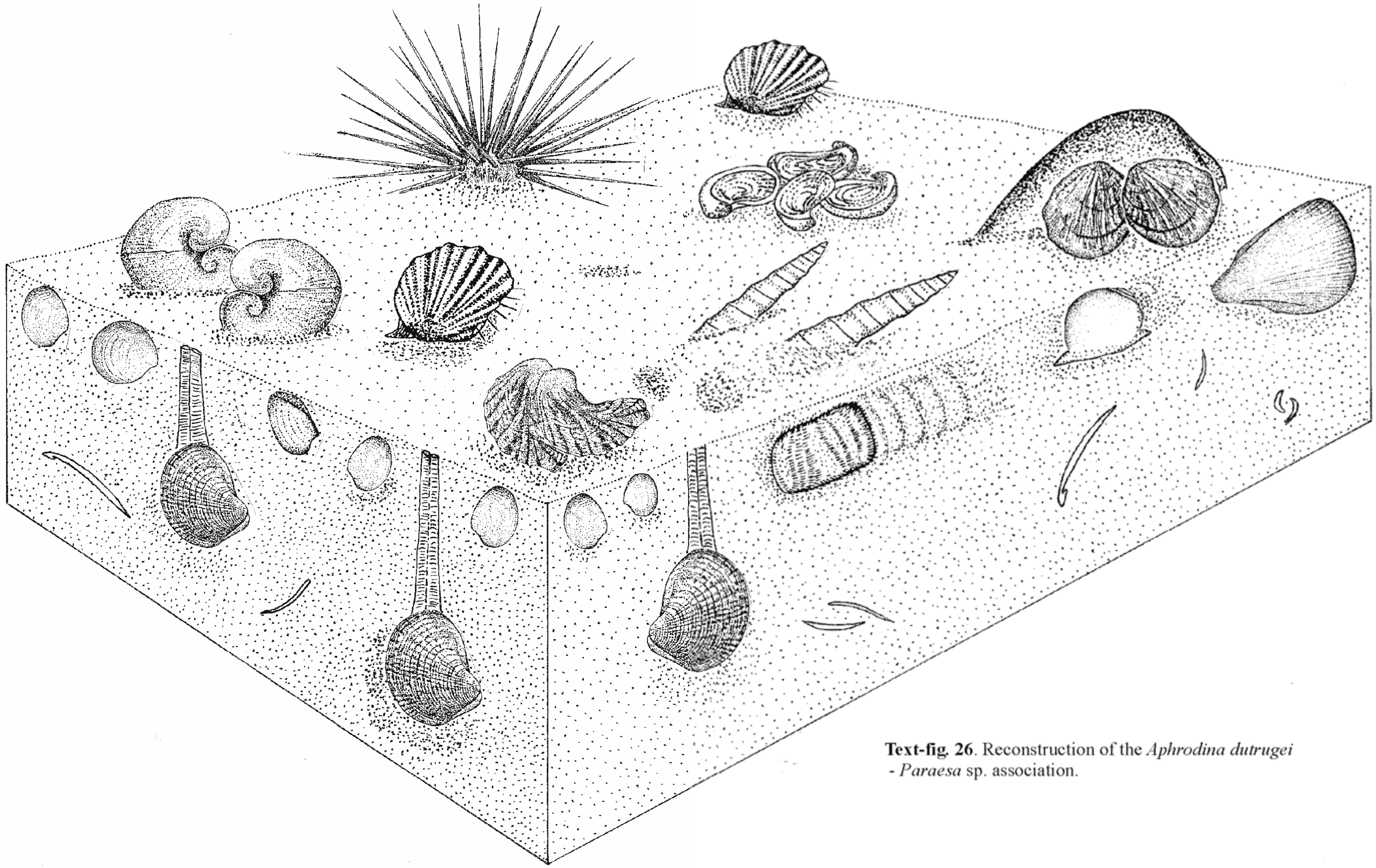


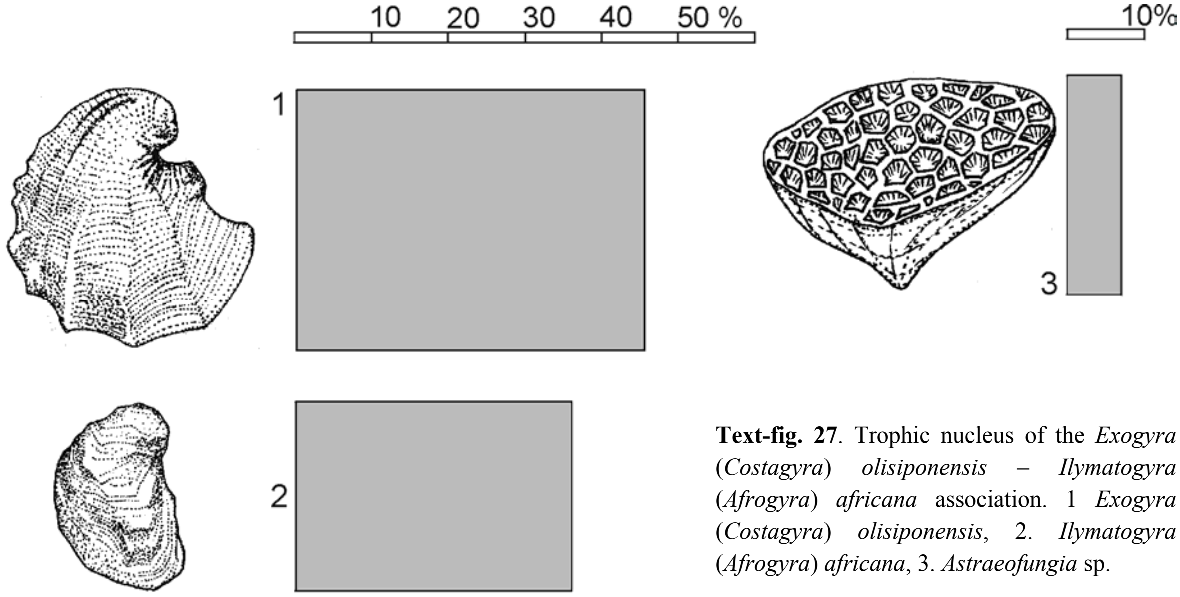
Text-fig. 26. Reconstruction of the *Aphrodina dutrugei* - *Paraesa* sp. association.

(B) *Exogyra* (*Costagyra*) *olisiponensis – Ilymatogyra* (*Afrogyra*) *africana* association

This association has been defined on the basis of five samples and 227 individuals. 11 species have been found. Members of the trophic nucleus are the oysters *Exogyra* (*Costagyra*) *olisiponensis* (47.6%) and *Ilymatogyra* (*Afrogyra*) *africana* (27.3%), as well as the colonial coral *Astraeofungia* sp. (6.2%). *Exogyra italica* (4.4%) occurs only in this association. Echinoids are represented by four species (three epifaunal, one infaunal). The association is strongly dominated by epifaunal organisms (97.8%), *Mecaster* sp. is the only infaunal element. Suspension-feeding oysters and *Plicatula fourneli* form the bulk of the fauna (90.7%), whereas microcarnivores (corals; 7.1%) are comparatively rare, as are deposit-/detritus-feeders (*Mecaster*; 2.2%). The *Exogyra* (*Costagyra*) *olisiponensis – Ilymatogyra* (*Afrogyra*) *africana* association exhibits a rather low diversity, species richness varying between 2 and 6 (mean: 4) and evenness values between 2.0 and 3.8 (mean: 2.8).

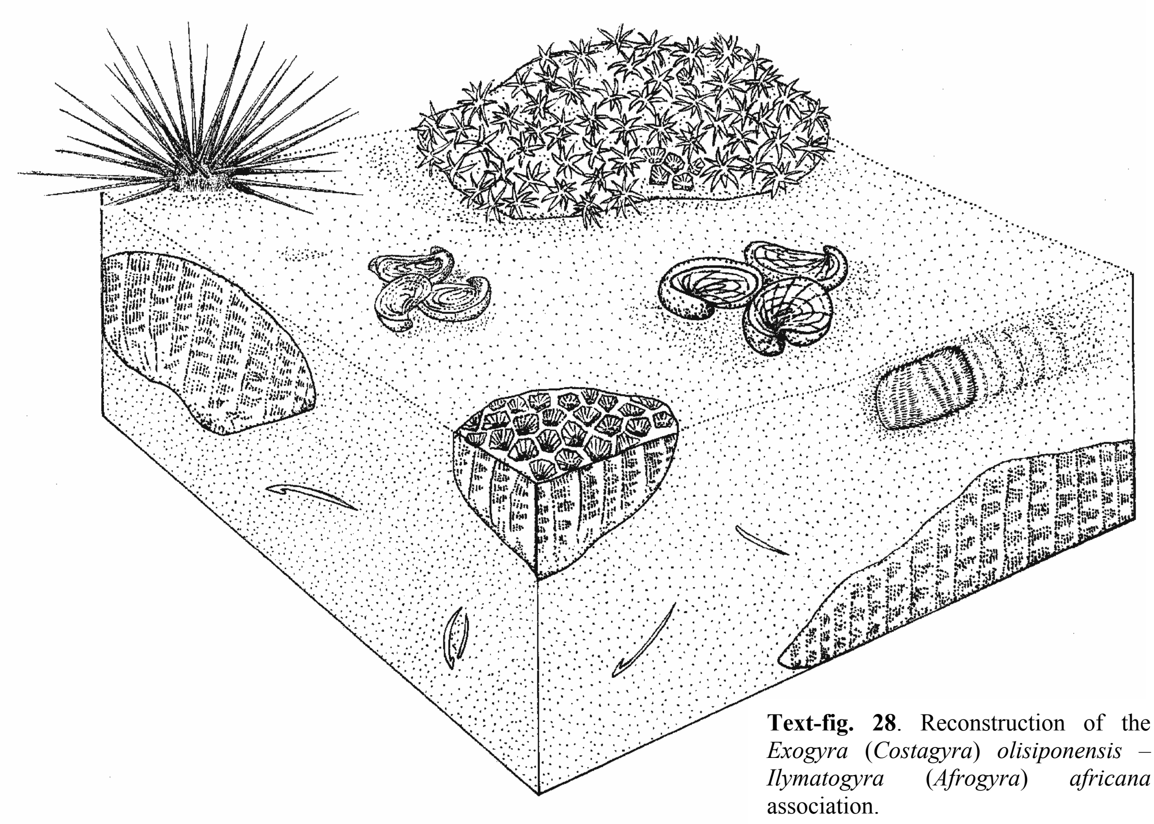
Oysters are thick-shelled and reach large sizes. They occur exclusively in shell-preservation, as do the echinoids. Corals are often recristallized internally which makes a precise identification difficult. In the case of *Ilymatogyra* (*Afrogyra*) *africana* the growth form "*crassa*" (MALCHUS 1990) predominates. Compared with *I.* (*Afrogyra*) *africana* "*typica*" the shape is more variable, the outer surface of the shell is covered with scaly growth lamellae and the individuals reach a larger size (MALCHUS 1990). In the course of this study it could be observed that the different growth forms of *I.* (*Afrogyra*) *africana* are at least partially substrate-related; whereas the "forma *typica*" was found predominantly in marls and marly limestones indicating a somewhat softer substrate, "forma *crassa*" dominates in purer limestones. Furthermore, "forma *typica*" seems to have preferred a reclining, "forma *crassa*" a cemented mode of life.

The *Exogyra* (*Costagyra*) *olisiponensis – Ilymatogyra* (*Afrogyra*) *africana* association has been found in bioclastic packstones and in slightly marly limestones of the western sections (At Taiyba, Ras En Naqb).



Text-fig. 27. Trophic nucleus of the *Exogyra* (*Costagyra*) *olisiponensis – Ilymatogyra* (*Afrogyra*) *africana* association. 1 *Exogyra* (*Costagyra*) *olisiponensis*, 2. *Ilymatogyra* (*Afrogyra*) *africana*, 3. *Astraeofungia* sp.

Discussion. Corals and echinoids indicate euhaline conditions, the sediment and thick-shelled oysters might point to a moderate to fairly high water energy. The depositional system was situated within the photic zone (corals), most probably above the fair-weather wave base. The strong dominance of suspension-feeding epifauna (97.8%) refers to a nutrient-rich and well oxygenated water column. The nearly complete lack of infauna might be due to a somewhat hardened substrate but is most probably a result of sample size effects (see also rarefaction plot). This might also explain the lack of gastropods in the *Exogyra* (*Costagyra*) *olisiponensis – Ilymatogyra* (*Afrogyra*) *africana* association, which could have been expected to occur. Another explanation for the absense of gastropods and infaunal bivalves is selective dissolution of aragonitic shell material during early diagenesis.

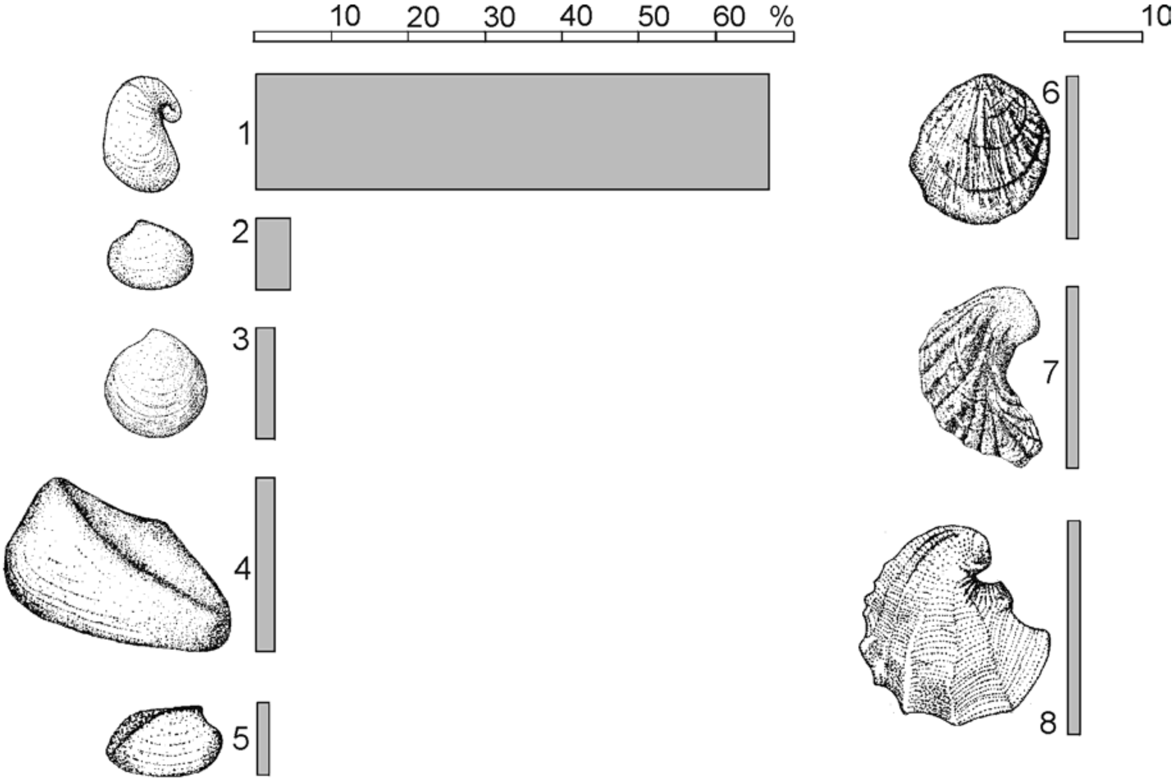


Text-fig. 28. Reconstruction of the *Exogyra* (*Costagyra*) *olisiponensis – Ilymatogyra* (*Afrogyra*) *africana* association.

8.5.2 Euhaline associations of marly limestones/marlstones

(C) *Ilymatogyra* (*Afrogyra*) *africana* association

Represented by three samples and 173 individuals, the *Ilymatogyra* (*Afrogyra*) *africana* association consists of 27 species, eight of which (*Ilymatogyra* (*Afrogyra*) *africana*, *Aphrodina dutrugei*, *Dosinia delettrei*, *Trigonarca*? *diceras*, *Schedotrapezium*? *acclivis*, *Plicatula fourneli*, *Amphidonte* (*Ceratostreon*) *flabellatum*, *Exogyra* (*Costagyra) olisiponensis*) belong to the trophic nucleus which consists completely of bivalves. The small, thick-shelled oyster *Ilymatogyra* (*Afrogyra*) *africana* forma *typica* dominates the association with 65.3%, epifaunal and infaunal echinoids represent 2.9%, gastropods (*Pterodonta deffisi*, *Tylostoma globosum*, *T. cossoni*) 2.3%. Epifaunal elements (82.7%) dominate strongly, infaunal elements being exclusively represented by small, shallow infaunal heterodont bivalves and rare irregular echinoids. Concerning their feeding mode, all bivalves are suspension-feeders (95%). The feeding mode of the gastropods and echinoids is the same as that for these groups in the *Aphrodina dutrugei – Paraesa* sp. association. As in that association, *Neolobites vibrayeanus* is the only representative of the nekton. The species richness varies strongly (2-18; mean: 10.3). Because of the dominance of *Ilymatogyra* (*Afrogyra*) *africana* forma *typica* evenness is low (1.1-5.9; mean: 3.1).



Text-fig. 29. Trophic nucleus of the *Ilymatogyra* (*Afrogyra*) *africana* association. 1. *Afrogyra africana* forma *typica*, 2. *Aphrodina dutrugei*, 3. "*Dosinia*" *delettrei*, 4. *Trigonarca*? *diceras*, 5. *Schedotrapezium*? *acclivis*, 6. *Plicatula fourneli*, 7. *Ceratostreon flabellatum*, 8. *Costagyra olisiponensis*.

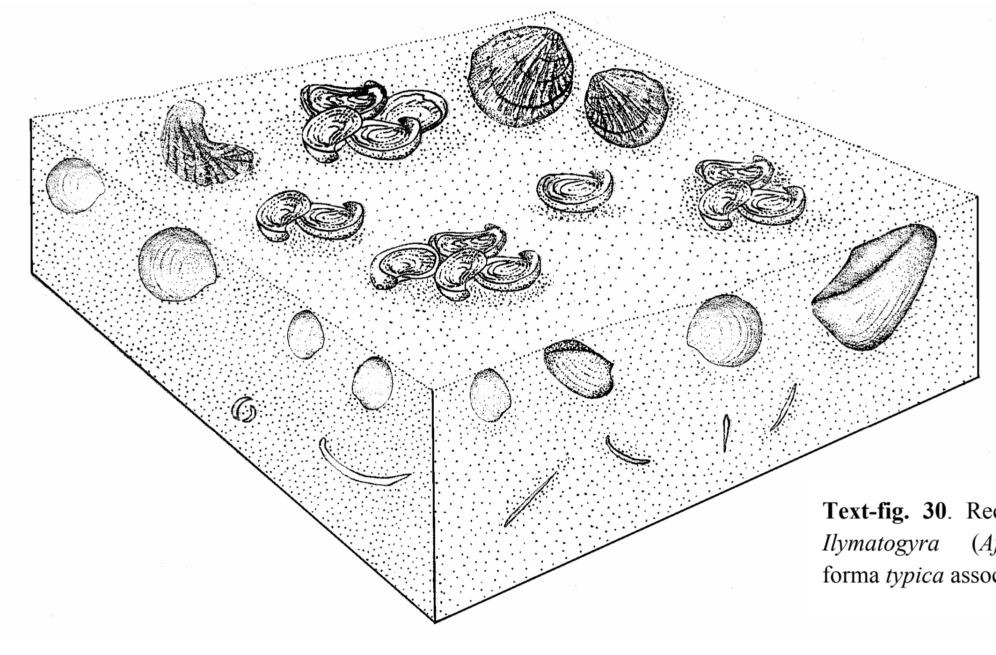
The preservation of the fauna is similar to that in the *Aphrodina dutrugei – Paraesa* sp. association. Infaunal bivalves and gastropods are preserved as double-valved internal moulds, whereas oysters and echinoids occur in shell preservation. The degree of fragmentation is very low. Oysters occur articulated and in situ as well as disarticulated. Some of them, especially *Exogyra olisiponensis*, exhibit drill holes of predatory gastropods.

The *Ilymatogyra* (*Afrogyra*) *africana* association was found in marly limestones and marls of the western sections (Dilagha, Ras en Naqb). The main difference to the *Aphrodina dutrugei – Paraesa* sp. association is the dominance of epifauna, mainly of *Ilymatogyra* (*Afrogyra*) *africana*, the lower number of species, the lack of large gastropods, and the more argillaceous nature of the sediment. Additionally, two rare epifaunal byssate bivalves were identified which were not found in the first association: *Plagiostoma* sp. and *Phelopteria* cf. *dalli*.

Discussion: All taxa of the trophic nucleus of the *Ilymatogyra* (*Afrogyra*) *africana* association are also present in the *Aphrodina dutrugei – Paraesa* sp. association. While in the latter the distribution of the single species is rather homogeneous, one species strongly dominates in the former. This dominance of *Ilymatogyra* (*Afrogyra*) *africana* "*typica*" might be due to the slightly higher clay content of the sediment. The substrate was slightly softer (as also suggested by the lack of large gastropods) than during times of deposition of the *Aphrodina dutrugei* – *Paraesa* sp. association, but stable enough to support free-living (*Ilymatogyra, Exogyra*), cementing (*Plicatula*,) and byssate (*Phelopteria*, *Plagiostoma*) epibenthos. The higher clay content possibly reflects an increased nutrient supply in the water column, which may have caused episodic depletion of oxygen in deeper layers of the substrate (as suggested by the dark colours of the sediment, few shallow infaunal elements and scarcity of deep infauna).

Stenohaline epifaunal and infaunal echinoids as well as rare ammonites document euhaline conditions. Additionally, shell size and thickness of oysters do not indicate salinity-controlled stress.

The depositional environment of the *Ilymatogyra* (*Afrogyra*) *africana* association was at or a little below the fair-weather wave base. Currents in connection with episodic storm events produced nearly monospecific well sorted oyster/*Plicatula* concentrations. They are a typical feature of the Cenomanian FHS Formation of the western sections.

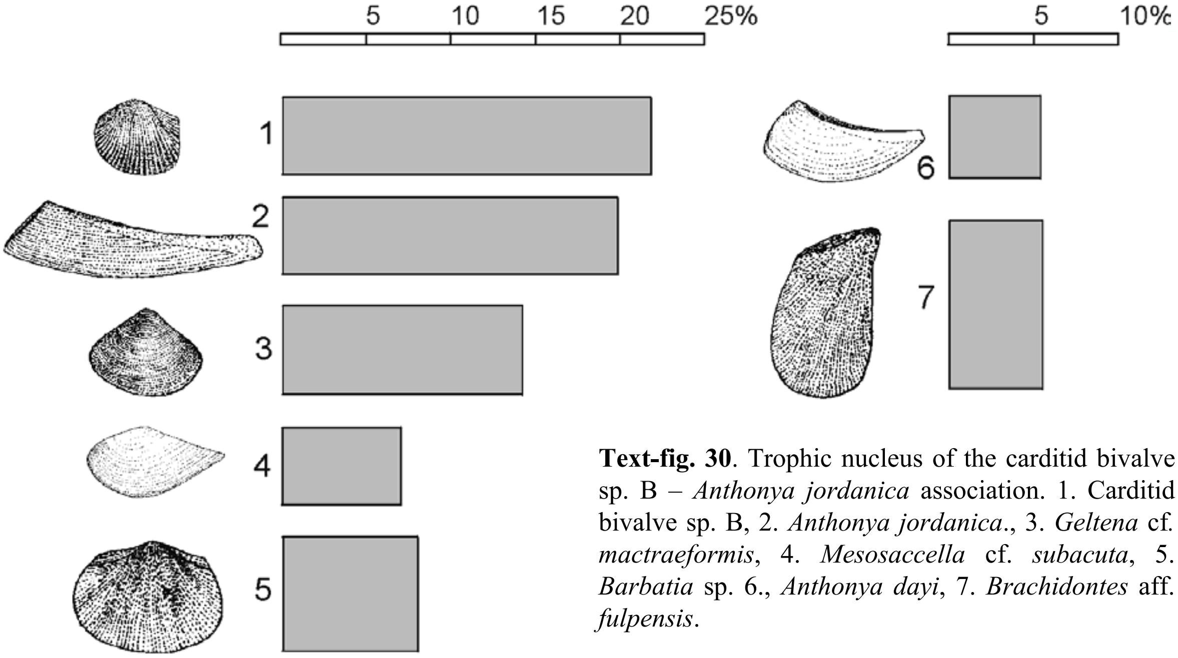


Text-fig. 30. Reconstruction of the *Ilymatogyra* (*Afrogyra*) *africana* forma *typica* association.

8.5.3 Euhaline associations of silty claystones and claystones

(D) Carditid bivalve sp. B – *Anthonya jordanica* association

This association is represented by four samples with 464 individuals and 25 species. The trophic nucleus consists of seven species, all of which are bivalves (carditid bivalve sp. B, 20.3%; *Anthonya jordanica*, 20.0%; *Geltena* cf. *mactraeformis* 14%; *Mesosaccella* sp., 7.9%; *Barbatia* sp., 7.1%; *Anthonya dayi*, 5.4%, and *Brachidontes* aff. *fulpensis*, 5.4%). Apart from very rare fragments of irregular echinoids (*Mecaster*) in sample J10-6, the benthic fauna consists exclusively of bivalves (97.1%) and gastropods (2.8%). In two samples (J7-2, J9-12) poorly preserved and compressed fragments of ammonites were found. The carditid bivalve sp. B – *Anthonya jordanica* association is strongly dominated by shallow infaunal elements (91.8%), most of which were suspension-feeders (87.5%). Deposit-feeding nuculids (*Nuculana*, *Mesosaccella*) and herbivorous/detritus-feeding gastropods account for 12.5%. All gastropods are trochiform and very small. Remarkably, deep infauna is totally absent. Microfossils are represented by abundant agglutinating foraminifera of the genus *Thomasinella*. Most probably, calcareous microfossils that one would expect in this environment were dissolved during diagenesis.



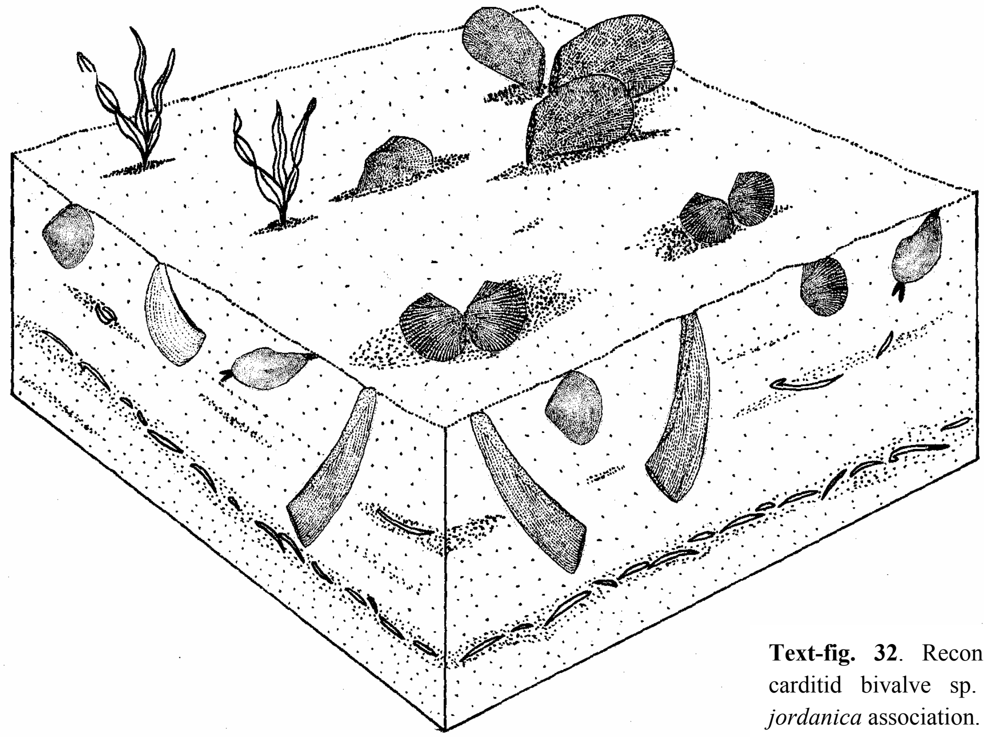
Text-fig. 30. Trophic nucleus of the carditid bivalve sp. B – *Anthonya jordanica* association. 1. Carditid bivalve sp. B, 2. *Anthonya jordanica*., 3. *Geltena* cf. *mactraeformis*, 4. *Mesosaccella* cf. *subacuta*, 5. *Barbatia* sp. 6., *Anthonya dayi*, 7. *Brachidontes* aff. *fulpensis*.

The association exhibits a moderate diversity, species richness varying between 6 and 12 (mean: 9.5) and evenness values between 3.3 and 5.4 (mean: 4.4). Bioturbation is very common in this association. Vertical and oblique sand-filled or pellet-filled burrows with diameters of about 1cm, *Thalassinoides* isp., and burrows of irregular echinoids could be recognised. Fragments of fossil wood were rarely observed. All elements of the carditid bivalve sp. B – *Anthonya jordanica* association are preserved as composite moulds. As hinges and other internal characteristics are not preserved, identification of most benthic organisms was possible only at the generic level. Most of the bivalves are disarticulated, single complete valves were found on bedding surfaces mostly in a convex-up position. Echinoids are without exception fragmented, occuring as plates 0.5-1 cm in diameter.

The association occurs exclusively in grey and yellowish, massive to faintly stratified claystones/silty claystones of the FHS and Harad formations in the middle part of the escarpment (sections 6, 7, 9, 10).

Discussion. The carditid bivalve sp. B – *Anthonya jordanica* association is the relic of a soft-bottom community. The very low percentage of epifauna with its small gastropods and occasional flat and thin-shelled *Camptonectes*, in contrast to the high percentage of infauna, indicates an at least temporarily soft, but not soupy substrate (the construction of burrows was possible). The dominance of shallow infaunal taxa was probably accentuated by currents that only reworked the upper sediment layers and concentrated such faunal elements on bedding planes. The deep infauna stayed in an autochthonous position while the shallow infauna, together with rare epifauna, was locally reworked (no size- and shape-sorting). In the course of local transport the valves became separated and arranged in the current-stable convex-up position. This implies that the carditid bivalve sp. B – *Anthonya jordanica* association is an impoverished parautochthonous association that secondarily became separated from its deep infauna. Another explanation for the absence of deep infaunal elements are reduced oxygen levels in deeper layers of the sediment. The presence of bioturbation that obliterated primary stratification makes the former explanation more plausible. Fragmentation of the echinoid tests may have been caused by predators and/or compaction.

Lithofacies, taphonomic and palaeontological data point to a low energy environment with occasional gentle currents. The sediments were deposited in a restricted part of the shallow shelf below the fair-weather wave base, most probably behind a sand-bar or a shoal. Storm waves slightly touched the seafloor. Burrowing echinoids indicate euhaline conditions.

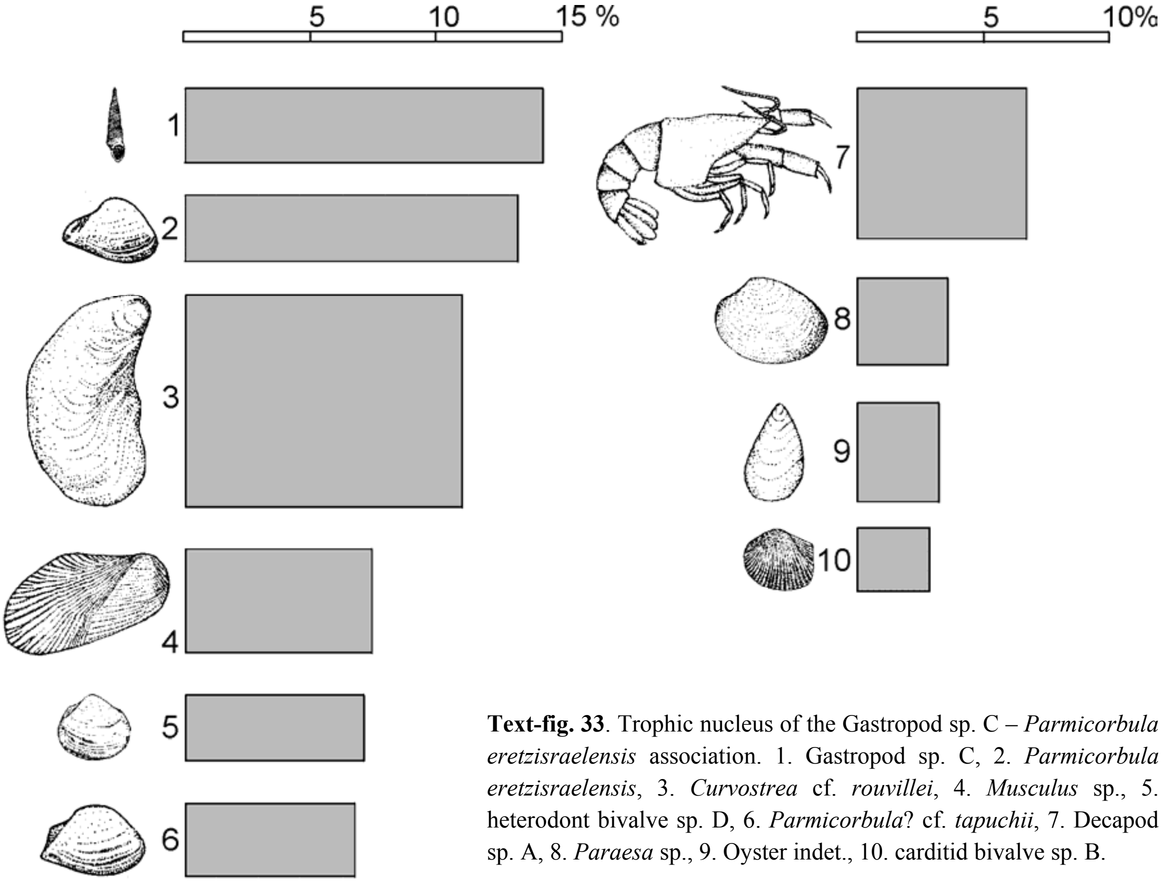


Text-fig. 32. Reconstruction of the carditid bivalve sp. B – *Anthonya jordanica* association.

(E) Gastropod sp. C – *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* association

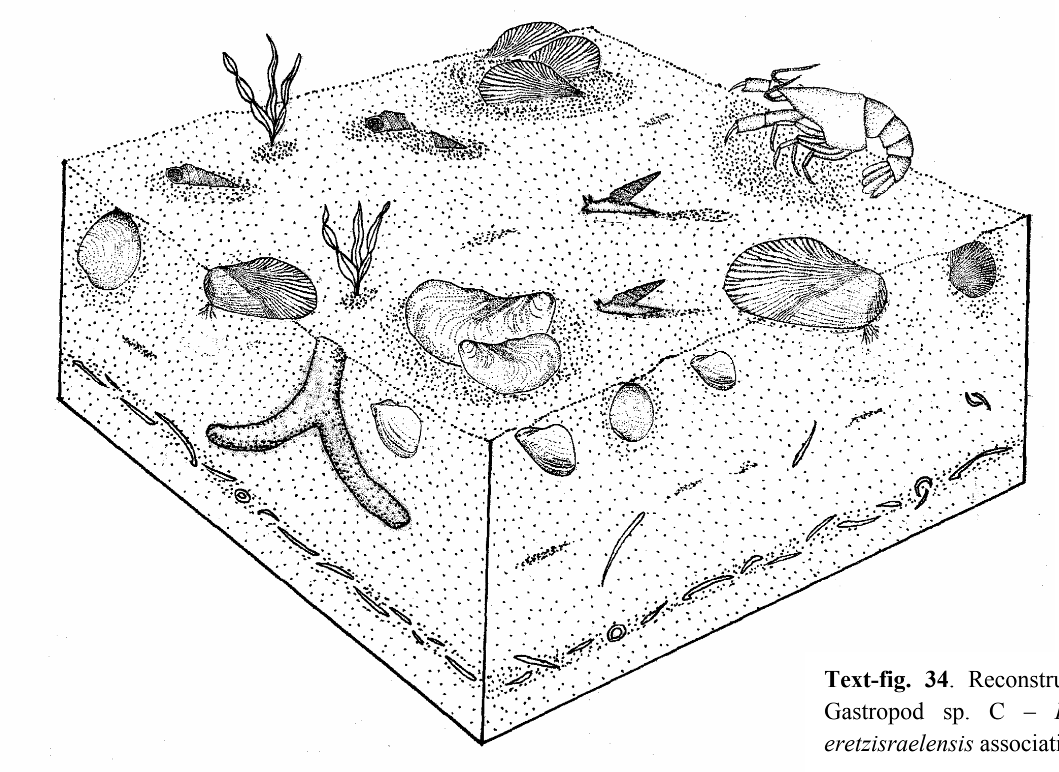
Four samples with 369 individuals representing 31 species have been grouped in this association. Dominant taxa are a small, high-trochiform gastropod (14.9%), the shallow infaunal suspension-feeding *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* (14.1%), and the epifaunal oyster *Curvostrea* cf. *rouvillei* (11.7%). Seven more species belong to the trophic nucleus: the shallow infaunal heterodont bivalve sp. D (10.3%), *Musculus* sp. (7.9%), *Parmicorbula*? cf. *tapuchii*, the glyphaeid decapod sp. A, *Paraesa* sp., and two more species of indeterminable bivalves. Infaunal elements are slightly more abundant (51.5%) than epifaunal (40.5%) and semi-infaunal (8%) ones. With respect to the feeding habits, suspension-feeders strongly prevail (76.7%). Two species of deposit-feeders occur: *Mesosaccella* cf. *subacuta* (2.2%) and the very rare infaunal echinoid *Mecaster* sp. (0.8%). Decapod sp. A and decapod sp. B most probably were scavengers/detritus-feeders. In contrast to the carditid bivalve sp. B – *Anthonya jordanica* association deep infauna is present in form of rare *Pholadomya vignesi*. Epifaunal oysters are represented by five species (*Ilymatogyra* (*Afrogyra*) *aficana*, *Curvostrea* cf. *rouvillei*, *Rhynchostreon* cf. *mermeti*, *Exogyra* (*Costagyra*) *olisiponensis* and oyster indet.) and reach 17.8%. Altogether, the benthic fauna of the gastropod sp. C – *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* association consists of 78.9% bivalves, 14.9% gastropods, 0.8% echinoids and 5.4% decapods. Rarely, some fragments of the compressed ammonite *Neolobites* sp. occur. Additionally, fish scales, shark teeth and bone fragments have been found.

Diversity values range between 7 and 15 (species richness) with a mean of 10.8 and 3.8-8.8 (evenness) with a mean of 5.7. The association is limited to light-grey/greenish grey claystone units of the Cenomanian FHS Formation. As in the carditid bivalve sp. B – *Anthonya jordanica* association all fossils occur as composite moulds. Shallow and deep infaunal bivalves as well as the decapods are compressed, but often articulated and in situ which indicates rapid burial.



Text-fig. 33. Trophic nucleus of the Gastropod sp. C – *Parmicorbula eretzisraelensis* association. 1. Gastropod sp. C, 2. *Parmicorbula eretzisraelensis*, 3. *Curvostrea* cf. *rouvillei*, 4. *Musculus* sp., 5. heterodont bivalve sp. D, 6. *Parmicorbula*? cf. *tapuchii*, 7. Decapod sp. A, 8. *Paraesa* sp., 9. Oyster indet., 10. carditid bivalve sp. B.

Discussion. As in the case of the carditid bivalve sp. B – *Anthonya jordanica* association a soft bottom fauna is documented. The percentage of epifauna is distinctly higher than in the former, but this epifauna consists mostly of small, trochiform gastropods which might have been adapted to softgrounds. Free-living oysters followed the iceberg strategy. The substrate was soft, but not soupy, indicated by many decapods and their burrows. Maybe the seafloor was stabilised by algal or microbial mats (this would explain the large number of gastropods). In contrast to the carditid bivalve sp. B – *Anthonya jordanica* association, the gastropod sp. C – *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* association represents an autochthonous community relic, although time-averaging probably played some role. Most probably, the environmental parameters changed several times from euhaline to brackish. Brackish conditions are indicated by layers with corbulids, nuculids and decapods, euhaline conditions by echinoids, ammonites and deep infaunal bivalves. Shell layers of disarticulated shallow infaunal bivalves (corbulids and nuculids) occur as in the carditid bivalve sp. B – *Anthonya jordanica* association. They are found in silt layers within the clay units. They point to occasional increased currents at the sea floor. The environment was very similar to the one of the carditid bivalve sp. B – *Anthonya jordanica* association. Most probably it was far more restricted or deeper, well below the fair-weather wave base (smaller grain size).



Text-fig. 34. Reconstruction of the Gastropod sp. C – *Parmicorbula eretzisraelensis* association.

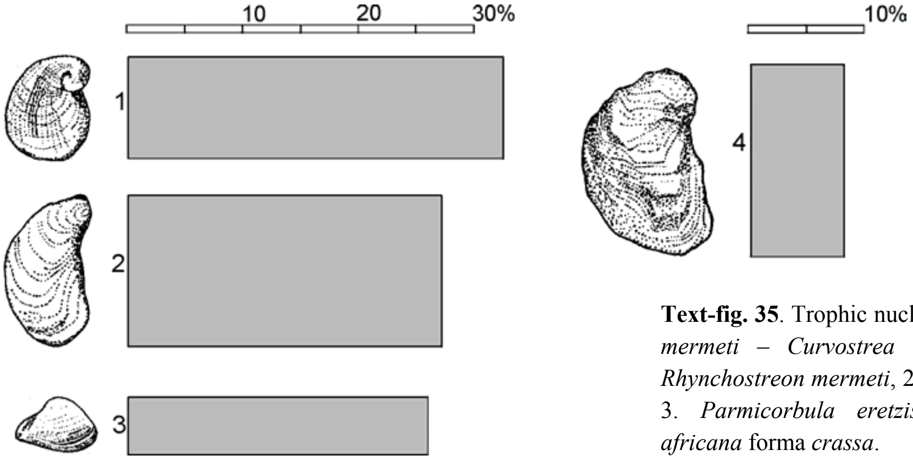
(F) *Rhynchostreon mermeti – Curvostrea* cf. *rouvillei* association

Represented by three samples and 149 individuals, the *Rynchostreon mermeti – Curvostrea* cf. *rouvillei* association consists of six species, four of which (*Rhynchostreon mermeti*, *Curvostrea* cf. *rouvillei*, *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* and *Ilymatogyra* (*Afrogyra*) *africana*) belong to the trophic nucleus. The other two species are *Parmicorbula*? cf. *tapuchii* and *Paraesa* sp.. All benthic taxa of this association are bivalves. Epifaunal oysters represent 63%, shallow infaunal bivalves (corbulids, *Paraesa*) 37%. Deep infauna and stenohaline organisms as well as microfossils are totally absent. Concerning their feeding mode, all benthic elements of this association are suspension-feeders.

The sediment is moderately bioturbated. Additionally, fragments of decapod crustaceans and fish scales were found.

Species richness is low (3-4; mean: 3.7), as is evenness (2.8-3.6; mean: 3.3). Oysters occur in growth position and with shell preservation. Infaunal bivalves are preserved as composite moulds. All three samples were found in the Cenomanian FHS Formation of section 11.

Discussion. The low diversity values, especially the low evenness, probably indicate certain stress conditions. In the case of the *Rynchostreon mermeti – Curvostrea* cf. *rouvillei* association, reduced salinity is rather unlikely because of the sequence stratigraphic context. The three samples forming the *Rynchostreon mermeti – Curvostrea* cf. *rouvillei* association are found in sediments of the maximum flooding zone, or at least in early highstand sediments of the Upper Cenomanian of section 6. The lack of stenohaline taxa may be due to selective preservation or sample size effects. The thick-shelled oysters also indicate lack of salinity-induced environmental stress. The substrate was, compared to that of the carditid bivalve sp. B – *Anthonya jordanica* and gastropod sp. C – *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* associations, coarser and more stable. Concentrations of oyster shells point to several storm events. The depositional environment was most likely a deeper part of the shelf between the fair-weather and the storm wave base.



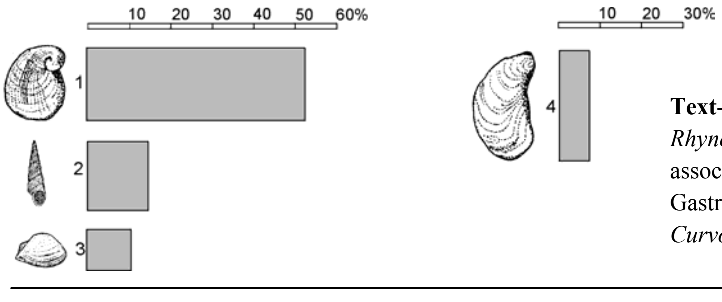
Text-fig. 35. Trophic nucleus of the *Rhynchostreon mermeti* – *Curvostrea rouvillei* association. 1. *Rhynchostreon mermeti*, 2. *Curvostrea* cf. *rouvillei*, 3. *Parmicorbula eretzisraelensis*, 4. *Afrogyra africana* forma *crassa*.

8.5.4 Brachyhaline associations of siltstones/sandy claystones/silty claystones

(G) *Rhynchostreon mermeti* – gastropod sp. C association

This association is represented by 216 individuals in three samples. The trophic nucleus consists of two epifaunal free-living oysters, *Rhynchostreon mermeti* (52.8%) and *Curvostrea* cf. *rouvillei* (7.8%), a small gastropod (14.4%) and the shallow infaunal bivalve *Parmicorbula*? cf. *tapuchii* (10.1%). Bivalves (83.7%) strongly dominate over gastropods (16.3%). Other benthic groups are absent. Epifaunal elements (81.5%) are distinctly more abundant than infaunal ones (18%). For *Nemodon* (*Pleurogrammatodon*) sp. (0.5%) a semi-infaunal mode of life is assumed. Suspension-feeding bivalves form the bulk of the fauna (83.3%), whereas deposit-/detritus-feeders are comparatively rare. Deep infauna has not been recorded, shallow infauna is rare and small-sized (*Mesosaccella*, *Anthonya*, *Parmicorbula*? cf. *tapuchii*, *Parmicorbula eretzisraelensis*). Non-benthic fossils are bone fragments, shark teeth (*Carcharoides* sp.) and rarely coalified wood. Ichnofossils are represented by *Rhizocorallium* isp.. In some layers, pyrite crystals occur.

The association exhibits a low diversity, caused by the dominance of *Rhynchostreon mermeti*. Species richness varies between 4 and 8 (mean: 5.3) and evenness values between 1.9 and 3.3 (mean: 2.5). The *Rhynchostreon mermeti* – gastropod sp. C association occurs in strongly bioturbated sandy or silty claystones, which alternate with sandstone layers, in the Cenomanian FHS and Harad formations in eastern parts of the escarpment. All shelly fauna is preserved as



Text-fig. 36. Trophic nucleus of the *Rhynchostreon mermeti* – Gastropod sp. C association. 1. *Rhynchostreon mermeti*, 2. Gastropod sp. C, 3. *Parmicorbula*? cf. *tapuchii*, 4. *Curvostrea* cf. *rouvillei*.

composite moulds.

Discussion. The low species richness, combined with the dominance of a single taxon, indicates environmental stress conditions. In contrast to the *Rynchostreon mermeti – Curvostrea* cf. *rouvillei* association, reduced salinity is most likely the main reason for this faunal distribution. Stenohaline species are absent. Additionally, the sedimentological context points to rapid changes in sedimentation: Repeatedly, the populations settling on a silty-argillaceous substrate were covered by coarser layers of sand which were incised into the finer material.

The opportunistic *Rhynchostreon mermeti* – gastropod sp. association consists mainly of free-living oysters and small trochiform gastropods, which indicate a somewhat soft substrate. Sand-filled *Rhizocorallium* burrows were produced in the overlying sand units and reached down into clays below.

Pyrite crystals in the claystones as well as the lack of deep infauna possibly point to a reduced oxygen content in deeper layers of the sediment. The depositional environment was similar to that of the *Rynchostreon mermeti – Curvostrea* cf. *rouvillei* association, but probably more variable. The sand units accumulated at times of higher water energy, for example, during storm events.

(H) *Brachidontes* sp. – *Parmicorbula*? cf. *tapuchii* association

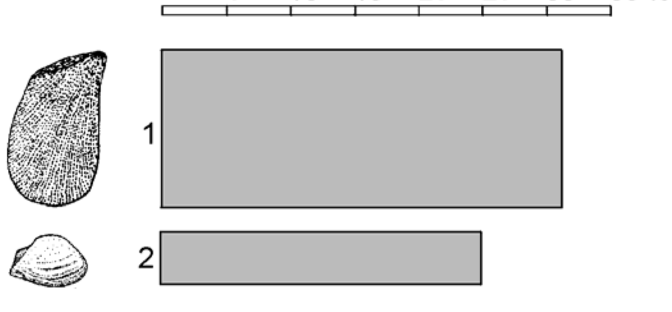
This association has been defined on the basis of two samples and 111 individuals. The epifaunal *Brachidontes* aff. *fulpensis* (32.4%) is the most abundant faunal element, followed by the shallow infaunal bivalve *Parmicorbula*? cf. *tapuchii* (25.2%), the inarticulate brachiopod *Lingula* sp. (16.2%), and an unidentifiable shallow infaunal heterodont bivalve (9.9%).

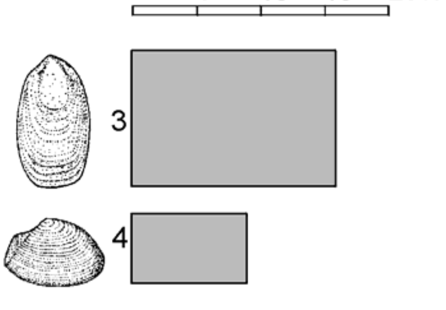
Altogether, eight species occur in the *Brachidontes* aff. *fulpensis* –*Parmicorbula*? cf. *tapuchii* association, among them the deep infaunal bivalve *Cercomya*? *jettei* (7.2%) and the crustacean decapod sp. B (4.5%). Additionally, plant fragments and fish scales have been found.

The association is dominated by infaunal organisms (67.6%), an exception is the epibyssate *Brachidontes*. With respect to the feeding habits, suspension-feeders prevail strongly (95.5%).

The absence of gastropods might be due to sample-size effects (see also the rarefaction plots), especially in this case, where sample sizes are comparatively small.

The *Brachidontes* aff. *fulpensis* –*Parmicorbula*? cf. *tapuchii* association exhibits a fairly low diversity, species richness varying between 4 and 5 (mean: 4.5) and evenness values between 2.6 and 3.6 (mean: 3.1). It was found in slightly bioturbated, greyish and yellowish clayey siltstones of the Cenomanian FHS Formation of sections 1 and 4. Bivalves occur as composite moulds, *Lingula* sp. sometimes occurs in shell preservation. Shells of benthic elements are occasionally disarticulated, but mostly not fragmented. Corbulids were found as single valves on bedding planes, some deep infaunal *Cercomya*? *jettei* are articulated and preserved in butterfly position.

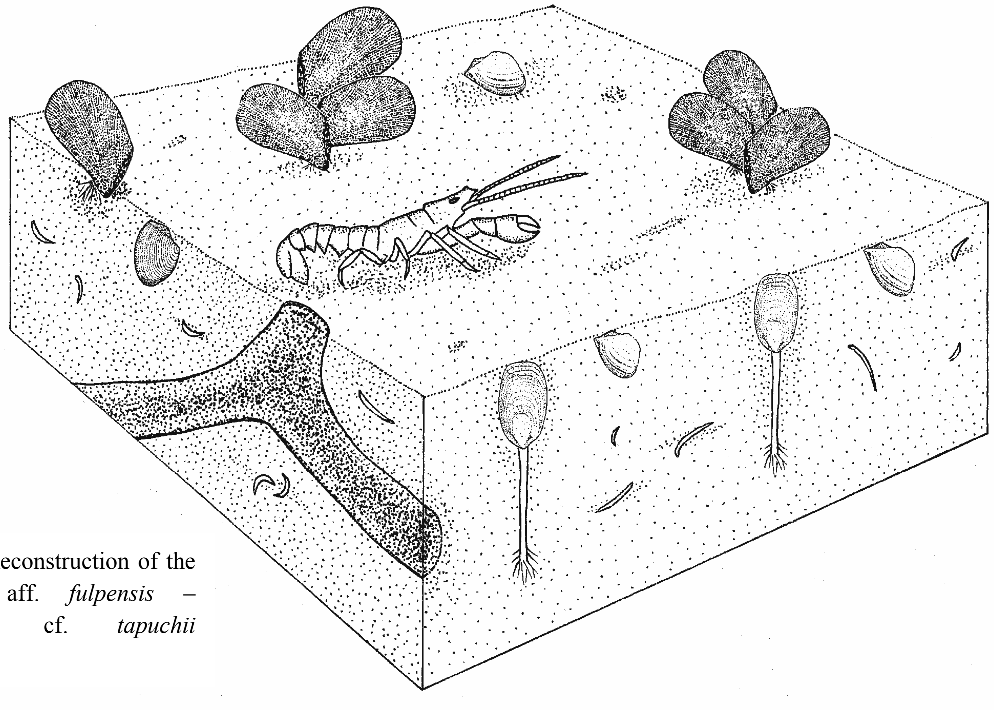




Text-fig. 37. Trophic nucleus of the *Brachidontes* aff. *fulpensis* – *Parmicorbula* cf. *tapuchii* association. 1. *Brachidontes* aff. *fulpensis*, 2. *Parmicorbula*? cf. *tapuchii*, 3. *Lingula* sp., 4. heterodont bivalve sp. E.

Discussion: The *Brachidontes* aff. *fulpensis – Parmicorbula*? cf. *tapuchii* association represents the relic of a brackish community. It exhibits very low diversity values, especially with respect to species richness. The presence of *Lingula* among small corbulids and *Brachidontes* points to reduced salinity values which most probably were below the values of the associations discussed earlier on. Except for ?*Cercomya*, whose ecologic range is unknown, all genera of the *Brachidontes* aff. *fulpensis* –*Parmicorbula*? cf. *tapuchii* association are known from brackish environments (e.g. FÜRSICH & KIRKLAND, 1986). Again, small shallow infauna as well as the silty sediment indicate a somewhat soft substrate, which was, however, more stable than in the gastropod sp. – *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* and *Rhynchostreon mermeti* – gastropod sp. C associations (coarser sediment, bioturbation, presence of decapods).

The most likely environment was a brackish lagoon.



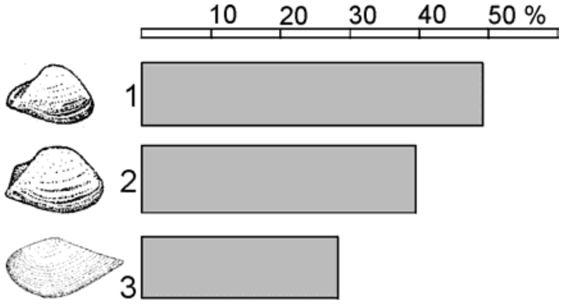
Text-fig. 38. Reconstruction of the *Brachidontes* aff. *fulpensis* – *Parmicorbula*? cf. *tapuchii* association.

(I) *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* – *Parmicorbula*? cf. *tapuchii* association

This association is represented by 346 individuals in six samples. The trophic nucleus consists of three species of shallow infaunal bivalves, *Parmicorbula eretzisraelensis* (49.4%), *Parmicorbula*? cf. *tapuchii* (28.6%), and *Mesosaccella* cf. *subacuta* (5.2%). Bivalves represent 99.7% of the association, only a single specimen of a trochiform gastropod has been found. Shallow infaunal bivalves form the bulk of the fauna (94.2%), epifaunal oysters represent 4.9%. *Inoperna* sp. is the only semi-infaunal species. The *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* - *Parmicorbula*? cf. *tapuchii* association is strongly dominated by suspension-feeders (94.6%), deposit-/detritus-feeders are represented by *Mesosaccella* cf. *subacuta* and gastropod sp. (0.3%). Rare decapod fragments and relicts of pellet-filled burrows also occur.

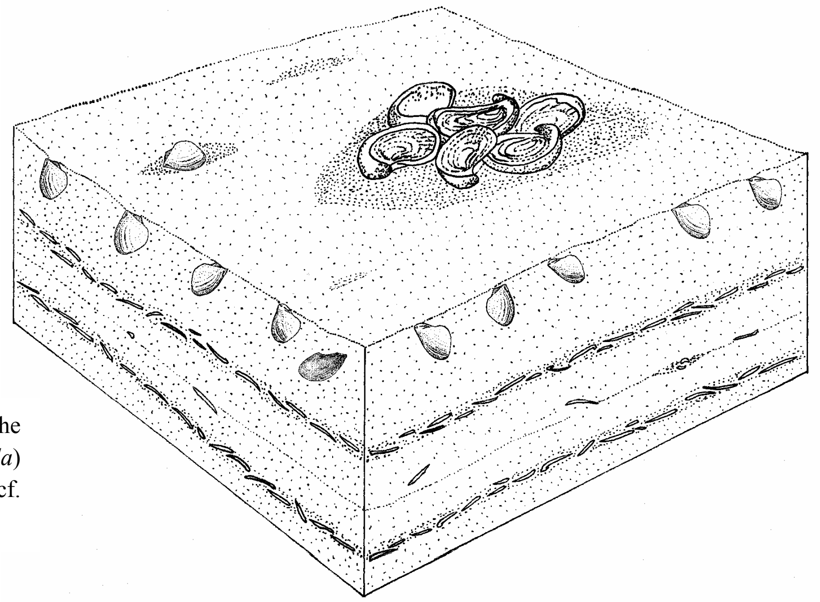
Diversity values are rather low, species richness varying from 3 to 8 (mean: 4.3), evenness from 1.8 to 4.2 (mean: 2.8).

The association was found in moderately bioturbated, greyish claystones of the lower and middle part of the Cenomanian FHS Formation of sections 1, 11, 12 and 4.



Text-fig. 39. Trophic nucleus of the *Parmicorbula* (*Caestocorbula*) *eretzisraelensis – Parmicorbula*? cf. *tapuchii* association. 1. *Parmicorbula eretzisraelensis,* 2. *Parmicorbula*? cf. *tapuchii,* 3. *Mesosaccella* cf. *subacuta.*

Discussion. The *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* - *Parmicorbula*? cf. *tapuchii* association represents a brackish water soft bottom community. Low diversity values indicate environmental stress conditions, in this case a soft substrate combined with reduced salinity values. The dominance of small, shallow infaunal taxa and the rare occurrence of only one species of epifaunal oyster (*Rhynchostreon mermeti*) support this assumption. Abundant plant debris points to a position not too far from the shore.



Text-fig. 40. Reconstruction of the *Parmicorbula* (*Caestocorbula*) *eretzisraelensis – Parmicorbula*? cf. *tapuchii* association.

8.6 Assemblages

(K) *Eomiodon* cf. *libanoticus* assemblage

Represented by only one sample with 130 individuals, the *Eomiodon* cf. *libanoticus* assemblage consists of 11 species, four of which (*Eomiodon* cf. *libanoticus*, *Paraesa* sp., "*Turritella*" *amotzi*, *Pholadomya vignesi*) belong to the trophic nucleus. The small, astarte-like, shallow infaunal *Eomiodon* dominates this assemblage with 57.7%, *Paraesa* sp. represents 8.4%, the small turritellid gastropod sp. C 7.7% and the deep infaunal *Pholadomya vignesi* 6.2%. The assemblage consists of 86.2% bivalves, 97.7% of which are infaunal, and 13.8% gastropods, all of which were most probably epifaunal. Altogether, the number of shallow infauna reaches 77.6%, deep infauna is represented by 6.2%, epifauna by 16.2% of the individuals. Concerning their feeding mode, all bivalves except *Mesosaccella* cf. *subacuta* (2.3%), which was a deposit-feeder, are suspension-feeders. All gastropods are very small and turriform. Most likely, they were substrate/deposit-feeders.

The very rare nekton is limited to mostly fragmented, compressed shells of *Neolobites* sp. and some tiny bone fragments and fish scales.

The *Eomiodon* cf. *libanoticus* assemblage was found in about four metres of claystone of the lower FHS Formation of section 1. All benthic species, even oysters, are preserved without their primary shell. Calcareous microfauna is absent in this layer, sieving the sediment yielded small pyritized plant and wood fragments.

Bioturbation is rare and limited to small, horizontal and oblique, pellet-filled burrows, 0.5 cm in diameter, which most likely were produced by decapod crustaceans. These decapods were not included into the cluster analysis, because they were only found as unidentifiable remains.

The distribution of the fauna in the claystone is irregular. There are thick parts with relatively homogeneously distributed benthic fauna partly still in growth position (*Corbula*, *Nuculana*, several individuals of *Eomiodon*). THey alternate with thin layers of shell concentrations consisting mainly of disarticulated, but not fragmented valves of *Eomiodon* and other small infaunal species. Indicators of full marine conditions such as *Pholadomya* and *Neolobites* are very rare.

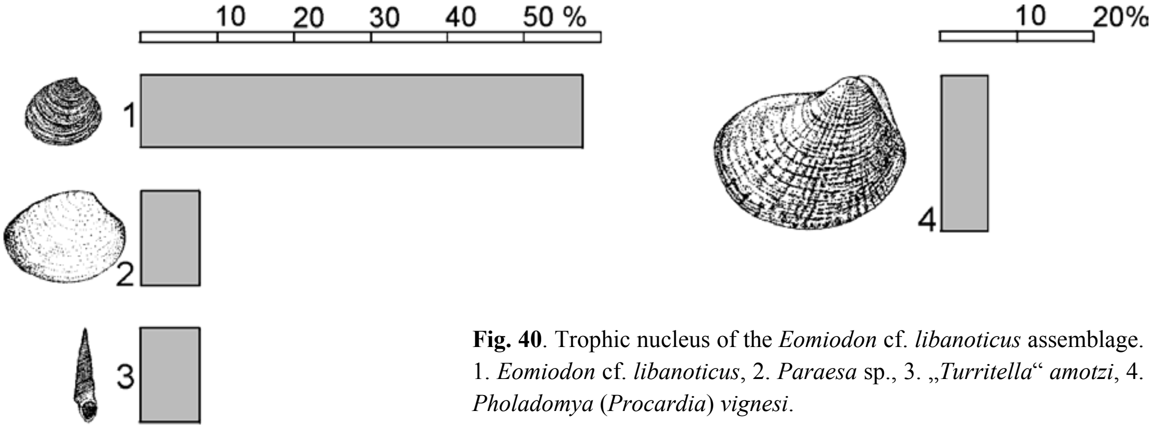


Fig. 40. Trophic nucleus of the *Eomiodon* cf. *libanoticus* assemblage. 1. *Eomiodon* cf. *libanoticus*, 2. *Paraesa* sp., 3. „*Turritella*“ *amotzi*, 4. *Pholadomya* (*Procardia*) *vignesi*.

Discussion. The environment of the *Eomiodon* cf. *libanoticus* assemblage was strongly influenced by salinity and substrate as limiting factors. Compared to the brackish soft bottom communities of the *Brachidontes* aff. *fulpensis* – *Parmicorbula*? cf. *tapuchii* and the *Parmicorbula eretzisraelensis* – *Parmicorbula*? cf. *tapuchii* association, the stability of the substrate was most likely the dominating ecological parameter. Indications of a soft substrate are mainly the restricted size of nearly all benthic species, especially of the epibenthos. Tiny individuals of the turriform "*Turritella*" *amotzi* and gastropod sp. C, as well as the small-sized oyster *Rhynchostreon mermeti* point to very soft substrate (e.g., WERNER 1986). The very small grain size of the sediment supports this assumption. Additionally, the dominance of *Eomiodon* cf. *libanoticus* among the small-sized infauna such as *Parmicorbula*? cf. *tapuchii* and *Protocardia judaica*, points to reduced salinity (see also BÖTTCHER, 1982). But the influence of fresh water from the mainland was not as high as in *Brachidontes* aff. *fulpensis* – *Parmicorbula*? cf. *tapuchii* association or in the *Crassostrea* sp. – decapod sp. B assemblage, which is indicated by the occurrence of *Paraesa* sp. and *Pholadomya vignesi* and the palaeogeographic setting. Section 1 was located about 30km from the coastline during the deposition of the claystones of the *Eomiodon* cf. *libanoticus* assemblage.

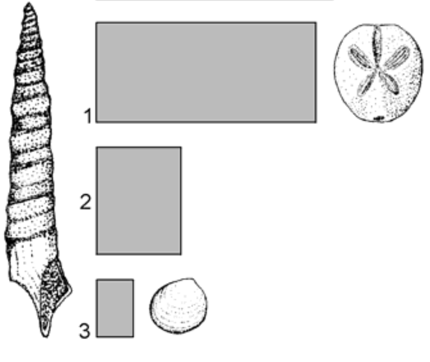
The fine-grained sediment is most probably also responsible for a temporarily reduced oxygen content in deeper layers of the sea floor indicated by small, pyritized wood fragments. The rare occurrence of bioturbation and scarcity deep infauna is due to the unstable substrate and at least partly to lowered oxygen conditions.

The environment of the *Eomiodon* cf. *libanoticus* assemblage was characterised by low water energy, a most of the time very soft substrate, slightly reduced salinity, and temporary reduced oxygen conditions in the sediment. Times of higher water energy such as storm events are represented by shell concentrations of shallow infauna. Storm events might also have swept shells of ammonites into this slightly brackish lagoon, but most probably ammonites and deep infaunal bivalves document short euhaline episodes. Altogether, this assemblage exhibits distinct signs of time-averaging. The water depth was most probably fairly shallow. The assemblage was found in the lower part of the transgressive phase of the Upper Cenomanian (*Neolobites*) sequence, above well developed lowstand deposits.

(L) *Mecaster* cf. *batnensis* – *Nerinea pauli* assemblage

This assemblage includes 9 species with 71 individuals. The infaunal echinoid *Mecaster* cf. *batnensis* (56.3%) is the most abundant faunal element, followed by the large, most probably semi-infaunal gastropod *Nerinea pauli* (21.1%) and an unidentifiable shallow infaunal heterodont bivalve (sp. B, 9.8%). Altogether, epifaunal and infaunal echinoids (*Mecaster* cf. *batnensis*, *Micropedina olisiponensis*, *Tetragramma variolare*) represent 60.5%, gastropods 25.5%, and bivalves 14% of the fauna. The assemblage is strongly dominated by infaunal organisms (71.7%). All infaunal taxa were shallow burrowers. The only epifaunal bivalve is the free-living oyster *Afrogyra africana*. With respect to the feeding habits, deposit/substrate feeders prevail strongly (85.5%).

The *Mecaster* cf. *batnensis* – *Nerinea pauli* assemblage was found in moderately bioturbated marls of the lower FHS Formation of section 18 (Dilagha). All echinoids occur in shell preservation, gastropods and infaunal bivalves as internal moulds, the large tests of *Nerinea pauli* invariably occur as broken pieces of 2-5cm length. *Afrogyra africana* represents the only bivalve with shell preservation. The dominance of echinoids and the low number of species and individuals of bivalves can be explained by selective dissolution of shell material and sample size effects. Tests of echinoids and oysters consist of high Mg-Calcite which is more stable than the aragonitic shell of gastropods, ammonites and infaunal bivalves. They therefore have a higher preservation potential. Thus the strong dominance of *Mecaster* cf. *batnensis* is thought to be an artefact. Still, some palaeoecological conclusions can be drawn, even though the original composition of species has been distorted.



Text-fig. 42. Trophic nucleus of the *Mecaster* cf. *batnensis* – *Nerinea pauli* association. 1. *Mecaster* cf. *batnensis*, 2. *Nerinea pauli*, 3. heterodont bivalve sp. B.

Discussion. At the time of deposition of the marls of the *Mecaster* cf. *batnensis* – *Nerinea pauli* assemblage section 18 was located relatively far from the shoreline. A slight siliciclastic input can be recognised by the clay content of the sediment. The underlying limestones with their rich fauna of the *Aphrodina dutrugei* – *Paraesa* sp. association represent euhaline conditions with a low degree of environmental stress. With increasing clay content the substrate became softer, which influenced at least partially the distribution of the epifauna. Nevertheless, this alone can not explain such a decrease in the number of species. The species composition of this assemblage is rather untypical. Infaunal echinoids (56.2%) and rare reclining oysters point to a somewhat soft substrate, which is also indicated by the marly sediment. In contrast, the large epifaunal gastropods (*Pterodonta deffisi*) needed a somewhat stable sea floor. Euhaline conditions are documented by the high abundance of echinoids. In an environment with fully marine conditions and a normal consistency of the substrate (no hard- or soupground), a high variety of species would be expected. However, there are only nine species. The low number of species and the untypical distribution of macrobenthic groups suggest that selective shell dissolution in conjunction with sample size effects affected this assemblage. The distribution of the different feeding-modes supports this statement. The fact that substrate/deposit feeders account for 85.8% of the fauna might point to food supply as a limiting factor. However, in euhaline systems such a high rate of deposit-feeders is very untypical. Increased terrestrial input, as indicated by the more argillaceous nature of the sediment, could explain higher amounts of organic debris in the substrate and therefore an increasing deposit-feeding infauna, but it can not explain the very low rate of suspension-feeders.

The *Mecaster* cf. *batnensis* – *Nerinea pauli* assemblage is interpreted to represent euhaline conditions in a deeper or restricted part of the shallow shelf.

(M) *Crassostrea* sp. - decapod sp. B assemblage

This assemblage is represented by only three species and 51 individuals. *Crassostrea* sp. (52.9%) which is relatively variable in shape, and the crustacean decapod sp. B. (27.5%) belong to the trophic nucleus. Additionally, another epifaunal oyster (*Curvostrea* cf. *rouvillei*, 19.6%) occurs. The oysters (72.5%) were epifaunal, most probably reclining. The decapod sp. B is thought to have been infaunal most of the time, but it could also leave its burrow. Concerning feeding habit, the oysters represent suspension-feeders, the decapods detritus-feeders/scavengers.

The *Crassostrea* sp. - decapod sp. B assemblage was found in a 40 cm thick greyish yellow to reddish yellow clayey siltstone with scattered sand grains. Small unidentifiable gastropods and vertebrate remains occur as accessory elements. The siltstones are moderately bioturbated.

All oysters are preserved as internal moulds and disarticulated. Decapods are compressed, often articulated, occasionally fragmented. The fauna depicts the relic of an autochthonous, maybe parautochthonous community. Currents are indicated by the disarticulated oyster shells.

Discussion. This assemblage represents the relic of a brachyhaline community. Very low diversity and the absence of stenohaline taxa point to a relatively high degree of environmental stress caused by reduced salinity, thought to be the most important ecological parameter controlling the faunal distribution. The sediment consists of impure silts, which facilitated the construction of burrows by the decapod sp. B. In contrast to other brackish communities (e.g., the *Parmicorbula eretzisraelensis* – *Parmicorbula*? cf. *tapuchii* association), the substrate consistency was not too soft. Selective dissolution of shell material might play a certain role to explain the low diversity, but sample size effects can be excluded because the siltstone layer was sampled extensively.

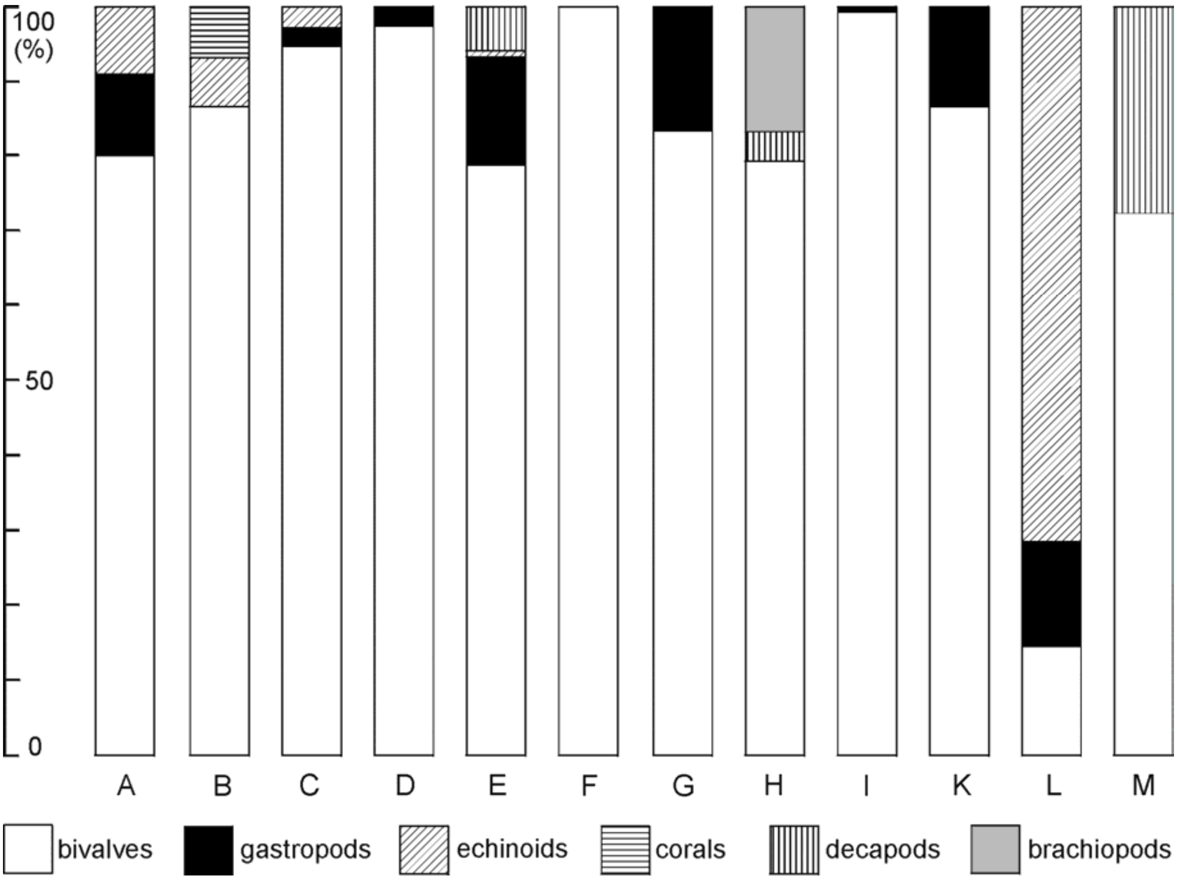
Faunal composition and the sediment point to an estuary or a shallow part of a brackish lagoon as depositional environment.

8.7 Comparative analysis of associations and assemblages

8.7.1 Faunal composition

Text-fig. 43 shows the distribution of the different macrobenthic groups in the associations and assemblages. Nearly all of the community relics of the southern Jordan Ajlun Group are strongly dominated by bivalves. The dominance of echinoids in assemblage II is thought to be due to selective preservation and sample size effects (see also 7.4). Gastropods are only minor elements except in associations A, E, and G where they account for 12.3 to 16.3%. In the *Eomiodon* cf. *libanoticus* assemblage gastropods reach 13.8%. The high percentage of gastropods in the *Mecaster* cf. *batnensis* assemblage is thought to be an artefact. Echinoids only occur in four associations and one assemblage. They are mostly limited to limestones and marls, only in association E fragments of infaunal echinoids were found in siliciclastic sediments. Stenohaline, articulate brachiopods are totally absent in all sections. *Lingula* sp. is the only representative of the brachiopods. Corals only occur in one association (C). Decapod crustaceans were found subordinately in two associations (E, H) In one assemblage they reach 27.5%.

Altogether, the abundance of strictly stenohaline groups such as echinoids and corals decreases to the east. This trend is also depicted by the ammonites. They occur mostly in sections 1-5, only during the sea level highstand of the Wadi Juhra Member and the Lower Upper Cenomanian they advanced far to the east (section 7 and section 9, respectively).



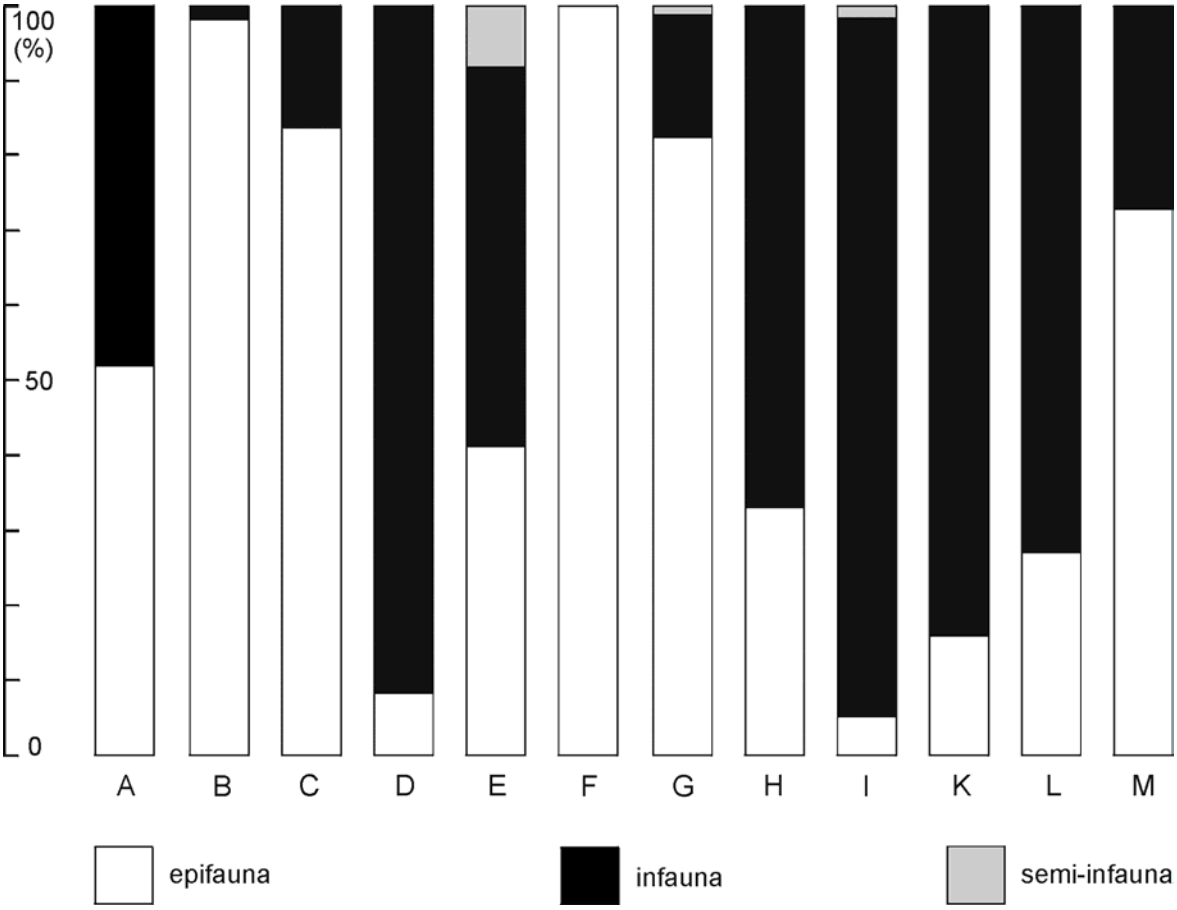
Text-fig. 43. Distribution of macrobenthic groups in the associations and assemblages. A = *Aphrodina dutrugei* – *Paraesa* sp, B = *Exogyra olisiponensis* – *Ilymatogyra africana*, C = *Ilymatogyra africana*, D = carditid bivalve sp. B – *Anthonya jordanica*, E = gastropod sp. C – *Parmicorbula eretzisraelensis*, F = *Rhynchostreon mermeti* – *Curvostrea* cf. *rouvillei*, G = *Rhynchostreon mermeti* – gastropod sp. C, H = *Brachidontes* aff. *fulpensis* – *Parmicorbula*? cf. *tapuchii*, I = *Parmicorbula eretzisraelensis* – *Parmicorbula*? cf. *tapuchii*, K = *Eomiodon* cf. *libanoticus*, L = *Mecaster* cf. *batnensis* – *Nerinea pauli*, M = *Crassostrea* sp. – decapod sp. B.

8.7.2 Life habits

The distribution of epifauna, infauna, and semi-infauna is documented in Text-fig. 44. The autecological data for each taxon can be found in chapter 7.6. Four associations are dominated by epifaunal elements and four by infauna. In the *Aphrodina dutrugei – Paraesa* sp. association epifauna and infauna are nearly equally abundant. Main components of the epifauna are reclining and cementing oysters, pectinid and plicatulid bivalves, most of the gastropods, regular echinoids and corals. The infauna is dominated by bivalves and irregular echinoids.

Most of the infauna is represented by shallow infaunal organisms. A deep infaunal mode of life is assumed for the relatively rare members of the Pholadomyidae, which occur in appreciable numbers only in one association in the north-western study area.

Epifauna is more abundant in calcareous substrates (limestones and marls; associations A, B, C) than in the fine-grained siliciclastics of the marginal marine environments. In contrast, these siliciclastic soft bottom communities (D, E, H, I) are dominated by shallow infauna. Exceptions are the oyster-rich associations F and G, which both occur in silty to sandy claystones. The high percentage of epifauna (oysters) might reflect a slightly higher stability of the substrate, but is thought to be enhanced by selective preservation leading to a concentration of thick calcitic organisms. The fact that no calcareous microfauna was found in the claystones, as well as the preservation of infauna as composite moulds in the siliciclastic sediments supports the assumption that calcareous material was dissolved during diagenesis. In the case of impure (silty-sandy) claystones a dissolution of thin-shelled infauna is more likely than in pure claystones with a very low porosity (see also chapter 7.4). For the *Crassostrea* sp. – Decapod sp. B assemblage similar processes are likely to have operated. Here, infauna reaches only 27.5%. Even the shells of oysters have been dissolved in this assemblage so that they are preserved only as imprints.

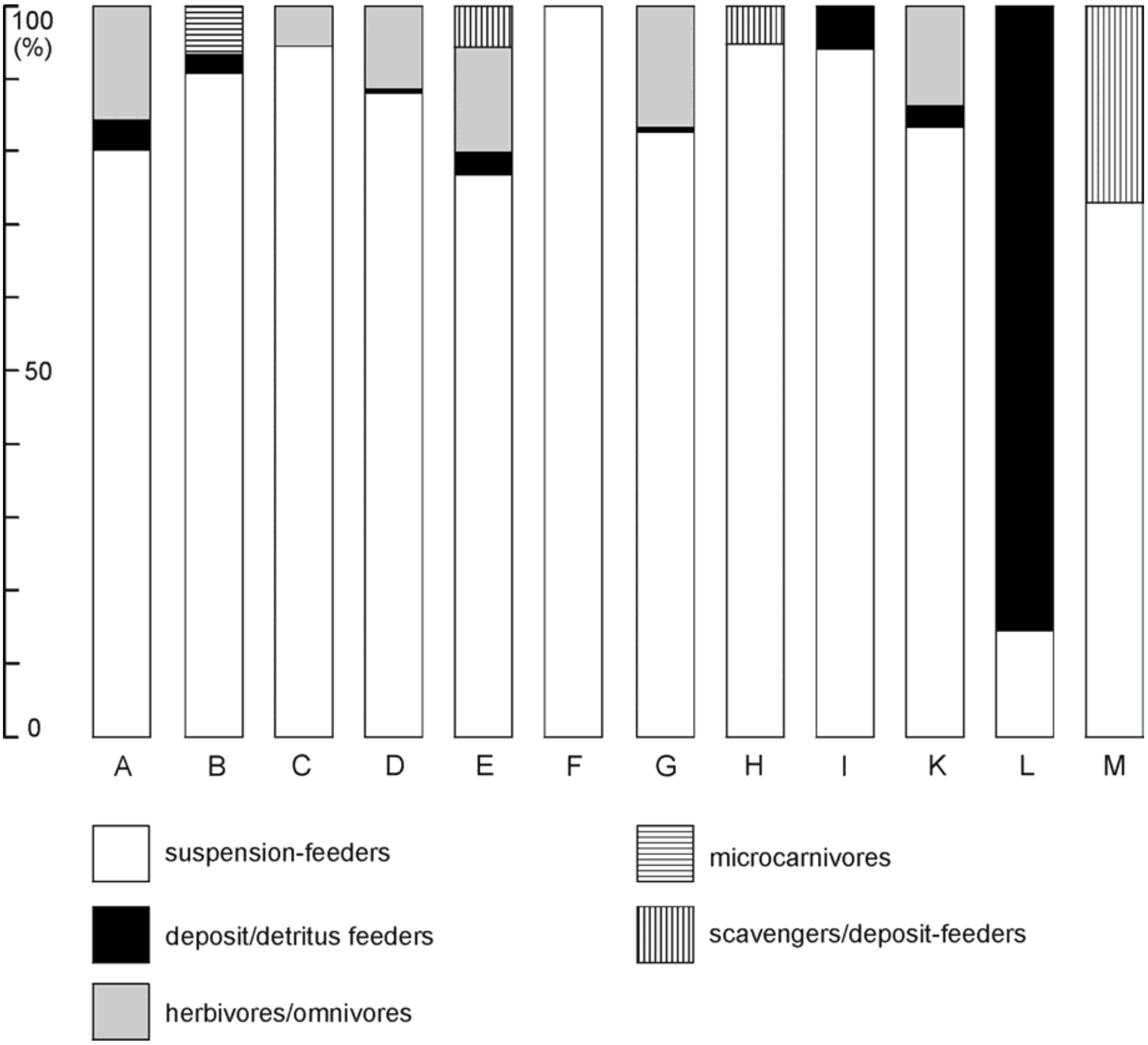


Text-fig. 44. Distribution of life habits in the associations and assemblages of the Upper Cretaceous of southern Jordan.

8.7.3 Feeding modes

All benthic associations and two of the assemblages of the Upper Cretaceous of southern Jordan are strongly dominated by suspension-feeders. They account for more than 75% of the individuals in all associations. Text-fig. 45 summarises the distribution of feeding modes. This distribution is closely related to the distribution of benthic groups. Out of 76 species of bivalves found in the Upper Cretaceous of southern Jordan, 72 were suspension-feeders and only four deposit-feeders. Other suspension-feeders are the lingulid brachiopods from association 4.2. Gastropods are thought to have been herbivorous or omnivorous, but some also might have been detritus-feeders. “*Turritella*” is thought to be a suspension-feeder. Some rare carnivorous gastropods occur in the fully marine carbonate platform environments of the *Aphrodina dutrugei* – *Paraesa* sp. association (Naticidae, Olividae). All the carnivorous gastropods are thought to were shallow burrowers. The corals were microcarnivorous, the decapods most probably scavengers or deposit-feeders.

Because the different benthic groups mostly represent different feeding modes, Text-fig. 45 shows a similar distribution as Text-fig. 43.



Text-fig. 45. Distribution of feeding modes in the associations and assemblages of the Upper Cretaceous of southern Jordan.

8.8 Relationship between macrobenthos and environmental parameters

8.8.1 Substrate

Text-fig. 46 shows the different lithologies, in which the associations and assemblages occur. Nearly all communities come from fine-grained sediments. Among limestones, wacke- and packstones predominate, in siliciclastics, clays and siltstones prevail. Furthermore, no association or assemblage occurs in calcareous (limestones or marls) as well as in siliciclastic substrates. This indicates a distinct preference of the benthic fauna for particular types of substrate. Furthemore, a geographic zonation of the associations is visible. The calcareous association A, B and C consist exclusively of samples from the western and north-western sections (1-6), while the remaining associations are represented by samples from sections 5-10. As associations A-C represent euhaline conditions, salinity did not control the distribution of the species. Instead, substrate features are thought to have been the decisive environmental parameters. The *Aphrodina dutrugei – Paraesa* sp. association was found exclusively in limestones of the open platform lagoon. The distribution of the different groups of organisms and life habits and the rather high values of diversity point to a low degree of environmental stress (chapter 8.5.1). In contrast, the oyster-dominated *Exogyra olisiponensis – Ilymatogyra africana* and *Ilymatogyra africana* associations were subject to a slightly increased siliciclastic input. In particular the latter association is characterised by a softer substrate caused by an increased clay content of the sediment. The dominating species (60%) is the small reclining oyster *Afrogyra africana* (forma *typica*). Cementing taxa such as *Plicatula* were most probably attached to secondary hard substrates (for example, shell fragments). The *Exogyra olisiponensis – Ilymatogyra africana* association occurs in limestones and marls of the western sections. It is dominated by large, thick-shelled oysters and corals. Although the corals exhibit adaptations to a soft substrate having a somewhat platy shape and light-weight construction, the sea floor was more stable than in the *Ilymatogyra africana* association. The lack of aragonitic fauna is most probably a result of selective dissolution.

Distincly stenohaline groups such as ammonites, corals, and echinoids occur in calcareous sediments (limestones and marls) in appreciable numbers. In contrast, they appear only subordinately in siliciclastic sediments.

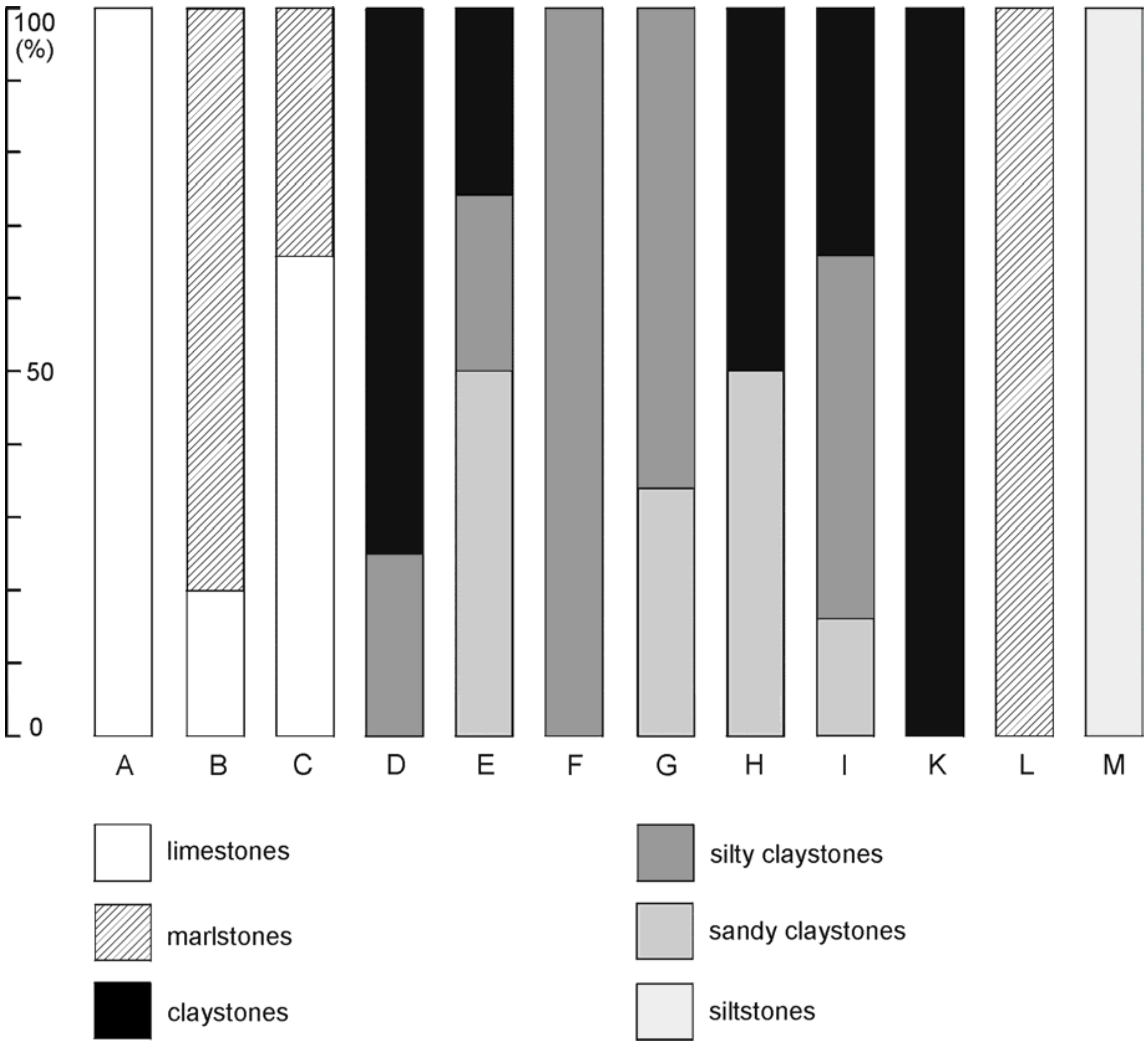
All the remaining associations occur in fine-grained siliciclastic sediments. Claystones predominate, pure siltstones occur in one assemblage only. Certainly, this apparent preference of the benthic fauna for fine-grained substrates is due to diagenetic dissolution of shells in coarser-grained sediments. Claystones exhibit the lowest porosity and therefore the highest preservation potential. Shells embedded in silt- or sandstones are dissolved more easily and faster (in the *Crassostrea* sp. – decapod sp. B assemblage even thick oyster shells are dissolved). To obtain more information on the substrate, the lithology of the remaining six associations was grouped into pure claystones, silty claystones, and sandy claystones (Text-fig. 46). A higher amount of coarse grains in the sediment indicates a higher stability of the substrate. Particularly, the distribution of life habits (epifaunal-infaunal) is largely controlled by the firmness and stability of the substrate. Typical soft bottom communities such as the carditid bivalve – *Anthonya jordanica* association show a high amount of mostly small, shallow infaunal elements. Here, the infauna reaches more than 90% of the benthic fauna. The rare epifauna, represented by *Brachidontes* aff. *fulpensis*, was attached to the substrate by fine byssal threads.

Another soft bottom community is the *Parmicorbula eretzisraelensis – Parmicorbula*? cf. *tapuchii* association (I). It was found in claystones and slightly silty claystones. The infauna accounts for 94%. The benthic fauna is dominated by small shallow infaunal corbulids. Areas of higher firmness of the substrate were colonised by rare epifaunal recliners (*Rynchostreon*).

The same trend is visible for the gastropod sp. – *Parmicorbula eretzisraelensis* (F) and the *Brachidontes* aff. *fulpensis – Parmicorbula*? cf. *tapuchii* (H) associations. The infauna (including semi-infauna) reaches 60% in the former, 67% in the latter association. The increased percentage of coarser grains (silt and sand) in the sediment supports the assumption that the substrate stability was higher. This is also indicated by burrows of crustaceans and the increased size of reclining oysters.

The oyster-dominated *Rhynchostreon mermeti – Curvostrea* cf. *rouvillei* and *Rhynchostreon mermeti* – gastropod sp. associations with their high amount of epifauna indicate a firmer substrate. They occur in sandy and silty claystones. As mentioned before, the distinct dominance of epifaunal calcitic organisms point to selective dissolution during diagenesis, which probably distorted the epifauna-infauna relation.

The assemblages show similar trends, although they are less significant. In the soft bottom *Eomiodon* cf. *libanoticus* assemblage (K), which occurs in claystones, infauna accounts for 84%.
The *Mecaster* cf. *batnensis* – *Nerinea pauli* assemblage (L) is characterised by its high number of infaunal echinoids. As stated before, euhaline organisms are mostly limited to limestones and marls. This assemblage was found in marls of the lower FHS Formation of section 2. The percentage of infauna and epifauna has been distorted by selective dissolution. The calcitic tests of echinoids have a high preservation potential, and there are no signs that infaunal organisms were destroyed by currents at the sea floor. In contrast, all epifaunal gastropods are fragmented.
The *Crassostrea* sp. – decapod sp. B assemblage (M) comes from siltstones of section 9. The relatively coarser sediment points to a higher stability of the substrate, which is reflected by the distribution of the fauna. Epifaunal oysters and burrowing decapods dominate this assemblage.



Text-fig. 46. Substrate relationships of the associations and assemblages. Nearly all communities occur in fine-grained sediments. Associations A, B, C, and assemblage K are found in the western sections.

8.8.2 Water energy and bathymetry

The environmental parameter water energy is closely linked with the substrate because it controls the distribution of the sediments. Naturally, there is a large variety of different facies in marginal marine settings (chapter 6). High water energy occurs at the shoreface, on shoals and during storms. Sediments of high water energy are coarse-grained and mostly poor in fossils. On the one hand such mobile substrates are less suitable for colonisation, on the other hand the preservation potential is very low because of the high porosity.

The nine associations and three assemblages from southern Jordan all occur in fine-grained sediments. The only exception is one sample of the *Aphrodina dutrugei – Paraesa* sp. association (A) which was found in grainstones. Great water depth is very unlikely because of the marginal marine position of the study area during that time, the maximum distance from the coastline being about 30-40 km. The highest sea level that was reached during the Cenomanian and Turonian is represented by the maximum flooding zone of the Lower Upper Cenomanian. The resulting water depth was between fair-weather and storm wave base, as is evidenced by fine-grained marlstones and intercalated storm layers with oyster concentrations (chapter 6.3).

Thus, the distribution of sediments was not controlled primarily by large-scale changes in water depth, but was influenced by the topography of the sea floor. In this context, lagoonal facies are highly significant for the fossil record, because they are characterised by sediments with a high preservation potential. The sea floor was differentiated into shoals and restricted (lagoonal) areas. In the calcareous sections of the north-western area relics of shoals were found in section 4 (chapter 6.4, grainstone facies). There, thick units of cross-bedded limestones point to very shallow bars, that separate a high energy belt from a restricted facies zone. Another very shallow facies are algal laminites, which were found at the top of the Naur Formation in the western sections. Laterally, fine-grained mud-, wacke-, and packstones were deposited (see also Text-fig. 50).

The eastern (siliciclastic) depositional system also exhibits evidence of a sea floor relief. Shoals and bars are represented by heavily bioturbated sandstones without body fossils. They are intercalated between thicker units of claystones. These claystones contain a rich benthic fauna and depict restricted lagoonal environments. In some cases, increased influx of fresh water from the hinterland caused brackish conditions. A strongly limited circulation of the sea water might have led to a salinity stratification and/or to oxygen shortage in the sediment. Indications were found in association G and assemblage K (chapter 8.5.4, 8.6).

In conclusion, water energy controlled the distribution of sediments and organisms in the depositional system. The fauna inhabiting high energy areas was not preserved except some of its traces. Thus, also the distribution of preservational zones is controlled by this environmental parameter.

8.8.3 Oxygen

Strongly restricted conditions which are characterised by fine-grained sediment and possible salinity stratification might lead to oxygen deficiency in the substrate. Additionally, the low porosity of the sediment impedes the circulation of water.

Extreme shortage of oxygen can lead to deposition of highly bituminous sediments or even black shales. Such sediments do not occur in the Ajlun Group of southern Jordan. The depositional environment was most probably too shallow, because black shales are mostly deposited on mid to deeper shelf areas. Some indications of oxygen depletion occur in the *Rhynchostreon mermeti* – gastropod sp. association and in the *Eomiodon* cf. *libanoticus* assemblage. In the sediments of both communities small pyrite crystals and pyritysed plant fragments occur. The high percentage of shallow infauna in the *Eomiodon* cf. *libanoticus* assemblage (K) points to oxygen shortage in deeper layers of the sediment, whereas in the *Rhynchostreon mermeti* – gastropod sp. association (4.1) the dominance of epifauna might indicate a higher position of the redox zone. The lack of infaunal trace fossils in both cases supports this assumption.

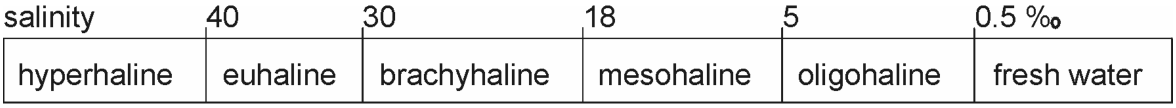
8.8.4 Salinity

As shown in chapter 8.8.4a, nearly all of the siliciclastic associations come from very fine-grained sediments. Thus, the consistency of the substrate can not be the only environmental parameter controlling the distribution of species. In very marginal marine settings salinity of the sea water was often described as an important environmental factor (e.g., FÜRSICH & KIRKLAND 1986, FÜRSICH & WERNER 1986, HOLZAPFEL 1998). A morphological differentiation of the depositional system into shoals and restricted lagoons in combination with high rainfall and large fluvial systems can result in the development of widespread brackish salinities. In contrast, restricted areas without fresh water supply might become hypersaline in hot, arid climates.

In benthic communities indicative of stress environments, i.e. those exhibiting low diversity and dominance of only few species, combined with the absence of stenohaline groups such as ammonites and echinoids, salinity might have played a decisive role in governing the distribution of benthic faunas.

In the Upper Cretaceous Ajlun Group of southern Jordan three associations and two assemblages are thought to have been influenced by reduced salinity values. The three associations come from slightly silty claystones and pure claystones, assemblage K from claystones, and assemblage M from siltstones. All of them are more or less soft bottom communities. Associations A and B and assemblage L represent fully marine (euhaline) conditions.

The classification of associations and assemblages on a salinity gradient (Text-fig. 48) was done on the base of the Venice system (OERTLI 1964).



Text-fig. 47. Salinity zones after Oertli (1964).

For the Upper Cretaceous communities of southern Jordan the salinity values of the sea water was estimated mainly on the base of faunal composition and lithology.

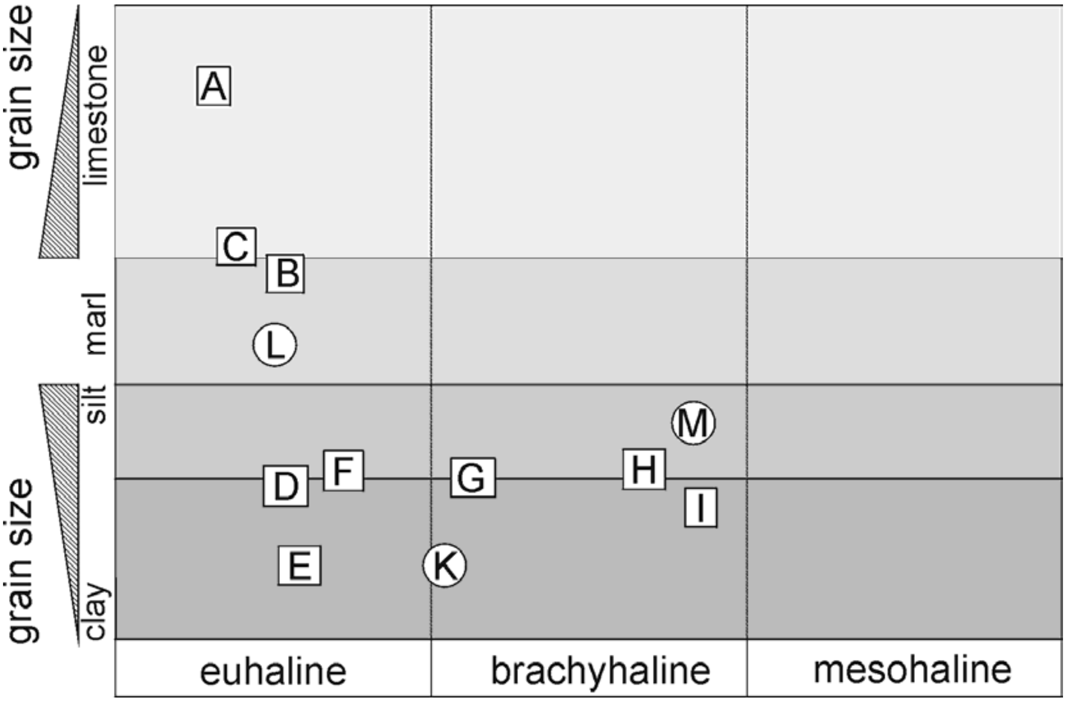
The lowest salinity (brachy- to mesohaline) is recorded by the *Parmicorbula eretzisraelensis* – *Parmicorbula*? cf. *tapuchii* association (I). It is characterised by very low diversity and the dominance of two species of corbulid bivalves (77%). All infaunal elements are small and represent shallow burrowers. Rare epifaunal oysters are smaller than in the euhaline sections in the north-west. Thin shells indicate environmental stress, but unfortunately most of the fauna is preserved as moulds. Remarkably, most of the samples of this association occur in the transgressive (basal) part of the *Neolobites* sequence. They represent most probably smaller regressive events intercalated within a larger transgressive framework.

The *Brachidontes* aff. *fulpensis* – *Parmicorbula*? cf. *tapuchii* association (H) is also interpreted as the relic of a brackish (brachyhaline) community. The diversity is slightly lower than in the above described association. The dominance of a particular taxon is not as striking as in the *Parmicorbula eretzisraelensis* – *Parmicorbula*? cf. *tapuchii* association, but the trophic nucleus consists of three euryhaline genera, which are known to tolerate reduced salinity. The increased percentage of epifauna and the occurrence of burrows point to a slightly firmer substrate. As depositional environment a brackish lagoon is proposed.

The limiting parameters of the *Rhynchostreon mermeti* – gastropod sp. association were most probably (slightly) reduced salinity, substrate consistency and, to a small extent, oxygen depletion within the sediment (chapter 8.5.4). Epifaunal oysters predominate and indicate a not too soft substrate. Intercalated, heavily bioturbated sand layers could have stabilised the sea floor. The diversity values, especially for the evenness, are higher than in the above described associations.

The *Eomiodon* cf. *libanoticus* assemblage is characterised by a soft substrate combined with occasionally reduced salinity. The comparatively high richness is at odds with the strong dominance of *Eomiodon*. Additionally, the instability of the substrate is indicated by the preservation of decapod crustaceans within their collapsed burrows. Rare ammonites and very rare deep infaunal bivalves (*Pholadomya vignesi*) indicate euhaline periods. Thus, time-averaging is evident in this assemblage.

In contrast to the *Eomiodon* cf. *libanoticus* assemblage, the substrate in the *Crassostrea* sp. – decapod sp. B assemblage was firmer. The sediment is coarser, and the fauna consists mainly of epifaunal oysters and burrowing decapods. As described before, the low diversity values are partly the result of selective preservation, but the preserved fauna points additionally to reduced salinity (chapter 8.6). This brachyhaline assemblage is interpreted as the relict of an estuarine community.



Text-fig 48. Distribution of the associations and assemblages from the Ajlun Group of southern Jordan according to salinity and substrate. For explanation of the numbers see Text-fig. 43. The division into different salinity zones follows the Venice System (OERTLI 1964): euhaline conditions 30-40°/$_{oo}$, brachyhaline 18-30°/$_{oo}$, mesohaline conditions 5-18°/$_{oo}$.

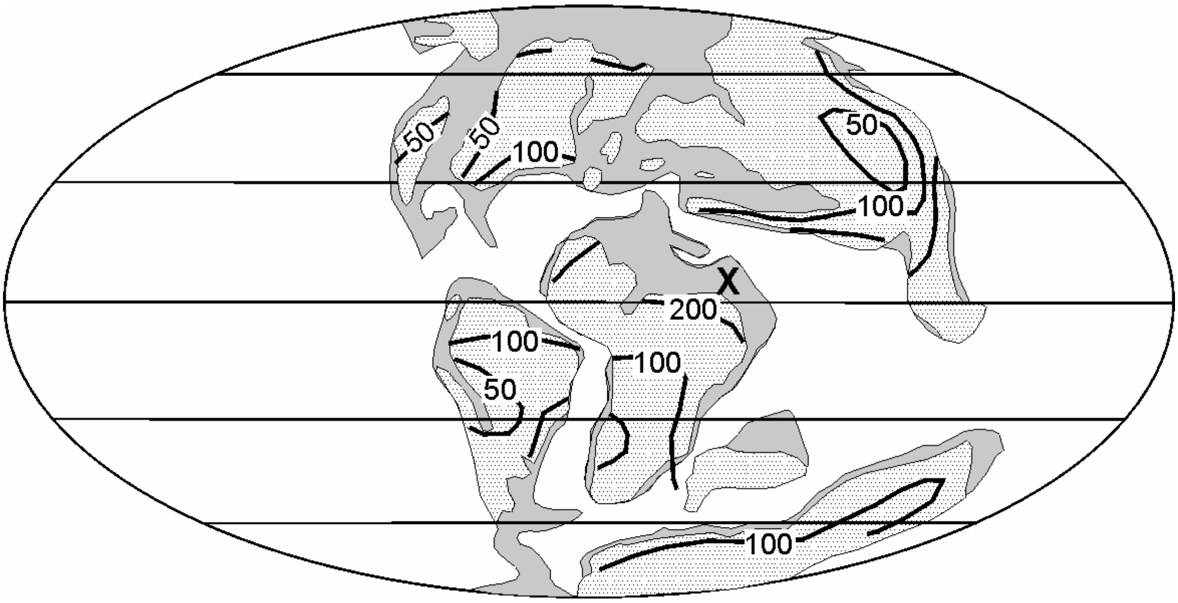
8.8.5 Climatical aspects

The Upper Cretaceous is thought to have been one of the warmest times of the late Phanerozoic. According to Barron (1983), the average global temperature was about 6°C higher than today. Polar regions were free of permanent ice. The mid-Cretaceous is characterised by high sea levels and large shelf seas. Anoxia are widespread.

Jordan was situated at the south-eastern margin of the Tethys Ocean (Text-fig. 2), with a palaeo-latitude of about 10° N. Therefore, it lay within the tropical belt. High precipitation and high water temperatures are very likely to have prevailed (Text-fig. 49).

Bender & Mädler (1969) described a humid-tropical plant association from Cenomanian claystones of the Batn El Ghoul area in southern Jordan. Some of their taxa were also found during this study in the lower part of section 10 (Pl. 12, Figs. 1-4). Lacovara et al. (2001) reported coastal environments with mangrove communities (*Weichselia reticulata*) from the Cenomanian of Egypt.

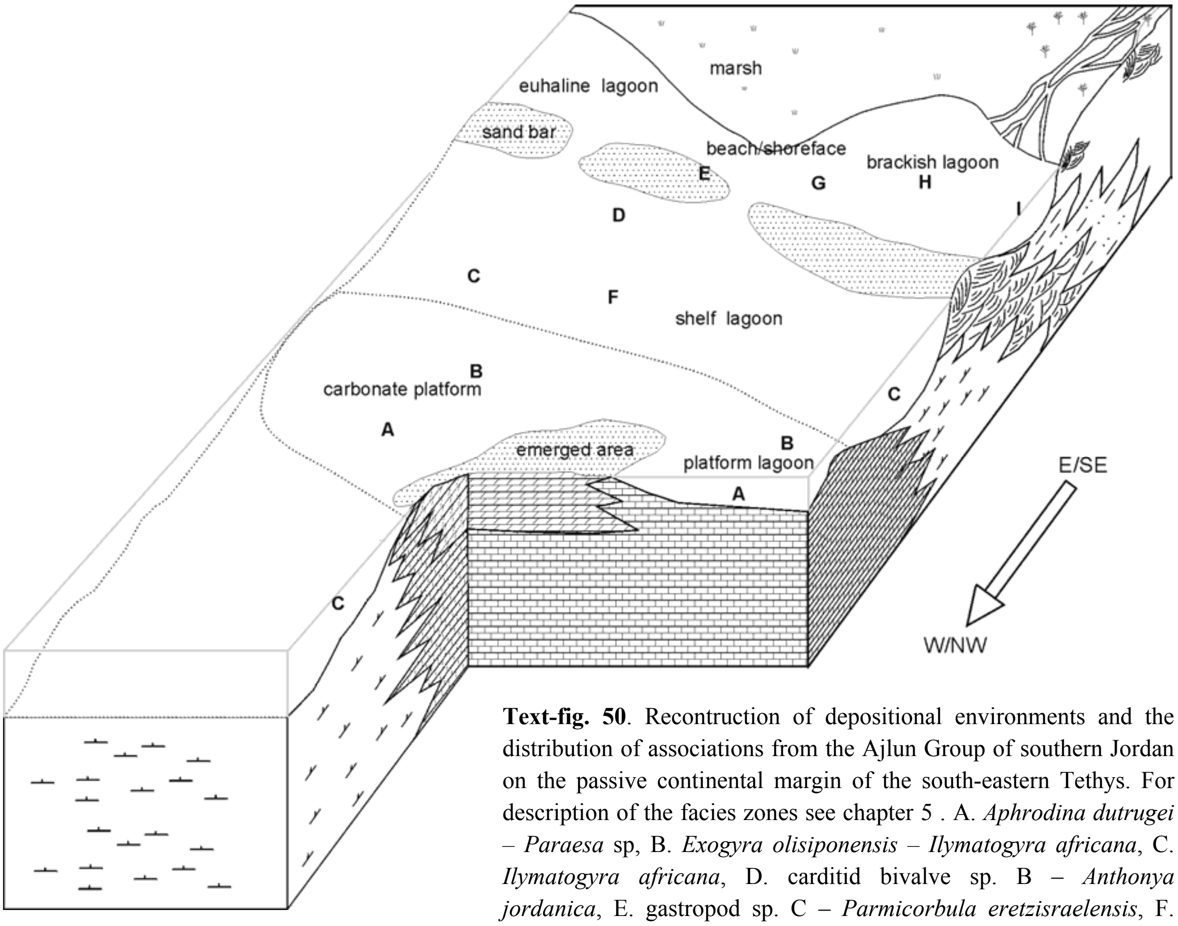
In the study area remains of large river systems in the Kurnub and Wadi As Sir Formation indicate extensive erosion and weathering on the mainland as a result of high rainfall. These river systems are the main mechanisms controlling the salinity of the marginal marine environments of the southern Jordan Cretaceous. High input of fresh water results in lower salinity of the sea water. Therefore the brackish associations described in chapter 8.5.4 are useful in palaeoclimatic conditions.



Text-fig. 49. Estimated distribution of rainfall during the middle Cretaceous after Francis & Frakes (1993; modified from Parrish et al. 1982). The dotted area indicates landmasses, the grey-shading indicates shelf seas. < 50 = low rainfall, 50-100 = moderately low rainfall, 100-200 = moderately high rainfall, >200 = high rainfall. The cross indicates the position of the study area.

9 Reconstruction of the depositional environment

Text-fig. 50 shows the distribution of different environments and associations in the Upper Cretaceous of southern Jordan. Not all associations are contemporaneous. During most of the Cenomanian, the shoreline was situated between section 9 and 11, except during the Lower Upper Cenomanian highstand which advanced more to the east. All sections east of section 11 are exclusively developed in terrestrial facies during the Cenomanian. Thick units of fluvial sandstones in channel facies are interbedded with thin clay layers and lenses which are interpreted as overbank sediments. Beach and shoreface deposits are characterised by bioturbated sandstones with ripple marks and shark teeth, but without benthic fauna which was dissolved during diagenesis. Fine-grained sediments of brackish or euhaline lagoons follow to the west and north-west. The associations G, H, and I were found in these deposits. Fresh water influx came via rivers from the mainland. The area between the shoreline and the carbonate platform offshore was differentiated into shoals and sandbars, which are characterised by cross-bedded, partly bioturbated sandstones and silts. The space between these shoals was filled with finer sediments, that record a rich benthic fauna. More to the west, a mixed siliciclastic-calcareous environment with marls and sandy limestones followed. The oyster-rich *Ilymatogyra africana* association (B) occured in this area.



Text-fig. 50. Recontruction of depositional environments and the distribution of associations from the Ajlun Group of southern Jordan on the passive continental margin of the south-eastern Tethys. For description of the facies zones see chapter 5 . A. *Aphrodina dutrugei – Paraesa* sp, B. *Exogyra olisiponensis – Ilymatogyra africana*, C. *Ilymatogyra africana*, D. carditid bivalve sp. B – *Anthonya jordanica*, E. gastropod sp. C – *Parmicorbula eretzisraelensis*, F. *Rhynchostreon mermeti – Curvostrea* cf. *rouvillei*, G. *Rhynchostreon mermeti* – gastropod sp. C, H. *Brachidontes* aff. *fulpensis – Parmicorbula*? cf. *tapuchii*, I. *Parmicorbula eretzisraelensis – Parmicorbula*? cf. *tapuchii*, K. *Eomiodon* cf. *libanoticus*, L. *Mecaster* cf. *batnensis – Nerinea pauli*, M. *Crassostrea* sp. – decapod sp. B.

West and north-west of the study area, the easternmost expression of the extensive Cenomanian carbonate platform is documented. The platform was subdivided into very shallow to subaerial parts (algal laminites, primary dolomites), and restricted lagoonal facies zones which yielded the *Aphrodina dutrugei - Paraesa* sp. association and the *Exogyra olisiponensis – Afrogyra africana* association. Shallow water conditions with high water energy are also documented by cross-bedded grainstones of section 4.

Altogether the depositional environment was very shallow (estimated water depth between 0 and 20 m). Even in the deeper areas of the Cenomanian sea level highstands storm beds and shell concentrations indicate that the water depth was at no time greater than the storm wave base.

10 Conclusions

- Sediments of the Upper Cretaceous Ajlun Group accumulated at the southern Tethyan margin. The shoreline was situated within the study area during the Cenomanian and Turonian. The studied sections offer a great insight into different facies zones developed at the transition between continental, marginal marine, and offshore carbonate platform environments.
- A large variety of sedimentary rocks were deposited during the Upper Cretaceous of southern Jordan. They range from clay to sandstones with all transitional stages via marls and sandy limestones to dolomites, algal laminites, and limestones.
- Palaeoecological methods turned out to be a useful tool for reconstructing the different depositional environments in the Upper Cretaceous of southern Jordan, although the fauna is mostly only moderately well preserved and aragonitic shells and calcareous microfossils have mostly been dissolved.
- 41 statistical samples were used for a Q mode cluster analysis, which resulted in nine associations and three assemblages. The dominating macrobenthic groups are bivalves, gastropods, and echinoids.
- The distribution of associations and assamblages is mainly controlled by the environmental parameters substrate and salinity.

11 Taxonomy

11.1 Class Bivalvia Linné, 1758

Subclass Palaeotaxodonta KOROBKOV, 1954
Order Nuculoidea DALL, 1889
Superfamily Nuculacea GRAY, 1824
Family Nuculidae GRAY, 1824
Genus *Nucula* LAMARCK, 1799
Subgenus *Nucula* LAMARCK, 1758
Type species. *Arca nucleus* LINNÉ, 1758.

Nucula (*Nucula*) sp.
Pl. 1, Figs. 1-2

Material. Two internal moulds of left valves. PIW 2002 VII 1-2.

Description. Outline triangular, inequilateral; moderately inflated, most likely equivalved; anterior and posterior margins straight, ventral margin broadly convex and finely crenulate; beak opisthogyrate, prominent; fine and closely spaced growth lamellae, crossed by very faint radial striae; hinge and internal structures not preserved.
Dimensions. Length 13.5 mm, height 9.6 mm.
Distribution. Very rare in claystones of the upper FHS Formation of the Batn El Ghoul area (section 9; sample J9-18).

Superfamily Nuculanacea ADAMS & ADAMS, 1858
Family Nuculanidae ADAMS & ADAMS, 1858
Genus *Nuculana* LINK, 1907
Subgenus *Nuculana* LINK, 1907
Type species. *Arca rostrata* CHEMNITZ, 1774.

Nuculana (*Nuculana*) aff. *perdita* (CONRAD, 1852)
Pl. 1, Fig. 3

aff. 1852 *Nucula perdita* sp. nov. – CONRAD: 223, pl. 17, fig. 96.
aff. ?1917 *Leda perdita* (CONRAD, 1852) – FOURTAU: 5, pl. 2, fig. 8.

Material: One left valve. PIW 2002 VII 3.

Description. Small, elongated-ovate, inequilateral and rather flat valve; anterior end blunt and rounded, posterior end pointed and slightly longer than anterior end; antero-dorsal margin straight to slightly convex, postero-dorsal margin slightly concave; ventral margin regularly convex; umbo rather broad and rounded, not prominent; surface of the shell ornamented with numerous fine commarginal ribs, most distinct on the posterior part of the shell; posterior umbonal carina separating an area from the main field; taxodont dentition clearly visible on the anterior hinge margin, there with about 14 teeth.

Remarks. This southern Jordan species shows similarities with D´ORBIGNY´s *Nucula mariae* from the Cretaceous of France. GARDENER (1884) and WOODS (1904) described *Leda mariae* and *Nuculana mariae* from the Gault (Albian) of England. These species differ from the present one by their more concave antero-dorsal margin, the distinctly more pointed umbo and the lack of ornamentation on the anterior shell surface. A distinct carina and area is absent in the English forms. FRAAS (1867) described *N. perdita* as a synonym of *N. scapha* from the Cretaceous of England. Because of its different outline, the Jordanian specimen is identified as *N.* aff. *perdita*. FOURTAU mentioned the species from the Campanian of Egypt.

Mesosaccella subacuta (STEPHENSON) from the Cenomanian of Texas (STEPHENSON 1952), from the ?Aptian Abu Ballas Formation of Egypt (BÖTTCHER 1982) and from Cenomanian claystones of southern Jordan shows a blunter and somewhat truncated posterior end; furthermore the outline of *Mesosaccella subacuta* exhibits a slightly concave zone at the posterior ventral margin.

Dimensions. Length 11.5 mm, height 6 mm.

Distribution. Claystone of the Cenomanian FHS-Formation of section 9 (sample J9-12).

Genus *Mesosaccella* CHAVAN, 1946

Type species. *Nucula foersteri* MÜLLER, 1847.

Mesosaccella cf. *subacuta* (STEPHENSON, 1952)

Pl. 1, Figs. 4-6

cf. 1952 *Yoldia*? s*ubacuta* sp. nov. – STEPHENSON: 58, pl. 10, figs. 17-18.
cf. 1982 *Mesosaccella subacuta* (STEPHENSON) – BÖTTCHER: 37, pl. 6, figs. 3-7.

Material. Several left and right disarticulated valves. PIW 2002 VII 4.

Description. Valves very small, elongated-ovate, inequilateral and relatively flat. Anterior end short and rounded, posterior end elongated; antero-dorsal and postero-dorsal margins straight, ventral margin regularly convex; umbo small, only slightly projecting; surface of the shells ornamented with fine commarginal ribs. Taxodont dentition clearly visible, posterior hinge margin carrying more teeth (17-18) than anterior hinge margin (12 teeth). Posterior hinge margin extends nearly to the posterior end of the valve.

Remarks. In contrast to *Nuculana* aff. *perdita* the present species is smaller and slightly more inflated, without postero-umbonal carina.

Mesosaccella subacuta of BÖTTCHER (1982) from the Abu Ballas Formation (?Apt) of Egypt is very similar, at least his figs. 3 and 4.

Dimensions. Length 5-11 mm, height 3-5 mm.

Distribution. Wadi Juhra Member (?Albian-Cenomanian) and FHS Formation (Upper Cenomanian) of sections 5, 6, 7, 9, and 10. (samples J5-36, J6-10, J6-24, J7-2, J7-20, J9-12, J9-18, J9-20, J10-6).

Mesosaccella sp.

Pl. 1, Figs. 7-9

Material. Four right valves. PIW 2002 VII 5-6.

Description. Rather small specimens, ovate, inequilateral and slightly inflated with the greatest inflation slightly in front of the umbo; posterior side shorter than anterior side and pointed; postero-dorsal margin slightly concave, postero-ventral margin straight to slightly concave; anterior side broad, with regularly rounded antero-ventral margin; rather blunt umbo situated two-thirds of the shell length from the anterior end; anterior row of teeth with more teeth (about 12) than posterior row (7-8); surface of shells ornamented with numerous (20-25) fine commarginal ribs.
Remarks: In contrast to *Mesosaccella* cf. *subacuta* the posterior end is distinctly shorter.
Dimensions. Length 12 / 11 / 9.5 / 6 mm, height 5.5 / 5.5 / 4.5 / 2.8 mm.
Distribution. Cenomanian claystones of the FHS-Formation of sections 7 and 10 (samples J7-2, J10-17).

Subclass Pteriomorphia BEURLEN, 1944
Order Arcoida STOLICZKA, 1871
Superfamily Arcacea LAMARCK, 1809
Family Arcidae LAMARCK, 1809
Subfamily Arcinae LAMARCK, 1809
Genus *Barbatia* GRAY, 1842
Subgenus *Barbatia* GRAY, 1842
Type species. *Arca barbata* LINNÉ, 1758.

Barbatia (*Barbatia*) sp.
Pl. 1, Figs. 12-13

Material. Several left and right valves. PIW 2002 VII 7.

Description. Shell small, moderately inflated, ovate-trapezoidal in outline, slightly inequilateral; anterior end slightly shorter than posterior end, umbo situated between half and 1/3 of the shell length from the anterior end, slightly protruding; hinge margin straight to gently sloping on both sides; hinge taxodont with short, oblique teeth, number of teeth higher posteriorly than anteriorly; anterior and posterior margins convex, ventral margin regularly rounded; with anterior umbonal carina; posterior umbonal carina faintly developed; outer shell surface ornamented with numerous radial ribs, which are more crowded on the flank than anterior and posterior of it; distance between the ribs approximately the same as width of the ribs.
Remarks. The specimens show similarities to *Barbatia marullensis* (D´ORBIGNY, 1844) from the Lower Greensand and Gault of England (WOODS 1899). The main differences are the slightly broader umbo, the straight ventral margin and the finer ornamentation in the English forms, but the specimens from Jordan are too poorly preserved to allow a precise identification or introduction of a new species. The genus *Barbatia* has not been described from the Cretaceous of Jordan up to now.
Dimensions. Length 15-22 mm; height 12-14 mm.
Distribution. Claystones of the FHS Formation of section 10 (sample J10-6).

Family Parallelodontidae DALL, 1898
Subfamily Grammatodontinae BRANSON, 1942
Genus *Nemodon* CONRAD, 1869

Type species. *Arca* (*Macrodon*) *eufalensis* GABB, 1860.

Nemodon? sp.

Pl. 1, Fig. 10-11

Material. Two composite moulds of right valves. PIW 2002 VII 8.

Description. Valves very small, trapezoidal in outline, inequilateral; anterior side shorter than posterior one, umbo fairly broad, situated at 1/3 of total shell length from the anterior end; hinge margin long and straight, teeth not visible. Anterior margin of the valve slightly concave; ventral margin slightly concave, with the indentation slightly posteriorly of the umbo; posterior margin convex, posterior umbonal carina slightly curved; valves ornamented with numerous radial ribs which are more crowded on the flank than anteriorly or posteriorly of it; on the flank additionally gentle commarginal striae.

Remarks. The genus *Nemodon* has not been recorded from Jordan up to now. A precise identification at the species level is not possible because the hinge is not seen. The classification as a representative of the Superfamily Arcacea is certain. The southern Jordan species is similar to *Grammatodon carinatus* (J. SOWERBY, 1813) from the Gault of Folkestone, England (WOODS 1899; pl. 8, fig.8), which reaches by far larger sizes (length: 21-45 mm, height 12-29 mm).

Dimensions. Length 7-8 mm; height 3.5-4 mm.

Distribution. Upper Cenomanian claystones (FHS-Formation) of section 9 (sample J9-12).

Subgenus *Pleurogrammatodon* ICHIKAWA & MAEDA, 1958

Type species. *Pleurogrammatodon splendens* ICHIKAWA & MAEDA, 1958.

Nemodon (*Pleurogrammatodon*) sp.

Pl. 1, fig. 17

Material. One slightly compressed composite mould of a right valve. PIW 2002 VII 9.

Description. Valve rather flat, outline subtrapezoidal to ovoid, inequilateral; anterior and posterior part of nearly equal length, but anterior part higher; byssal gap present; umbo fairly broad, osituated mesially; hinge margin long and straight; anterior margin short and wing-shaped, concave dorsally, convex ventrally; ventral margin nearly straight and oblique; posterior margin slightly convex, with a short wing-like extension dorsally; teeth below umbo not seen, anterior teeth long, slightly shorter than posterior ones, orientated parallel to the hinge margin or slightly curved downwards; surface ornamented with numerous fine radial and commarginal striae.

Remarks. The Genus *Nemodon* is limited to the Upper Cretaceous of northern America, Asia, and Madagascar. The subgenus *Pleurogrammatodon* is known from Japan, Madagascar, and Canada. The Jordanian specimen was classified as *Nemodon* because of the typical dentition. The strongly inequilateral outline is peculiar, and might indicate a new species.

Dimensions. Length 61 mm , height 44 mm.

Distribution. Upper Cenomanian claystones of the FHS formation of the Batn El Ghoul area (sample J9-21).

Family Noetiidae STEWART, 1930
Subfamily Noetiinae STEWART, 1930
Genus *Noetia* GRAY, 1857
Type species. *Arca reversa* J. DE C. SOWERBY, 1833.
Subgenus *Icanopsis* OLSSON, 1944
Type species. *Icanopsis acariformis* OLSSON, 1944.

Noetia? (*Icanopsis*) sp.
Pl. 1, Fig. 16

Material. Composite moulds of two fragmented, slightly compressed left valves. PIW 2002 VII 10.

Description. Valves regularly inflated, outline rounded-quadrangular to ovate; inequilateral, most likely equivalved; anterior end longer than posterior one; umbo pointed, slightly prosogyrate and strongly protruding beyond the hinge margin, shifted posteriorly; hinge margin straight and moderately long; dentition not visible; anterior margin slightly convex; ventral margin broken; posterior margin straight and oblique; posterior umbonal carina straight; surface ornamented with numerous, very fine radial striae; on the main area of the shell additionally fine commarginal striae are seen.

Remarks. Up to now, neither genus nor subgenus have been mentioned from Jordan.

Noetia? (*Icanopsis*) sp. superficially resembles *Palestinarca palestina* WHITFIELD, 1891, which has been recorded from the Aptian of Lebanon by VOKES (1946). Because of the poor preservation and compression a precise comparison is very difficult, but *P. palestina* appears to be more elongated posteriorly and to have a more oblique posterior margin.

Dimensions. Length 21 mm, height about 18 mm.

Distribution. Claystones of the Lower? Cenomanian Wadi Juhra Member of section 7 (sample J7-2).

Superfamily Limopsacae DALL, 1895
Family Glycymeridae NEWTON, 1922
Subfamily Arcullaeinae NEWELL, 1969
Genus ?*Trigonarca* CONRAD, 1862
Type species. *Cucullaea macoensis* CONRAD, 1860.

Trigonarca? *diceras* (SEGUENZA, 1882)
Pl. 1, Figs. 14-15

1882 *Arca diceras* nov.sp. – SEGUENZA: 96, pl. 14, figs. 1a, b.
1912 *Arca (Trigonoarca) diceras* (SEGUENZA) – PERVINQUIÈRE: 102, pl. 7, figs. 23 a,b, 25, 26.
1917 *Arca diceras* Seguenza. – FOURTAU: 8.
1961 *Arca (Idonearca) diceras* (SEGUENZA) – ABBASS: 23, pl. 2, fig. 10.

Material. Several, mostly articulated, moderately preserved internal moulds from the western sections. One specimen with shell remains. PIW 2002 VII 11-15.

Description. Valves moderately inflated, elongated posteriorly, equivalved; strongly inequilateral; anterior end very short, umbo situated about 1/5 of shell length fram the anterior end; anterior margin rounded, ventral margin straight and slightly oblique, posterior margin also straight and very oblique forming an angle of about 50° with the ventral margin; umbo very prominent; sharp and straight posterior umbonal carina separating a depressed postero-dorsal area from the flank; area forming a slope with a radial furrow; remains of the taxodont dentition preserved on one specimen; posterior teeth and hinge margin form an angle of 45° whereby the angle distally increases; surface ornamented with faint commarginal growth lines.

Remarks. The classification as *Trigonarca* was mainly based on the outline and dentition, which render ABBASS´ identification (1961) as *Idonearca* unlikely. *Trigonoarca passyana* from the Upper Greensand of England (WOODS 1904) is very similar, but shows a fine radial pattern in addition to the commarginal growth lines.

Dimensions. Length 42-65 mm, maximal height 30-39 mm.

Distribution. Cenomanian of Tunisia (PERVINQUIÈRE 1912) and Egypt (FOURTAU 1917; ABBASS 1961), Upper Cenomanian of Algeria (BUSSON et al. 1998). Upper Cenomanian of south-western Jordan (samples J1-3B, J1-5A, J2-3, J3-9, J4-1).

Ordnung Mytiloida FÉRUSSAC, 1822
Superfamily Mytilacea RAFINESQUE, 1815
Family Mytilidae RAFINESQUE, 1815
Genus Brachidontes SWAINSON, 1840
Subgenus *Brachidontes* SWAINSON, 1840
Type species. *Modiola sulcata* LAMARCK, 1819.

Brachidontes (*Brachidontes*) aff. *fulpensis* STEPHENSON, 1952
Pl. 1, Fig. 21

1952 *Brachidontes fulpensis* sp. nov. – STEPHENSON: 85, pl. 20, figs. 10-13.

Material. Several composite moulds of left and right valves. PIW 2002 VII 16-21.

Description. Outline subtriangular to mytiliform, moderately inflated, nearly equivalved, strongly inequilateral; umbo small, prosogyrate and situated terminally; anterior umbonal ridge prominent; slope anterior of this ridge steep, part of shell posterior to the ridge broadly rounded; postero-dorsal part of shell feebly inflated; postero-ventral margin curved; ornamented with numerous, closely spaced radial ribs which partly bifurcate.

Remarks. *Brachidontes* (*Brachidontes*) *fulpensis* from the Cenomanian of Texas decribed by STEPHENSON (1952) is very similar to the Jordanian specimens, which reach only half to two-thirds of the size of the American specimens.

Septifer lineatus SOWERBY described by BLANCKENHORN (1934: 207, pl. 10, figs. 50-51) from the Wadi Mousa, central Jordan, belongs most prabably to the genus *Brachidontes*.

Dimensions. Length 14-26 mm, height 11-15 mm.

Distribution. Cenomanian Woodbine Formation of Texas (STEPHENSON 1952); Upper Cenomanian of the FHS Formation of section 2 and 9, Turonian Wadi As Sir Formation or Ras En Naqb (samples J2-1, J5-68B, J9-21, J9-26B, J10-6, J10-17).

Subfamily Crenellinae ADAMS & ADAMS, 1857
Genus *Musculus* RÖDING, 1798
Subgenus *Musculus* RÖDING, 1798
Type species. *Mytilus discors* LINNÉ, 1767.

Musculus (*Musculus*) sp.
Pl. 1, Fig. 18-20

Material. Several composite moulds of disarticulated left and right valves. PIW 2002 VII 22-23.

Description. Shells very small, outline mytiliform, moderately inflated, nearly equivalved, strongly inequilateral; umbo rather broad, prosogyrate and subterminal; posterior umbonal ridge separating a small anteroventral triangular area from the flank; area ornamented with radial, partly bifurcating ribs; postero-dorsally these ribs are slightly curved; ornamentation of the flank typically divided into three parts: an anterior and a posterior field with close-spaced, partly bifurcating ribs, which are more crowded towards the central area, which is ornamented only with commarginal growth lamellae.

Remarks. This genus is recorded here for the first time from the Cretaceous of Jordan and adjacent countries.

Dimensions. Length 9-16 mm, height 4-6 mm.

Distribution. Upper Cenomanian to Turonian claystones of the FHS to Wadi As Sir Formation of the Ras en Naqb area (samples J5-45 and J7-16).

Subfamily Lithophaginae ADAMS & ADAMS, 1857
Genus *Inoperna* CONRAD in KERR, 1875
Type species. *Modiolus* (*I.*) *carolinensis* CONRAD, 1875.

Inoperna cf. *transjordanica* (BLANCKENHORN, 1934)
Pl. 2, Fig. 1

cf. 1934 *Modiola transjordanica* sp. nov. – BLANCKENHORN: 206, pl. 10, figs. 48-50.

Material. Two incomplete composite moulds of left valves. PIW2002 VII 24.

Description. Valves rather flat to moderately inflated, outline elongated to modioliform; strongly inequilateral, most probably equivalved; umbo relatively broad, subterminate, situated at about 1/5 of shell length from anterior end; hinge margin straight; posterior part of the shell higher than anterior one; ventral margin nearly straight and oblique, slightly concave; broad posterior umbonal ridge; surface of valves ornamented with commarginal ribs; these ribs are strong posterior to and across the umbonal ridge. Originating at the dorsal margin, they bifurcate dorsally of the umbonal ridge and are weakly developed on the anterior part of the ridge. Additionally, fine commarginal growth lines are developed between the strong ribs.

Remarks. The specimens are similar to those described by BLANCKENHORN (1934), but the southern Jordanian form seems to be more coarsly ornamented. The inadequate description and poor quality of the figures in BLANCKENHORN do not allow a precise comparison.

Dimensions. Estimated length 45-50 mm, height at umbo 11 mm.

Distribution. BLANKENHORN described this species from the Cenomanian of Israel (Es-Salt) and from the Turonian of central Jordan (Wadi Mujib, Kerak). In southern Jordan it occurs in the Upper Cenomanian FHS formation of the Batn El Ghoul area (sample J9-20).

Superfamily Pinnacea LEACH, 1819
Family Pinnidae LEACH, 1819
Genus *Pinna* LINNÉ, 1758
Subgenus *Pinna* LINNÉ, 1758
Type species. *Pinna rudis* CHILDREN, 1823.

Pinna (*Pinna*) sp.
Pl. 2, Fig. 2

Material. One incomplete left valve. Umbonal area and posterior end broken off. PIW 2002 VII 25.

Description. Valve relatively flat, outline modioliform; strongly inequilateral, most probably equivalved; umbo not preserved, but most likely located at the anterior end; shell expanding towards the posterior end; ventral margin straight and oblique, at least in the preserved part; ornamented with radial ribs, which are most distinct at the margin, and commarginal growth lines.

Remarks. Because of the fragmented nature of the specimen a precise identification is not possible. There are certain similarities to *Modiolus* (*M.*) *higazyi* from the Cenomanian of Egypt described by ABBASS (1962).

Dimensions. No precise measurement possible.

Distribution. Very rare in the Upper Cenomanian FHS formation of the Ras En Naqb area (sample J5-45).

Order Pterioida NEWELL, 1965
Suborder Pteriina NEWELL, 1965
Superfamily Pteriacea GRAY, 1847 (1820)
Family Bakevelliidae KING, 1850
Genus *Phelopteria* STEPHENSON, 1952
Type species. *Pteria*? *dalli* STEPHENSON, 1936.

Phelopteria cf. *dalli* (STEPHENSON, 1952)
Pl. 2, Fig. 3

cf. 1936 *Pteria*? *dalli* sp. nov. – STEPHENSON: 389, pl. 3, figs. 19-20.
cf. 1952 *Phelopteria dalli* (STEPHENSON) – STEPHENSON: 68, pl. 14, figs. 4-14.

Material. Two articulated internal moulds. One slightly fragmented specimen in shell preservation. PIW 2002 VII 26.

Description. Outline subtrigonal to pterioid, slightly inequivalved; valves relatively thin, strongly inequilateral and moderately inflated, the left valve slightly more than the right valve; umbo slightly prominent, located at about 1/3 of the total shell length from the anterior end; anterior wing strongly compressed, but partly fragmented; posterior wing triangular, compressed, and larger than anterior one, separated from the flank by broad depression; postero-dorsal margin long and straight forming aa acute angle with the slightly concave posterior margin; surface and wings ornamented with commarginal growth lamellae.

Remarks. *Phelopteria dalli* from the Cenomanian of Northern America is slightly more slender than the Jordanian specimens, but size and shape of the wings and ornamentation of the valves are very similar. ?*Pteria* (*Electroma*) *tihensis* described by ABBASS (1962) from the Cenomanian of Sinai is certainly no *Electroma*, but a *Phelopteria*.

Dimensions. Length 65 mm, height 52 mm (central Jordanian specimen). The south-west Jordanian forms exhibit a length of 42 and 55 mm, and a height of 37 and 43 mm.

Distribution. Cenomanian Woodbine Formation of Texas (STEPHENSON 1952), Cenomanian of Egypt (ABBASS 1962); Upper Cenomanian FHS Formation of Dilagha (sample J2-3).

Phelopteria sp.

Pl. 2, Fig. 4

Material. One composite mould of a slightly fragmented left valve. PIW 2002 VII 27.

Description. Outline subtrigonal to pterioid, reaching the largest length at the hinge margin; strongly inequilateral, relatively flat; umbo slightly extending beyond the hinge margin, located at about 1/4 to 1/3 of the shell length from the anterior end; both wings triangular and strongly compressed forming an acute angle with the posterior and the anterior margin, respectively; anterior and ventral margin regularly convex, posterior margin slightly concave; surface with commarginal growth lamellae which are not visible on the wings.

Remarks. This specimen is probably a juvenile individual of *Phelopteria* cf. *dalli*.

Dimensions. Length of the hinge margin 14 mm, height 8 mm.

Distribution. Claystones of the Upper FHS Formation (Cenomanian-Turonian) of the Ras En Naqb area (sample J5-45).

Genus *Pseudoptera* MEEK, 1873

Type species. *Avicula anomala* J. DE C. SOWERBY, 1836.

Pseudoptera sp.

Pl. 2, Fig. 5

Material. One composite mould of a complete left valve. PIW 2002 VII 28.

Description. Outline subtrigonal, valves thin and flat; strongly inequilateral, most probably gaping posteriorly; antero-dorsal margin short and slightly curved, antero-ventral margin long and oblique; ventral margin slightly sinuous; rostrum high and sharp forming a distinct posterior wing which is ornamented with fine commarginal striae and separated from main area of shell by a radial, slightly curved, rounded ridge; posterior margin of the wing convex, forming a pointed end with the long and straight postero-dorsal margin; anterior part of the shell compressed with narrow but relatively compressed auricle; flank between the two wings ornamented with very fine commarginal ribs;

anterior auricle additionally with 5-6 thin radial ribs; umbo pointed and prominent; remains of a long lateral tooth seen at the posterior hinge margin.

Remarks. The uncommon genus *Pseudoptera* is limited to the Cretaceous. *Avicula anomala* J. DE C. SOWERBY, 1836 from the Albian of England is very similar, but bears an additional radial ornamentation and the anterior wing is more pointed. Five species of *Pseudoptera* were described by WOODS (1905) from the Cretaceous of England which all differ from the Jordanian specimen in outline and size.

Of the four species of *Pseudoptera* from the Cenomanian of Texas (STEPHENSON 1952) *P. serrata* is the most similar form, but also exhibits an additional radial ornamentation.

Dimensions. Length 61 mm, height 42 mm.

Distribution. Upper Cenomanian claystones of the Upper FHS Formation of the Ras En Naqb area (sample J5-45).

Superfamily Pectinacea RAFINESQUE, 1815
Family Pectinidae RAFINESQUE, 1815
Genus *Camptonectes* AGASSIZ in MEEK, 1864
Subgenus: *Camptonectes* AGASSIZ in MEEK, 1864
Type species. *Camptonectes (Camptonectes) lens* (J. SOWERBY, 1818).

Camptonectes (*Camptonectes*) aff. *curvatus* (GEINITZ, 1843)
Pl. 2, Figs. 6-7

aff. 1843 *Pecten curvatus* sp. nov. – GEINITZ: 16, pl. 3, fig. 13.
aff. 1903 *Pecten* (*Camptonectes*) *curvatus* GEINITZ – WOODS: 159, pl. 29, fig. 7a-b.

Material. Three composite moulds of left valves. PIW 2002 VII 29.

Description. Valves small, outline subcircular, higher than long; umbo pointed, mesially placed, and not protruding beyond the hinge margin; anterior auricle of the left valve smaller than posterior one, both triangular and separated from the disk by a furrow; right valve with byssal notch; antero- and postero-dorsal margins slightly concave to straight, forming an angle of 85-87°; ventral margin regularly rounded; surface of shell ornamented with numerous radial to divaricate, partly bifurcating ribs; ribs are separated by sharp interspaces of nearly the same width; auricles ornamented with a reticulate pattern; length of the straight hinge margin about 2/3 to 3/4 of the total length.

Remarks. The genus *Camptonectes* has not been described from the Cenomanian of Jordan up to now. *Pecten* (*Camptonectes*) *curvatus* from the Upper Greensand (Albian) of England described and figured by WOODS (1903) is nearly identical. Only the umbo seems to be a bit broader, and the dorsal angle is slightly smaller (about 82°). *Pecten* (*Camptonectes*) *martinensis* STEPHENSON, 1952 from the Cenomanian of Texas exhibits a larger anterior auricle, and the ornamentation of the central part of the disk is indistinct.

Dimensions. Length 9.3 mm, 9.5 mm, 10 mm; height 11 mm, 11 mm, 12 mm.

Distribution. Silty claystones of the Upper Cenomanian FHS Formation from the Ras En Naqb area (sample J5-45).

Camptonectes (*Camptonectes*) sp.
Pl. 2, Fig. 8

Material. Several moulds of left and right, disarticulated valves. PIW 2002 VII 30-33.

Description. Outline and shape similar to *C*. aff. *curvatus*, but larger; without radial ornamentation but only a faint commarginal pattern; radial elements present only at the base of the auricles which are smaller than in *C*. aff. *curvatus*.
Dimensions. Length 9-18 mm; height 9–18 mm.
Distribution. Claystones of the Wadi Juhra Member (Cenomanian) and FHS Formation (Upper Cenomanian) of the middle part of the escarpment (sections 7 and 8). Upper Cenomanian limestones of the western sections (samples J4-1, J7-2, J9-12, J9-21).

Genus *Neithea* DROUET, 1825
Subgenus: *Neithea* DROUET, 1825
Type species. *Pecten aequicostatus* LAMARCK, 1819.

Neithea (Neithea) shawi (PERVINQUIÈRE, 1912)
Pl. 2, Figs. 9-10

1912 *Pecten* (*Neithea*) *shawi* sp. nov. – PERVINQUIÈRE: 136, pl. 9, figs. 1-6.
1934 *Pecten* (*Vola*) *shawi* (PERVINQUIÈRE) – BLANCKENHORN: 191, pl. 9, fig. 24, pl. 10, fig. 75.
1962 *Neithea aequicostata* (LAMARCK) – ABBASS: 51, pl. 6, fig. 16.

Material. Several left and right valves, rarely articulated. PIW 2002 VII 34-38.

Description. Valves equilateral, strongly inequivalved, higher than long and subtriangular; auricles of the right valve small and triangular, mostly broken; byssal notch present; antero- and postero-dorsal margins slightly concave, ventral margin regularly convex; umbo straight and strongly curved; ornamented with 17-20 radial ribs, interspaces broader than ribs; left valve flat, with triangular equi-sized left and right auricles.
Dimensions. Length 12-42 mm, height 13-47 mm.
Distribution: Cenomanian of Tunisia (PERVINQUIÈRE 1912), Egypt (ABBASS 1962) and Upper Cenomanian Naur and FHS formations of south-western Jordan (sections 1-5; samples J1-3B, J2-3A, J3-9, J4-1, J5-18).

Subgenus: *Neitheops* STEWART, 1930
Type species. *Neithea grandicosta* GABB, 1869.

Neithea (*Neitheops*) *syriaca* (CONRAD, 1852)
Pl. 2, Fig. 13

1852 *Janira syriaca* sp. nov. – CONRAD: 230, pl. 1, fig. 6.

Material. One slightly fragmented left valve. PIW 2002 VII 39.

Description. Shell generally similar to *N. shawi*, but ventral margin not rounded; about six prominent radial folds make the ventral margin appear angular; radial folds separated by 4-5 smaller, closely-spaced, irregular, radial ribs; equal-sized triangular posterior and anterior auricle.
Remarks. Several similar species have been described from the Cenomanian of the southern Tethyan realm. The ornamentation of *Janira dutrugei* COQUAND (1862: 219, pl. 8, figs. 1-2) is characterised by an arrangement of thicker and thinner ribs, without any ribs being as prominent as in *N. syriaca*. *Janira tricostata* COQUAND (1862: 219, pl. 8, figs. 3-4) exhibits three smaller ribs in the interspaces between the prominent ones; in *N. shawi* (PERVINQUIÈRE, 1912: 136, pl. 9, figs. 1-6) the ribs are of equal size.
Dimensions. Length 23 mm, height about 22 mm.
Distribution. The age of *Janira syriaca* described by CONRAD (1852) from Abeih, Syria, is rather uncertain. CONRAD stated “probably Jurassic” which is very unlikely. BLANCKENHORN (1934) described several Cretaceous taxa from the same locality.
In southern Jordan it was found very rarely in the basal FHS Formation (Upper Cenomanian) east of Ras En Naqb (section 6).

Genus *Plicatula* LAMARCK, 1801
Subgenus: *Plicatula* LAMARCK, 1801
Type species. *Spondylus plicatus* LINNÉ 1758.

Plicatula (Plicatula) fourneli COQUAND, 1862
Pl. 3, Figs. 1-2

1862 *Plicatula fourneli* sp. nov. – COQUAND: 220, pl. 16, fig. 5, 6.
1882 *Plicatula fourneli* COQUAND – SEGUENZA: 171.
1891 *Plicatula fourneli* COQUAND – THOMAS & PERON: 203.
1904 *Plicatula fourneli* COQUAND – FOURTAU: 311.
1912 *Plicatula fourneli* COQUAND – PERVINQUIÈRE: 153, pl. 10, fig. 2-6.
1917 *Plicatula fourneli* COQUAND – FOURTAU: p. 22.
1961 *Plicatula fourneli* COQUAND – ABBASS: 59, pl. 7, fig. 15.
1999 *Plicatula* cf. *fourneli* COQUAND – BUSSON et al.: 35.

Material. Several articulated specimens in shell preservation from the western sections; numerous disarticulated valves in shell concentrations. PIW 2002 VII 40-42.

Description. Inequivalved, relatively variable in outline, rounded triangular to ovate; equilateral to slightly inequilateral; higher than long; right valve moderately convex, occasionally with a small attachment area; antero- and postero-dorsal margins straight to slightly concave, ventral margin strongly convex; monomyar, imprints of adductor relatively large and rounded, sub-central; pallial line entire; hinge with straight, rather flat crurae; surface ornamented with imbricating, strong, commarginal growth lines and radial ribs which exhibit tubercles and spines.
Remarks. *P. fourneli* is a typical and widespread species of *Plicatula* in the Cenomanian of the southern and eastern Tethyan realm. It differs from *P. auressensis* COQUAND, 1862 by a larger size and the different ornamentation.
Dimensions. Length 20-52 mm, height 24-61 mm.

Distribution. Cenomanian of Northern Africa. Upper Cenomanian FHS Formation of south-western Jordan (samples J2-3A, J2-3, J4-1).

Plicatula (Plicatula) auressensis COQUAND, 1862
Pl. 1, Figs. 11-12

1862 *Plicatula auressensis* sp. nov. – COQUAND: 222, pl. 16, figs. 14-16.
1904 *Plicatula auressensis* COQUAND – FOURTAU: 312.
1912 *Plicatula auressensis* COQUAND – PERVINQUIÈRE: 153, pl. 10, figs. 2-6.
1917 *Plicatula auressensis* COQUAND – FOURTAU: 20.
1961 *Plicatula auressensis* COQUAND – ABBASS: 61, pl. 7, figs. 17-19.
1999 *Plicatula auressensis* COQUAND – BUSSON et al.: 34.

Material. Numerous disarticulated left and right valves and several articulated specimens. PIW 2002 VII 43-45.

Description. Outline and inflation of the specimens is similar to *P. fourneli*, but smaller and with a different ornamentation; *P. auressensis* exhibits 10-12 radial ribs which are irregularly curved without spines and tubercles; there is no strong imbrication of growth lamellae as in *P. fourneli*.
Dimensions. Length 15-30 mm, height 22-37 mm.
Distribution. Cenomanian of northern Africa (COQUAND 1862; FOURTAU 1904; PERVINQUIÈRE 1912; ABBASS 1962) and Upper Cenomanian of the FHS Formation of south-western Jordan (samples J1-5, J1-5A, J3-10).

Superfamily Limacea RAFINESQUE, 1815
Family Limidae RAFINESQUE, 1815
Genus *Plagiostoma* J. SOWERBY, 1814
Type species. *Plagiostoma giganteum* STOLICZKA, 1871.

Plagiostoma tithensis (ABBASS, 1962)
Pl. 3, Fig. 4

1962 *Lima* (*Plagiostoma*) *tithensis* sp. nov. – ABBASS: 47, pl. 8, fig. 4

Material. One well preserved left valve. PIW 2002 VII 46.

Description. Outline oblique-ovate, inequilateral; anterior side longer than posterior one; valves slightly longer than high, moderately inflated; anterior margin slightly concave, ventral margin regularly curved; anterior auricle broken; posterior auricle triangular; postero-dorsal margin straight and shorter than antero-dorsal margin; an umbonal carina separating the deeply recessed anterior area; surface ornamented with numerous fine radial striae, which are preserved incompletely, and fine commarginal growth lines.
Remarks. The Jordanian specimen shows only half the size of ABBASS‘ *Plagiostoma*. The other features are nearly identical.
Dimensions. Length 34 mm, height 31 mm.

Distribution: Cenomanian of Sinai (ABBASS 1962) and south-western Jordan (Dilagha; sample J2-3).

Plagiostoma sp.
Pl. 3, Fig. 3a-b

Material. One fragmented, articulated specimen. PIW 2002 VII 47.

Description. Outline oblique-ovate, inequilateral, much higher than long; valves moderately inflated, equivalved; anterior end shorter than posterior one; anterior margin slightly convex, ventral margin strongly convex; preserved part of the posterior margin nearly straight; umbo prominent; auricles broken; surface ornamented with 28 distinct, broad, radial ribs separated by deep interspaces.

Remarks. Similar to *Lima iteriana* (PICTET & ROUX, 1852) described by PERVINQUIÈRE (1912) from the Cenomanian of Algeria, but the Jordanian specimen is very poorly preserved and does not allow a precise identification.

Dimensions. Length about 35 mm, height 44 mm.

Distribution. Cenomanian of the basal FHS Formation of south-western Jordan (Dilagha; sample J2-3).

Suborder Ostreina FERUSSAC, 1822
Superfamily Ostreoidea RAFINESQUE, 1815
Family Gryphaeidae VIALOV, 1936
Subfamily Exogyrinae VIALOV, 1936
Tribus Nanogyrini MALCHUS, 1990
Genus *Amphidonte* FISCHER DE WALDHEIM, 1829
Type species. *Amphidonte humboldtii* FISCHER DE WALDHEIM, 1829.
Subgenus *Ceratostreon* BAYLE, 1878
Type species. *Exogira spinosa* MATHERON, 1843.

Amphidonte (*Ceratostreon*) *flabellatum* (GOLDFUSS, 1833)
Pl. 3, Fig. 8a-b

1833 *Exogyra flabellata* sp. nov. – GOLDFUSS: 38, pl. 87, fig. 6a-b.
For synonymy see MALCHUS (1990) and AQRABAWI (1993).

Material. Numerous disarticulated valves from the western sections. PIW 2002 VII 48-52.

Description. Specimens medium-sized and thick-shelled; shape very variable, outline high-ovate to rounded or sickle-shaped; strongly inequivalved and inequilateral; left valve strongly convex and with more or less spirally incurved umbo; moderately sized attachment area at the umbo; radial ornamentation varying, mostly closely spaced at the umbo, becoming more widely spaced and more distinct folds on the flank, partly bifurcating; many specimens with distinct carina which runs, slightly curved, from the umbo to the ventral margin; adductor scar relatively large and tear-shaped; right valve smaller, flat; with radial ribs that partly exhibit tubercles and commarginal growth lamellae; many specimens exhibit drill holes.

Remarks. *Amphidonte flabellatum* is a typical Upper Cretaceous oyster of the Mediterranean Tethys realm.

Dimensions. Length 29-58 mm; height 26-36 mm.

Distribution. According to DHONDT (1984) and MALCHUS (1990) the species occurs in the Albian to Cenomanian, probably also Aptian, of the Tethys, Asia, Africa and Madagascar. According to FRENEIX (1986) it occurs up to the Coniacian. In south-western Jordan it is found in the Cenomanian of the Naur and FHS Formation (samples J1-3B, J2-3A, J3-9, J3-10, J5-18).

Tribe Exogyrini VIALOV, 1936
Genus *Ilymatogyra* STENZEL, 1971
Type species. *Ilymatogyra arietina* (ROEMER, 1852).
Subgenus *Afrogyra* MALCHUS, 1990
Type species. *Ilymatogyra* (*Afrogyra*) *africana* (LAMARCK, 1801).

Ilymatogyra (Afrogyra) africana (LAMARCK, 1801)
Pl. 3, Figs. 5-7

1801 *Gryphaea africana* sp. nov – LAMARCK: 399, pl. 189, figs. 5-6.
For synonymy see MALCHUS (1990) and AQRABAWI (1993).

Material. Numerous disarticulated and articulated valves from the western sections. PIW 2002 VII 53-67.

Description. Valves small to medium-sized; strongly inequivalved, inequilateral; outline high-ovate to tear-shaped, width strongly varying; left valve strongly convex, with a small and helicoidally incurved beak; ornamented with irregularly spaced scaly growth lamellae; attachment area small to medium-sized in forma "*crassa*", typically very small in forma "*typica*"; right valve flat to moderately convex, with close-spaced, scaly growth lamellae; adductor scar kidney-shaped and located relatively close to the posterior margin.

Remarks. MALCHUS (1990) distinguished between the two form groups "forma *typica*" and "forma *crassa*". The morphotype "*crassa*" reaches a larger size and exhibits a more distinct carina. The left valve is less convex than in "forma *typica*". These two types occur in Egypt geographically separated in different lithofacies: while "forma *typica*" dominates in clay and siltstones, "forma *crassa*" prefers marls and marly limestones. According to MALCHUS (1990) there are numerous transitional stages between these two ecophenotypes.

In southern Jordan similar observations were made; both morphotypes are present, "forma *typica*" occurs in marlstones representing a reclining life habit on a relatively soft substrate, whereas "forma *crassa*" dominates in calcareous and marly sediments revealing a cemented life habit. Because of the fact, that the two forms of *Afrogyra africana* represent different environments, the growth forms were kept separate in the cluster analysis.

Dimensions. Length 15-26 mm, height 20-36 mm ("forma *typica*").
Length 20-36 mm, height 28-52 mm ("forma *crassa*").

Distribution. Cenomanian of Portugal, Italy, Egypt, Syria, Madagascar and Peru. In the Cenomanian of central Jordan (AQRABAWI 1993) and in the Upper Cenomanian (FHS Formation) of south western Jordan (samples J1-5A, J2-1, J2-2, J2-3A, J3-8A, J3-9, J3-10, J4-1, J5-18, J5-42, J5-48, J6-26A, J6-33, J6-34, J8-12).

Genus *Laevigyra* MALCHUS, 1990

Type species. *Laevigyra luynesi* (LARTET, 1872).

Laevigyra dhondtae MALCHUS, 1990

1990 *Laevigyra dhonthae* gen. et. sp. nov. – MALCHUS: 126, pl. 8, figs. 5-9.
1993 *Laevigyra dhonthae* MALCHUS – AQRABAWI: 73, pl. 17, figs. 17-18.

Material. Several left valves. PIW 2002 VII 68.

Description. Valves small and thick-shelled; strongly inequivalved, inequilateral; shape relatively variable, outline mostly drop-shaped to high-ovate or rounded; shape similar to *Afrogyra africana* “forma *typica*” from which it differs by the smooth surface which only occasionally exhibits some growth lines; anterior margin straight to slightly convex, ventral margin regularly convex, posterior margin straight to slightly concave; left valve with strongly incurved helicoidal beak and very small attachment area; adductor scar medium-sized and rounded, located postero-dorsally.

Remarks. *L. dhondtae* is relatively rare in the study area. Most specimens exhibit drill holes.

Dimensions. Length 9-14 mm; height 16-30 mm.

Distribution. Upper Cenomanian of Egypt and central Jordan (MALCHUS 1990, AQRABAWI 1993). In south-western Jordan in the Upper Cenomanian FHS Formation between Ras En Naqb and At Taiyba (samples J1-5, J2-3A, J5-18).

Genus *Rhynchostreon* BAYLE, 1878

Type species. *Rhynchostreon chaperi* BAYLE, 1878.

Rhynchostreon mermeti (COQUAND, 1862)

Pl. 3, Figs. 9-10

1862 *Ostrea mermeti* sp. nov. – COQUAND: 234, pl. 23, figs. 3-5.
For synonymy see MALCHUS (1990) and AQRABAWI (1993).

Material. Several, mostly disarticulated specimens. In the claystones of the eastern escarpment preserved as composite moulds. PIW2002 VII 69-82.

Description. Shell small to medium-sized, outline rounded to high ovate or drop-shaped; strongly inequivalved, inequilateral; left valve strongly convex, with more or less strongly incurved, large umbo; attachment area very small or not visible; ornamented with commarginal growth lamellae varying in strength, and fine to moderately strong radial ribs; right valve flat to slightly concave, ornamented with scaly, commarginal growth lamellae; ligamental area small and narrow; imprint of adductor muscle almost circular, located postero-centrally.

Remarks. As for *Afrogyra africana*, two morphotypes were observed by MALCHUS (1990). "Forma *minor*" is smaller than "forma *typica*", exhibits a smaller umbonal area, and the umbo is less twisted. All specimens found in the study area in southern Jordan belong to "forma *minor*".
Dimensions. Length 14-23 mm, height 22-32 mm.
Distribution. Cenomanian of Italy, Portugal, northern Africa, central Africa, Madagascar. In central Jordan both morphotypes occur in the Cenomanian (AQRABAWI 1993), in southern Jordan in the Upper Cenomanian FHS and Harad formations of sections 1-10 (samples J1-5B, J5-18, J5-36, J6-26A, J6-29, J6-32, J6-33, J7-20, J8-12, J8-16, J9-18, J9-20, J9-21, J10-17).

Genus *Exogyra* SAY, 1820
Subgenus *Exogyra* SAY, 1820
Type species. *Exogyra costata* SAY, 1820.

Exogyra (*Exogyra*) *italica* (SEGUENZA, 1882)
Pl. 4, Fig. 1a-b

1882 *Exogyra oxyntas* (COQUAND, 1862) var. *italica* – SEGUENZA: 178, pl. 18, fig. 1.
1993 *Exogyra* (*Exogyra*) *italica* (SEGUENZA, 1882) – AQRABAWI: 66, pl. 4, figs. 1-2.

Material. Several left valves. PIW 2002 VII 83.

Description. Very large specimens; outline irregularly high-ovate and strongly variable, inequivalved, inequilateral; left valve strongly inflated, umbo strongly incurved; surface of left valve ornamented with numerous, scaly, imbricated growth lamellae; umbo with indication of radial folds; attachment area small; adductor scar large and subovate, slightly indented dorsally; right valves ovate and only slightly convex, ornamented with strong growth lamellae.
Remarks. *Exogyra italica* represents the largest oyster species which occurs in southern Jordan. Remarkably, it was not mentioned by MALCHUS (1990) from Egypt, although the composition of oysters is nearly identical in Egypt and Jordan. Maybe *Exogyra italica* is only a growth variety of *Costagyra olisiponensis*.
Dimensions. Length about 60-65 mm, height 100-112 mm.
Distribution: Cenomanian of Italy (SEGUENZA 1882). In southern Jordan from the Cenomanian of Wadi Jamil (AQRABAWI 1993) and At Taiyba (sample J1-5B).

Subgenus *Costagyra* VIALOV, 1936
Type species. *Exogyra olisiponensis* SHARPE, 1850.

Exogyra (*Costagyra*) *olisiponensis* SHARPE, 1850
Pl. 3, Figs. 12-13

1850 *Exogyra olisiponensis* sp. nov – SHARPE: 185, figs. 1-2.
For synonymy see MALCHUS (1990) and AQRABAWI (1993).

Material. Numerous, mostly disarticulated valves from all western sections. PIW 2002 VII 84-93.

Description. Strongly variable in size and shape, strongly inequivalved and inequilateral; left valve very thick and strongly convex, outline high-ovate to subcircular, occasionally rounded-triangular; anterior margin straight, ventral margin convex, posterior margin close to the umbo slightly concave; umbo generally small and blunt, helicoidal; attachment area small to medium-sized; left valve ornamented with smooth or scaly growth lamellae and, typically, sharp, irregular, wide-spaced, radial folds; in some specimens also with short spines; right valve only slightly convex, with concentric, scaly growth lamellae and sharp radial ribs in the anterior part; imprint of adductor large, ovate, with a small concave dorsal indentation.

Remarks. Together with *Afrogyra africana* "forma *typica*" and *Rhynchostreon mermeti* the most common oyster species in the study area.

Dimensions. Length 40-85 mm, height 52-95 mm.

Distribution. Widespread in the Upper Cretaceous, mostly recorded from Cenomanian deposits (Mediterranean Tethyan realm, Africa, Near East, also North and South America and Central Asia). In the Cenomanian FHS Formation of south-western Jordan (samples J1-5B, J2-3A, J2-3, J3-9, J3-10, J5-42, J5-45, J5-46, J6-33, J6-34).

Subfamily Pycnodonteinae STENZEL, 1959
Tribus Pycnodontini MALCHUS, 1990
Genus *Pycnodonte* FISCHER DE WALDHEIM, 1835
Type species. *Pycnodonte radiata* FISCHER DE WALDHEIM, 1835.
Subgenus *Phygraea* VIALOV, 1936
Type species. *Gryphaea pseudovesicularis* GÜMBEL, 1861.

Pycnodonte (*Phygraea*) *vesiculosum* (J. SOWERBY, 1823)
Pl. 3, fig. 11a-b

1823 *Gryphaea vesiculosa* sp. nov. – J. SOWERBY: 93, pl. 369, figs. 1-7.
For synonymy see MALCHUS (1990) and AQRABAWI (1993).

Material. One articulated, moderately preserved specimen. PIW 2002 VII 94.

Description. Inequivalved, inequilateral shell; outline high-ovate with a short and relatively broad rostrum at the posterior end; umbo prominent, rather pointed and opisthogyrate; attachment area not visible; left valve moderately inflated, ornamented with closely-spaced growth lamellae; right valve less inflated and slightly smaller; umbonal part slightly broader and not as prominent as in the left valve; internal features not visible.

Remarks. The specimen is extensively bored, the left valve more so than the right.

Dimensions. Length 30 mm, height 30 mm.

Distribution. *Pycnodonte* (*Phygraea*) *vesiculosum* is a very widespread Cretaceous oyster. It is recorded from the Albian to Cenomanian of Europe (England, France, Italy), India, North Africa, Angola, and the Near East. From Jordan it was described by AQRABAWI (1993) from the Cenomanian north of Amman; in south-western Jordan it occurs rarely in the FHS Formation of Dilagha (section 2, sample J2-3).

Subfamily Liostrinae MALCHUS, 1990
Tribus Curvostreini MALCHUS, 1990
Genus *Curvostrea* VIALOV, 1936
Type species. *Ostrea rouvillei* COQUAND, 1862.

Curvostrea cf. *rouvillei* (COQUAND, 1862)
Pl. 4, Figs. 2, 4

cf. 1862 *Ostrea rouvillei* sp. nov. – COQUAND: 232, pl. 22, figs. 8-10.
For synonymy see MALCHUS (1990) and AQRABAWI (1993).

Material. Several disarticulated valves in shell preservation from the western sections, several composite moulds from the eastern escarpment. PIW 2002 VII 95-105.

Description. Valves relatively small, inequilateral and slightly inequivalved; outline high-ovate to kidney-shaped; right valve less convex than left valve; ornamented with weak and irregular, sometimes slightly wavy growth lines; umbo often curved backwards and very small; adductor scar ovate to subcircular, located postero-ventrally; ligamental area high-triangular and narrow.
Dimensions. Length 6-14 mm, height 11-34 mm.
Distribution. Upper Cretaceous (Cenomanian to Santonian) of Europe (Germany, France), central Africa (Niger, Congo, Cameroon), North Africa (Morocco, Algeria, Tunisia, Egypt), Near East. In the study area the species occurs in the Upper Cenomanian of the FHS Formation (samples J1-3B, J1-5, J1-5A, J3-10, J5-45, J6-29, J6-32, J7-16, J8-12, J8-16, J9-18).

Tribus Ambigostreini MALCHUS, 1990
Genus *Ambigostrea* MALCHUS, 1990
Type species. *Ambigostrea dominici* MALCHUS, 1990.

Ambigostrea cf. *dominici* MALCHUS, 1990
Pl. 4, fig. 3a-b

1990 *Ambigostrea dominici* sp. nov. – MALCHUS: 179, pl. 21, figs. 1-3.

Material. Several left valves. PIW 2002 VII 106.

Description. Valves small, inequilateral, inequivalved; outline high-ovate to triangular; left valve strongly convex; anterior margin straight to slightly convex, ventral margin regularly convex, posterior margin slightly concave; umbo somewhat blunt; left valve ornamented with stepped, distinct growth lamellae and regularly arranged radial ribs which are fine and closely spaced at the umbo, and coarser near the ventral margin; attachment area relatively large; ligamental area oblique-triangular; adductor scar ovate to kidney-shaped, situated close to the posterior margin.
Dimensions. Length 18-24 mm, height 23-31 mm.
Distribution. Upper Cenomanian of Egypt (MALCHUS 1990) and Ras En Naqb, south-western Jordan (section 5; sample J5-18).

Subclass Palaeoheterodonta NEWELL, 1965
Order Trigonioida DALL, 1889
Superfamily Trigoniacea LAMARCK, 1819
Family Trigoniidae LAMARCK, 1819
Genus *Trigonia* BRUGUIÈRE, 1789
Subgenus *Trigonia* BRUGUIÈRE, 1789
Type species. *Venus sulcata* HERMANN, 1781.

Trigonia (*Trigonia*) cf. *ethra* COQUAND, 1880
Pl. 4, Fig. 8

cf. 1912 *Trigonia ethra* COQUAND – PERVINQUIÈRE: 218, pl. 15, figs. 4-7.

Material. One moderately preserved right valve. PIW 2002 VII 107.

Description. Outline trigonal, strongly inequilateral; valve moderately inflated; beak opisthogyrate and rather prominent; area broad; ornamentation of the area not preserved; flanks ornamented with about 16 distinct, sharp, divaricate ribs, which are separated from each other by fairly broad interspaces; narrow, smooth field between marginal carina and flank.

Dimensions. Length 28 mm, height 30 mm.

Distribution. Cenomanian of Sinai (PERVINQUIÈRE 1912) and south-west Jordan (FHS Formation, section 3; sample J3-9).

Trigonia (*Trigonia*) sp.
Pl. 4, Fig. 7

Material. One imprint of a right valve. PIW 2002 VII 108.

Description. Valve very small, moderately inflated; outline trigonal, strongly inequilateral; beak opisthogyrate; area relatively broad and separated into two parts, of which the outer one is slightly wider; area ornamented with obscure tranverse lines; flank ornamented with about 13-14 sharp commarginal ribs which are separated by wide interspaces.

Remarks. Similar to, but much smaller than, *Trigonia* cf. *ethra*, maybe a juvenile specimen. Trigoniid bivalves are very rare in the study area.

Dimensions. Length 11 mm, height 12 mm.

Distribution. Cenomanian? silty claystones of the FHS Formation from the Batn El Ghoul area (section 10; sample J10-6).

Subclass Heterodonta NEUMAYR, 1884
Order Veneroida ADAMS & ADAMS, 1856
Superfamily Lucinacea FLEMING, 1828
Family Lucinidae FLEMING, 1828
Subfamily Lucininae FLEMING, 1828
Genus *Lucina* BRUGUIÈRE, 1797
Type species. *Venus jamaicensis* SPENGLER, 1784.

“*Lucina*” sp.
Pl.5, Fig. 3

Material. Four partly fragmented, disarticulated valves. PIW 2002 VII 109.

Description. Valves relatively thin and flat; equivalve, inequilateral; length and height nearly equal; outline irregularly subcircular; umbo small, prosogyrate and not very prominent, located slightly behind the mid-line; antero-dorsal margin long and slightly convex; postero-dorsal margin shorter; ventral margin strongly convex; surface ornamented with numerous fine commarginal growth lines; hinge plate long and narrow; remains of a long anterior lateral tooth seen in one specimen.
Remarks. The genus has not been recorded from Jordan up to now. *Lucina benvenistii* SHALEM, 1928 from the Lower Cenomanian of Motza, Israel (SHALEM 1928; BLANCKENHORN 1934) is distinctly smaller and more ovate in outline. The shape of *Lucina usieli* SHALEM (in BLANCKENHORN 1934: pl. 12, fig. 118) from the same locality resembles more closely a small arcticid bivalve.
Dimensions. Length of the complete specimen 43 mm, height 43 mm.
Distribution. Cenomanian? euhaline claystones of the FHS Formation of Batn El Ghoul (section 10; sample J10-6).

Superfamily Carditacea FLEMING, 1820
Family Carditidae FLEMING, 1820

Carditid bivalve sp. A
Pl. 5, Figs. 9-10

Material. Several composite moulds of left and right valves. PIW 2002 VII 110-111.

Description. Valves tiny, moderately inflated, outline trigonal, inequilateral; length and height nearly equal; umbo prosogyrate, somewhat prominent, slightly incurved and shifted anteriorly; anterior margin concave, ventral and posterior margins convex; surface ornamented with about 10 distinct, widely-spaced radial ribs separated by furrows V-shaped in cross-section; remains of commarginal growth lines.
Remarks. A precise identification is impossible due to lack of information about the hinge and internal features. *Cardita dubertreti* BLANCKENHORN, 1934 from the Senonian of Lebanon is similar with respect to outline, ornamentation, and number of ribs, but is about 7 times larger. *Xenocardita lacunaris* (HAMLIN, 1884) from the Aptian of Lebanon has 15 radial ribs and reaches also a distinctly larger size. The Jordanian specimens are most probably juveniles but without knowledge of the hinge it is not possible to assign them to *X. lacunaris*.
Dimensions. length 1-1.5 mm, height 1-1.5 mm.
Distribution. Cenomanian Wadi Juhra Member and Harad Formation of southern Jordan (sections 7 and 10; samples J7-2 and J10-6).

Carditid bivalve sp. B.
Pl. 5, Figs. 7-8

Material. Several composite moulds of disarticulated left and right valves. PIW 2002 VII 112-116.

Description. Valves small, moderately inflated; outline trigonal to trigonal-subovate, slightly inequilateral, longer than high; beak prosogyrate, relatively broad; anterior part slightly larger than posterior part; posterior margin straight to slightly convex, ventral and posterior margins convex; surface ornamented with about 30 distinct radial ribs, remains of commarginal growth lines visible; remains of an anterior umbonal ridge; there the radial ribs are more widly spaced.

Dimensions. length 5-7 mm, height 4-6 mm.

Distribution. Cenomanian FHS Formation of the Ras En Naqb-Batn El Ghoul escarpment (samples J5-45, J6-10, J9-12, J9-18, J10-6).

Superfamily Crassatellacea FÉRUSSAC, 1822
Family Astartidae D´ORBIGNY, 1844
Subfamily Opinae CHAVAN, 1952
Genus *Opis*? DEFRANCE, 1825
Type species. *Trigonia cardissoides* LAMARCK, 1819.

Opis? sp.
Pl. 5, Fig. 11

Material. Imprint of a compressed right valve. PIW 2002 VII 117.

Description. Outline rounded trigonal, inequilateral, higher than long; umbo fairly prominent, slightly incurved and moved anteriorly; anterior and posterior margins nearly straight and strongly oblique; ventral margin smooth and regularly convex; surface ornamented with numerous fine, relatively widely-spaced, regularly arranged, commarginal ribs.

Remarks. Because of the poor preservation and lack of information on hinge and internal features, a precise identification is not possible.

Dimensions. Length 14 mm, height 18 mm.

Distribution. Upper Cenomanian claystones of the FHS-Formation of the Batn El Ghoul area (section 9).

Family Crassatellidae FÉRUSSAC, 1822
Subfamily Crassatellinae FÉRUSSAC, 1822
Genus *Crassatella* LAMARCK, 1799
Type species. *Mactra cygnaea* LAMARCK, 1799.

"*Crassatella*" sp.
Pl. 5, Fig. 1

Material. Several composite moulds of right and left valves. PIW 2002 VII 118-119.

Description. Valves small and inequilateral; equivalved, moderately inflated; outline subtriangular to elongate- ovate; umbo moderately pointed, prosogyrate and moved anteriorly, located about 1/3 of shell length from the anterior end; anterior margin straight and oblique, ventral margin regularly convex, posterior margin truncated; postero-dorsal margin straight; surface of shell ornamented with numerous fine commarginal growth lines; ventral margin very fine crenulated.
Remarks. A precise identification is not possible because hinge and internal features are not known. Outline and external features point to a member of the family Crassatellidae.
Dimensions. Length 12-14 mm, height 8-9 mm.
Distribution. Upper Cenomanian claystones of the FHS Formation of the Batn El Ghoul area. (sections 8 and 9; samples J8-12, J9-20).

Genus *Anthonya* GABB, 1864
Type species. *Anthonya cultriformis* GABB, 1864.

Anthonya dayi VOKES, 1941
Pl. 5, Fig. 2

1941 *Anthonya dayi* sp. nov. – VOKES: 9, pl. 2, fig. 7.

Material. Several disarticulated, poorly to moderately preserved composite moulds. PIW 2002 VII 120.

Description. Valves relatively small, equivalved, elongated, strongly inequilateral; anterior margin slightly convex, ventral margin regularly curved, anterior margin short and truncated; postero-dorsal margin long and concave; umbo pointed, located 1/4 to 1/5 of shell length from the anterior end; hinge characterised by two very small, slightly rounded trigonal cardinal teeth and one long anterior as well as one long posterior lateral tooth, which run parallel to the hinge margin; surface ornamented with several thin commarginal ribs, which are separated by wide interspaces; at the ventral margin, the ribs are more closely-spaced.
Remarks. The Jordanian specimens resemble very closely the specimens from the Cenomanian of Lebanon described and figured by VOKES (1941). The smaller size of the Jordanian forms might be due to a softer substrate in Jordan (claystones) in contrast to Lebanon (limestones).
Dimensions. Length 9-25 mm; height 4-9 mm.
Distribution. Cenomanian of Hajula (Lebanon Mountains) and Cenomanian FHS Formation of Batn El Ghoul (section 10; sample J10-6).

Anthonya jordanica sp. nov.
Pl. 5, Figs. 4-6

Derivation of name. The species name is derived from the Country Jordan, where it first has been found.
Holotype. PIW 2002 VII 120; **paratypes**. PIW 2002 VII 121-122.
Additional material. Numerous disarticulated, mostly moderately to well preserved specimens. PIW 2002 VII 123.

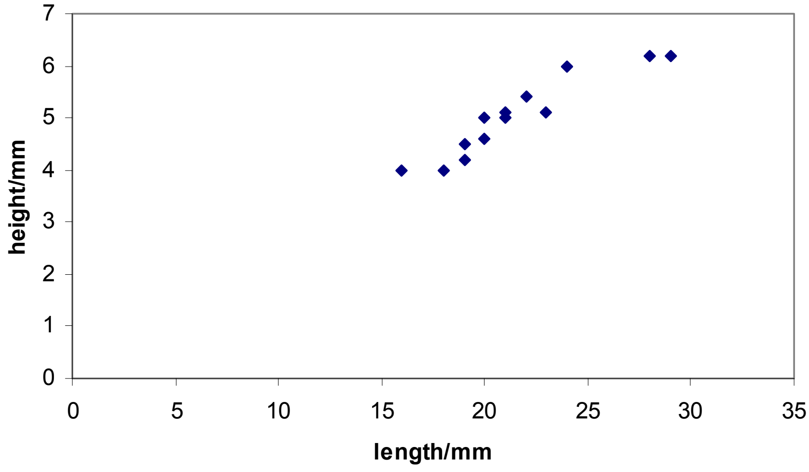
Diagnosis. Strongly elongated *Anthonya* with a short and straight anterior margin, a very long concave postero-dorsal margin and a truncated posterior margin.

Description. Valves flat and very elongated posteriorly, equivalved; strongly inequilateral; anterior margin short and straight, occasionally slightly concave close to the umbo; posterior end much longer than in *A. dayi* VOKES, 1941, postero-dorsal margin regularly concave, in some specimens nearly straight; umbo pointed, located at about 1/8 of the shell length from the anterior end; hinge very similar to *A. dayi*, with two triangular cardinal teeth and long laterals, which run parallel to the dorsal margin; ornamented with numerous fine commarginal ribs which are much closer-spaced as in *A. dayi*.

Remarks. *Anthonya* is a relatively rare Cretaceous genus with a limited number of species. *A. cultriformis* GABB, 1864 from the Upper Cretaceous of California is, compared to *A. jordanica*, shorter and higher, altogether more compact. *A. cantiana* WOODS, 1904 from the Folkestone Beds of England (Upper Aptian) is also shorter. *Anthonya* sp. from the Lower Greensand (Aptian) of Atherfield, England, is characterised by a convex anterior margin and a shorter posterior end (WOODS 1904). *A. dayi* from the Cenomanian of the Lebanon (VOKES 1941) and southern Jordan exhibits a distinctly shorter posterior end.

Dimensions. Length 21-33 mm, height 4-8 mm.

Distribution. Lower FHS Formation (Cenomanian) of Batn El Ghoul (section 10) and Wadi Juhra Member (Cenomanian) east of Ras En Naqb (section 6). Samples J6-10, J7-2, J8-12, J9-21, J10-6.



Text-fig. 51. Length-height ratio of *Anthonya jordanica* sp. nov.

Superfamily Cardiacea LAMARCK, 1809
Family Cardiidae LAMARCK, 1809
Subfamily Cardiinae LAMARCK, 1809
Genus *Granocardium* GABB, 1869
Subgenus *Granocardium* GABB, 1869
Type species. *Cardium carolinum* D´ORBIGNY, 1844.

Granocardium (*Granocardium*) *productum* (J. DE C. SOWERBY, 1832)
Pl. 5, Fig. 12

1832 *Cardium productum* sp. nov. – J. DE C. SOWERBY in SEDGWICK & MURCHISON: 417, pl. 39, fig. 15.

1912 *Cardium* (*Trachycardium*) *productum* SOWERBY – PERVINQUIÈRE: 259, pl. 19, figs. 25-27.

1917 *Cardium productum* SOWERBY – FOURTAU: p.81.
1958 *Cardium* (*Trachycardium*) *productum* (SOWERBY) – BARBER: 26, pl.9, figs. 2-3.
1999 *Granocardium productum* (SOWERBY) – BUSSON et al.: p. 36.

Material. Several internal moulds of articulated specimens. PIW 2002 VII 124-126.

Description. Moulds relatively large, strongly inflated; outline ovate to rounded-triangular, much higher than long; equivalved, slightly inequilateral; umbo large, orthogyrate and prominent, rather strongly incurved; imprints of distinct anterior and posterior adductor scars of nearly equal size; anterior margin convex, posterior margin straight, ventral margin slightly convex; valve increases in height posteriorly; hinge margin straight; remains of regularly arranged radial ribs; ventral margin most probably crenulated.

Remarks. The Jordanian specimens are very similar to *Granocardium productum* from the Upper Cretaceous of Tunisia (PERVINQUIÈRE 1912). *G. productum* differs from *Trachycardium*? *mermeti* (COQUAND, 1962) by its smaller umbo, a smaller lunule and area and a finer ornamentation. Furthermore, *G. mermeti* reaches a larger size.

Dimensions. Length 29–43 mm, height 40–53 mm.

Distribution. Upper Cretaceous of France, Sicily, India; Turonian of Tunisia (PERVINQUIÈRE 1912), Cenomanian of Egypt (FOURTAU 1917) and Upper Cenomanian limestones of the lower FHS Formation of south-west Jordan (sections 2-4). Samples J2-3, J3-10, J4-1.

Granocardium (*Granocardium*) cf. *desvauxi* (COQUAND, 1862)

Pl. 5, Figs. 13-14

cf. 1862 *Cardium desvauxi* sp. nov.– COQUAND: 206, pl. 11, figs. 3-4.
cf. 1912 *Cardium* (*Trachycardium*) *desvauxi* (COQUAND) – PERVINQUIÈRE: 260.
cf. ?1962 *Granocardium hassani* sp. nov. – ABBASS: 122, pl. 20, fig. 2-3.

Material. One well preserved and two slightly compressed internal moulds. PIW 2002 VII 127.

Description. Valves strongly inflated, subequivalved, higher than long; outline rounded-quadrangular, nearly equilateral; anterior and posterior margins slightly convex; ventral margin regularly rounded; umbo nearly orthogyrate; hinge margin straight; surface ornamented with very fine, radial ribs which, are arranged in pairs, and radial rows of fine tubercles in the interspaces between the pairs which can only be observed in well preserved specimens.

Dimensions. Length 48 mm, height 54 mm.

Distribution. Cenomanian of Algeria (COQUAND 1862). Egypt (ABBASS 1962) and Upper Cenomanian limestones of the FHS Formation of south-west Jordan (section 3; sample J 3-9).

Granocardium (*Granocardium*) cf. *carolinum* (D´ORBIGNY, 1843)

Pl. 6, Figs. 1-2

cf. 1843 *Cardium carolinum sp. nov.* – D´ORBIGNY: 29, pl. 245.
cf. 1981 *Granocardium* cf. *carolinum* (D´ORBIGNY) – AMARD et al.: 75, pl. 1, fig, 1-2.
cf. 1999 *Granocardium* aff. *carolinum* (D´ORBIGNY) – BUSSON et al.: 36.

Material. Several, moderately preserved, articulated, internal moulds. PIW 2002 VII 128-131.

Description. Moulds moderately to strongly inflated, outline circular to rounded quadrangular, slightly higher than long; equivalved and nearly equilateral; umbo prominent and nearly orthogyrate, somewhat pointed and slightly incurved; anterior and posterior margins convex, ventral margin regularly convex; hinge margin straight; ornamentation not preserved.

Remarks. Very similar to the specimen figured by AMARD et al. (1981) from the Cenomanian of Algeria. However, due to the preservation as internal moulds, the ornamentation is not preserved in both cases.

Dimensions. Length 27–35 mm, height 29–40 mm.

Distribution. Upper Cretaceous of France (D´ORBIGNY 1843). In the Cenomanian of Algeria and in the Upper Cenomanian limestones of south-west Jordan together with *Neolobites vibrayeanus*. Samples J2-3, J3-9, J3-10, J4-1.

Subfamily Trachycardiinae STEWART, 1930
Genus *Trachycardium* MÖRCH, 1853
Subgenus *Trachycardium* MÖRCH, 1853
Type species. *Trachycardium* (*Trachycardium*) *isocardia* LINNÉ, 1758.

Trachycardium? *mermeti* (COQUAND, 1862)
Pl. 6, Figs. 3-4

1862 *Cardium mermeti* sp. nov. – COQUAND: 207, pl. 11, figs. 6-7.
1912 *Cardium (Trachycardium) mermeti* COQUAND – PERVINQUIÈRE: 261.
1917 *Cardium mermeti* COQUAND – FOURTAU: 81.

Material. Several internal moulds of articulated specimens. PIW 2002 VII 132-134.

Description. Moulds large, strongly inflated; outline triangular, much higher than long; equivalved, slightly inequilateral; umbones very prominent, pointed, slightly prosogyrate and incurved; adductor scars subequal; anterior and posterior margins nearly straight to slightly convex; ventral margin strongly convex; hinge margin short and straight; remains of distinct, regularly arranged radial ribs and interspaces of the same width; ventral margin most probably crenulated.

Remarks. Without the hinge a precise identification of the genus is not possible, but the Jordanian specimens are correspond perfectly to the Algerian and Tunisian specimens of COQUAND and PERVINQUIÈRE. The ?subspecies *Trachycardium mermeti* var. *msegguemensis* from the Maastrichtian of Algeria described by COLLIGNON (1971) is less inflated, broader and inequivalved. It is very questionable wether that taxon belongs to *Trachicardium mermeti* COQUAND.

Dimensions. Length 47-53 mm, height 60-78 mm.

Distribution. Upper Cretaceous of Algeria (COQUAND 1862), Cenomanian of Tunesia (PERVINQUIÈRE 1912) and Egypt (FOURTAU 1917). Upper Cenomanian limestones of the lower FHS Formation of south-western Jordan (sections 1-3). Samples J1-3B, J3-9, J3-10.

Subfamily Protocardiinae KEEN, 1951
Genus *Protocardia* VON BEYRICH, 1845
Subgenus *Protocardia* VON BEYRICH, 1845
Type species. *Cardium hillanum* J. SOWERBY, 1813.

Protocardia (*Protocardia*) cf. *judaica* (HAMLIN, 1884)
Pl. 6, Fig. 6

cf. 1884 *Cardium* (*Protocardia*) *judaicum* sp. nov. – HAMLIN: 50, pl. 4, fig. 5.
cf. 1946 *Protocardia judaica* HAMLIN – VOKES: 186, pl. 8, figs. 1-7.
cf. 1982 *Protocardia* (*Protocardia*) *judaica* HAMLIN – BÖTTCHER: 50, pl. 8, figs. 12-13.

Material. Two composite moulds of right valves. PIW 2002 VII 135.

Description. Relatively small, moderately inflated; outline subcircular, nearly equilateral; slightly longer than high; umbo prominent, relatively broad and nearly orthogyrate; posterior, anterior and ventral margins regularly convex; hinge margin straight to slightly convex; surface ornamented with remains of widely-spaced commarginal ribs on the flank and anterior end, posterior slope with numerous fine radial ribs.

Remarks. The two Jordanian specimens resemble very closely the Egyptian forms of BÖTTCHER (1982), although the preservation is not perfect. *P. hillana* (J. SOWERBY, 1813), a widespread Cenomanian species, is characterised by a larger size and a finer commarginal ornamentation.

Dimensions. Length 13-22 mm, height 12-21 mm.

Distribution. Albian of the Lebanon, ?Albian Abu Ballas Formation of Egypt (BÖTTCHER 1982), Upper Cenomanian claystones of the FHS Formation of Ras En Naqb (section 5). Sample J5-36.

Protocardia (*Protocardia*) *coquandi* (SEGUENZA, 1882)
Pl. 6, Fig.5

1882 *Cardium coquandi* sp. nov. – SEGUENZA: 86, pl. 11, fig. 1a-b.
1912 *Cardium* (*Protocardia*) *coquandi* SEGUENZA – PERVINQUIÈRE: 266, pl. 19, fig. 23.
1962 *Protocardia shabrawitensis* nov. sp. – ABBASS: 126, pl. 21, fig. 6.

Material. One internal mould of a nearly complete right valve. PIW 2002 VII 136.

Description. Large, strongly inflated; outline rounded quadrangular, higher than long, nearly equilateral; umbo very prominent, more pointed than in *P. judaica*, orthogyrate, and mesially placed; hinge margin straight to slightly convex; anterior and posterior margins slightly convex, ventral margin strongly convex; posterior slope ornamented with distinct, closely spaced radial ribs, main shell and anterior slope with rather closely spaced, commarginal ribs.

Remarks. ABBASS (1962) separated *Protocardia shabrawitensis* from *P. coquandi* because of the broader, radially ornamented posterior slope. However, the inner margin of this slope is not clearly visible in PERVINQUIÈRE´s (1912) figures (at least in his fig. 23). Maybe figures 22 and 24 of PERVINQUIÈRE (1912) belong to another species. His fig. 23 is nearly identical with the Jordanian specimen, as is fig. 6 of ABBASS.

Dimensions. Length 54 mm, height 66 mm.

Distribution. Cenomanian of Tunisia (PERVINQUIÈRE 1912), Egypt (ABBASS 1962) and the Upper Cenomanian of Ras En Naqb, south-western Jordan (section 5). Sample J5-18.

Superfamily Mactracea LAMARCK, 1809
Family Mactridae LAMARCK, 1809
Subfamily Mactrinae LAMARCK, 1809
Genus *Geltena* STEPHENSON in VOKES, 1946
Type species. *Geltena subequilatera* STEPHENSON in VOKES, 1946.

Geltena cf. *mactraeformis* VOKES, 1946
Pl. 6, Figs. 7-9

cf. 1946 *Geltena mactraeformis* sp. nov. – VOKES: 204, pl. 9, figs. 22-25.

Material. Numerous disarticulated valves as composite moulds. PIW 2002 VII 137-140.

Description. Valves small, rather thin, moderately inflated; equivalved, nearly equilateral; margins smooth; outline subtrigonal, slightly longer than high; umbones prominent and prosogyrate, located nearly mesially; anterior and posterior margins nearly straight, ventral margin broadly rounded; surface ornamented with numerous, closely-spaced, fine commarginal ribs and very narrow interspaces; hinge and internal features not preserved.

Remarks. The species has been identified on the basis of outline and ornamentation, thus it is fairly uncertain. The externally similar genus *Cymbophora* GABB, 1869 is characterised by a narrow resilifer, which is bordered by accessory lamellae and a distinct pallial sinus. These features are not present in the Jordanian specimens.

Dimensions. Length 6-16 mm, height 5-14 mm.

Distribution. Aptian of the Olive Mountains, Lebanon (VOKES 1946), Cenomanian of the Wadi Juhra Member and FHS Formation between Ras En Naqb and Batn El Ghoul (section 6-9). Samples J6-10, J7-2, J9-12, J9-20.

Superfamily Tellinacea DE BLAINVILLE, 1814
Family Tellinidae DE BLAINVILLE, 1814
Subfamily Tellininae DE BLAINVILLE, 1814

“Tellina“ sp.
Pl. 6, Fig. 13

Material. Six moderately preserved right valves. PIW 2002 VII 141-143.

Description. Valves small and flat, outline ovate, longer than high; slightly inequilateral; umbo small, not prominent and mesially placed; antero- and postero-dorsal margins straight and oblique; anterior and posterior margins convex; posterior end slightly higher and truncated; surface of the shell ornamented with numerous fine and closely-spaced, commarginal growth lines.

Remarks. Shape and outline similar to *Linearia* sp., but without radial ornamentation.

Dimensions. Length 20-21 mm; height 13 mm.

Distribution. Cenomanian claystones (FHS Formation) of Ras En Naqb (section 5) and Batn El Ghoul area (section 9). Samples J5-36, J5-45, J9-12.

Genus *Linearia* CONRAD, 1860

Type species. *Linearia metastriata* CONRAD, 1860.

Linearia? sp.

Pl. 6, Fig. 14

Material. Three composite moulds of left valves. PIW 2002 VII 144-145.

Description. Valves rather small, flat to moderately inflated, longer than high, sub-elliptical in outline; slightly inequilateral with a longer anterior side; antero- and postero-dorsal margins straight, anterior and posterior ends convex, ventral margin regularly curved; umbo very small and pointed, slightly prominent, located about 3/5 of shell length from the anterior margin; ornamented with very fine commarginal ribs, which are crossed by radial striae, at least on the anterior part of the shell.

Remarks. *Linearia olea* from the Aptian of the Lebanon Mountains described by VOKES (1941) is very similar in outline and shape, but that species does not carry a radial pattern. Hinge and internal structures are not preserved in the Jordanian specimens.

Dimensions. Length 15-22 mm; height 12-14 mm.

Distribution. Cenomanian claystones of the FHS Formation (sections 7 and 10). Samples J7-16, J10-6.

Superfamily Arcticacea NEWTON, 1891

Family Arcticidae NEWTON, 1891

Genus *Arctica* SCHUMACHER, 1817

Type species. *Venus islandica* LINNÉ, 1767.

Arctica cordata (SHARPE, 1850)

Pl. 6, Fig. 12

1850 *Cyprina cordata* sp. nov. – SHARPE: 182, pl. 15, figs. 2a-b.
?1862 *Cyprina africana* sp. nov. – COQUAND: 202, pl. 11, figs. 18-19.
1912 *Cyprina cordata* SHARPE – PERVINQUIÈRE: 223, pl. 16, figs. 1-2.
1917 *Cyprina cordata* SHARPE – FOURTAU: 62.
1934 *Cyprina cordata* SHARPE – BLANCKENHORN: 248.
1998 *Arctica cordata* (SHARPE) – BUSSON et al.: 35.

Material. Several internal moulds of articulated specimens from the western sections. PIW 2002 VII 146-147.

Description. Valves strongly inflated, the thickest part below the umbo; outline ovate; umbones prosogyrate, located close to the anterior margin; inequilateral and equivalved; anterior side very short, slightly indented dorsally, lunule present; antero-margin convex; ventral margin broadly convex; posterior end long with convex margin; postero-dorsal margin straight to slightly convex; adductor scars distinct, isomyar; some specimens with remains of a weak commarginal ornamentation.

Remarks. *Arctica cordata* is a very widespread Cenomanian species.

Dimensions. Length 23-44 mm, height 18-32 mm.

Distribution. Cenomanian of Portugal (SHARPE 1850), Tunisia (PERVINQUIÈRE 1912), Egypt (FOURTAU 1917) and Lebanon (BLANCKENHORN 1934). Upper Cenomanian Naur Limestone and FHS Formations of At Taiyba, Dilagha and Ras en Naqb (sections 1-4). Samples J3-10, J4-1.

Arctica? sp.

Pl. 6, Fig. 15

1934 *Platopis*? *triangularis* WHITFIELD, 1891– BLANCKENHORN: 221, pl. 11, fig. 82a-c.

Material. Three fragmented specimens. PIW 2002 VII 148.

Description. Outline trigonal, inequilateral; valves slightly inflated, umbones prominent, slightly shifted anteriorly; equivalved; anterior end short, near the umbo concave, otherwise regularly curved; ventral margin broadly convex; posterior end with a straight and distinct carina; area flat to slightly concave; no lunule or escutcheon; remains of a closely-spaced, distinct, commarginal ornamentation visible.

Remarks. The Jordanian specimens correspond perfectly with *Platopis*? *triangularis* described by BLANCKENHORN (1934) from Israel and Jordan. The genus *Platopis* is not valid, outline and ornamentation resemble possibly the genus *Arctica*, but without hinge and internal features a precise identification is not possible.

Dimensions. Length 18-24 mm, height 16-23 mm.

Distribution. Aptian of Syria (BLANCKENHORN 1934). Upper Cenomanian limestones of the FHS Formation of At Taiyba (section 1; sample J1-5A).

Genus *Schedotrapezium*? STEWART, 1930

Type species. *Trapezium carinatum* GABB, 1864.

Schedotrapezium? *acclivis* (CONRAD, 1852)

Pl. 6, Figs. 10-11

1852 *Arca acclivis* sp. nov. – CONRAD: 216, pl. 5, fig. 35.
1934 *Arca acclivis* CONRAD – BLANCKENHORN: 213, pl. 10, figs. 65, 66, 68, 69.
1958 *Trigonarca* aff. *acclivis* (CONRAD) – BARBER: 15, pl. 6, fig. 6.

Material. Several internal moulds of articulated specimens. PIW 2002 VII 149-153.

Description. Outline subovate to trapezoidal, umbones relatively pointed, located close to the anterior end; equivalved and inequilateral; antero-dorsal margin slightly concave, antero-ventral margin convex; ventral margin broadly convex; posterior end longer than anterior one; posterior margin obliquely truncated; external ligament area indicated; distinct posterior umbonal carina separating a flat to slightly concave area; adductor scars isomyar, pallial line entire; surface with remains of moderately spaced commarginal ribs.

Remarks. *Arca acclivis* described and figured by CONRAD (1852) from Bhamdun, Lebanon and by BLANCKENHORN (1934) from Israel und Jordan are nearly identical. A taxodont hinge which would point to the genus *Arca* is neither visible nor has it been described by these authors. Outline and shape indicate a genus of the family Arcticidae.

Schedotrapezium has been reported from the Upper Cretaceous of northern America (STEWART 1930). Its occurrence in western Africa and Europe is uncertain.

The Cenomanian *Sexta navicula* described by STEPHENSON (1952) from Texas is similar, but more inflated, the umbo is slightly more blunt and located more mesially.

Dimensions. Length 15-28 mm, height 10-20 mm.

Distribution. Cretaceous of Bhamdun, Lebanon (CONRAD 1852), Lower Turonian of Nigeria (BARBER 1958), Lower Cenomanian of Wadi Sebbeh, Es Salt, and Ajlun Musa (Jordan), Cenomanian of eastern Israel (Jerusalem and Hebron area) and Turonian of Dschebel Oscha, Jordan (BLANCKENHORN 1934). Upper Cenomanian limestones of the Naur and FHS formations of At Taiyba, Dilagha and Ras en Naqb (sections 1-3). Samples J1-3B, J1-5, J1-5A, J2-3A, J3-10.

Genus *Veniella*? STOLICZKA, 1870
Type species. *Venilia conradi* MORTON, 1833.

Veniella? *trapezoidalis* (COQUAND, 1862)
Pl. 6, Fig. 16

1822 *Cyprina trapezoidalis* sp. nov. – COQUAND: 201, pl. 11, figs. 16-17.
1912 *Cyprina trapezoidalis* COQUAND – PERVINQUIÈRE: 223, pl. 16, fig. 10a-b.

Material. One well preserved internal mould. PIW 2002 VII 154.

Description. Valves strongly inflated, obliquely ovate; equivalved, strongly inequilateral; anterior end shorter, umbo slightly anterior of the middle of the shell; anterior margin convex, ventral margin straight and oblique, posterior margin straight to faintly convex; umbones prominent, relatively pointed, prosogyrate; sharp and straight postero-dorsal carina separating a strongly inclined area; adductor scars distinct, isomyar; ornamentation not preserved.

Remarks. A precise identification is impossible, because hinge and ornamentation are not known. The genus *Cyprina* is not valid. Comparisons with *Cyprina picteti* in PERVIQUIÈRE (1912) which is preserved with shell might point to the genus *Veniella*.

Dimensions. Length 55 mm, height 43 mm.

Distribution: Cenomanian of Algeria (COQUAND 1862) and Tunisia (PERVINQUIÈRE 1912). Upper Cenomanian of the lower FHS Formation of Dilagha (section 2; sample J2-3).

Genus *Venilicardia*? STOLICZKA, 1870
Type species. *Cyprina bifida* ZITTEL 1865.

Venilicardia? cf. *cordiformis* (D´ORBIGNY, 1843)
Pl. 7, Fig. 7

cf. 1843 *Cyprina cordiformis* sp. nov. – D´ORBIGNY: 101, pl. 273.
cf. 1981 *Venilicardia cordiformis* (D´ORBIGNY) – AMARD et al.: 79, pl. 1, fig. 6.
cf. 1999 *Venilicardia cordiformis* (D´ORBIGNY) – BUSSON et al: 36.

Material. One left and one right valve, and one articulated specimen, partly with shell preservation. PIW 2002 VII 155.

Description. Large, moderately inflated, outline subcircular to lucinoid, height and length nearly equal; equivalved, inequilateral; umbones prominent, orthogyrate, mesially placed; anterior and posterior margins convex, ventral margin strongly convex; adductor scars nearly isomyar; surface ornamented with numerous, strong commarginal ribs.

Remarks. *Venilicardia*? cf. *cordiformis* was found very rarely in the study area. The fact that it is not mentioned by COQUAND (1862) or PERVINQUIÈRE (1912) points to a rare Cenomanian species. The Jordanian specimens are very similar to the forms described by AMARD et al. (1981) from Algeria, although their ornamentation is not preserved.

Because the hinge is not known accommodation of the Jordanian specimens in *Venilicardia* is doubtful.

Dimensions. Length 39, 48, and 72 mm, height 38, 50, and 68 mm.

Distribution. Upper Cenomanian of Algeria and south-western Jordan (section 4).Together with *Neolobites vibrayeanus*. Sample J4-1.

Family Neomiodontidae CASEY, 1955
Genus *Eomiodon* COX, 1935
Type species. *Eomiodon indicus* COX, 1935.

Eomiodon cf. *libanoticus* (FRAAS, 1878)
Pl. 4, Figs. 9-10

cf. 1878 *Astarte libanotica* sp. nov. – FRAAS: 301, pl. 5, fig. 1.
cf. 1946 *Protocyprina libanotica* (FRAAS) – VOKES: 172, pl. 5, figs. 1-12.
cf. 1982 *Eomiodon libanoticus* (FRAAS) – BÖTTCHER: 52, pl. 8, figs. 18-20.

Material. Numerous composite moulds of left and right valves. PIW 2002 VII 156.

Description. Small, equivalved, slightly inflated; outline relatively variable, mostly subcircular to ovate; slightly inequilateral; umbones prosogyrate and relatively broad, slightly protruding beyond the hinge margin, mesial or shifted slightly anteriorly; hinge margin nearly straight; anterior, posterior and ventral margins convex; interior of ventral margin smooth; surface ornamented with 10-14 distinct commarginal, relatively widely spaced ribs; broad ribs covered with fine commarginal lamellae, which are only visible on well preserved specimens; hinge not preserved.

Remarks. *Eomiodon* is a genus known to occur in environments with reduced salinities (HUCKRIEDE 1967; FÜRSICH 1981). In Jordan, it occurs together with *Nuculana*, *Parmicorbula*, and small gastropods which might indicate brackish conditions. The Jordanian specimens are very similar to the Egyptian forms described by BÖTTCHER (1982), also found in beds representing lowered salinity. They are distinctly smaller than *Protocyprina libanotica* (VOKES, 1946) from Lebanon.

Dimensions. Length 4-8 mm, height 4-7 mm.

Distribution. Aptian of the Lebanon Mountains (VOKES 1946), in the Aptian? Abu Ballas Formation of Egypt (BÖTTCHER 1982), and in claystones of the Upper Cenomanian FHS Formation of Ras En Naqb (section 5). Sample J5-36.

Superfamily Veneracea RAFINESQUE, 1815
Family Veneridae RAFINESQUE, 1815
Subfamily Pitarinae STEWART, 1930
Genus *Aphrodina* CONRAD 1869
Subgenus *Aphrodina* CONRAD 1869

Type species. *Meretrix tippana* CONRAD, 1858.

Aphrodina (*Aphrodina*) *dutrugei* (COQUAND, 1862)

Pl. 7, Figs. 1-2

1862 *Venus dutrugei* sp. nov. – COQUAND: 193, pl. 7, figs. 5, 6.

Material. Numerous internal moulds of articulated specimens. PIW 2002 VII 157-164.

Description. Specimens small, moderately inflated; outline ovate, equivalved, inequilateral; umbones prosogyrate, slightly prominent, located about 1/3 of shell length from the anterior end; antero-dorsal margin with small concave indention, remaining shell margins convex and smooth; no escutcheon visible; pallial line with distinct sinus; remains of a weak, closely-spaced, commarginal ornamentation visible in some specimens.

Remarks. The Jordanian specimens closely resemble *Venus dutrugei* described by COQUAND (1862) from the Upper Cretaceous of Algeria, but are distinctly smaller.

Dimensions. Length 12-26 mm, height 10-18 mm.

Distribution. *Aphrodina* (*Aphrodina*) *dutrugei* occurs fairly commonly in the basal FHS Formation of south-western Jordan (At Taiyba, Dilagha, Ras En Naqb). Samples J1-5, J1-5A, J2-1, J2-3A, J2-3, J3-9, J3-10, J4-1.

Subfamily Dosiniinae DESHAYES, 1853
Genus *Dosinia* SCOPOLI, 1777

Type species. *Chama dosin* ADANSON, 1757.

"*Dosinia*" *delettrei* (COQUAND, 1862)

Pl. 7, Figs. 3-4

1862 *Venus delettrei* sp. nov. – COQUAND: 194, pl. 8, figs. 3-4.
1912 *Dosinia delettrei* (COQUAND) – PERVINQUIÈRE: 270, pl. 20, figs. 4-6.
1962 *Dosinia delettrei* (COQUAND) – ABBASS: 151, pl. 23, figs. 8-9.
1981 *Dosinia delettrei* (COQUAND) – AMARD et al.: 81, pl. 1, fig. 5.

Material. Numerous internal moulds of articulated specimens. PIW 2002 VII 165-170.

Description. Moderately inflated, equivalved, slightly inequilateral; outline nearly circular; anterior margin straight to slightly convex, ventral margin regularly rounded, posterior margin convex; hinge margin straight; umbones small and prosogyrate, situated slightly anteriorly of mid-line; small subcircular lunule and narrow escutcheon indicated, but due to preservation as internal moulds not certain; adductor scars nearly isomyar, pallial line with sinus; remains of fine and closely spaced commarginal striae.

Remarks. Widespread Cenomanian species whose precise generic position remains uncertain because no information is available on the hinge.

Dimensions. Length 13-32 mm, height 14-32 mm.

Distribution. Cenomanian of Algeria (COQUAND 1862), Tunisia (PERVINQUIÈRE 1912) and Egypt (ABBASS 1962). In south-western Jordan, the taxon occurs in Upper Cenomanian limestones and marlstones of the basal FHS formation of At Taiyba, Dilagha and Ras En Naqb (sections 1-6). Samples J1-3B, J1-5, J1-5A, J2-2, J2-3A, J4-1.

“*Dosinia*“ sp.

Material. One internal mould. PIW 2002 VII 171.

Description. Moderately inflated, equivalved, inequilateral; length and height nearly equal; outline rounded-quadrangular to rounded-rectangular; anterior and ventral margins convex; posterior margin straight to slightly convex; postero-dorsal margin straight and slightly oblique; umbones pointed and prosogyrate, located anteriorly; posterior umbonal carina indistinct and slightly curved, separating a relatively large trigonal field; imprints of adductors isomyar, located close to the margins; remains of a commarginal ornamentation visible.

Remarks. The similar *Cyprina africana* COQUAND, 1862 from the Cenomanian of Algeria is more elongated, the umbo is more pointed and located more mesially. Additionally, the triangular area is smaller.

The lack of information on the hinge and the poorly preserved ornamentation and internal features prelude a precise identification.

Dimensions. Length 49 mm, height 52 mm.

Distribution. Very rare in the Upper Cenomanian basal FHS Formation of Ras En Naqb (section 4). Sample J4-1.

Subfamily Tapetinae ADAMS & ADAMS, 1857

Genus *Paraesa* CASEY, 1952

Type species. *Venus faba* J. DE C. SOWERBY, 1827.

Paraesa sp. aff. *Venus reynesi* (COQUAND, 1862)

Pl. 7, Figs. 5-6

aff. 1862 *Venus reynesi* sp. nov. – COQUAND: 193, pl. 7, figs. 11-12.
aff. 1912 *Venus reynesi* COQUAND – PERVINQUIÈRE: 275.
aff. 1917 *Venus reynesi* COQUAND – FOURTAU: 89.

aff. 1934 *Venus reynesi* COQUAND – BLANCKENHORN: 251, pl. 13, fig. 151a-b, pl. 14, fig. 154.

Material. Numerous internal moulds of articulated specimens. Several disarticulated valves as composite moulds. PIW 2002 VII 172-183.

Description. Valves relatively thin, moderately inflated; inequilateral, equivalved; outline ovate; margins smooth, anterior and posterior margin strongly convex, ventral margin broadly convex, postero-dorsal margin nearly straight; umbones moderately prominent, located about 1/3 of shell length from the anterior margin; signs of a lunule; surface ornamented with weak, closely spaced, commarginal growth lines; adductor scars small and isomyar; remains of pallial line with sinus; hinge plate narrow, cardinalia rounded triangular, reaching the base of the hinge plate; lateral teeth not visible.

Remarks. One specimen from Cenomanian claystones exhibits an imprint of the hinge which allows an identification as *Paraesa*. *Venus reynesi* described by COQUAND (1862), PERVINQUIÈRE (1912), and BLANCKENHORN (1934) are very similar in outline and occur at the same stratigraphical level, but none of them exhibits a hinge or other internal features.

Dimensions. Length 9-31 mm, height 5-19 mm.

Distribution. *Venus reynesi* has been recorded from Italy, Algeria, Tunisia, Egypt, Israel, and central Jordan (BLANCKENHORN 1934). In southern Jordan it was found in limestones, marls, and claystones of the Upper Cenomanian FHS Formation (sections 1-7). Samples J1-3B, J1-5, J1-5A, J2-1, J3-9, J5-36, J6-24, J6-26A, J6-52, J7-2, J7-16, J9-18.

Order Myoida STOLICZKA, 1870
Suborder Myina STOLICZKA, 1870
Superfamily Myacea LAMARCK, 1809
Family Corbulidae LAMARCK, 1818
Subfamily Corbulinae GRAY, 1823
Genus *Corbula* BRUGUIÈRE, 1797
Type species. *Corbula sulcata* LAMARCK, 1801.

"*Corbula*" sp.
Pl. 7, Figs. 8-9

Material. Seven imprints of right valves. PIW 2002 VII 184-185.

Description. The "*Corbula*" sp. is the largest of the southern Jordan corbulids; shell moderately inflated, inequivalved, outline ovate, umbones prosogyrate, moderately prominent, located slightly anteriorly of the mid-line; inequilateral; antero- and postero-dorsal margins straight and slightly oblique; anterior margin strongly convex, ventral margin broadly rounded, posterior margin truncated; remains of fine commarginal striae on the surface of the shell.

Remarks. Hinge and internal features are not preserved.

Dimensions. Length 4-7 mm, height 2-4 mm.

Distribution. Claystones of the Turonian Wadi As Sir Formation of section 5 (Ras En Naqb) and section 6. Samples J5-68B, J6-52.

Genus *Corbulomima* VOKES, 1945
Type species. *Corbulomima nuciformis* VOKES 1945.

Corbulomima? cf. *aligera* (Hamlin, 1884)
Pl. 7, Fig. 10

cf. 1884 *Corbula aligera* sp. nov. – HAMLIN: 38, pl. 4, figs. 6a-d.
cf. 1886 *Corbula aligera* HAMLIN – NOETLING: 839.
cf. 1934 *Corbula aligera* HAMLIN – BLANCKENHORN: 263.
cf. 1934 ?*Platopis* ? *gracilis* sp. nov. – BLANCKENHORN: 222, pl. 11, figs. 83-84.
cf. 1946 *Corbulomima aligera* (HAMLIN) – VOKES: 205, pl. 10, figs. 7-13.
cf. 1982 *Corbulomima* cf. *aligera* (HAMLIN) – BÖTTCHER: 56, pl. 9, fig. 8.

Material. Several poorly preserved, disarticulated left and right valves. PIW 2002 VII 186.

Description. Valves small, only slightly inflated; inequivalved; outline rounded trigonal, inequilateral; umbones broad, located 1/2 to 1/3 of shell length from the anterior margin; anterior margin straight to slightly convex, ventral margin broadly convex, posterior margin pointed; surface ornamented with distinct, widely spaced commarginal ribs; sharp posterior umbonal carina, which is typical of the species, is poorly preserved.

Remarks. The missing hinge and the poor preservation make the identification difficult and doubtful.

Dimensions. Length 10-13 mm, height 7-8 mm.

Distribution. Upper Cretaceous of Syria (HAMLIN 1887), Aptian of the Lebanon (BLANCKENHORN 1934; VOKES 1946). In southern Jordan in Cenomanian claystones of the Harad Formation at Batn El Ghoul (section 10). Sample J10-6.

Subfamily Caestocorbulinae VOKES, 1945
Genus *Caestocorbula* VINCENT, 1910
Type species. C*orbula henckeliusiana* NYST, 1836.

Caestocorbula? cf. *tapuchii* (SHALEM, 1928)
Pl. 7, Figs. 11-13

cf. 1928 *Corbula tapuchii* sp. nov. – SHALEM: 87, pl. 4, fig. 17.
cf. 1934 *Corbula tapuchii* SHALEM – BLANCKENHORN: 264, pl. 14, figs. 178-179.

Material. Numerous disarticulated valves preserved as internal and composite moulds. PIW 2002 VII 187-202.

Description. Very small species, moderately inflated; inequilateral, inequivalved, left valve slightly smaller than right valve, outline rounded triangular; right valve more inequilateral than right valve, with elongated posterior end exhibiting a small triangular rostrum; anterior margin convex, posterior margin nearly straight forming an acute angle with the ventral margin; ventral margin with a slight concave indentation anteriorly; umbones nearly mesial; distinct and sharp posterior umbonal ridge; surface of valves ornamented with fine commarginal ribs.

Remarks. *P. eretzisraelensis* (SHALEM, 1928) exhibits a longer and more quadrangular rostrum.
Dimensions. Length 4-7 mm, height 2-4 mm.
Distribution: *C. tapuchii* was described from Lower Cenomanian marlstones of Israel (SHALEM 1928; BLANCKENHORN 1934). In southern Jordan it occurs in Upper Cenomanian clay- and siltstones of the FHS Formation of the Ras En Naqb area and the middle part of the escarpment (section 5, 7, 8). Samples J5-36, J5-37, J5-45, J5-68B, J6-10, J6-24, J6-29, J6-32, J6-52, J7-20, J8-12, J9-12, J9-18, J9-20, J9-21, J9-26B.

Subgenus *Parmicorbula* VOKES, 1944
Type species. *Corbula neaeroides* BLANCKENHORN, 1890.

Caestocorbula (*Parmicorbula*) *eretzisraelensis* (SHALEM, 1928)
Pl. 7, Figs. 14-16

1928 *Corbula eretzisraelensis* sp. nov. – SHALEM: 85, pl. 4, fig. 16a-s.
1934 *Corbula eretzisraelensis* SHALEM – BLANCKENHORN: 264, pl. 14, figs. 173-177.
1982 *Caestocorbula* sp. – BÖTTCHER: 57, pl. 9, figs. 9-13.

Material. Numerous composite moulds of disarticulated valves. PIW 2002 VII 203-212.

Description. Individuals very small, moderately to strongly inflated, inequivalved and inequilateral, right valve more inequilateral than left one; right valve with elongated posterior end, forming a rectangular rostrum (ventral angle slightly more than 90°, dorsal angle about 90°); ventral margin regularly convex, anterior margin strongly convex; umbones mesial; surface ornamented with fine commarginal striae, which are best visible near the ventral margin; outline of left valve rounded triangular, slightly smaller than right valve.
Remarks. *Corbula eretzisraelensis* occurs near- monospecific layers, occuring mostly disarticulated but not fragmented, indicating slight currents at the sea floor. Corbulid bivalves are typical of environments with reduced salinity. The fact that in southern Jordan they mostly occur in beds lacking stenohaline taxa indicates brackish environments at the time of deposition.
Dimensions. Length 4-8 mm, height 2-4 mm.
Distribution. Lower Cenomanian of Jerusalem (SHALEM 1928) and Motza (BLANCKENHORN 1934). In southern Jordan the species occurs in claystones of the Upper Cenomanian FHS Formation between Ras En Naqb and Batn El Ghoul (sections 5-9). Samples J5-37, J6-24, J6-26A, J6-29, J6-32, J6-52, J7-16, J7-20, J9-18, J9-20.

Ordnung Hippuritoida NEWELL, 1965
Superfamily Hippuritacea GRAY, 1848
Family Requieniidae DOUVILLÉ, 1914
Genus *Toucasia* MUNIER-CHALMAS, 1873
Type species. *Requienia carinata* MATHERON, 1843.

cf. *Toucasia matheroni* (COQUAND, 1862)
Pl. 7, Fig. 18, Pl. 8, Fig. 1

cf. 1862 *Caprina matheroni* sp. nov. – COQUAND: 223, pl. 17, figs. 10-11.

Material. Several, mostly fragmented specimens, partly in shell preservation. PIW 2002 VII 213.

Description. Specimens inequivalved, left valve larger than right valve; both valves coiled, *Diceras*-shaped; left valve slightly more incurved; valves keeled and carinate; hinge and internal features not preserved; pattern of radial striae and concentric growth lines seen on some specimens.
Remarks. The genera *Toucasia* and *Kugleria* BOUWMAN, 1938 are very similar externally; they differ only in features of the hinge and muscle insertion, which are not preserved in the Jordanian specimens. The ornamentation on some of the individuals suggest *Toucasia*.
Distribution. *Caprina matheroni* was described by COQUAND (1862) from the Cretaceous (l'étage provencien) of Algeria. In southern Jordan, cf. *Toucasia matheroni* occurs in a single limestone bed of the basal FHS Formation of Dilagha (section 2). Sample J2-1.

Genus *Radiolites* LAMARCK, 1801
Type species. *Ostracites angeiodes* PICOT DE LAPEIROUSE, 1781.

Radiolites? sp.
Pl. 7, Fig. 17

1934 *Radiolites*? sp. – BLANCKENHORN: 230, fig. 103a-b.

Material. Several poorly preserved fragments of internal moulds. PIW 2002 VII 214.

Description. The moulds indicate a slightly curved, conical valve, which is irregularly chambered; chambers getting broader and higher upwards; margins of the chambers wavy; cross-section sub-triangular, occasionally rounded-quadrangular; some specimens with signs of radial striae on the exterior side.
Remarks. Very similar to BLANCKENHORN´s (1934) specimens, but too poorly preserved to allow a precise identification. Only two species of rudistid bivalves have been found in the study area, which points to a certain empoverishment of the fauna. The reason for this phenomenon which is also recognisable in the groups of echinoids and gastropods, might be the very marginal marine position of the environment.
Distribution. Common only in some limestone beds of the Naur and lower FHS lormations of the Ras En Naqb area (sections 5). Sample J5-18.

Order uncertain
Family uncertain
Genus uncertain

Heterodont bivalve sp. A
Pl. 8, Fig. 11

Material. Three internal moulds. PIW 2002 VII 215.

Description. Specimens small, moderately inflated; outline ovate, inequilateral, equivalved; anterior and posterior margins strongly convex, ventral margin broadly rounded, posterodorsal margin straight; umbones moderately prominent, prosogyrate, situated about 1/4 -1/3 of shell length from the anterior end; anterior end distinctly shorter than posterior end; ornamented with 3-4 widely spaced, strong commarginal folds and most probably intercalated fine commarginal growth lines.

Remarks. Most probably these specimens belong to the Order Veneroida, but Myoida cannot be excluded. A more precise identification is not possible because of the poor preservation of the internal moulds.

Dimensions. Length 20, 20, and 22 mm; height 12, 14, and 17 mm.

Distribution. Upper Cenomanian limestones of the basal FHS Formation of At Taiyba (section 1). Sample J1-5A.

Heterodont bivalve sp. B
Pl. 8, figs. 14-15

Material. Several moderately preserved internal moulds. PIW 2002 VII 216-218.

Description. Specimens small, moderately inflated; outline subcircular to oblique-ovate; inequilateral, equivalved; umbones small, pointed, slightly protruding, prosogyrate, located about 1/3 of the shell length from the anterior end; margins convex and smooth, postero-dorsal margin straight and oblique; posterior end higher than anterior end; remains of closely-spaced, commarginal ribs visible.

Remarks. These small heterodont bivalves resemble "*Dosinia*" *delettrei*, but they are not as circular; ?*Schedotrapezium acclivis* (CONRAD, 1852) exhibits a similar outline, but has a distinct posterior umbonal ridge which is absent in heterodont bivalve sp. B. Probably, these specimens belong to the family Arcticidae.

Dimensions. Length 12-15 mm, height 11.5-14 mm.

Distribution. Upper Cenomanian limestones of the basal FHS Formation of At Taiyba (section 1) and Dilagha (section 2). Samples J1-5A, J2-2, J2-3.

Heterodont bivalve sp. C
Pl. 8, Fig. 13

Material. One right valve with remains of the original shell and one composite mould. PIW 2002 VII 219.

Description. Valves small, moderately inflated; outline subtrigonal to ovate, inequilateral, equivalved; umbones relatively broad and prominent, prosogyrate, located about 1/3 of the shell length from the anterior end; anterior and posterior margins smooth and strongly convex, ventral margin broadly rounded; postero-dorsal margin straight; signs of small lunule; surface ornamented with strong commarginal ribs separated by interspaces of the same width.

Remarks. Most probalbly this species belongs to the Veneroida, but without knowledge on the hinge a precise statement is not possible.

Dimensions. Length 9 and 14 mm, height 7 and 11 mm.

Distribution. Upper Cenomanian limestones of the basal FHS Formation of At Taiyba (section 1). Sample J1-5A.

Heterodont bivalve sp. D
Pl. 7, Fig. 19

Material. Several moderately well preserved valves. PIW 2002 VII 220-222.

Description. Valves very small, outline subcircular, inequilateral, most probably equivalved; anterior, posterior and postero-dorsal margins convex, ventral margin broadly rounded; umbo prosogyrate, not very prominent, slightly anterior of the mid-line; surface nearly smooth, with remains of a fine, closly-spaced, commarginal ornamentation close to the crenulated ventral margin.

Dimensions. Length 7 mm, heigth 7 mm.

Distribution. Upper Cenomanian claystones of the FHS Formation west of Batn El Ghoul (sections 7 and 9). Samples J7-16, J9-18, J9-26B.

Heterodont bivalve sp. E
Pl. 8, Fig. 12

Material. Several poorly preserved composite moulds. PIW 2002 VII 223-227.

Description.Valves small and flat; outline ovate, nearly equilateral, most probably equivalved; distinctly longer than high; umbones small, pointed and straight, slightly protruding beyond hinge line; anterior margin strongly convex, ventral margin broadly rounded and smooth, posterior margin somewhat truncated, possibly gaping; signs of an posterior umbonal ridge; surface ornamented with very fine, closey-spaced, commarginal ribs.

Remarks. This species most probably belongs to the order Veneroida, possible superfamilies include Mactracea, Tellinacea and Veneracea.

Dimensions. Length 16 mm, height 6.5 mm.

Distribution. Cenomanian and Turonian claystones of sections 5-9. Samples J5-45, J5-68B, J7-16, J8-16, J9-20.

Subclass Anomalodesmata DALL, 1889
Order Pholadomyoida NEWELL, 1965
Superfamily Pholadomyacea GRAY, 1847
Family Pholadomyidae GRAY, 1847
Genus *Pholadomya* G. B. SOWERBY, 1823
Type species. *Pholadomya candida* GRAY, 1847.
Subgenus *Procardia* MEEK, 1871
Type species. *Isocardia*? *hodgei* MEEK, 1871.

Pholadomya (*Procardia*) *vignesi* (LARTET, 1877)
Pl. 8, Figs. 2-3

1877 *Pholadomya vignesi* sp. nov.– LARTET: 126, Pl. 11, fig. 9.
1890 *Pholadomya vignesi* LARTET – BLANCKENHORN: 94, pl. 5, figs. 14-17.
1912 *Pholadomya vignesi* LARTET – PERVINQUIÈRE: 290, pl. 21, figs. 8a-b, 9.
1917 *Pholadomya vignesi* LARTET – FOURTAU: 93, pl. 7, fig. 6.
1933 *Pholadomya vignesi* LARTET – FURON: 267, pl. 9, fig. 5.
1998 *Pholadomya* (*Procardia*) *vignesi* (LARTET) – BUSSON et al.: 34.

Material. Numerous, mostly articulated, composite moulds from all western sections, several compressed composite moulds from section 4. PIW2002 VII 228-231.

Description. Shells equivalved, strongly inequilateral; shape relatively variable; outline broadly elongated; strongly inflated, thickest part slightly below the umbo; posterior end distinctly longer than anterior end; umbones prominent and prosogyrate, located 1/4 to 1/5 of the shell length from the anterior end; anterior end short; ventral margin broadly rounded, posterior end gaping; postero-dorsal margin straight; characteristic ornamentation consisting of 15-18 radial and commarginal ribs, forming a grid-like pattern on the surface.

Dimensions. Length 25-52 mm, height 24-34 mm.

Distribution. *Pholadomya* (*Procardia*) *vignesi* represents a very common Cenomanian species of the southern and south-eastern Tethys. It has been recorded from the Dead Sea area by LARTET (1877), from Syria by BLANCKENHORN (1934), from Tunisia by PERVINQUIÈRE (1912), from the Sinai by FOURTAU (1917), from Algeria by BUSSON et al. (1998), and from north-western Niger by FURON (1933). In southern Jordan it was discovered in limestones of the lower FHS Formation of the western sections (At Taiyba - Ras En Naqb) and rarely in fully marine claystones of the Batn El Ghoul area (sections 1-5, 9). Samples J1-3B, J2-1, J3-9, J9-18.

Subgenus *Pholadomya* G. B. SOWERBY, 1823
Type species. *Pholadomya candida* GRAY, 1847

Pholadomya (*Pholadomya*) cf. *pedernalis* ROEMER, 1852
Pl. 8, Fig. 4

cf. 1852 *Pholadomya pedernalis* sp. nov. – ROEMER: 45, pl. 6, fig. 4.
cf. 1912 *Pholadomya pedernalis* ROEMER – PERVINQUIÈRE: 288, pl.21, figs. 5-7.
cf. 1958 *Pholadomya* aff. *pedernalis* ROEMER – BARBER: 28, pl. 8, fig. 5, pl. 9, figs. 8-9.
cf. 1962 *Pholadomya pedernalis* ROEMER – ABBASS: 161, pl. 24, fig. 4.
cf. 1999 *Pholadomya pedernalis* ROEMER – BUSSON et al.: 34.

Material. One moderately preserved internal mould. PIW 2002 VII 232.

Description. Specimen equivalved, strongly inequilateral; highly inflated, thickest part slightly below the umbo; outline broadly elongated to ovate; posterior end longer than anterior end, and longer than in *Pholadomya vignesi*, umbones subterminal, prosogyrate and less prominent than in *P. vignesi*, located about 1/5 of the shell length from the anterior end; anterior end short; ventral margin broadly convex, posterior end gaping; postero-dorsal margin straight, narrow escutcheon indicated; surface ornamented with distinct, relatively wide-spaced, commarginal ribs.

Remarks. *Pholadomya* (*P.*) *pedernalis* has not been recorded from Jordan up to now.

Dimensions. Length 42 mm, height 24 mm.

Distribution. This species has been originally described by ROEMER (1852) from the Turonian of Texas. Furthermore it was mentiones from the Cenomanian of Tunisia, Egypt, Algeria and Nigeria. In southern Jordan it occurs very rarely in the basal FHS Formation of Dilagha (section 2).

Pholadomya? sp.
Pl. 8, Fig. 5a-b

Material. Six internal moulds of articulated specimens. PIW 2002 VII 233-234.

Description. Specimens large, equivalved, inequilateral, strongly inflated; outline broadly ovate, posterior end much longer than anterior one; umbo broad, prosogyrate and prominent, located at about 1/4 of shell length from the anterior end; anterior margin convex, ventral margin broadly rounded, posterior end gaping; postero-dorsal margin straight; remains of thick commarginal ribs.

Remarks. This species reaches a larger size than *P. vignesi* and *P. pedernalis*. It differs also in outline and ornamentation, and most likely represents another species. However, due to preservation a precise identification is not possible.

Dimensions. Length 57-78 mm, height 48-58 mm.

Distribution. Basal FHS Formation (Cenomanian) of Dilagha (section 2) and Ras En Naqb (section 4). Samples J2-3, J4-1.

Superfamily Pandoracea RAFINESQUE, 1815
Family Laternulidae HEDLEY, 1918
Genus *Cercomya* AGASSIZ, 1843
Type species. *Cercomya pinguis* AGASSIZ, 1843.

Cercomya? *jettei* (COQUAND, 1862)
Pl. 8, Figs. 6-7

1862 *Anatina jettei* sp. nov. – COQUAND: 190, pl. 6, fig. 3.
?1999 *Cercomya* sp. cf "*Anatina*" *jettei* COQUAND – BUSSON et al.: 36.

Material. Four articulated composite moulds in "butterfly-position". PIW 2002 VII 235.

Description. Equivalved, strongly inequilateral specimens; outline broadly ovate to rounded-quadrangular; relatively compressed, greatest inflation slightly below the umbo; posterior end elongated; umbo pointed, located about 1/3 of the shell length from the anterior end; ventral margin long and straight to slightly convex; posterior end slightly gaping; postero-dorsal margin straight; sign of a slightly curved posterior umbonal carina; surface ornamented with widely-spaced, commarginal ribs, which are most distinct on the flank.

Remarks. *Anatina jettei* COQUAND closely corresponds to the specimens from Jordan. A precise identification of the genus is not possible due to the poor preservation.

Dimensions. Length 25-30 mm, height 11-14 mm.
Distribution. Cenomanian of Algeria (COQUAND 1862) and Upper Cenomanian claystones of the FHS Formation of the Batn El Ghoul area (section 9). Sample J9-26B.

Genus *Periplomya* CONRAD, 1870
Type species. *Periploma applicata* CONRAD, 1858.

Periplomya sp.
Pl. 8, figs. 8-9

1982 *Periploma*? sp. – BÖTTCHER: 60, pl. 9, fig. 17.

Material. Two composite moulds of right valves. PIW 2002 VII 236.

Description. Valves small, flat and most likely thin-shelled; outline elongated-ovate, inequilateral, most probably equivalved; umbones small and slightly protruding, moved anteriorly; anterior margin strongly convex, posterior margin somewhat truncated, ventral margin broadly rounded; posterior end slightly gaping; remains of the typical transverse external slit on one of the valves seen; surface ornamented with numerous fine commarginal growth lines; internal features not preserved.
Remarks. *Periploma*? sp. described by BÖTTCHER (1982) from the ?Aptian of Sinai resembles closely the Jordanian specimens. Most probably, they belong to the genus *Periplomya*.
Dimensions. Length 7.5 and 9 mm, height 5 and 7 mm.
Distribution. ?Aptian of the Abu Ballas Formation of Egypt (BÖTTCHER 1982), Upper Cenomanian FHS formation of southern Jordan (section 9). Sample J9-18.

11.2 Class Gastropoda Cuvier, 1797

Subclass Prosobranchia MILNE EDWARDS, 1848
Order Archaeogastropoda THIELE, 1925
Superfamily Trochacea RAFINESQUE, 1815
Family Trochidae RAFINESQUE, 1815
Subfamily Angariinae THIELE, 1924
Genus *Calliomphalus* COSSMANN, 1888
Type species. *Turbo squamulosus* LAMARCK, 1804.

Calliomphalus orientalis (DOUVILLÉ, 1916)
Pl. 9, Fig. 3

1916 *Metriomphalus orientalis* sp. nov. – DOUVILLÉ: 145, pl. 8, fig. 31.
1992 *Calliomphalus* (*Calliomphalus*) *orientalis* (DOUVILLÉ) – ABDEL GAWAD & GAMEIL: 71, pl. 2, fig. 1.

Material. Two internal moulds. PIW 2002 VII 237-238.

Description. Spire conical, a bit wider than high, phaneromphalous; whorls continuously enlarging, whorl section and aperture rounded.

Remarks. Due to preservation as internal moulds the typical ornamentation of *Calliomphalus* with its spiral rows and hollow spines is not present on the Jordanian specimens, but according to ABDEL GAWAD & GAMEIL (1992) who figured a specimen with shell preservation as well as an internal mould, the described form most probably belongs to *Calliomphalus*.

Dimensions. Width 13 mm, height 12 mm.

Distribution. Upper Albian (DOUVILLÉ 1916) and Cenomanian of Egypt (ABDEL GAWAD & GAMEIL 1992), Cenomanian of south-western Jordan (Ras En Naqb, section 4).

Suborder Neritopsina COX & KNIGHT, 1960
Superfamily Neritacea RAFINESQUE, 1815
Family Neritopsidae GRAY, 1847
Genus *Neritopsis* GRATELOUP, 1832
Type species. *Neritopsis radula* LINNÉ, 1758.

Neritopsis (*Neritopsis*?) sp.
Pl. 9, Fig. 2a-b

Material. One well preserved specimen in shell preservation. PIW 2002 VII 239.

Description. Shell small and globular, with 2-3 rapidly enlarging whorls; last whorl comparatively large, forming nearly the entire bulk of the shell; aperture very large, most probably orbicular, but broken. Spire depressed; shell surface ornamented with crenulated spiral cords and several wide-spaced, sharp, prosocline ridges (collabral ribs) which change into rows of little knots posteriorly; no umbilicus.

Remarks. *Neritopsis* (?*Neritopsis*) sp. is very rare in Cenomanian euhaline calcareous sediments of southern Jordanian. It differs from *Seminerita safrensis* ABBASS (1963: 29, pl. 1, fig. 7) in the lower number of prosocline ridges which stand closer together in ABBASS' specimens and in the crenulated spiral cords. Very similar is *Nerita multigranosa* VON KOENEN (1889) from the Lower Turonian of Pindiga, Nigeria, figured by BARBER (1958: 31, pl. 9, figs. 4-5) and from the Upper Cretaceous of Cameroon (RIEDEL 1932). The only difference is the higher number of collabral ribs. The subgenus *Neritoptyx* OPPENHEIM, 1892 differs from the subgenus *Neritopsis* in having a prominent parietal tubercle, which is not visible in the Jordanian specimen.

Dimensions. width 10mm, height 10mm.

Distribution. Cenomanian FHS Formation of south-western Jordan (section 1).

Order Caenogastropoda Cox, 1959
Superfamily Littorinacea GRAY, 1840
Family Purpurinidae ZITTEL, 1895
Genus *Coronatica* BLANCKENHORN, 1927

Type species. Not defined by BLANCKENHORN (1927) when erecting the genus. He included *Neritopsis ornata* Fraas, 1878 and two new species (*C. purpuroidea* and *C. biconica*) into *Coronatica*.

Coronatica cf. *ornata* (FRAAS, 1878)
Pl. 9, Fig. 7

cf. 1878 *Neritopsis ornata* sp. nov. – FRAAS: 66, pl. 6, fig. 6.
cf. 1900 *Natica ornata* FRAAS – BÖHM: 197, figs. 7-9.
cf. 1927 *Coronatica ornata* gen. nov. FRAAS – BLANCKENHORN: 134.

Material. One fragmented, slightly compressed composite mould. PIW 2002 VII 240.

Description. Shape globose, naticid, nearly as wide as high, whorls fast, but continuously enlarging; flat apical area between upper margin of the strongly and irregularly ribbed last whorl and the suture; apical area ornamented with fine growth lines and thicker ribs, which form distinct knots at the outer margin; apex and aperture not preserved.

Remarks. The Jordanian specimen is about 1½ times larger than the lower Cretaceous specimens from Lebanon described by BÖHM (1900). Additionally, the ribs on the outer surface of the last whorl are more distinct which could indicate different preservation conditions; BLANCKENHORN's specimens from the Lebanon reach the same size as the here described one.

Dimensions. Width 28 mm, height about 30 mm.

Distribution. Lower Cretaceous sandstones from Lebanon (BÖHM 1900; BLANCKENHORN 1927), Cenomanian FHS Formation at Dilagha (south-western Jordan, section 2).

Superfamily Cerithiacea FLEMING, 1822
Family Potamididae WENZ, 1938
Genus *Pyrazus* MONTFORT, 1810
Type species. *Pyrazus baudini* MONTFORT, 1810.

Pyrazus cf. *valeriae* DE VERNEUIL & DE LORIÈRE, 1868
Pl. 9, Fig. 4

cf. 1916 *Pyrazus valeriae* DE VERNEUIL & DE LORIÈRE – DOUVILLÉ: 136, pl. 18, figs. 6-8.
cf. 1992 *Pyrazus valeriae* DE VERNEUIL & DE LORIÈRE – ABDEL GAWAD & GAMEIL: 74, pl. 2, figs. 11-12.

Material. One fragmented, slightly compressed composite mould. PIW 2002 VII 241.

Description. Three continuously enlarging whorls of the turriculate spire are preserved. Whorl section rounded to rounded-quadrangular; suture deep and slightly wavy; ornamented with 8-9 strong axial ridges per whorl, which are crossed by 11-12 fine spiral cords separated by narrow interspaces; aperture not preserved.

Remarks. Typical feature of *Pyrazus* is the deep, rounded canal at the rounded aperture which is not preserved in the Jordanian specimen, but the specimen closely resembles the figures and description OF DOUVILLÉ (1916). *Pyrazus magharensis* from the Albian of Sinai (ABBASS 1963: 54, pl. 3, fig. 11)) exhibits 20-25 spiral cords.

Dimensions. No precise measurements possible due to fragmentation and compression. Height of the fragment 31 mm, width of the lowest whorl about 20 mm.

Distribution. Lower Cretaceous of Spain (DE VERNEUIL & DE LORIÈRE 1868), Albian of northern Sinai (DOUVILLÉ 1916), Cenomanian of Nezzazat, Egypt (ABDEL GAWAD & GAMEIL 1992), Cenomanian FHS Formation of Dilagha, south-western Jordan (section 2).

Family Turritellidae WOODWARD, 1851
Genus Turritella LAMARCK, 1799
Type species. *Turritella terebra* LINNÉ, 1758.

“*Turritella*” *amotzi* SHALEM, 1928
Pl. 10, Fig. 10

1928 *Turritella amotzi* sp. nov. – SHALEM: 88, pl. 4, fig. 20a-g.

Material. Numerous moderately to poorly preserved composite moulds. PIW 2002 VII 242-246.

Description. Tiny turriculate gastropod with about 6-9 whorls; whorl sides straight to slightly convex, whorls ornamented with about 7 spiral cords, of which the upper two and the fourth are crenulated, the other ones smooth; suture fairly deep; aperture not preserved, but according to SHALEM (1928) possibly rounded.

Remarks. “*T.” amotzi* occurs in marginal marine softground environments. It has never been recorded from calcareous sediments. SHALEM (1928) described only 5-6 spiral cords. However, his fig. 20c exhibits at least 8 spiral cords.

Dimensions. Height 6-8 mm, width about 2-3 mm.

Distribution. Cenomanian claystones of Jerusalem, Israel (SHALEM 1928), Upper Cenomanian claystones of the FHS Formation (section 5-9). Samples J5-36, J6-10, J7-2, J8-16, J9-21.

Superfamily Strombacea RAFINESQUE, 1815
Family Strombidae RAFINESQUE, 1815
Genus *Strombus* LINNÉ, 1758
Type species. *Strombus pugilis* LINNÉ, 1758.

”*Strombus*“ *incertus* (D´ORBIGNY, 1842)
Pl. 10, Figs. 1-2

1842 *Pterocera incerta* sp. nov. – D`ORBIGNY: 308, pl. 215, fig. 1.
1912 *Strombus* (?) *incertus* (D´ORBIGNY) – PERVINQUIÈRE: 27, pl. 2, figs. 19-23.
1916 *Strombus* (?) *incertus* (D´ORBIGNY) – GRECO: 160, pl. 19, fig. 10.
1933 *Strombus incertus* (D´ORBIGNY) – FURON: 265, pl. 9, figs. 7a, b.
1958 *Strombus incertus* (D´ORBIGNY) – BARBER: 33, pl. 9, fig. 1.
1992 *Strombus incerta* (D´ORBIGNY) – ABDEL GAWAD & GAMEIL: 81, pl. 3, fig. 17.

Material. 10 moderately to well preserved internal moulds. PIW 2002 VII 247-248.

Description. Very large gastropod with a conical shape; spire low and depressed, flat or only slightly protruding above the basal whorl; basal whorl with straight or slightly convex sides and several spiral grooves, of which only the upper four are visible in one specimen; suture deep; aperture wide and highly ovate.

Remarks. The shape of the moulds point to a representative of the family Strombidae. A precise identification is not possible due to the lack of information on the shell.

Dimensions. Height 80-150 mm, width 65-105 mm.

Distribution. "*Strombus*" *incertus* is a well known and widespread Cenomanian gastropod. It has been recorded from Southern Europe (D´ORBIGNY 1842) and in Northern Africa (PERVINQUIÈRE 1912; GRECO ABDEL GAWAD & GAMEIL 1992) and in the Lower Turonian of Central Africa (BARBER 1958). In southern Jordan, it occurs in the Cenomanian of Ras En Naqb and Dilagha (sections 2 and 4). Samples J2-1, J4-1.

Family Aporrhaiidae GRAY, 1850
Genus *Aporrhais* COSTA, 1778
Type species. *Aporrhais pespelicani* LINNÉ, 1758

"*Aporrhais*" *turriculoides* (CONRAD, 1852)
Pl. 9, Fig. 9a, b

1852 *Chenopus turriculoides* sp. nov. – CONRAD in LYNCH: 220, pl. 10, fig. 62.
1927 *Rostellaria* ? *turriculoides* (CONRAD) – BLANCKENHORN: 171.

Material. Several moderately preserved internal moulds. PIW 2002 VII 249-250.

Description. Shape fusiform with a high spire consisting of 5-6 convex and continuously enlarging whorls; suture deep; basal whorl large with a short anterior canal; typically of moulds of Apporhaidae, the basal whorl extends slightly over the earlier whorl indicating the wing- or finger-shaped processes; aperture high and narrow.

Remarks. There is confusion with the very similar *Rostellaria dutrugei* COQUAND (1862) which has a more angular, nearly quadrangular outer surface of the whorls. At least the specimens of *Apporhais*? *dutrugei* described by PERVINQUIÈRE (1912) and *Pterodonticeras*? *dutrugei* described by ALBANESI & BUSSON (1974) might belong to "*Apporhais*" *turriculoides*.

Dimensions. Height 48-53 mm, width 14-26 mm.

Distribution Upper Cretaceous of Lebanon (CONRAD 1852), Cenomanian of south-western Jordan (sections 1 and 3).

Superfamily Naticacea FORBES, 1838
Family Naticidae FORBES, 1838
Genus *Tylostoma* SHARPE, 1849
Type species. *Tylostoma globosum* SHARPE, 1849.

Tylostoma globosum SHARPE, 1849
Pl. 9, Fig. 5

1849 *Tylostoma globosum* sp. nov. – SHARPE: 379, pl. 9, figs. 5-6.
?1852 *Natica syriaca* sp. nov. – CONRAD in LYNCH: 220, pl. 12, fig. 70.
1912 *Tylostoma globosum* SHARPE – PERVINQUIÈRE: 53, pl. 4, fig. 9.
1916 *Tylostoma globosum* SHARPE – GRECO: 143, pl. 17, figs. 11, 12.
?1963 *Tylosoma* (*Tylostoma*) *gadensis* sp. nov. – ABBASS: 90, pl. 10, fig. 2.
1974 *Tylostoma globosum* SHARPE – ALBANESI & BUSSON: 309, pl. 25, fig. 1.
1992 *Tylostoma globosum* SHARPE – ABDEL GAWAD & GAMEIL: 81, pl. 4, fig. 9.

Material. Several well preserved to strongly compressed internal moulds. PIW 2002 VII 251-255.

Description. Shape globose, with an obtuse and very low spire consisting of 4-5 rounded and nearly smooth whorls; deep and furrowed suture line; whorl section ovate, aperture not preserved; distinct imprints of varices at intervals of half a whorl.

Remarks. The genus *Tylostoma* was erected by SHARPE (1849) who described four species of *Tylostoma* from the Turonian of Portugal. *Tylostoma globosum* is by far the most widespread form. *T. ovatum* Sharpe (1849: 379, fig. 7-8) is very similar but exhibits a higher spire and a broader aperture; still, it might be conspecific (both specimens are preserved as moulds).

Natica syriaca from the Cretaceous of Syria described and figured by CONRAD (1852) is most probably conspecific as is *T. gadensis* of ABBASS (1963).

Dimensions. Height 31-50 mm, width 32–45 mm.

Distribution. *Tylostoma globosum* is a widespread and easily identifiable Cretaceous gastropod of the Tethyan realm especially in the Turonian of Portugal (SHARPE 1849), Tunisia (PERVINQUIÈRE 1912), Algeria (ALBANESI & BUSSON 1974), also in Albian to Turonian of Egypt (ABDEL-GAWAD & GAMEIL 1992). In south-western Jordan it occurs in the FHS Formation (Cenomanian) of Dilagha (section 2) and the Ras En Naqb area (sections 3-4). Samples J2-1, J2-2, J2-3, J3-10, J4-1.

Tylostoma cossoni THOMAS & PERON, 1889
Pl. 9, Fig. 6a, b

1889 *Tylostoma cossoni* sp. nov. – THOMAS & PERON: 57, pl. 19, figs. 24-25.
1916 *Tylostoma cossoni* THOMAS & PERON – GRECO: 144, pl. 17, fig. 13.
1971 *Tylostoma cossoni* THOMAS & PERON – COLLIGNON: 147, pl. A, fig. 7.
1974 *Tylostoma* (*Tylostoma*) *cossoni* THOMAS & PERON – ALBANESI & BUSSON: 308, pl. 25, figs. 2-3.
1992 *Tylostoma cossoni* THOMAS & PERON – ABDEL GAWAD & GAMEIL: 82, pl. 3, figs. 18-19.

Material. Several mostly well preserved internal moulds. PIW 2002 VII 256-257.

Description. Moulds small- to medium-sized, smaller than *T. globosum*; shape broadly ovate, with a pyramidal spire consisting of 4-5 whorls; whorls convex and tabulated apically which makes the spire appearing step-like; suture line very deep; whorl-section ovate; aperture not preserved.

Remarks. *T. cossoni* differs from *T. globosum* in the higher, pyramidal spire and the less globose shape. *T. punctatum* SHARPE (1849: 378, fig. 3-4) has a higher last whorl.

Dimensions. Width 26-40mm, height 34-45mm.

Distribution. *T. cossoni* has been recorded from the Turonian of Tunisia (THOMAS & PERON 1889), Algeria (COLLIGNON 1971; ALBANESI & BUSSON 1974) and from the Albian to Cenomanian of Egypt (ABDEL GAWAD & GAMEIL 1992). In southern Jordanian it occurs in the FHS Formation of At Taiyba, Dilagha, and the Ras En Naqb area. Samples J2-3, J3-1.

Superfamily doubtful
Family Columbellinidae FISCHER, 1884
Genus *Columbellina* D´ORBIGNY, 1842

Type species. *Columbellina monodactylus* D´ORBIGNY, 1842.

Columbellina fusiformis DOUVILLÉ, 1916

Pl. 9, Fig. 8

1916 *Columbellina fusiformis* sp. nov. – DOUVILLÉ: 132, pl. 18, figs. 1-3.
1963 *Columbellina* (*Columbellina*) *fusiformis* (DOUVILLÉ) – ABBASS: 82, pl. 8, figs. 1-3.
1982 *Columbellina fusiformis* DOUVILLÉ – BÖTTCHER: 32, pl. 5, fig. 8.
1992 *Columbellina fusiformis* DOUVILLÉ – ABDEL GAWAD & GAMEIL: 80, pl. 3, figs. 9-12.

Material. One moderately preserved, fragmented composite mould. PIW 2002 VII 258.

Description. Shape typically fusiform with a high conical spire consisting of six continuously enlarging, convex whorls separated from each other by deep sutures; outer surface of the whorls ornamented with about 10 distinct, slightly oblique, axial ridges and wider interspaces which both are crossed by fine spiral cords; last volution half as high as the complete mould with a long anterior canal which is not complete; parts of the aperture broken away, the preserved part is fairly long and narrow; apex broken off.

Remarks. *C. fusiformis* described by BÖTTCHER (1982) is only half as high as the Jordanian specimen which could be explained by the lower salinity of the Egyptian sediments which was 20-25 ‰ according to BÖTTCHER´s boron analysis. The Jordanian form comes from a horizon representing fully marine conditions. A fine tuberculation of the spirals as mentioned by ABBASS (1963) is not visible.

Dimensions. Width 25 mm, height 60 mm.

Distribution. Albian of Sinai (DOUVILLÉ 1916; ABBASS 1963), ?Aptian of the Abu Ballas Formation of south-western Egypt (BÖTTCHER 1982), Cenomanian of the Nezzazat area, Egypt (ABDEL GAWAD & GAMEIL 1992); Upper Cenomanian of Dilagha, south-western Jordan (section 2).

Genus *Pterodonta* D´ORBIGNY, 1842

Type species. *Pterodonta inflata* D´ORBIGNY, 1842.

Pterodonta deffisi THOMAS & PÉRON, 1889

Pl. 9, figs. 10, 14

1916 *Pterodonta deffisi* THOMAS & PÉRON – GRECO: 158, pl. 19, figs. 13-14.

1963 *Pterodonta gigantea* sp. nov. – ABBASS: 83, pl. 7, figs. 1-2, 6-7.
1992 *Pterodonta deffisi* THOMAS & PÉRON – ABDEL GAWAD & GAMEIL: 80, pl. 3, figs. 14-16.

Material. Several moderately preserved internal moulds. PIW 2002 VII 259-264.

Description. Medium-sized gastropod with a slender, fusiform shape and an acute spire; number of whorls less than in *Colombellina fusiformis*, about 3-4; whorls slightly convex and overlapping, separated by a shallow suture; high basal whorl with a concave lower part and a long anterior canal accounting by far for more than half of the height of the complete specimen; aperture high-ovate.

Remarks. The specimens resemble very closely the figures and descriptions of GRECO (1916) and ABDEL-GAWAD & GAMEIL (1992). In agreement with ABDEL GAWAD & GAMEIL, at least figs. 1, 2, 6 and 7 of *Pterodonta gigantea* ABBASS (1963) belong to *P. deffisi*.

Dimensions. Width 20-25 mm, height about 42-51 mm.

Distribution: Cenomanian of Tunisia (GRECO 1916) and Egypt (ABBASS 1963; ABDEL GAWAD & GAMEIL 1992). Cenomanian Naur and FHS formations of south-western Jordan (sections 1-4). Samples J1-3B, J2-1, J2-2, J2-3, J3-9, J4-1.

Pterodonta cf. *subinflata* COQUAND, 1862
Pl. 9, Fig. 12a, b

cf. 1862 *Pterodonta subinflata* sp. nov. – COQUAND: 179, pl. 6, fig. 1.

Material. Two slightly fragmented, moderately preserved internal moulds. PIW 2002 VII 265.

Description. Moulds small to medium-sized, shape ovate, pointed at the apex; spire conical, with 3-4 fairly rapidly enlarging, slightly convex whorls, separated by a shallow suture; remains of fine spiral cords seen; aperture drop-shaped.

Remarks. *Pterodonta subinflata* described and figured by COQUAND (1862) is about 2 ½ times larger than the Jordanian specimens which might be juveniles.

Dimensions.Width 22-23 mm, height about 33-35 mm.

Distribution. Upper Cretaceous of Algeria (COQUAND 1862), Cenomanian of At Taiyba (section 1).

Genus *Pterodonticeras* BLANCKENHORN, 1927
Type species: *Pterodonticeras germeri* BLANCKENHORN, 1927

Pterodonticeras germeri BLANCKENHORN, 1927
Pl. 10, Fig. 9

1927 *Pterodonticeras germeri* sp. nov. – BLANCKENHORN: 168, pl. 5, figs. 90-92.

Material. Four partly fragmented internal moulds. PIW 2002 VII 266-267.

Description. Specimens large, ovate; spire high-conical, with 4 continuously enlarging, convex whorls; the basal whorl with a broadly concave median furrow and strongly enlarging at the aperture forming a large, wing-shaped stucture; suture deep; aperture partly broken off, but most probably high and narrow.

Remarks. The ornamentation with a spiral cord in the first whorls and three axial ribs described by BLANCKENHORN (1927) is not preserved on the internal mould, but the typical shape points to *Pterodonticeras germeri* BLANCKENHORN, 1927. Similar species are *Rostellaria augei* (COQUAND, 1862:) and *Pterocera peinii* (COQUAND 1862). *R. augei* is distinctly more slender, *P. peinii* is smaller, but might be a conspecific juvenile.

Dimensions. Height 80-86 mm, width 61-64 mm.

Distribution. Cenomanian of Israel and Jordan (BLANCKENHORN 1927), Cenomanian of the Ras En Naqb area (sections 3 and 4). Samples J3-9, J4-1.

Superfamily Volutacea RAFINESQUE, 1815
Family Olividae BRUGUIÈRE, 1789
Subfamily Pseudolivinae FISCHER, 1884
Genus *Pseudoliva* SWAINSON, 1840
Type species. *Pseudoliva plumbea* CHEMNITZ, 1795.

aff. *Pseudoliva ambigua* BINKHORST, 1861
Pl. 10, Fig. 4

aff. 1912 *Pseudoliva ambigua* BINKHORST – PERVINQUIÈRE: 64, pl. 5, figs. 1-2.

Material. One compressed composite mould. PIW 2002 VII 268.

Description. Very small and rare gastropod with a fusiform shape; four rapidly enlarging, strongly convex whorls ornamented with about 14-16 strong and slightly curved axial ribs, separated from each other by wider interspaces in the upper three whorls; these interspaces seem to exhibit fine spiral striae; basal whorl with strong sigmoidal axial ribs; suture deep and wavy; aperture not visible.

Remarks. The specimen is similar to the figures of PERVINQUIÈRE (1912), but due to the moderate quality of these figures and their Maastrichtian age the identification is doubtful.

Dimensions. Height 9 mm, width of the basal whorl 4.5 mm.

Distribution. Upper Cretaceous of Belgium (BINKHORST 1861), Maastrichtian of Algeria (PERVINQUIÈRE 1912); The southern Jordanian specimen was found in Cenomanian claystones of the FHS Formation (section 9). Sample J9-20.

Subclass Opisthobranchia MILNE EDWARDS, 1848
Order Cephalaspidea FISCHER, 1883
Family Acteonidae ADAMS, 1800
Genus *Globiconcha* D´ORBIGNY, 1842

Globiconcha rotundata D´ORBIGNY, 1842
Pl. 9, Fig. 11

1842 *Globiconcha rotundata* sp. nov. – D´ORBIGNY: 143, pl. 169, fig. 17.

1971 *Globiconcha rotundata* D´ORBIGNY – COLLIGNON: 161, pl. A, fig. 3.
1974 *Globiconcha rotundata* D´ORBIGNY – ALBANESI & BUSSON: 320, pl. 28, figs. 3-4.

Material. Two slightly compressed and fragmented internal moulds. PIW 2002 VII 269.

Description. Shape globose, spire low; three rapidly enlarging convex whorls, basal whorl large, accounting for more than 3/4 of the complete height; the first two whorls protruding moderately above the basal whorl, less than in *Tylostoma globosum*; suture deep, aperture high and narrow.

Remarks. *G. rotundata* differs from *Tylostoma globosum* SHARPE, 1849, by the lack of varices and the smaller aperture, from *T. cossoni* THOMAS & PERON, 1889 by the lower spire and the more globose shape.

Dimensions. Height 29-30 mm, width 27-29 mm.

Distribution. Turonian of France (D´ORBIGNY 1842), Lower Turonian of Algeria (COLLIGNON 1971; ALBANESI & BUSSON 1974), Cenomanian or Turonian of Ras En Naqb (section 4).

Superfamily Nerineoidea Zittel, 1873
Family Nerineidae ZITTEL, 1873
Genus *Nerinea* DESHAYES, 1827
Type species. *Nerinea tuberculosa* (DEFRANCE).

“*Nerinea*” *gemmifera* COQUAND, 1862
Pl. 10, Fig. 5

1862 *Nerinea gemmifera* sp. nov. – COQUAND: 177, pl. 4, fig. 4.
1927 *Nerinea cochlaeformis* CONRAD var. *pauxilla* (HAMLIN, 1884) – BLANCKENHORN: 150, pl. 3, fig. 57.

Material: One moderately preserved fragment of a composite mould consisting of two whorls. PIW 2002 VII 270.

Description. Shape turriculate as far as can be judged from the two whorls; whorls strongly concave with a distinct median spiral furrow separating an upper and a lower half both of which exhibiting about 20 axial ribs which end in tubercles; on the upper half of the whorls remains of fine spiral striae are seen; suture deep.

Remarks. There is confusion about the numerous species of Tethyan nerineid gastropods. BLANCKENHORN combined *N. cretacea* CONRAD, 1852, *N. cochlaeformis* CONRAD, 1852, *N. syriaca* CONRAD, 1852, *N. gemmifera* LARTET, 1874, *N. coquandiana* FRAAS, 1867, *N. mamillae* FRAAS, 1867, *N. gigantea* FRAAS, 1878, *N. pauxilla* HAMLIN, 1884, and *N. subgigantea* BLANCKENHORN, 1890 in *Nerinea cochlaeformis* CONRAD. A detailed revision based on outer and internal features is urgently needed.

In this study, three species of nerineids are distinguished: “*N.*” *gemmifera* with low, ornamented whorls, “*N.*” *pauli* with high and smooth whorls, and “*N.*” *subaequalis* with whorls that are separated furrow into a higher upper half and a narrower lower half by a median spiral.

Dimensions. Height of the fragment 31 mm, width 23 mm.

Distribution. Cenomanian of Lebanon (BLANCKENHORN 1927), Cenomanian FHS Formation of Ras En Naqb (section 4). Sample J4-1.

"*Nerinea*" *pauli* COQUAND, 1862
Pl. 10, Figs. 6-7

1862 *Nerinea pauli* sp. nov. – COQUAND: 177, pl. 4, fig. 3.
1912 *Nerinea pauli* COQUAND – PERVINQUIÈRE: 33, pl. 2, figs. 25-26.

Material. Numerous fragments of slightly compressed internal moulds with 2-3 whorls each. PIW 2002 VII 271-274.

Description. Fragments indicate large turriculate nerineids with an estimated height greater than 20 cm; whorls separated in upper and a lower half by a deep, median, spiral furrow, both halves straight and forming distincly concave sides.

Remarks. *Nerinea pauli* figured by COQUAND (1862) seems to have higher volutions, which can be explained by a preservation. The Jordanian specimens are compressed which makes their whorls to appear broader and less high.

Dimensions. Height of single whorls 12-21 mm, estimated width of a whorl 28-42 mm.

Distribution. Upper Lower Cretaceous ("l'etage urgonien") of Algeria (COQUAND 1862), Aptian of Tunisia (PERVINQUIÈRE 1912), Cenomanian Naur and FHS formations of the Ras En Naqb area and Dilagha (sections 2-5). Samples J2-1, J2-2, J3-10, J5-18.

"*Nerinea*" *subaequalis* (D´ORBIGNY, 1842)
Pl. 10, Fig. 8

1842 *Nerinea subaequalis* sp. nov. – D´ORBIGNY: 93, pl. 192, figs. 5-6.
1916 *Nerinea subaequalis* D´ORBIGNY – GRECO: 146, pl. 17, fig. 16.
1927 *Nerinea* cf. *subaequalis* D´ORBIGNY – BLANCKENHORN: 149, pl. 3, figs. 52-54.
1992 *Aptyxiella* (*Nerinoides*) *subaequalis* (D´ORBIGNY) – ABDEL GAWAD & GAMEIL: 77, pl. 3, fig. 5.

Material. Two fragmented internal moulds consisting of four whorls each. PIW 2002 VII 275-276.

Description. Shape near-cylindrical, with nearly parallel sides; smaller than "*N.*" *gemmifera* and "*N.*" *pauli*; whorls straight and smooth, whorl section rhomboidal; suture deep and oblique; whorls separated by a distinct furrow in an upper and a lower half, of which the upper is higher; according to BLANCKENHORN (1927), each of the halves exhibit a spiral row of 10 little knots per side, which are not preserved in the Jordanian specimens. ABDEL GAWAD & GAMEIL (1992) describe a rhombic aperture.

Dimensions. Width 7-8 mm.

Distribution. Turonian of France (D`ORBIGNY 1842) and Egypt (GRECO 1916), in the Cenomanian of Sinai (ABDEL GAWAD & GAMEIL 1992) and Israel (BLANCKENHORN 1927). In southern Jordan the species occurs in the Upper Cenomanian of Dilagha (section 2) and north of Ras En Naqb (section 3). Samples J2-1, J3-10.

Superfamily Architectonicacea GRAY, 1840
Family Architectonicidae GRAY, 1840

Genus *Torinia* GRAY, 1842
Type species. *Torinia cylindracea* CHEMNITZ, 1781.
Subgenus *Climacopoma* FISCHER, 1885
Type species. *Torinia (Climacopoma) patula* (LAMARCK, 1804).

Torinia (*Climacopoma*) *animi* ABBASS, 1963
Pl. 9, Fig. 1a-b

1963 *Torinia* (*Climacopoma*) *animi* sp. nov. – ABBASS: 43, pl. 1, figs. 1, 1a.

Material. Two slightly compressed internal moulds. PIW 2002 VII 277.

Description. Small specimens with low conical spire, base nearly flat, with moderately wide umbilicus; whorls convex, sharp-edged marginally and separated by linear suture lines; whorl section rhomboidal; apices are not preserved.

Remarks. The Jordanian specimens resemble closely *Torinia* (*Climacopoma*) *animi* described and figured by ABBASS (1963) from Egypt. Due to preservation as internal moulds, the crenulated margin of the umbilicus is not present in the Jordanian forms.

Dimensions. Diameter 20 and 25 mm, height 14 and 15 mm.

Distribution. Cenomanian of Egypt (ABBASS 1963), Cenomanian (FHS Formation) of south-western Jordan (sections 3 and 4). Sample J3-10.

Superfamily doubtful
Family doubtful

Gastropod sp. A
Pl. 10, Fig. 3

Material. One moderately preserved internal mould. PIW 2002 VII 278.

Description. Medium-sized, high-trochiform gastropod; mould consisting of four whorls of which the uppermost one is broken off; whorls convex, with a sharp spiral carina situated at 2/3 of the height from the upper margin of the whorl; whorl section rounded to slightly ovate; aperture broken.

Remarks. This specimen shows similarities to *Apporhais* (*Dimorphosoma*) sp. described by BLANCKENHORN (1927) from the Cenomanian of Ajlun Musa (Jordan), but due to the preservation as an internal mould the ornamentation, in the case of BLANCKENHORN´s specimens 8 spiral cords and 7 axial ribs, is not visible.

Dimensions. Height 38 mm, width of the basal whorl 21 mm.

Distribution: Cenomanian Naur or FHS Formation of Ras En Naqb (section 4). Sample J4-1.

Gastropod sp. B
Pl. 9, Fig. 13

?1862 *Fusus incomptus* sp. nov. – COQUAND: 186, pl. 2, fig. 40.

Material. One well preserved composite mould. PIW 2002 VII 279.

Description. Small trochiform gastropod with step-shaped whorls; four continuously enlarging whorls separated by a deep suture; whorls ornamented with two fine spiral lines and about eight sharp, slightly curved axial ribs, forming knots at the crossing points and including a quadrangular interspace; at the top of each whorl a flat apical area is developed which exhibits remains of the axial ribs; aperture not visible.

Remarks. This very rare species is similar to *Fusus incomptus* COQUAND (1862) but the characteristic long anterior canal is not seen in the Jordanian specimen. Therefore, a precise identification is not possible.

Dimensions. Height 13 mm, width of the basal whorl 10 mm.

Distribution. Cenomanian marginal marine, silty claystones from the eastern escarpment (section 9, Batn El Ghoul area). Sample J9-12.

Gastropod sp. C
Pl. 10, Fig. 11

Material. Numerous moderately preserved and compressed composite moulds. PIW 2002 VII 280-288.

Description. Very small turriculate gastropod with more than ten whorls; whorl sides straight to slightly convex; whorls hardly distinguishable because of a very inconspicuous suture; whorls ornamented with four sharp spiral cords separated by wider interspaces; aperture unknown.

Remarks: Similar to "*Turritella*" *amotzi* from which it differs by the ornamentation and the less oblique suture. This small turritellid gastropod apparently was adapted to soft grounds.

Dimensions. Height about 5-12 mm.

Distribution. Upper Cenomanian claystones of the FHS Formation (section 5-9). Samples J5-36, J5-45, J7-2, J7-16, J8-12, J8-16, J8-18, J9-18, J9-21.

11.3 Class Echinoidea Leske, 1778

The here described echinoids will be published in a separate paper (BERNDT 2002)

Superorder Echinacea CLAUS, 1876
Order Hemicidaroidea BEURLEN, 1937
Family Pseudodiadematidae POMEL, 1883
Genus *Heterodiadema* COTTEAU, 1864
Type species. *Hemicidaris libyca* DESOR, 1846.

Heterodiadema libycum (AGASSIZ & DESOR, 1846)
Pl. 11, Figs. 1a-c, 2a-b

1846 *Hemicidaris libyca* sp. nov. – AGASSIZ & DESOR: 338.

1980 *Heterodiadema libycum* (AGASSIZ & DESOR) – GEYS: 449, pl. 8.
1985 *Heterodiadema libycum* (AGASSIZ & DESOR) – BANDEL & GEYS: 106, pl. 4, figs. 6-7, pl. 5, figs. 1-2.
1995 *Heterodiadema libycum* (AGASSIZ & DESOR) – NÉRAUDEAU et al.: 406, fig. 3e.
1997 *Heterodiadema libycum* (AGASSIZ & DESOR) – NÉRAUDEAU & COURVILLE: 839, fig. 6.6.
2002 *Heterodiadema libycum* (AGASSIZ & DESOR) – AHMAD & AL-HAMMAD: 462, pl. 5, figs. 11-12.

Material. 18 mostly complete specimens. PIW 2001 III 1-3.

Description. Regular diademoid echinoid with nearly rounded outline (top view) and an inflated profile. Apex area fairly wide (diameter 25 % of the test) and slightly sunken. Ambulacral width reaching about half the width of the interambulacralia; interambulacral area consisting of two rows of 14 plates, each of which strongly crenulated and carrying one perforate main tubercle; main tubercles decrease in size towards the adapical side as well as towards the apex.

Ambulacral area consisting of more numerous but smaller plates, about 18 to 20, also with one main tubercle on each plate.

Dimensions. Diameter 10-32 mm, height 5-13 mm.

Distribution. *Heterodiadema libycum* is common in the Ras En Naqb area, where it occurs concentrated in a single 20-25 cm thick, coarse-grained, bioclastic limestone bed. It was also found in bioturbated limestones and marls of the basal FHS-Formation of At Taiyba. Samples J2-2, J2-3, J3-10, J4-1.

Genus *Tetragramma* AGASSIZ, 1840

Type species. *Cidarites variolaris* BRONGNIART, 1822.

Tetragramma variolare (BRONGNIART, 1822)

Pl. 11, Fig. 6a, b

1822 *Cidarites variolaris* sp. nov. – BRONGNIART: 84, p. 390, pl. 5, fig. 9.
1914 *Diplopodia variolaris* (BRONGNIART) – FOURTAU: 15.
1925 *Diplopodia variolaris* (BRONGNIART) – BLANCKENHORN: 85.
1985 *Tetragramma variolare* (BRONGNIART) – GEYS: 107, pl. 5, figs 3-4.
1990 *Tetragramma variolare* (BRONGNIART) – ALI: 102, fig. 3.
1995 *Tetragramma variolare* (BRONGNIART) – NÉRAUDEAU et al.: 407, fig. 3c.

Material. 15 mostly well preserved specimens. PIW 2001 III 4-5.

Description. Outline of test rounded-pentagonal; height rather small, reaching only 38-40 % of the diameter; large pentagonal apical area not preserved; ambulacral area consisting of two rows of 14-16 plates with one main perforate tubercle each and numerous smaller tubercles at the margins of the plates; ambulacral width reaching about half the width of the interambulacral area; two rows of 14-16 interambulacral plates each wearing two main perforate tubercles with the bigger one in the center (about the same size as the ambulacral tubercles).

Dimensions. 20-28 mm in diameter, height 9-12 mm.

Distribution. *Tetragramma variolare* is a common form in lime- and marlstones of the Upper Cenomanian FHS Formation of the western sections (2-6). Samples J2-3, J3-10, J6-34.

Order Arbacioida GREGORY, 1900
Family Arbaciidae GRAY, 1855
Genus *Goniopygus* AGASSIZ 1838
Type species. *Goniopygus peltatus* AGASSIZ, 1838.

Goniopygus menardi (DESMAREST, 1825)
Pl. 11, Figs. 4-5

1825 *Echinus menardi* sp. nov. – DESMAREST in DEFRANCE: 101, pl. 37.
1838 *Goniopygus menardi* (DESMAREST) – AGASSIZ: 22, pl. 3, figs. 29-36.
1925 *Goniopygus menardi* (DESMAREST) – BLANCKENHORN: 84.
1985 *Goniopygus menardi* (DESMAREST) – BANDEL & GEYS: 111, pl. 9, figs. 2-6.
1985 *Goniopygus* cf. *menardi* (DESMAREST) – GEYS: 138, pl. 3, figs. 8-9, pl. 4, fig. 1.

Material. 12 specimens. PIW 2001 III 8-10.

Description. Small regular echinoid with a hemisperical test; outline circular, height reaching 60% of the diameter; ambulacral area with half the width of the interambulacral area; two rows of 12-15 ambulacral plates, which are compound and trigeminate and carry one large tubercle each. Interambulacral plates larger, with 8-10 plates per row and one large tubercle each; apical system large, consisting of 10 smooth genital plates.
Dimensions. Diameter 12-18 mm, height 6-10 mm.
Distribution. Upper Cenomanian limestones of the basal FHS Formation of At Taiyba and Ras En Naqb (sections 1, 3, and 5). *Goniopygus menardi* is less abundant than *Heterodiadema* and *Tetragramma*. Samples J1-5, J3-9, J3-10, J5-42.

Family uncertain
Genus *Micropedina* COTTEAU, 1866
Type species. *Echinus olisiponensis* FORBES, 1850.

Micropedina olisiponensis (FORBES, 1850)
Pl. 11, Fig. 3a-c

1850 *Echinus olisiponensis* sp. nov. – FORBES in SHARPE: 195, pl. 25, fig. 1.
1991 *Micropedina olisiponensis* (FORBES). – SMITH & BENGTSON: 32, pl. 6A, figs. 24-25.
1995 *Micropedina olisiponensis* (FORBES). – NÉRAUDEAU et al.: 411, fig. 3d.
1997 *Micropedina olisiponensis* (FORBES). – NÉRAUDEAU & COURVILLE: 840, figs. 6.1, 6.8, 6.11.

Material. 10 mostly well preserved specimens. PIW 2001 III 6-7.

Description. Test small and circular in outline, sub-conical.; height reaching 64 to 83% of the test diameter; apical plates not preserved, the corresponding gap reaching 17-18% of the test diameter;

margins of the ambulacral areas straight from apex to peristome; ambulacral width 35% of interambulacral width; ambulacral area consisting of two rows with 24-28 compound plates, which wear two main tubercles and one or two smaller ones; three pairs of pores belong to each plate; interambulacral plates broad and low (4-5 times broader than high),with 21-23 plates in each column; ornamentation of the interambulacral plates not uniform, consisting of 3-5 main tubercles and some smaller ones.

Remarks. According to SMITH & BENGTSON (1991) the test becomes subglobular in larger, i. e. adult forms. The Jordan forms are all sub-conical and clearly smaller than the Brazilian ones, which could indicate juvenil specimens.

Dimensions. Diameter 12-25 mm, height 10-16 mm.

Distribution. Upper Cenomanian limestones at Dilagha and Ras En Naqb (sections 2, 3, and 6). Samples J2-2, J2-3A, J3-10, J6-34.

Superorder Gnathostomata ZITTEL, 1879
Order Holectypoida DUNCAN, 1889
Family Holectypidae LAMBERT, 1899
Genus *Holectypus* DESOR, 1842
Type species. *Discoidea depressa* AGASSIZ, 1839.

Coenholectypus larteti (COTTEAU, 1869)
Pl. 11, Fig. 7a-c

1869 *Holectypus larteti* sp. nov. – COTTEAU: 537.
1890 *Holectypus larteti* COTTEAU – BLANCKENHORN: 66.
1925 *Holectypus larteti* COTTEAU – BLANCKENHORN: 90, pl. 7, figs. 10-11.
1992 *Coenholectypus larteti* (COTTEAU, 1869). – SMITH: 266.

Material. 3 specimens. PIW 2001 III 11-12.

Description. Test rather large (the largest of the here described echinoids) and compressed, outline sub-pentagonal, oral side slightly concave, invaginated at the peristome; ambulacral areas lancet-shaped, reaching 35-36% of the interambulacra width marginally; pores small and circular, in pairs close together on the apical side, less close on the adapical side; ambulacral plates elongated and low, about 5-7 times longer than high, with about 5 tubercles per plate marginally, and 2-3 at the apex; interambulacral plates with twice the width of the ambulacral plates, wearing about 9 tubercles marginally and two apically; biggest tubercles occuring on the oral side close to the margin; apical system with 5 small genital plates. Periproct poorly preserved, located marginally.

Dimensions. Diameter 26-49 mm; height 12-22 mm.

Distribution. Limestones of the FHS Formation in the Ras En Naqb area (sections 3 and 5). Sample J3-10.

Superorder Atelostomata ZITTEL, 1879
Order Cassiduloida CLAUS, 1880
Family Archiaciidae COTTEAU & TRIGER, 1869
Genus *Archiacia* AGASSIZ, 1847

Type species. *Archiacia sandalina* AGASSIZ, 1847.

Archiacia sp.
Pl. 11, Figs.12a-b

Material. 6 more or less compressed specimens. PIW2001III 19-20.

Description. Small to medium-sized irregular echinoids, which underwent compactional distortion; ambulacra petaloid with the biggest width close to the apex; petal III short; apical region tetrabasal and situated anteriorly; four relatively large gonopores; peristome in all specimens not visible, periproct marginal adapical.

Remarks. Because of the poor preservation of no precise identification is possible.

Distribution. Limestones of the basal FHS Formation of the Dilagha area. Sample J2-3A.

Order Spatangoida CLAUS, 1876
Family Hemiasteridae CLARK, 1917
Genus *Hemiaster* AGASSIZ, 1847
Type species. *Spatangus bufo* BRONGNIART, 1822.
Subgenus *Mecaster* POMEL, 1883
Type species. *Hemiaster fourneli* AGASSIZ, 1847.

Hemiaster (*Mecaster*) *syriacus* (CONRAD, 1852)
Pl. 11, Fig. 10a-c

1852 *Holaster syriacus* sp. nov. – CONRAD in LYNCH: 212, pl. 1, fig. 2.
1890 *Hemiaster syriacus* (CONRAD) – BLANCKENHORN: 68.
1925 *Hemiaster syriacus* (CONRAD) – BLANCKENHORN: 103, pl. 8, figs. 33-35.

Material. One well preserved specimen. PIW 2001 III 13.

Description. Test rounded heart-shaped in outline, inflated, posteriorly higher than anteriorly, greatest width slightly anterior of the middle; underside convex, especially the posterior part; posterior side truncated with high-positioned anal area; broad, petaloid ambulacral areas, the anterior pair a bit longer and broader than the posterior pair; the frontal unpaired ambulacrum relatively broad and sunken from the apex to the ambitus, ending in a rather distinct indentation at the anterior end of the test; apical disc centrally; bean-shaped peristome broader than high in cross-section and situated 26% of the length from the anterior end; periproct circular to slightly ovate and positioned close to the apical side; well developed peripetalous fasciole.

Dimensions. Length 37 mm, width 35 mm, height 22 mm.

Distribution. Marlstones of the basal FHS Formation of the Ras En Naqb area (section 3). Sample J3-8A.

Hemiaster (*Mecaster*) cf. *batnensis* (COQUAND, 1862)
Pl. 11, Fig. 11a-c

1862 *Hemiaster batnensis* sp. nov. – COQUAND: 248, pl. 26, figs. 6-8
1991 *Mecaster batnensis* (COQUAND) – SMITH & BENGTSON: 56, pl. 12, figs. A-L, pl. 13, figs. A-L.

Material. 43 small (juvenile?) specimens. PIW 2001 III 17-18.

Description. Test longer than broad, width only 70% of length, inflated, posteriorly much higher than anteriorly; posterior end truncated; adapical side convex, especially between peristome and posterior margin; peristome situated at 27 % of the test length from the anterior margin. Apex subcentral, situated at 60% of the test length from the anterior margin; apical disc with madreporite separating posterior genital plates; ambulacra petaloid, anterior pair longer than posterior pair; anterior unpaired ambulacrum relatively long, broad and sunken; periproct small and rounded-ovate, higher than broad, lies close to the apical side; distinct peripetaleous fasciole.

Remarks. The apical area is very similar to the specimens described by SMITH & BENGTSON (1991) from the Cenomanian of Brazil, but in their specimens the anterior and posterior petals have the same length.

Distribution. Marlstones of the Upper Cenomanian FHS Formation at At Taiyba and Ras En Naqb (sections 1, 2, 3, and 5). Samples J1-5, J2-2, J3-9, J5-45.

Hemiaster (*Mecaster*) *luynesi* (COTTEAU, 1867)
Pl. 11, figs. 8, 9a-c

1877 *Hemiaster luynesi* COTTEAU – LARTET: 150, pl. 13, figs. 4-6.
1925 *Hemiaster* cf. *luynesi* COTTEAU – BLANCKENHORN: 104, pl. 8, figs. 36 a-d.

Material. 14 specimens. PIW 2001 III 14-16.

Description. Test heart-shaped, in contrast to *M. syriacus* broader than long and less inflated; greatest width distinctly anteriorly of the middle; adapical side convex, but less convex than in *M. syriacus*. Posterior end truncated, but not as high as in *M. syriacus*; periproct ovate and pointed at the top, lying close to the ambitus; ambulacral areas broad and petaloid, the anterior petal pair distinctly longer and broader than the posterior pair; elongate isopores in the petals; broad frontal ambulacrum relatively short; apical disc nearly centrally, with four large gonopores; peristome situated 24% of the test length from the anterior margin and oval in cross-section (broader than high).

Dimensions. Length 13-35 mm, width 14-38 mm.

Distribution. Limestones of the Naur Formation and the lower FHS Formation of Dilagha and Ras En Naqb (sections 2 and 3). Samples J2-3A, J3-8A, J3-10.

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14. Plates

Plate 1

Figs 1-2. *Nucula* (*Nucula*) sp. **1**. External view of left valve. Cenomanian FHS Formation, sample J9-18; x3.-PIW 2002 VII 1. **2**. External view of left valve. Cenomanian FHS Formation, sample J9-18; x5.- PIW 2002 VII 2.

Fig. 3. *Nuculana* (*Nuculana*) aff. *perdita* (CONRAD, 1852). External view of left valve. Cenomanian FHS Formation, sample J9-12; x3.- PIW 2002 VII 3.

Figs 4-6. *Mesosaccella* cf. *subacuta* (STEPHENSON, 1952). External view of left valves, Cenomanian FHS Formation. Sample J9-18; x3.- PIW 2002 VII 4.

Figs. 7-9. *Mesosaccella* sp. **7**, **8**. External view of right valves.- PIW 2002 VII 5. **9**. External view of left valve. Cenomanian Wadi Juhra Member, sample J7-2; x3.- PIW 2002 VII 6.

Figs. 10-11. *Nemodon*? sp. External view of right valves. Cenomanian FHS Formation, sample J9-12; x5.- PIW 2002 VII 8.

Figs. 12-13. *Barbatia* (*Barbatia*) sp. External view of right valves. Cenomanian FHS Formation, sample J10-6; x2.- PIW 2002 VII 12-13.

Figs 14-15. *Trigonarca*? *diceras* (SEGUENZA, 1882). Internal moulds of left valves. Basal FHS Formation, sample J4-1; x1.- PIW 2002 VII 11-12.

Fig. 16. *Noetia* (*Icanopsis*?) sp. Internal mould of left valve. Cenomanian Wadi Juhra Member, sample J7-2; x2.- PIW 2002 VII 10.

Fig. 17. *Nemodon* (*Pleurogrammatodon*) sp. Composite mould of right valve. Cenomanian FHS Formation, sample J9-21; x1.- PIW 2002 VII 9.

Figs. 18-20. *Musculus* (*Musculus*) sp. **18**, **20**. Composite moulds of left valves.- PIW 2002 VII 22. **19**. Composite mould of right valve. Cenomanian FHS Formation, sample J5-45; x3.- PIW 2002 VII 23.

Fig. 21. *Brachidontes* (*Brachidontes*) aff. *fulpensis* (STEPHENSON, 1952). Composite mould of right valve. Turonian Wadi As Sir Formation, sample J5-68B; x2.- PIW 2002 VII 16.

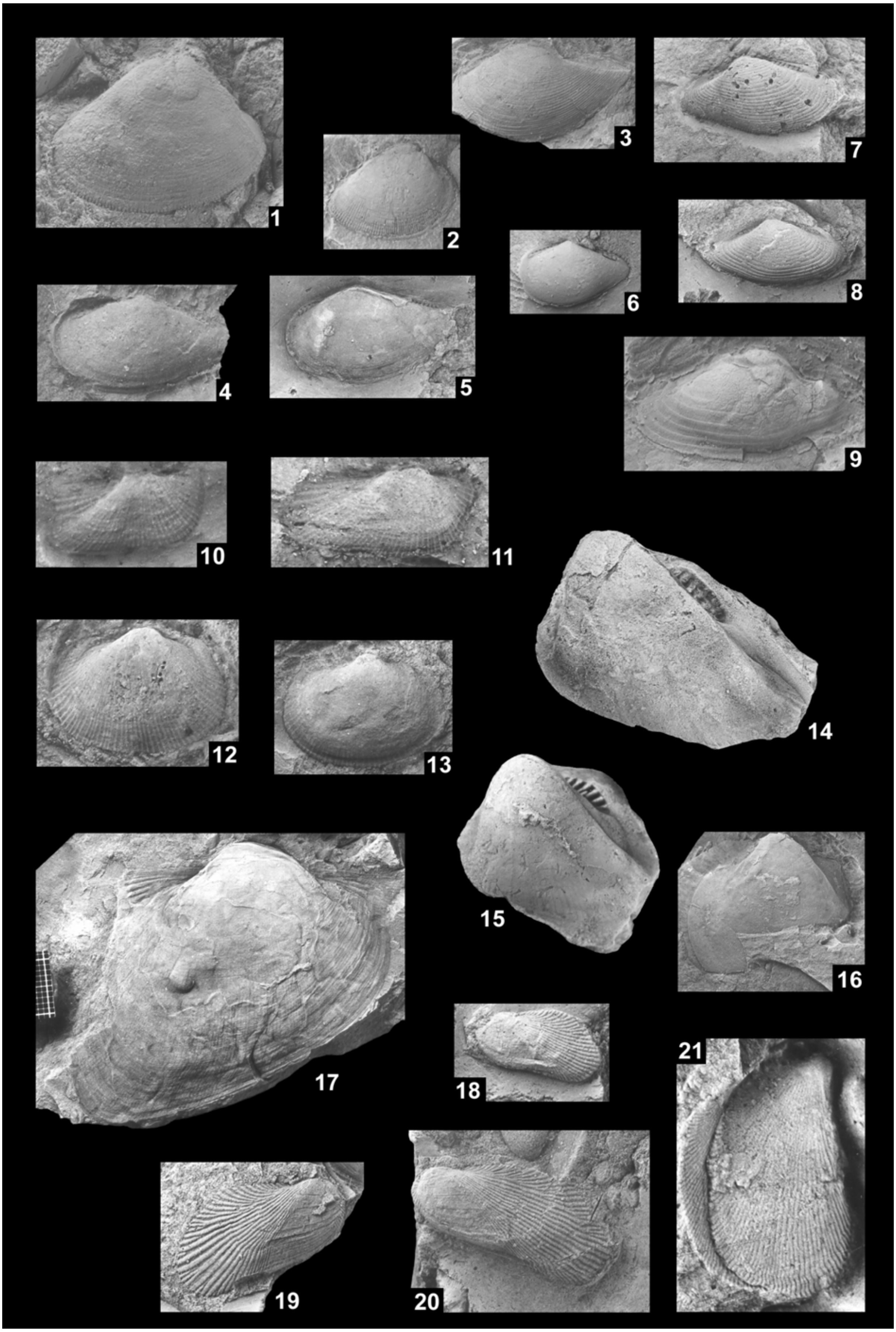
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Plate 2

Fig. 1. *Inoperna* cf. *transjordanica* (BLANCKENHORN, 1934). Composite mould of left valve. Cenomanian FHS Formation, sample J9-20; x1.- PIW 2002 VII 24.

Fig. 2. *Pinna* sp. Composite mould of left valve. Cenomanian FHS Formation, sample J5-45; x1.- PIW 2002 VII 25.

Fig. 3. *Phelopteria* cf. *dalli* (STEPHENSON, 1952). External view of left valve. Cenomanian FHS Formation, sample J2-3; x1.- PIW 2002 VII 26.

Fig. 4. *Phelopteria* sp. Composite mould of left valve. Cenomanian FHS Formation, sample J5-45; x3.- PIW 2002 VII 27.

Fig. 5. *Pseudoptera* sp. Composite mould of left valve. Cenomanian FHS Formation, sample J5-45: x 1.- PIW 2002 VII 28.

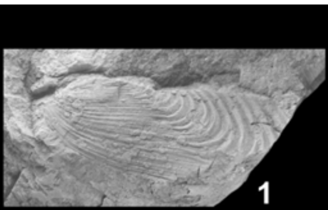
Figs. 6-7. *Camptonectes* (*Camptonectes*) aff. *curvatus* (GEINITZ, 1843). Composite moulds of left valves. Cenomanian FHS Formation, sample J5-45; x2.- PIW 2002 VII 29.

Fig. 8. *Camptonectes* (*Camptonectes*) sp. Internal mould of left valve. Cenomanian FHS Formation, sample J9-21; x2.- PIW 2002 VII 30.

Figs. 9-10. *Neithea* (*Neithea*) *shawi* (PERVINQUIÈRE, 1912). **9**. External view of right valve.- PIW 2002 VII 34. **10**. External view of left valve. Cenomanian FHS Formation, section 5; x1.- PIW 2002 VII 35.

Figs. 11-12. *Plicatula* (*Plicatula*) *auressensis* COQUAND, 1862. External view of left valves. Cenomanian FHS Formation, section 1; x2.- PIW 2002 VII 43-44.

Fig. 13. *Neithea* (*Neitheops*) *syriaca* (CONRAD, 1852). External view of left valve. Cenomanian FHS Formation, section 6; x1.- PIW 2002 VII 39.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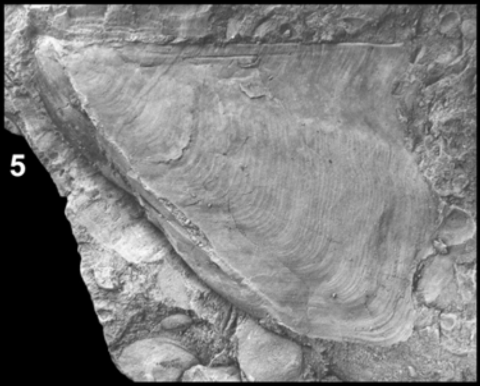
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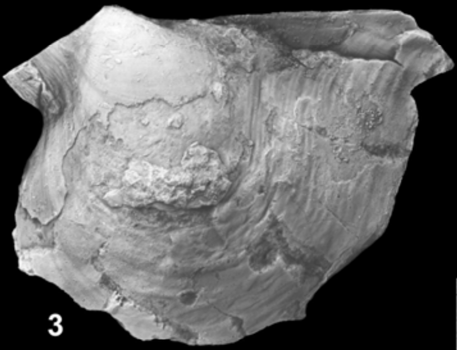
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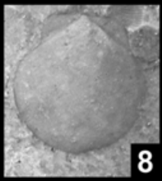
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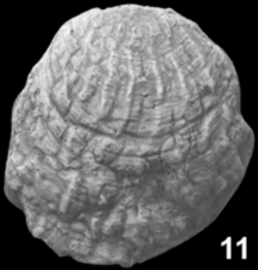
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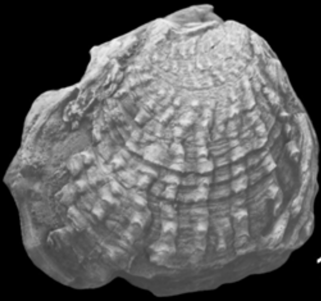
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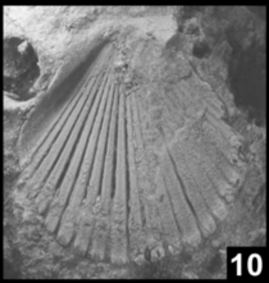
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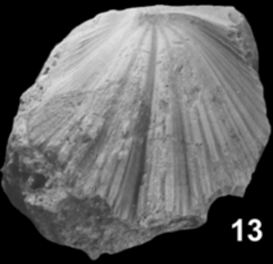
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Plate 3

Fig. 1. *Plicatula* (*Plicatula*) *fourneli* COQUAND, 1862. 1. External view of right valve.- PIW 2002 VII 40. 2. External view of left valve.- PIW 2002 VII 41. Cenomanian FHS Formation, sample J2-3; x1.

Fig. 3. *Plagiostoma* sp. **a**. External view of right valve; **b**. external view of left valve. Basal FHS Formation, sample J2-3; x1.- PIW 2002 VII 47.

Fig. 4. *Plagiostoma tithensis* (ABBASS, 1962). External view of left valve. Cenomanian FHS Formation, sample J2-3; x1.- PIW 2002 VII 46.

Fig. 5. *Ilymatogyra* (*Afrogyra*) *africana* forma *typica* (LAMARCK, 1801). External view of left valve. Cenomanian FHS Formation, sample J2-3A; x1.- PIW 2002 VII 53.

Figs. 6,7a-b. *Ilymatogyra* (*Afrogyra*) *africana* forma *crassa* (LAMARCK, 1801). **6**, **7a**. External view of left valves.- PIW 2002 VII 60-61. **7b**. External view of right valve.- PIW 2002 VII 62. Cenomanian FHS Formation, sample J1-5A; x1.

Fig. 8. *Amphidonte* (*Ceratostreon*) *flabellatum* (GOLDFUSS, 1833). **a**. External view of left valve, **b**. internal view of left valve. Cenomanian FHS Formation, sample J2-3A; x1.- PIW 2002 VII 48.

Figs. 9-10. *Rhynchostreon mermeti* (COQUAND, 1862). **9**. Composite mould of right valve, sample J10-17.- PIW 2002 VII 69. **10**. External view of right valve, sample J5-18.- PIW 2002 VII 75. Cenomanian FHS Formation; x2.

Figs. 11. *Pycnodonte* (*Phygraea*) *vesiculosum* (SOWERBY, 1823). **a**. External view of left valve; **b**. external view of right valve. Cenomanian FHS Formation, sample J2-3; x1.- PIW 2002 VII 94.

Figs. 12, 13a-13b. *Exogyra* (*Costagyra*) *olisiponensis* SHARPE, 1850. **12**, **13a**. External view of left valves.- PIW 2002 VII 84, 88. **13b**. External view of right valve.- PIW 2002 VII 89. Cenomanian FHS Formation, sample J1-5B; x1.

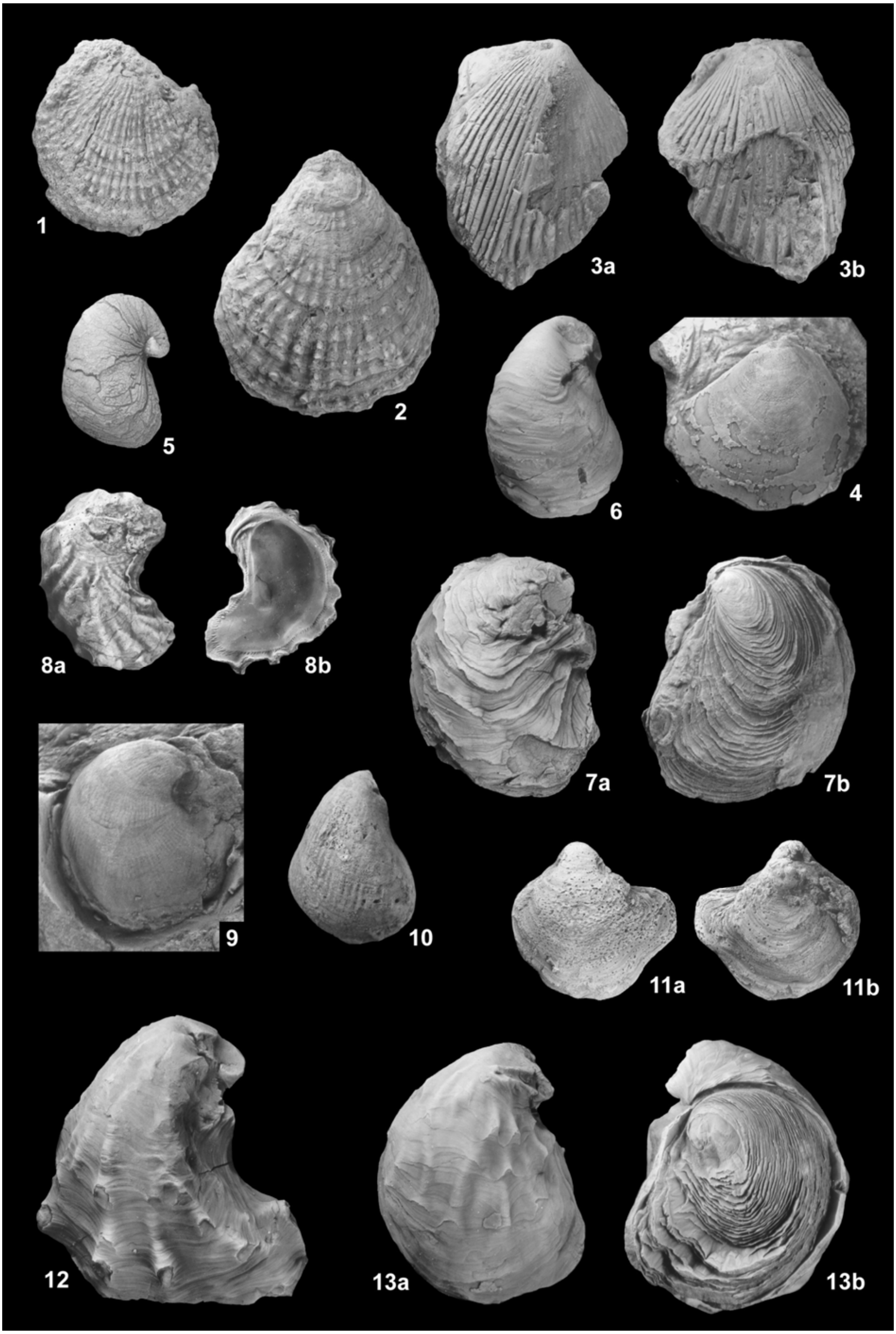
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Plate 4

Fig. 1. *Exogyra* (*Exogyra*) *italica* (SEGUENZA, 1882). **a**. External view of left valve; **b**. internal view of left valve. Cenomanian FHS Formation, sample J1-5B; x1.- PIW 2002 VII 83.

Figs. 2, 4. *Curvostrea* cf. *rouvillei* (COQUAND, 1862). **2a**. External view of left valve; **2b**. internal view of left valve. Cenomanian FHS Formation, sample J1-3B; x1.- PIW 2002 VII 95. **4**. External view of right valve. Cenomanian FHS Formation, sample J9-18; x2.- PIW 2002 VII 99.

Fig. 3. *Ambigostrea* cf. *dominici* MALCHUS, 1990. **a**. External view of left valve; **b**. internal view of left valve. Cenomanian FHS Formation, sample J5-18; x1.- PIW 2002 VII 106.

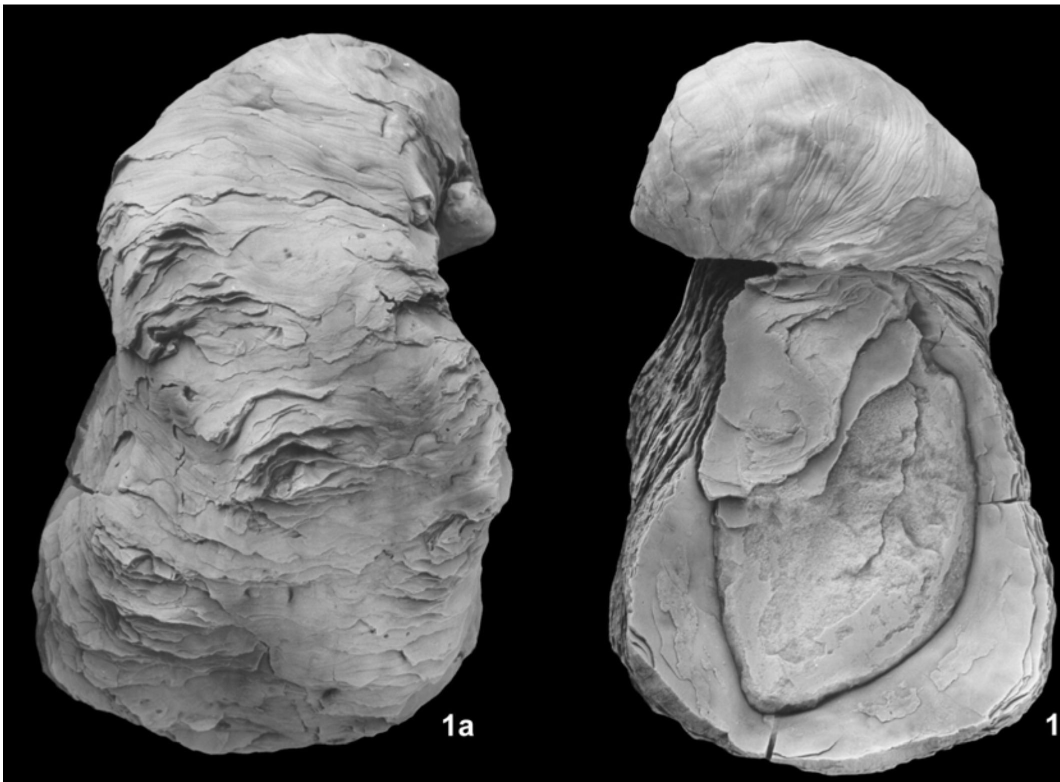
Fig. 5. Oyster indet.. Internal view of left valve. Cenomanian FHS Formation, sample J8-12; x2.- PIW 2002 VII 289.

Fig. 6. *Crassostrea* sp.. Internal view of right valve. Cenomanian FHS Formation, sample J9-26B; x1.- PIW 2002 VII 290.

Fig. 7. *Trigonia* (*Trigonia*) sp.. Imprint of a right valve. Cenomanian FHS Formation, sample J10-6; x3.- PIW 2002 VII 108.

Fig. 8. *Trigonia* (*Trigonia*) cf. *ethra* COQUAND, 1862. External view of right valve. Cenomanian FHS Formation, sample J3-9; x1.- PIW 2002 VII 107.

Figs. 9-10. *Eomiodon* cf. *libanoticus* (FRAAS, 1878). Composite moulds of left valves. Cenomanian FHS Formation, sample J5-36; x4.- PIW 2002 VII 156.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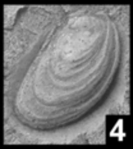
3a 3b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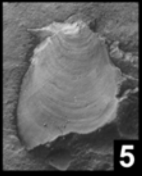
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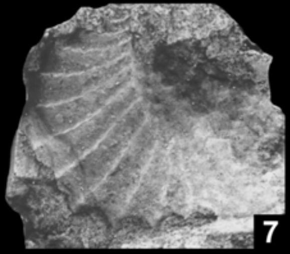
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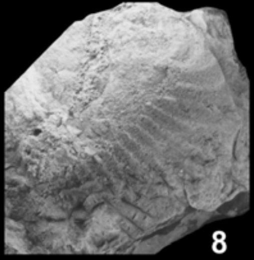
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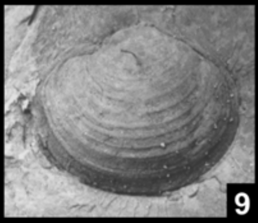
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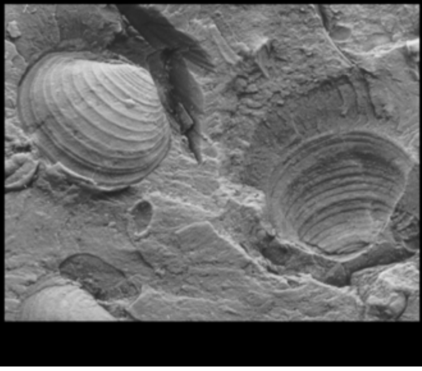
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Fig. 1. "*Crassatella*" sp.. Composite mould of left valve. Cenomanian FHS Formation, sample J9-20; x2.- PIW 2002 VII 118.

Fig. 2. *Anthonya dayi* VOKES, 1941. Composite mould of left valve. Cenomanian FHS Formation, sample J10-6; x2.- PIW 2002 VII 120.

Fig. 3. "*Lucina*" sp.. Composite mould of right valve. Cenomanian FHS Formation, sample J10-6; x1.- PIW 2002 VII 109.

Figs. 4-6. *Anthonya jordanica* sp. nov. **4**. Composite mould of left valve. Cenomanian FHS Formation, sample J10-6; x2.- PIW 2002 VII 123. **5**. Composite mould of left valve. Cenomanian Wadi Juhra Member, sample J6-10, x2.- PIW 2002 VII 120. **6**. Composite mould of right valve. Cenomanian FHS Formation, sample J10-6, x2.- PIW 2002 VII 121.

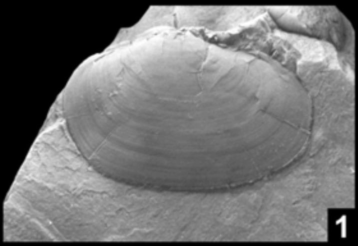
Figs. 7-8. Carditid bivalve sp. B. **7**. Composite mould of left valve. Cenomanian FHS Formation, sample J9-12; x3.- PIW 2002 VII 112. **8**. Composite mould of right valve. Cenomanian FHS Formation, sample J9-12; x3.- PIW 2002 VII 113.

Figs. 9-10. Carditid bivalve sp. A. **9**. Composite mould of left valve. Cenomanian FHS Formation, sample J7-2; x8.- PIW 2002 VII 110. **10**. Composite mould of right valve. Cenomanian FHS Formation, sample J7-2; x8.- PIW 2002 VII 111.

Fig. 11. *Opis*? sp. Imprint of right valve. Cenomanian FHS Formation, section 9; x4.- PIW 2002 VII 117.

Fig. 12. *Granocardium* (*Granocardium*) *productum* (J. DE C. SOWERBY, 1832). External view of right valve. Cenomanian FHS Formation, sample J2-3; x1.- PIW 2002 VII 124.

Figs. 13-14. *Granocardium* (*Granocardium*) *desvauxi* (COQUAND, 1862). **13** Right valve, external view (**a**); anterior view (**b**).- PIW 2002 VII 128. **14**. external view of a compressed left? valve. Cenomanian FHS Formation, sample J3-9; x1.- PIW 2002 VII 127.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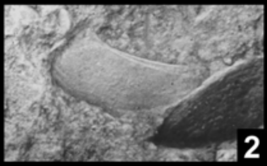
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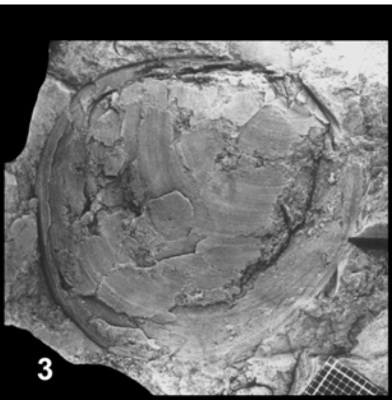
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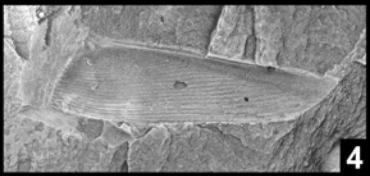
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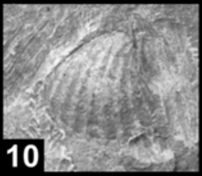
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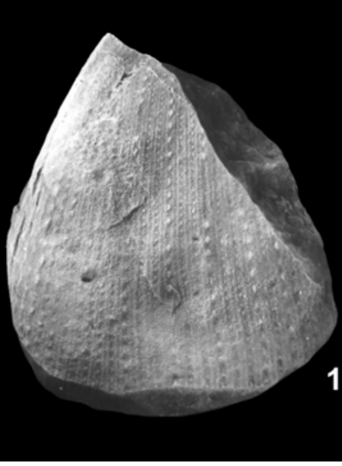
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Plate 6

Figs 1-2. *Granocardium* (*Granocardium*) cf. *carolinum* (D´ORBIGNY, 1843). **1**. Internal mould, external view of right valve; **2**. anterior view. Cenomanian FHS Formation, sample J3-9; x1.- PIW 2002 VII 129.

Figs. 3-4. *Trachycardium* (*Trachycardium*?) *mermeti* (COQUAND, 1862). **3**. Internal mould, anterior view. PIW 2002 VII 132. **4**. Internal mould, external view of right valve.- PIW 2002 VII 133. Cenomanian FHS Formation, sample J3-10; x1.

Fig. 5. *Protocardia* (*Protocardia*) *coquandi* (SEGUENZA, 1882). Internal mould, external view of right valve. Cenomanian FHS Formation, sample J5-18; x1.- PIW 2002 VII 136.

Fig. 6. *Protocardia* (*Protocardia*) cf. *judaica* (HAMLIN, 1884). Composite mould of right valve. Cenomanian FHS Formation, sample J5-36; x2.- PIW 2002 VII 135.

Figs. 7-9. *Geltena* cf. *mactraeformis* VOKES, 1946. **7**, **8**. Composite moulds of right valves, external view. Cenomanian FHS Formation, sample J9-12; x3. PIW 2002 VII 137-138. **9**. Composite mould of left valve, external view. Cenomanian Wadi Juhra Member, sample J8-2; x3.- PIW 2002 VII 139.

Figs. 10-11. *Schedotrapezium*? *acclivis* (CONRAD, 1852). **10a**, **11**. Internal moulds, external view of right valves. **10b**. Dorsal view. Cenomanian FHS Formation, sample J1-5; x1.- PIW 2002 VII 149-50.

Fig. 12. *Arctica cordata* (SHARPE, 1850). **a**. Internal mould, external view of right valve; **b**. anterior view. Cenomanian FHS Formation, sample J4-1; x1.- PIW 2002 VII 146.

Fig. 13. "*Tellina*" sp.. Internal mould of right valve, external view. Cenomanian FHS Formation, sample J9-12; x1.- PIW 2002 VII 141.

Fig. 14. *Linearia*? sp.. Composite mould of left valve, external view. Cenomanian FHS Formation, sample J10-6; x1.- PIW 2002 VII 144.

Fig. 15. *Arctica*? sp.. **a**. External view of right valve; **b**. dorsal view. Cenomanian FHS Formation, sample J1-5A; x1.- PIW 2002 VII 148.

Fig. 16. *Veniella*? *trapezoidalis* (COQUAND, 1862). Internal mould of left valve, external view. Cenomanian FHS Formation, sample J2-3; x1.- PIW 2002 VII 155.


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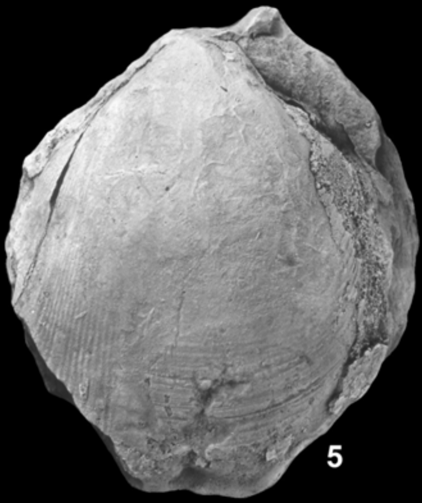
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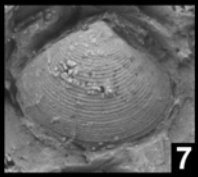
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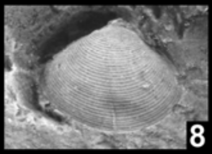
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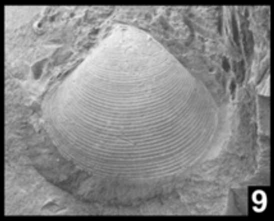
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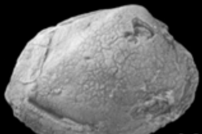
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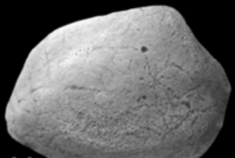
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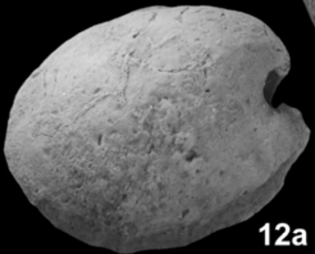
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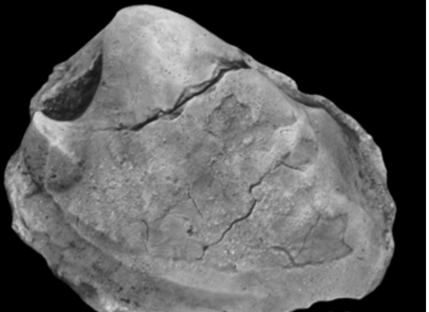
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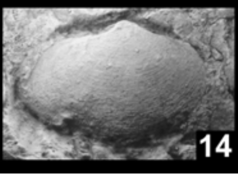
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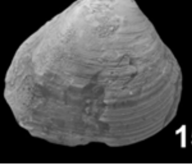
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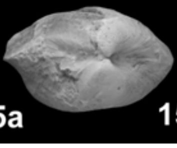
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Plate 7

Figs. 1-2. *Aphrodina* (*Aphrodina*) *dutrugei* (COQUAND, 1862). **1a**, **2**. Internal moulds, external view of right valves, **1b**. Dorsal view. Cenomanian FHS Formation, sample 2-3; x1.- PIW 2002 VII 157-158.

Figs. 3-4. "*Dosinia*" *delettrei* (COQUAND, 1862). **3a**, **4**. Internal moulds, external view of right valves; **3b**. dorsal view. Cenomanian FHS Formation, sample J1-5A; x1.- PIW 2002 VII 165-166.

Figs. 5-6. *Paraesa* sp. aff. *Venus reynesi* COQUAND, 1862. **5a**. Composite moulds of left and right valves, external view; x1, **5b**. Detail view of the hinge, right valve; x3.- PIW 2002 VII 172. **6**. Composite mould of right valve, external view; x1.- PIW 2002 VII 174. Cenomanian FHS Formation, sample J5-36.

Fig. 7. *Venilicardia*? cf. *cordiformis* (D´ORBIGNY, 1843). External view of left valve. Cenomanian FHS Formation, sample J4-1; x1.- PIW 2002 VII 155.

Figs. 8-9. "*Corbula*" sp.. **8**. Composite mould of left valve, external view.- PIW 2002 VII 184. **9**. Composite mould of a right valve, external view.- PIW 2002 VII 185. Turonian Wadi As Sir Formation, sample J6-52; x3.

Fig. 10. *Corbulomima* cf. *aligera* (HAMLIN, 1884). Composite mould of a right valve, external view. Cenomanian FHS Formation, sample J10-6; x3.- PIW 2002 VII 186.

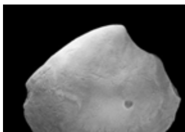
Figs. 11-13. *Caestocorbula*? cf. *tapuchii* (SHALEM, 1928). **11**, **12**. Composite moulds of right valves, external view.- PIW 2002 VII 187-188. **13**. Composite mould of left valve, external view.- PIW 2002 VII 189. Cenomanian FHS Formation, sample J9-18; x3.

Figs. 14-16. *Caestocorbula* (*Parmicorbula*) *eretzisraelensis* (SHALEM, 1928). **14**, **15**. Composite moulds of right valves, external view.- PIW 2002 VII 203-204. **16**. Composite mould of left valve, external view.- PIW 2002 VII 205. Cenomanian FHS Formation, sample J9-18; x3.

Fig. 17. *Radiolites*? sp.. Internal mould of right valve. Cenomanian FHS Formation, sample J5-18; x1.- PIW 2002 VII 214.

Fig. 18. cf. *Toucasia matheroni* (COQUAND, 1862). Internal mould. Cenomanian FHS Formation, sample J2-1; x1.- PIW 2002 VII 213.

Fig. 19. Heterodont bivalve sp. D. Composite mould of right valve. Cenomanian FHS Formation, sample J9-18; x3.- PIW 2002 VII 220.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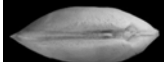
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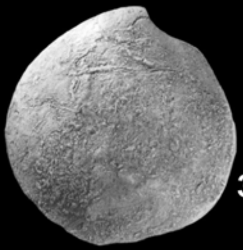
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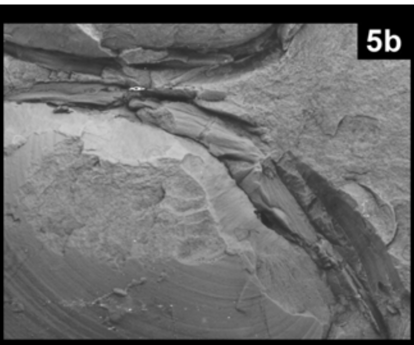
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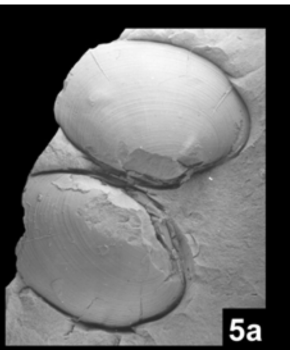
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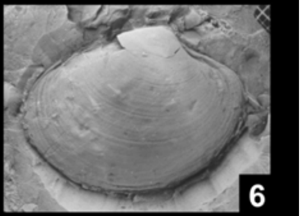
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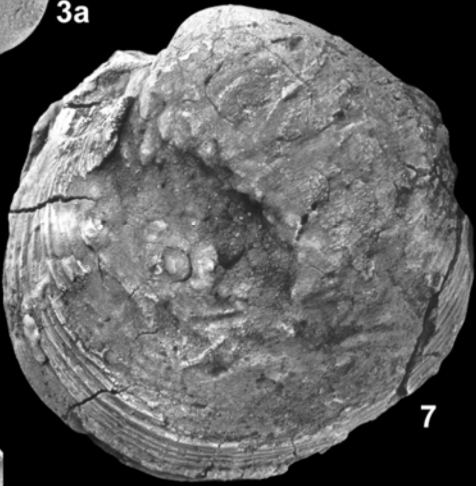
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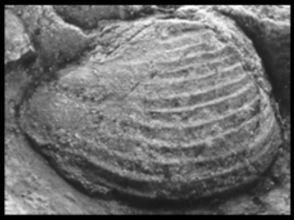
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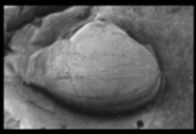
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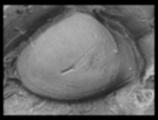
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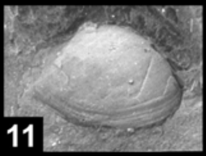
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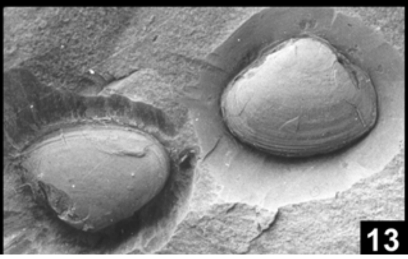
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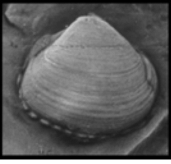
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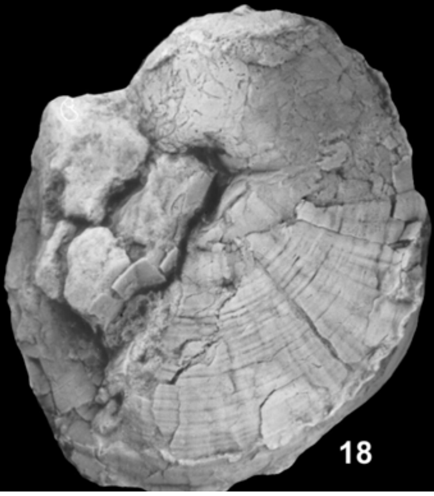
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Plate 8

Fig. 1. cf. *Toucasia matheroni* (COQUAND, 1862). Anterior view of both valves. Cenomanian FHS Formation, sample J2-1; x1.- PIW 2002 VII 213.

Figs. 2-3. *Pholadomya* (*Procardia*) *vignesi* (LARTET, 1877). Composite moulds. **2**. Right valve view.- PIW 2002 VII 228. **3**. Left valve view.- PIW 2002 VII 229. Cenomanian FHS Formation, sample J1-3B; x1.

Fig. 4. *Pholadomya* (*Pholadomya*) cf. *pedernalis* ROEMER, 1852. Internal mould, right valve view. Cenomanian FHS Formation, section 2; x1.- PIW 2002 VII 232.

Fig. 5. "*Pholadomya*" sp. Internal mould. **a**. Left valve view; **b**. dorsal view. Cenomanian FHS Formation, sample J4-1; x1.- PIW 2002 VII 233.

Figs. 6-7. *Cercomya*? *jettei* (COQUAND, 1862). **6**. Composite moulds, right valve view; **7**. composite moulds, dorsal view. Cenomanian FHS Formation, sample J9-26B; x1.- PIW 2002 VII 235.

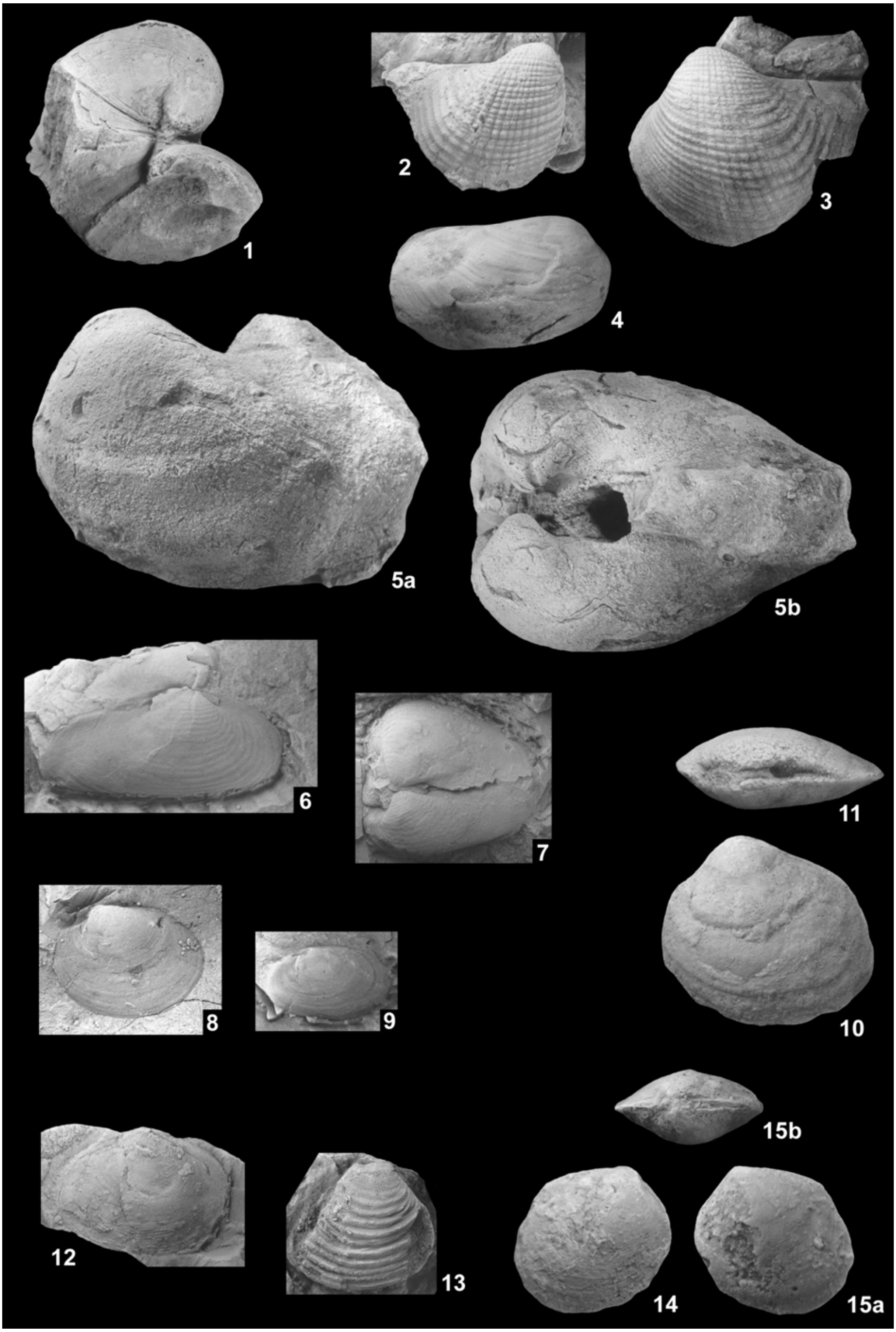
Figs. 8-9. *Periplomya*? sp.. Composite moulds of right valves. **8**. Left valve view; **9**. dorsal view. Cenomanian FHS Formation, sample J9-18; x3.- PIW 2002 VII 236.

Figs. 10-11. Heterodont bivalve sp. A. **10**. Internal mould, external view of left? valve, **11**. Dorsal view. Cenomanian FHS Formation, sample J1-5A; x2.- PIW 2002 VII 215.

Fig. 12. Heterodont bivalve sp. E. Composite mould of left? valve. Turonian Wadi As Sir Formation, sample J5-68B; x2.- PIW 2002 VII 223.

Fig. 13. Heterodont bivalve sp. C. External view of right valve. Cenomanian FHS Formation, sample J1-5A; x2.- PIW 2002 VII 219.

Figs. 14-15. Heterodont bivalve sp. B. Internal moulds of articulated specimens. **14**.Right valve view.- PIW 2002 VII 216. **15a**. Left valve view, **15b**. dorsal view.- PIW 2002 VII 217. Cenomanian FHS Formation, sample J1-5A; x2.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Tafel 9

Fig. 1. *Torinia* (*Climacopoma*) *animi* ABBASS, 1963. Internal mould. **a**. Apical view; **b**. apertural view. Cenomanian FHS Formation, sample J3-10; x2.- PIW 2002 VII 277.

Fig. 2. *Neritopsis* (*Neritopsis*?) sp. in shell preservation. **a**. Apical view; **b**. side view. Cenomanian FHS Formation, section 1; x3.- PIW 2002 VII 239.

Fig. 3. *Calliomphalus orientalis* (DOUVILLÉ, 1916). Internal mould. **a**. Apical view; **b**. apertural view. Cenomanian FHS Formation, section 4; x2.-237.

Fig. 4. *Pyrazus* cf. *valeriae* DE VERNEUIL & DE LORIÈRE, 1868. Composite mould, lateral view. Cenomanian FHS Formation, section 2; x2.- PIW 2002 VII 241.

Fig. 5. *Tylostoma globosum* SHARPE, 1849. Internal mould, lateral view. Cenomanian FHS Formation, sample J2-3; x1.- PIW 2002 VII 251.

Fig. 6. *Tylostoma cossoni* THOMAS & PERON, 1889. Internal mould. **a**. Apertural view; **6b**. lateral view. Cenomanian FHS Formation, sample J3-1; x1.- PIW 2002 VII 256.

Fig. 7. *Coronatica* cf. *ornata* (FRAAS, 1878). Composite mould, lateral view. Cenomanian FHS Formation, section 2; x1.5.- PIW 2002 VII 240.

Fig. 8. *Columbellina fusiformis* DOUVILLÉ, 1916. Internal mould, apertural view. Cenomanian FHS Formation, section 2; x1.- PIW 2002 VII 258.

Fig. 9. "*Aporrhais*" *turriculoides* (CONRAD, 1852). Internal mould. **a**. Apertural view; **b**. lateral view. Cenomanian FHS Formation, section 3; x2.- PIW 2002 VII 249.

Fig. 10, 14. *Pterodonta deffisi* THOMAS & PERON, 1889. Internal moulds. **10a**. Apertural view; **10b**, **14**. lateral view. Cenomanian FHS Formation, **10a, b** from sample J2-1.- PIW 2002 VII 259; **14** from sample J1-3B.- PIW 2002 VII 260; x1.

Fig. 11. *Globiconcha rotundata* D´ORBIGNY, 1842. Internal mould, apertural view. Cenomanian FHS Formation, section 4; x1.- PIW 2002 VII 269.

Fig. 12. *Pterodonta* cf. *subinflata* COQUAND, 1862. Internal mould. **a**. Apertural view; **b**. lateral view. Cenomanian FHS Formation, section 1; x1.- PIW 2002 VII 265.

Fig. 13. Gastropod sp. B. Composite mould, lateral view. Cenomanian FHS Formation, sample J9-12; x2.- PIW 2002 VII 279.

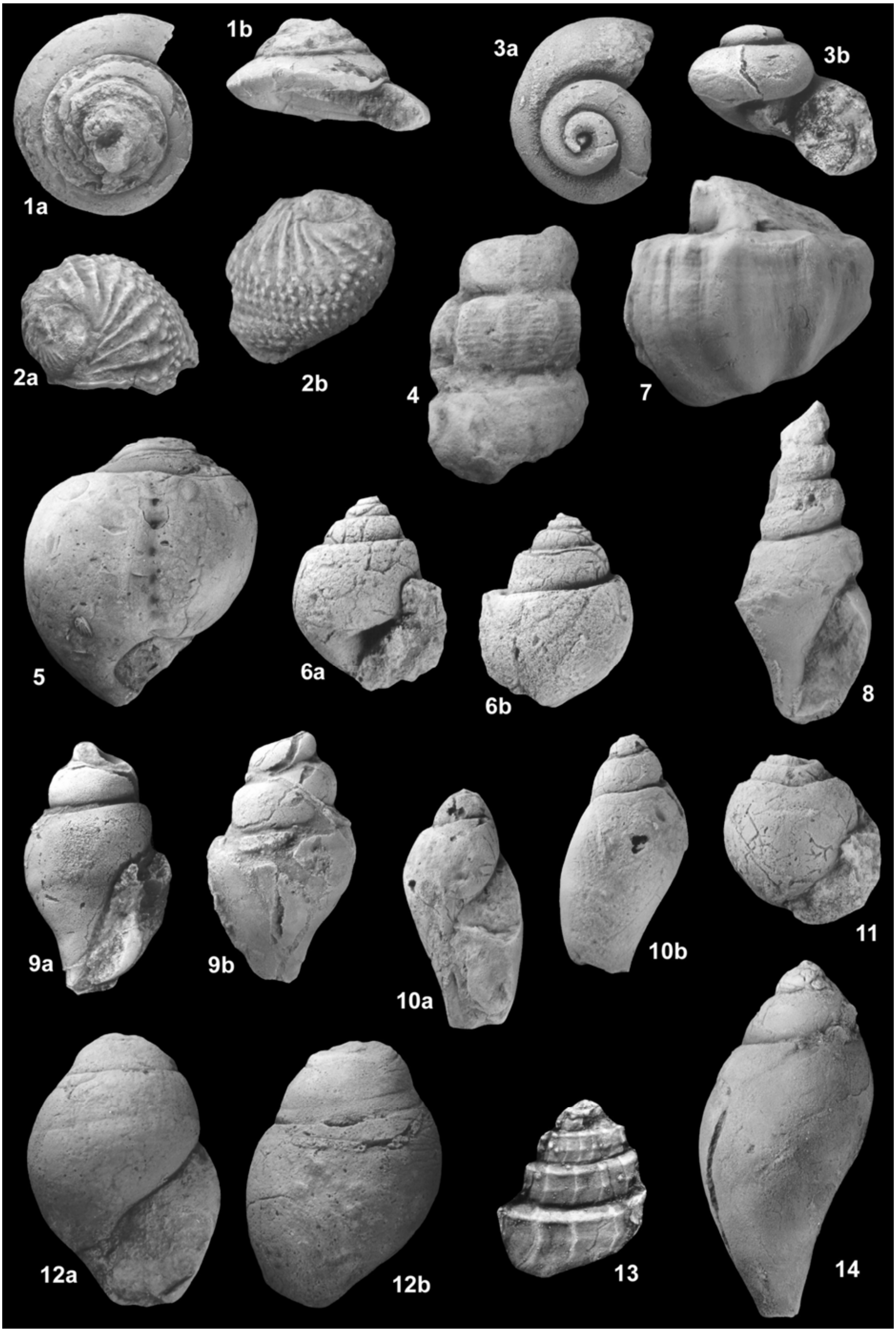
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Plate 10

Figs. 1-2. "*Strombus incertus*" (D´ORBIGNY, 1842). Internal moulds. **1a**, **2**. Apertural view; **1b**. apical view. Cenomanian FHS Formation, sample J2-1; x1.- PIW 2002 VII 247-248.

Fig. 3. Gastropod sp. A. Internal mould, lateral view. Cenomanian FHS Formation, section 4; x1.- PIW 2002 VII 278.

Fig. 4. aff. *Pseudoliva ambigua* BINKHORST, 1861. Composite mould, lateral view. Cenomanian FHS Formation, sample J9-20; x3.- PIW 2002 VII 268.

Fig. 5. *Nerinea gemmifera* COQUAND, 1862. Composite mould, lateral view. Cenomanian FHS Formation, sample J4-1; x1.- PIW 2002 VII 270.

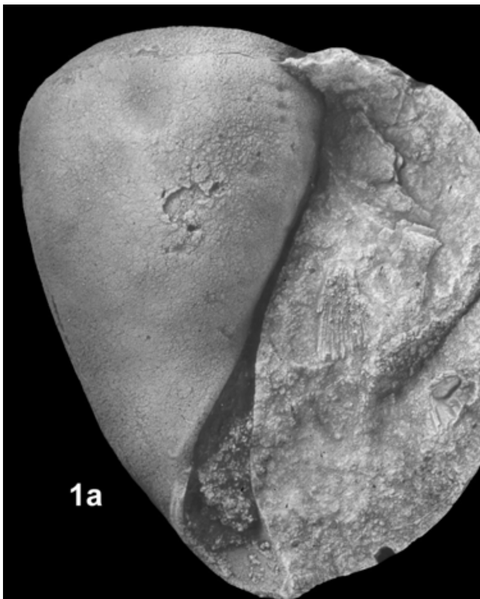
Figs. 6-7. *Nerinea pauli* COQUAND, 1862. Internal moulds, lateral view. Cenomanian FHS Formation, sample J2-2; x1.- PIW 2002 VII 271-272.

Fig. 8. *Nerinea subaequalis* D´ORBIGNY, 1842. Internal mould, lateral view. Cenomanian FHS Formation, sample J2-1; x1.- PIW 2002 VII 275.

Fig. 9. *Pterodonticeras germeri* BLANCKENHORN, 1927. Internal mould, lateral view. Cenomanian FHS Formation, sample J4-1; x1.- PIW 2002 VII 266.

Fig. 10. "*Turritella*" *amotzi* SHALEM, 1928. Composite mould, lateral view. Cenomanian FHS Formation, sample J5-36; x5.- PIW 2002 VII 242.

Fig. 11. Gastropod sp. C. Composite mould, lateral view. Cenomanian FHS Formation, sample J5-36; x5.- PIW 2002 VII 280.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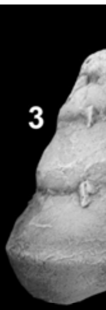
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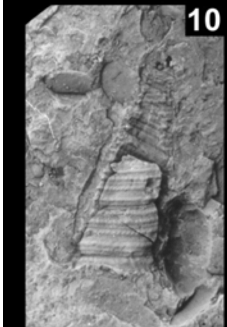
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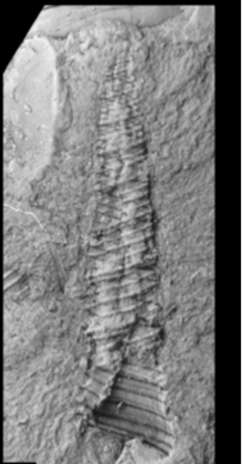
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Plate 11

Figs. 1-2. *Heterodiadema libycum* (AGASSIZ & DESOR, 1846). **1a**. Apical view; **1b, 2a**. oral view; **1c, 2b**. lateral view. Cenomanian FHS Formation, sample J4-1; x1.- PIW 2001 III 1-2.

Fig. 3. *Micropedina olisiponensis* (FORBES, 1850). **a**. Apical view; **b**. oral view; **c**. lateral view. Cenomanian FHS Formation, sample J4-1; x1.- PIW 2001 III 6.

Figs. 4-5. *Goniopygus menardi* (DESMAREST, 1825). **4**, **5a**. Apical view; **5b**. lateral view. Cenomanian FHS Formation, section 4; x1.- PIW 2001 III 8-9.

Fig. 6. *Tetragramma variolare* (BRONGNIART, 1822). **a**. Oral view; **b**. lateral view. Cenomanian FHS Formation, section 4; x1.- PIW 2001 III 4.

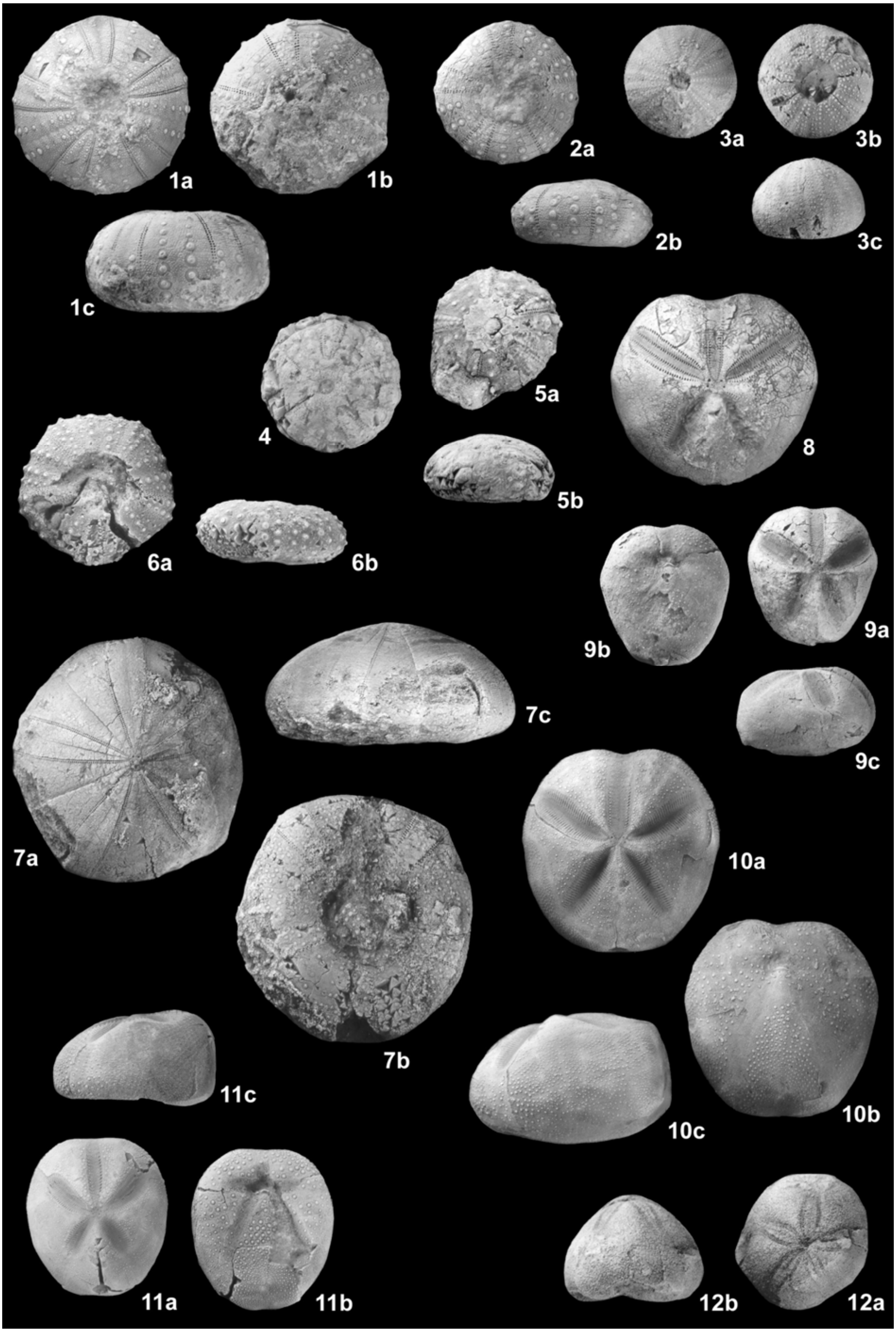
Fig. 7. *Coenholectypus larteti* (COTTEAU, 1869). **7a**. Apical view, **7b**. Oral view, **7c**. Lateral view. Cenomanian FHS Formation, section 4; x1.- PIW 2001 III 11.

Figs. 8-9. *Hemiaster* (*Mecaster*) *luynesi* (COTTEAU, 1867). **8, 9a**. Apical view; **9b**. oral view; **9c**. lateral view. Cenomanian FHS Formation, section 3; x1.- PIW 2001 III 14-15.

Fig. 10. *Hemiaster* (*Mecaster*) *syriacus* (CONRAD, 1852). **a**. Apical view; **b**. oral view, **c**. lateral view. Cenomanian FHS Formation, section 3; x1.- PIW 2001 III 13.

Fig. 11. *Hemiaster* (*Mecaster*) cf. *batnensis* (COQUAND, 1862). **a**. Apical view; **b**. oral view; **c**. lateral view. Cenomanian FHS Formation, sample J2-2; x1.- PIW 2001 III 17.

Figs. 12. *Archiacia* sp.. **a**. Apical view; **b**. lateral view. Cenomanian FHS Formation, sample J2-3A; x1.- PIW 2001 III 19.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7a
10a
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10c
10b
11a
11b
12b
12a

Plate 12

Fig. 1. *Phragmites*? *cretaceus* LESQUERREUX, 1874. Cenomanian FHS Formation, section 10; x1.- PIW 2002 VII 291.

Fig. 2. *Sideroxytophylum angustifolium* BENDER & MÄDLER, 1969. Cenomanian FHS Formation, section 10; x1.- PIW 2002 VII 292.

Figs. 3-4. Unidentified leave fragments. Cenomanian FHS Formation, section 10; x1.- PIW 2002 VII 293.

Fig. 5. *Astraeofungia* sp.. Cenomanian FHS Formation, section 6; x1.- PIW 2002 VII 294.

Fig.6. *Meandraraea* sp.. Cenomanian FHS Formation, section 6; x1.- PIW 2002 VII 295.

Fig. 7-8. *Columnocoenia*? sp.. Cenomanian FHS Formation, section 5; x1.- PIW 2002 VII 296.

Fig. 9. Unidentified coral. Cenomanian FHS Formation; section 2; x1.- PIW 2002 VII 297.

Fig. 10. *Aspidiscus cristatus* (MILNE EDWARDS & HAIME, 1848). Cenomanian FHS Formation, section 5.- PIW 2002 VII 298.


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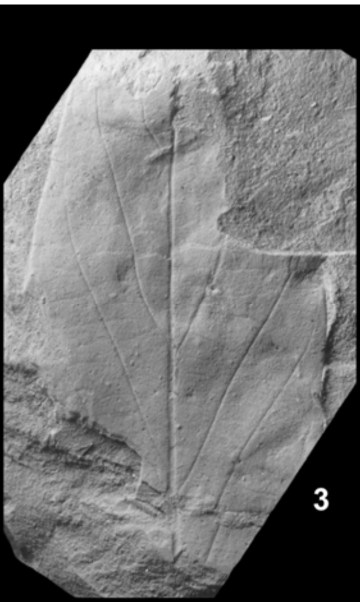
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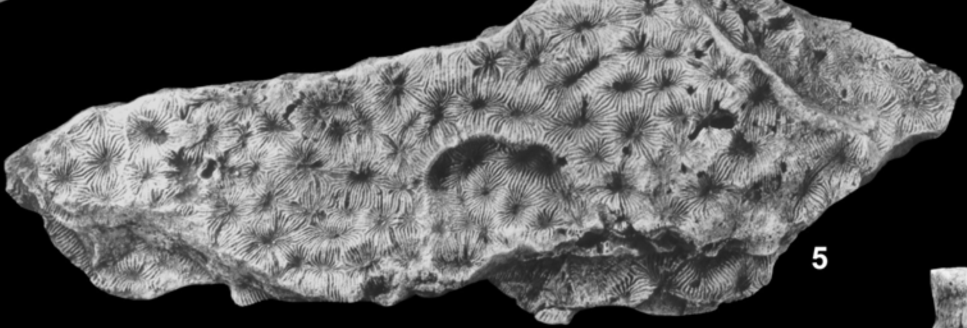
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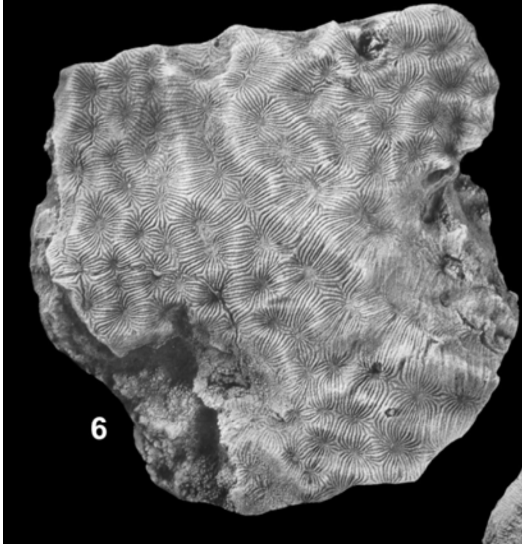
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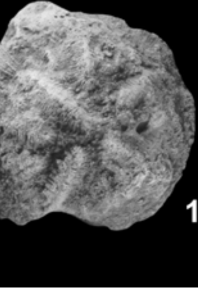
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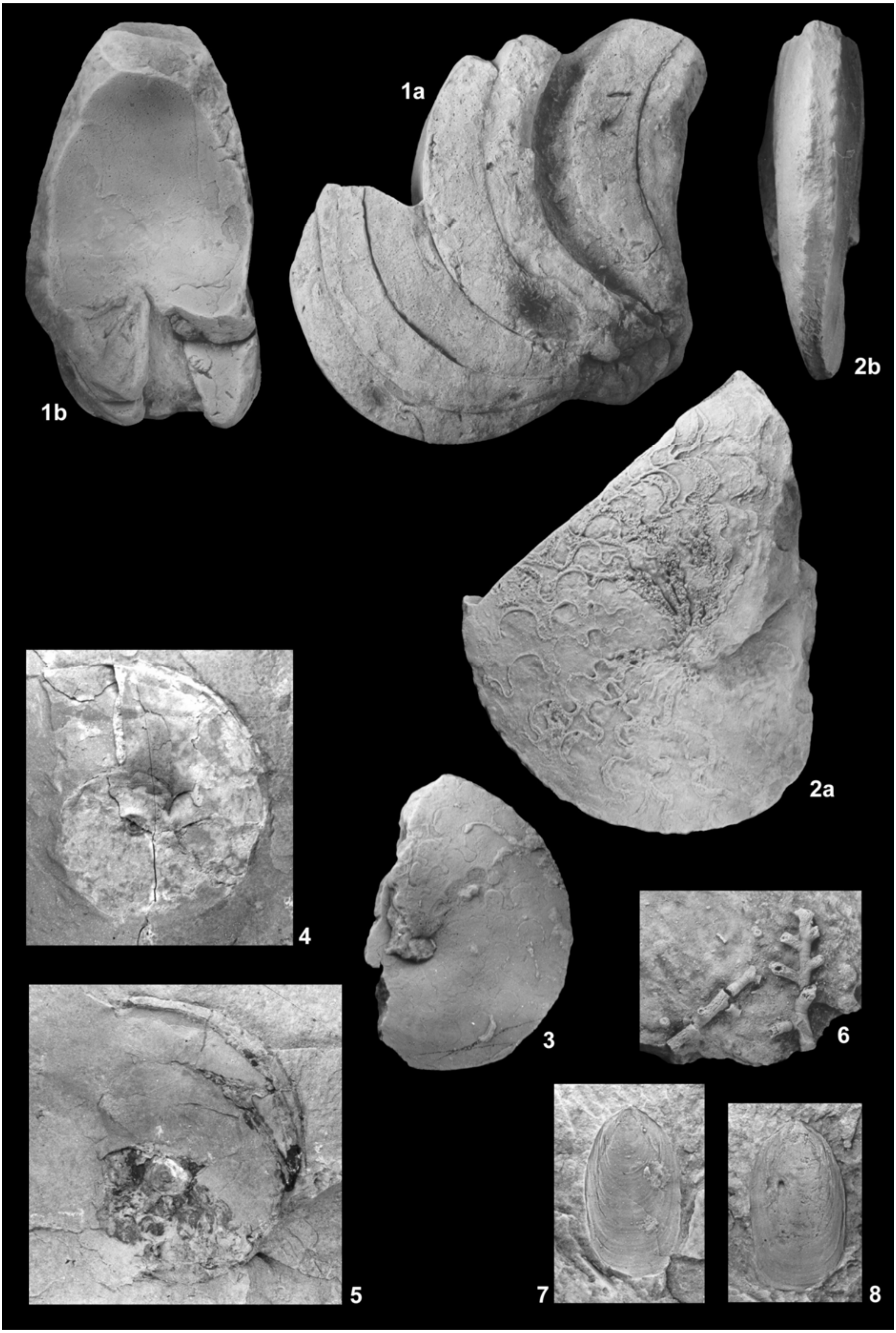
Plate 13

Fig. 1. *Angulithes mermeti* (COQUAND, 1862). Internal mould. **a**. Fornt view; **b**. lateral view. Cenomanian FHS Formation, section 2; x1.- PIW 2002 VII 299.

Figs. 2-5. *Neolobites vibrayeanus* (D´ORBIGNY, 1841). **2a**. Internal mould, lateral view; x1; **2b**. ventral view; x1.- PIW 2002 VII 300. **3**. Lateral view; x1.- PIW 2002 VII 301. **4, 5**. compressed internal moulds from claystones, lateral view; x2.- PIW 2002 VII 302-303. Cenomanian FHS Formation. **2a**, **2b**, **3**. From At Taiyba (section 1), **4**, **5**. From section 9.

Fig. 6. *Graysonia*? sp.. Cenomanian Naur Formation, section 11; x1.- PIW 2002 VII 304.

Figs. 7-8.“*Lingula*“ sp.. Cenomanian FHS Formation, sample J9-26B; x2.- PIW 2002 VII 305-306.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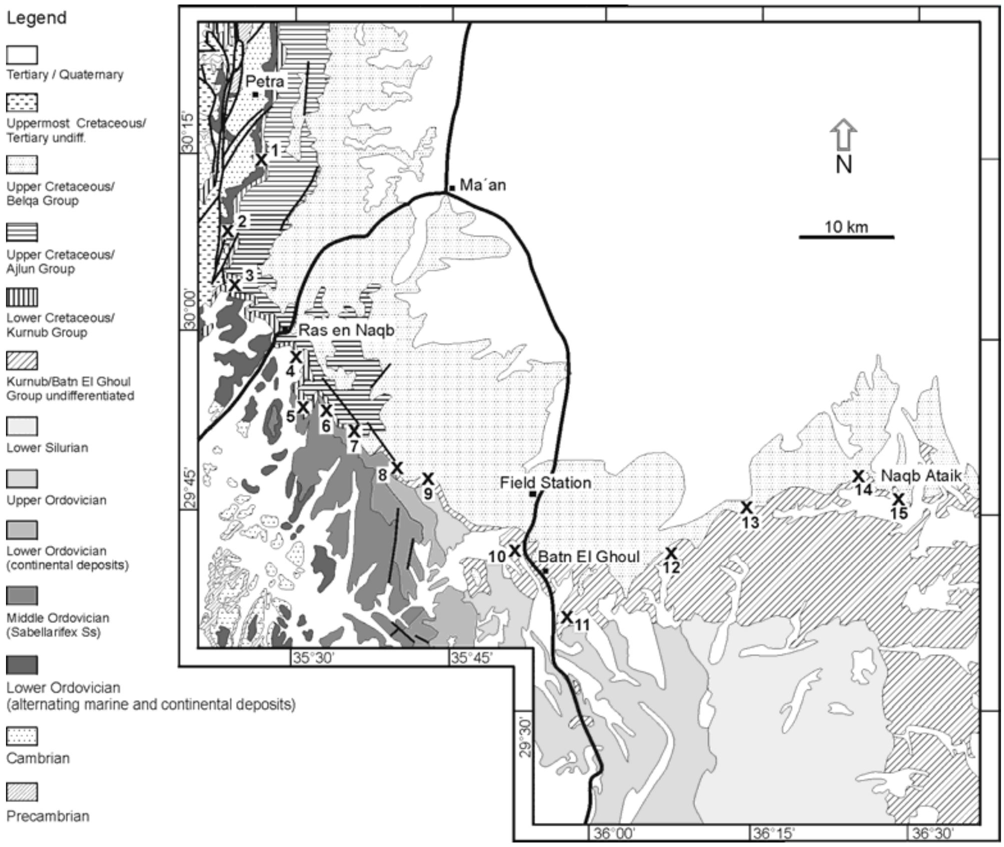
15 Appendix

15.1 Position of the sections (GPS data)

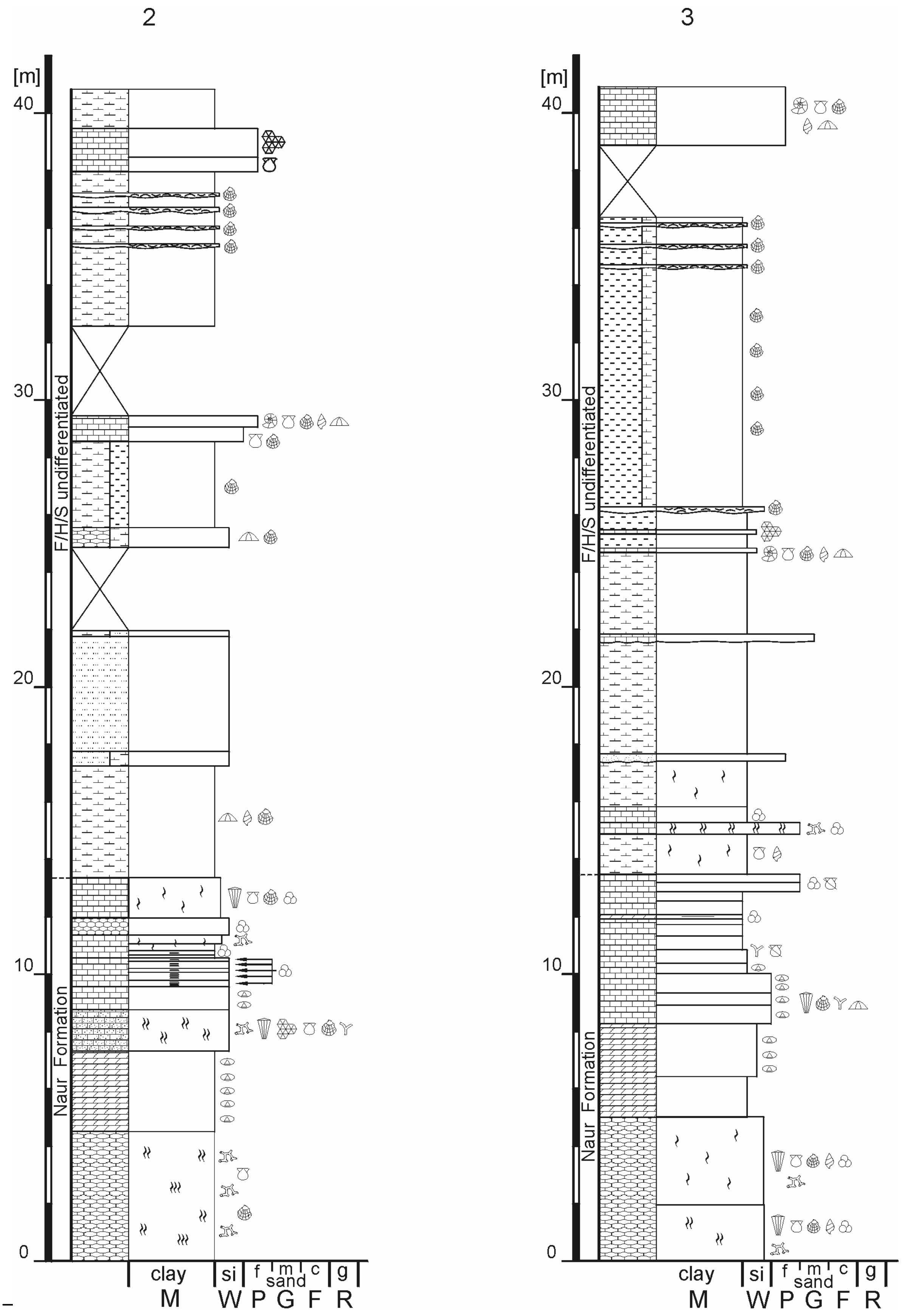
Section	N	E
1	30° 14’ 21.6“	035° 27’ 17.1“
2	30° 07’ 45.6“	035° 24’ 11.0“
3	30° 04‘ 14.6“	035° 25‘ 13.1``
4	29° 58‘ 32.9“	035° 30‘ 50.5“
5	29° 55‘ 42.4“	035° 33‘ 52.2“
6	29° 53‘ 21.6“	035° 34‘ 43.2“
7	29° 51‘ 38.7“	035° 37‘ 20.9“
8	29° 55‘ 42.4“	035° 41‘ 13.2“
9	29° 48‘ 52.0“	035° 43‘ 15.0“
10	29° 43‘ 46.5“	035° 49‘ 05.5“
11	29° 36‘ 32.0“	035° 57‘ 39.6“
12	29° 42‘ 27.8“	036° 07‘ 28.8“
13	29° 46‘ 55.7“	036° 17‘ 46.8“
14	29° 48‘ 09.8“	036° 23‘ 03.9“
15	29° 47‘ 22.4“	036° 28‘ 40.0“

Detailed sections



15.2 Detailed sections

Section 2 and 3



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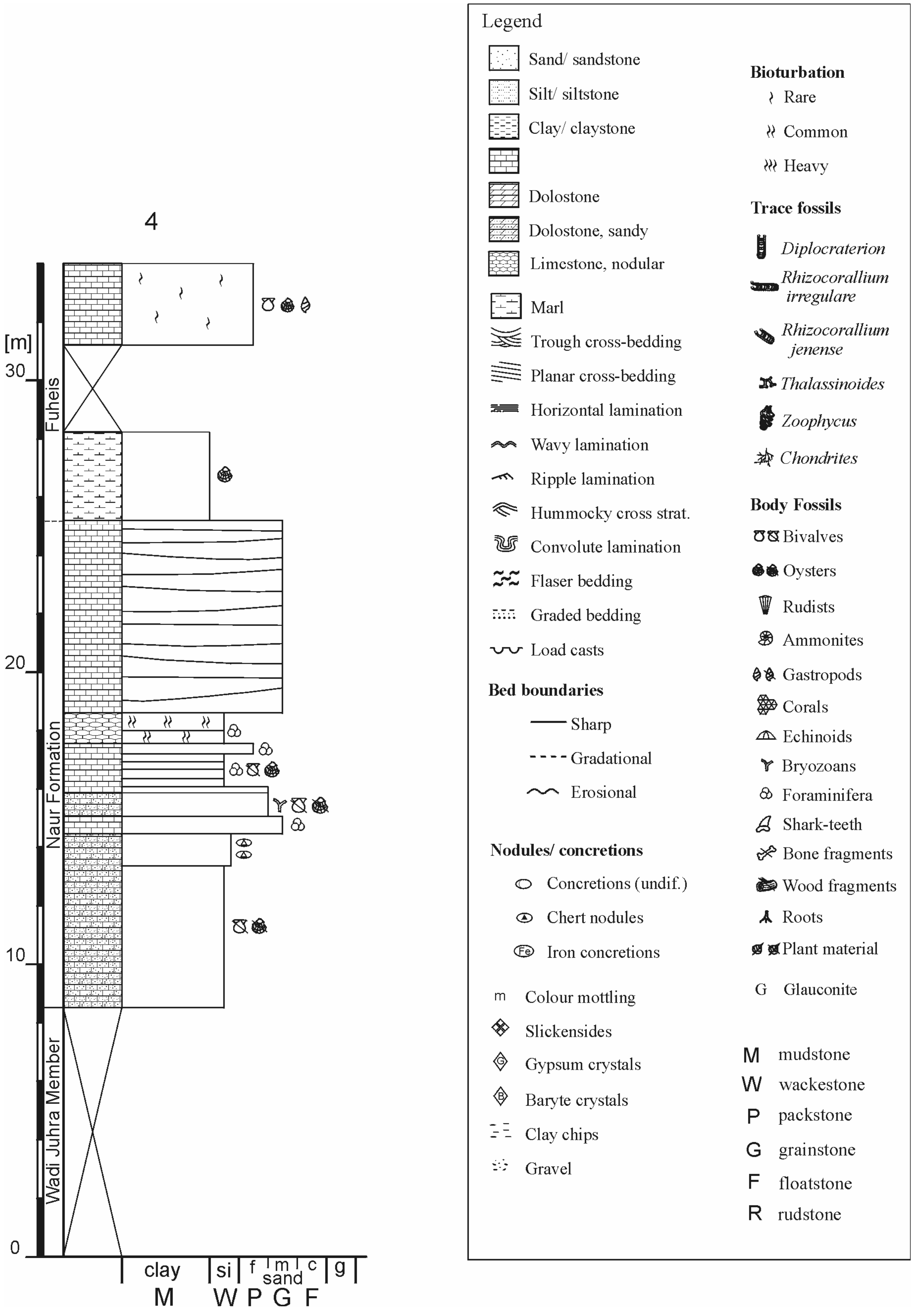
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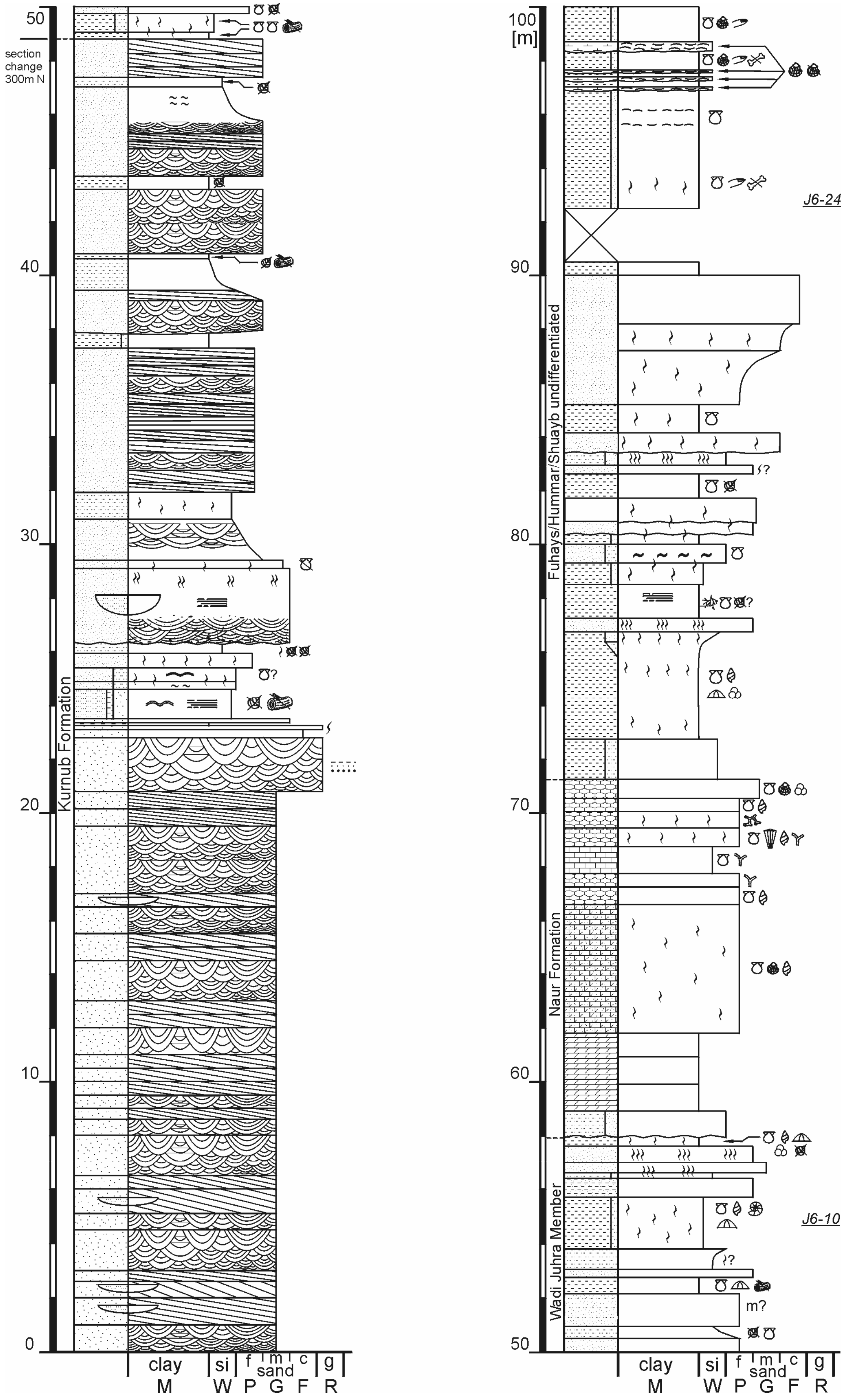
Silt/ siltstone
Clay/ claystone
Dolostone
Dolostone, sandy
Limestone, nodular
Marl
Trough cross-bedding
Planar cross-bedding
Horizontal lamination
Wavy lamination
Ripple lamination
Hummocky cross strat.
Convolute lamination
Flaser bedding
Graded bedding
Load casts
Bed boundaries
Sharp
Gradational
Erosional
Nodules/ concretions
Concretions (undif.)
Chert nodules
Iron concretions
m Colour mottling
Slickensides
Gypsum crystals
Baryte crystals
Clay chips
Gravel
Bioturbation
Rare
Common
Heavy
Trace fossils
Diplocraterion
Rhizocorallium irregulare
Rhizocorallium jenense
Thalassinoides
Zoophycus
Chondrites
Body Fossils
Bivalves
Oysters
Rudists
Ammonites
Gastropods
Corals
Echinoids
Bryozoans
Foraminifera
Shark-teeth
Bone fragments
Wood fragments
Roots
Plant material
G Glauconite
M mudstone
W wackestone
P packstone
G grainstone
F floatstone
R rudstone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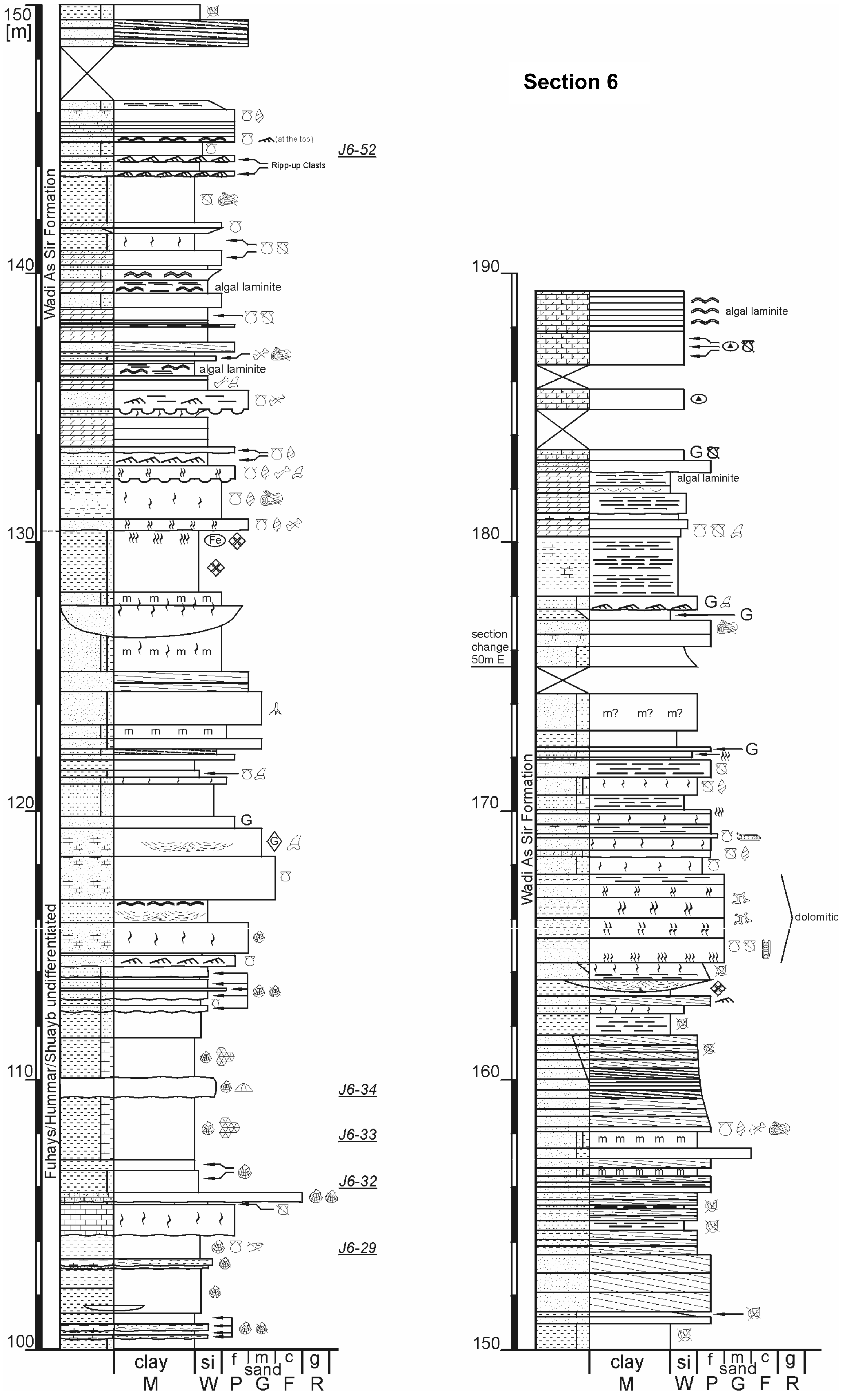
Section 6
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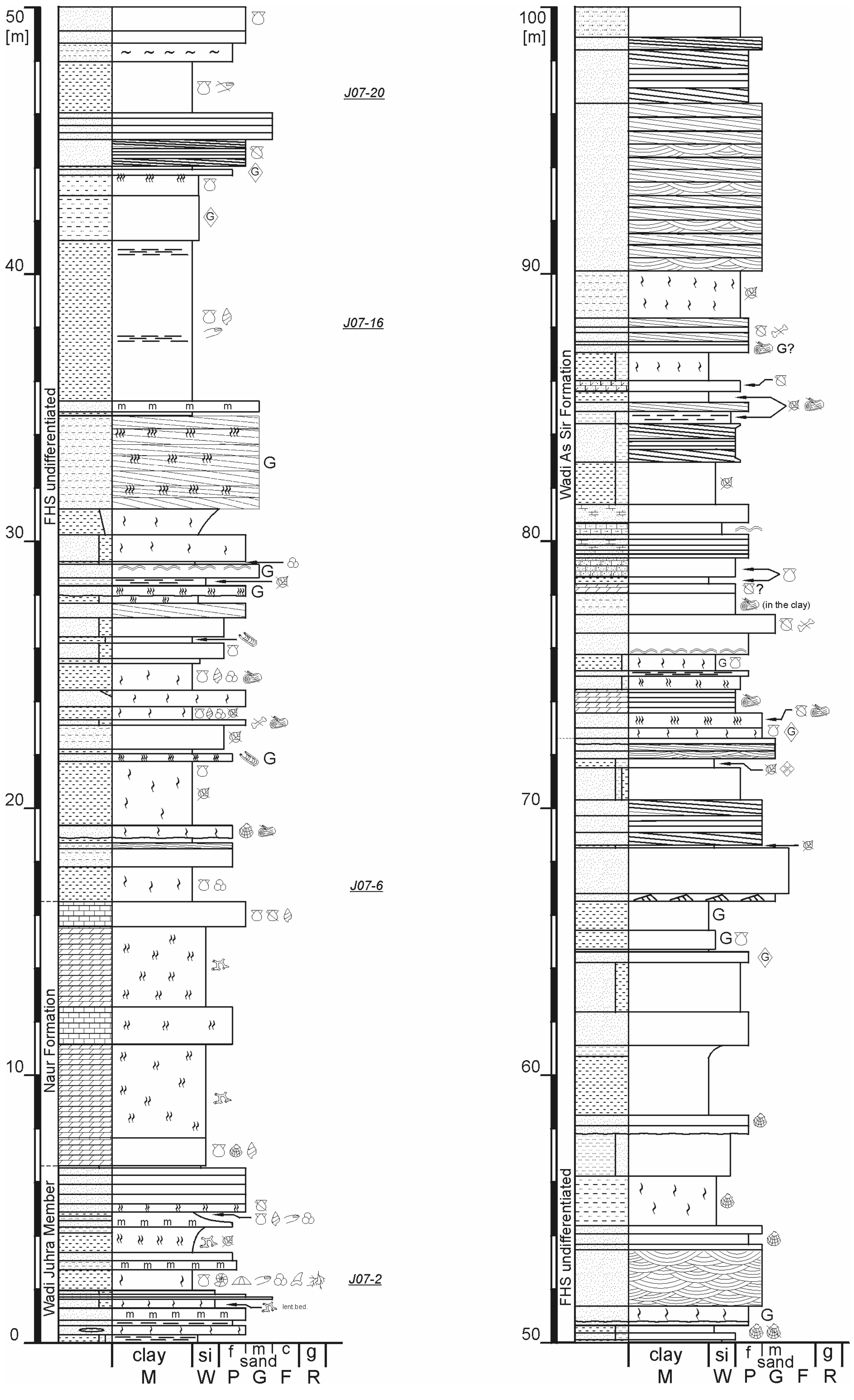
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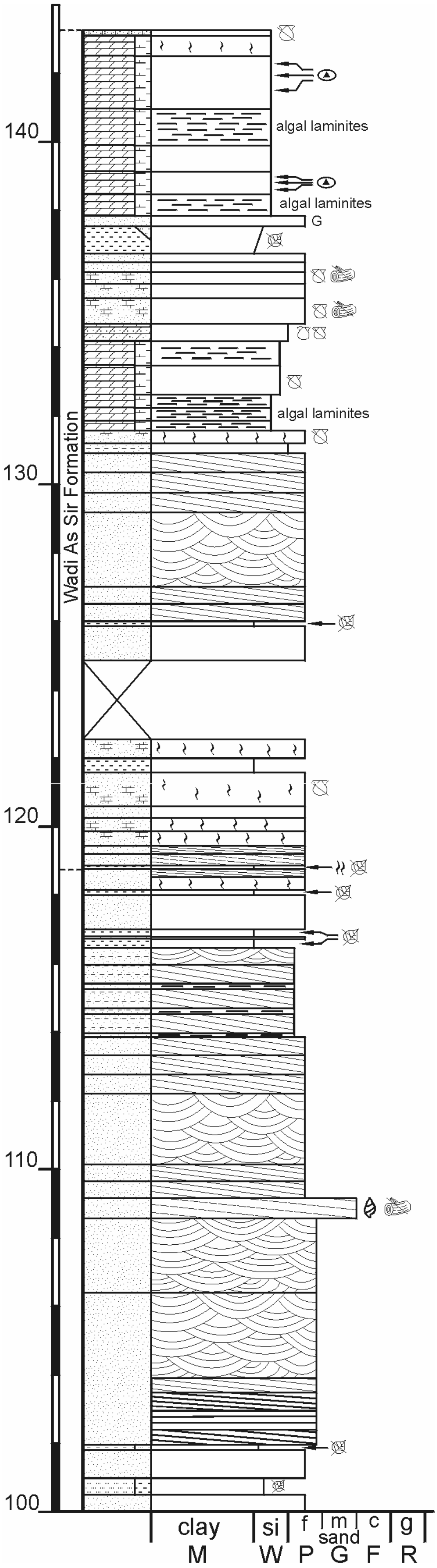
Section 7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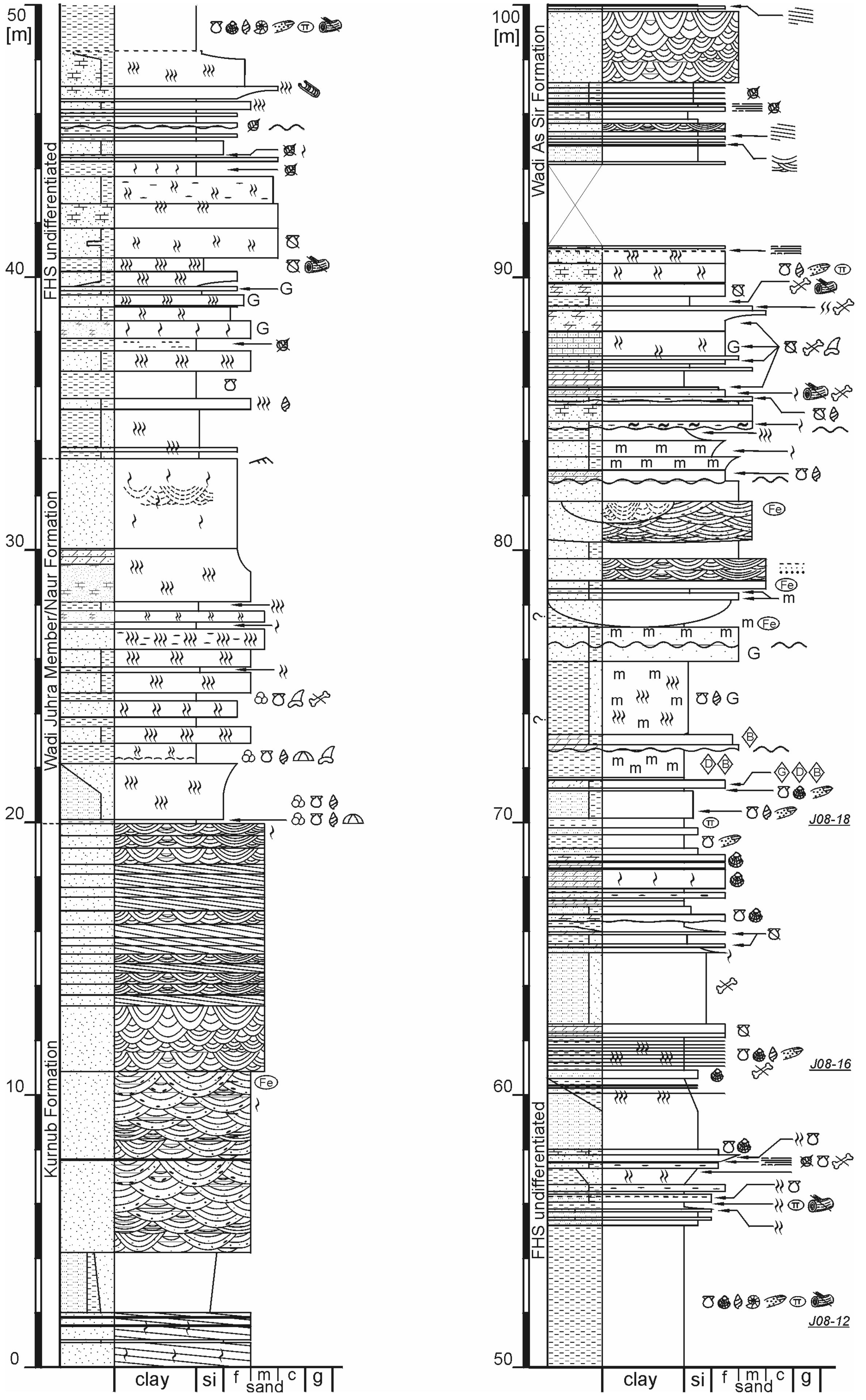
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FHS undifferentiated
Wadi Juhra Member/Naur Formation
Kurnub Formation
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Wadi As Sir Formation
FHS undifferentiated
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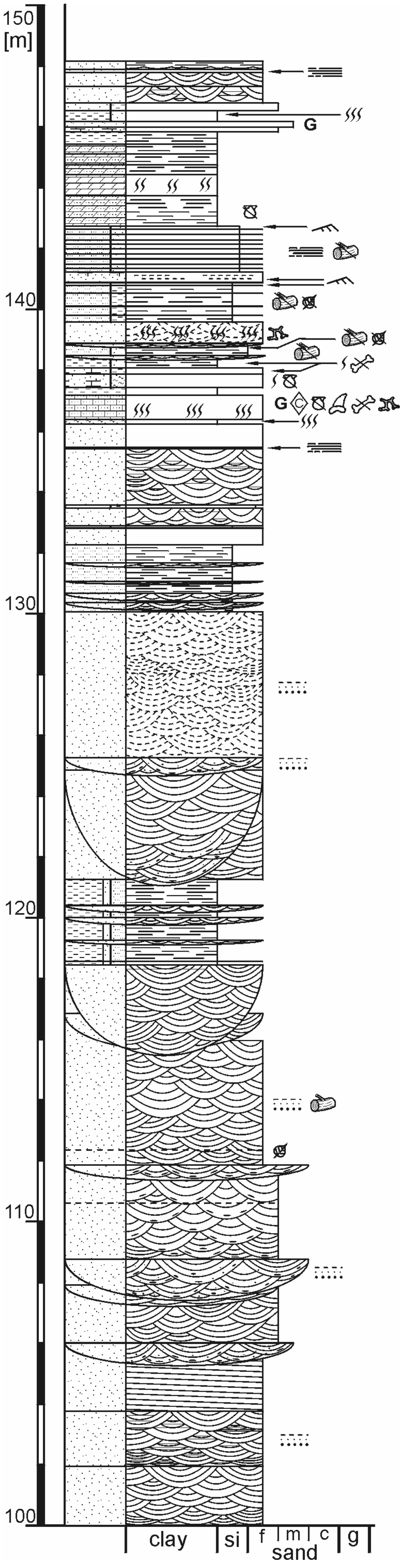
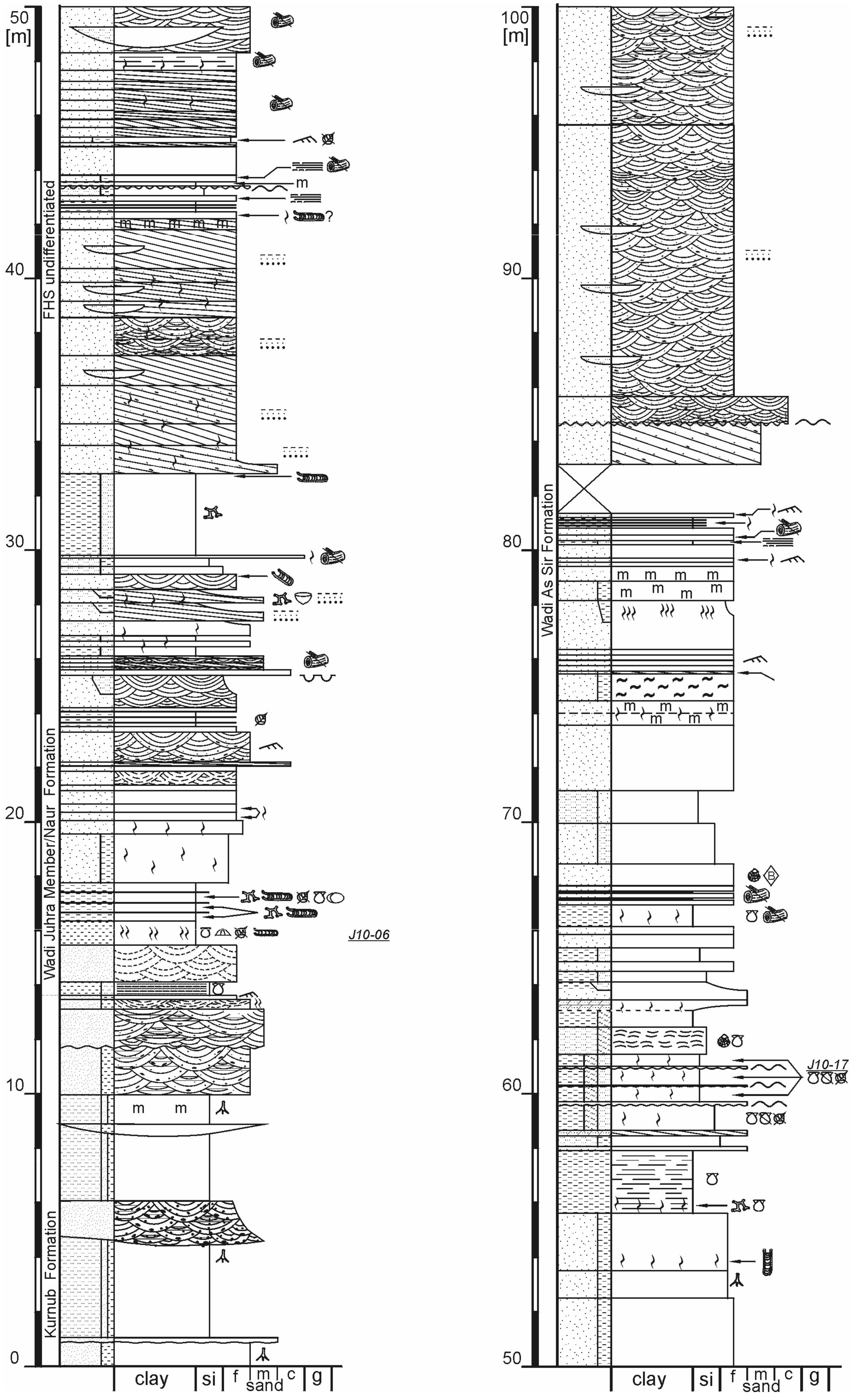
Section 8

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FHS undifferentiated
Wadi Juhra Member/Naur Formation
Kurnub Formation
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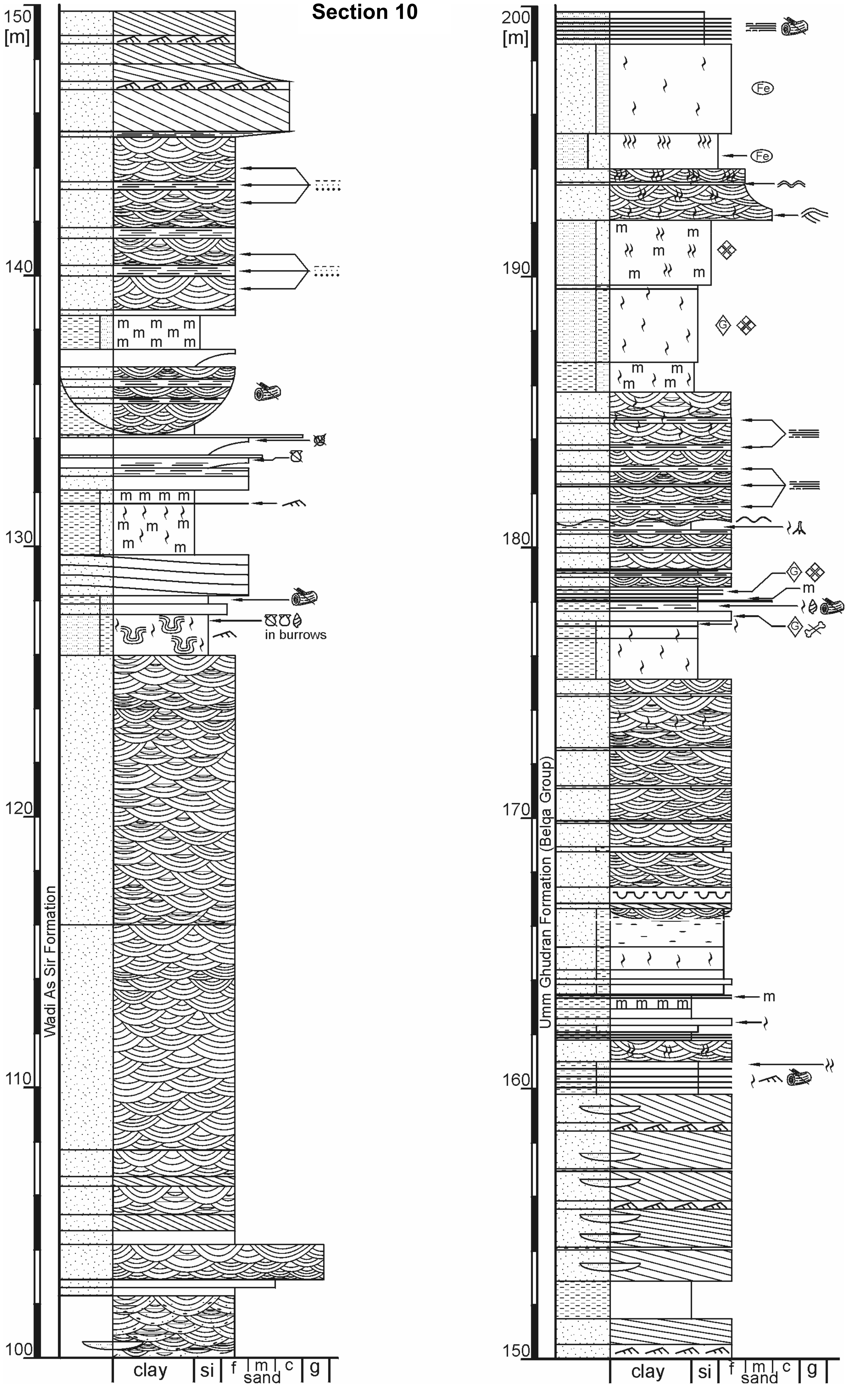
Wadi As Sir Formation
J10-17
B


Section 10
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Wadi As Sir Formation
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Umm Ghudran Formation (Belqa Group)
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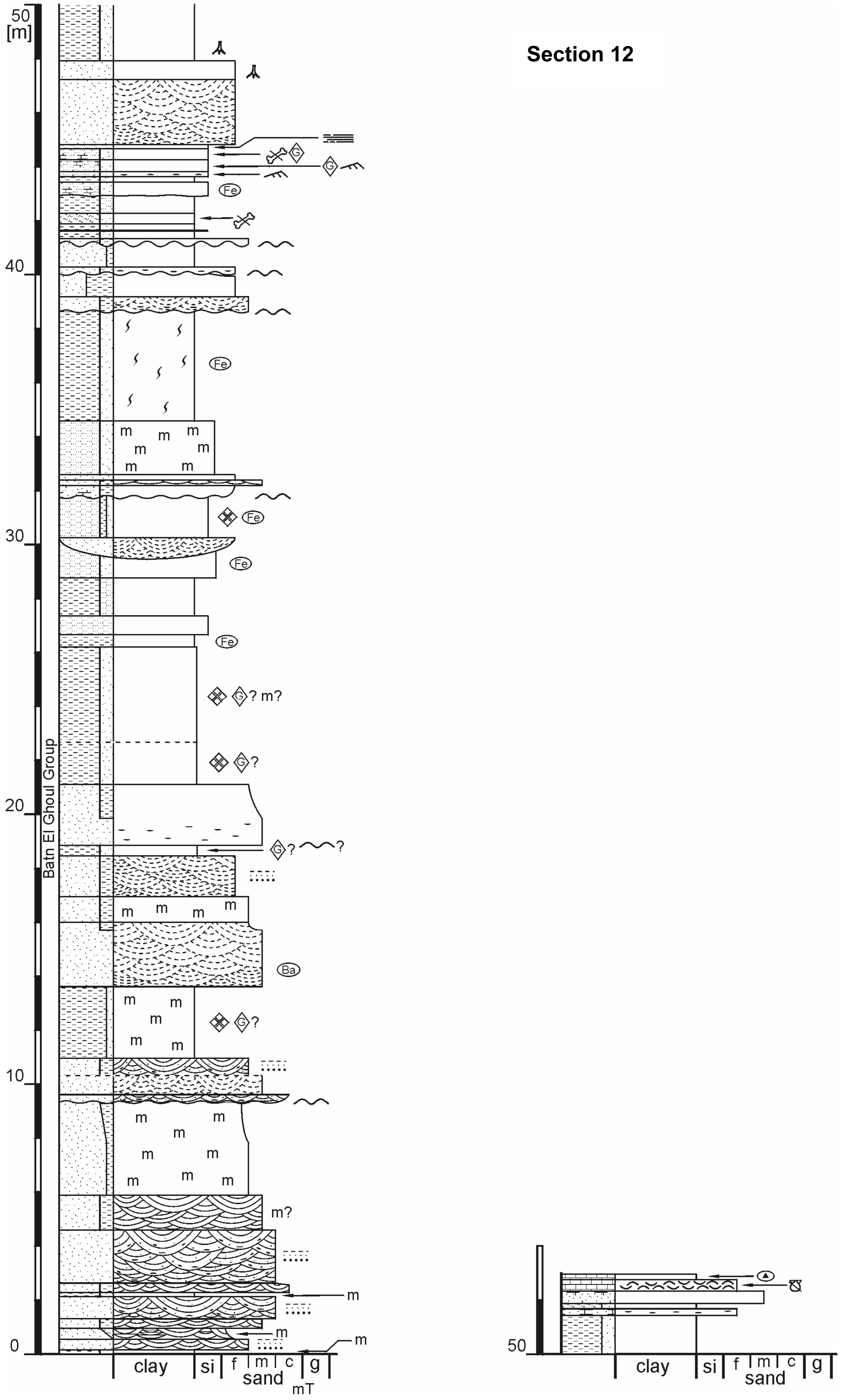
Section 12
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Batn El Ghoul Group
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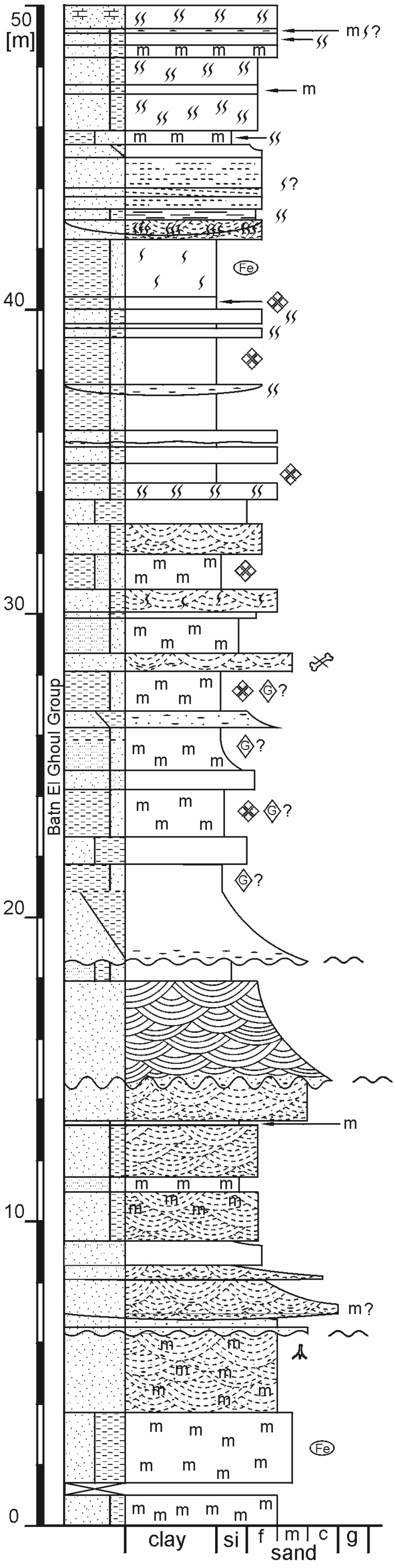
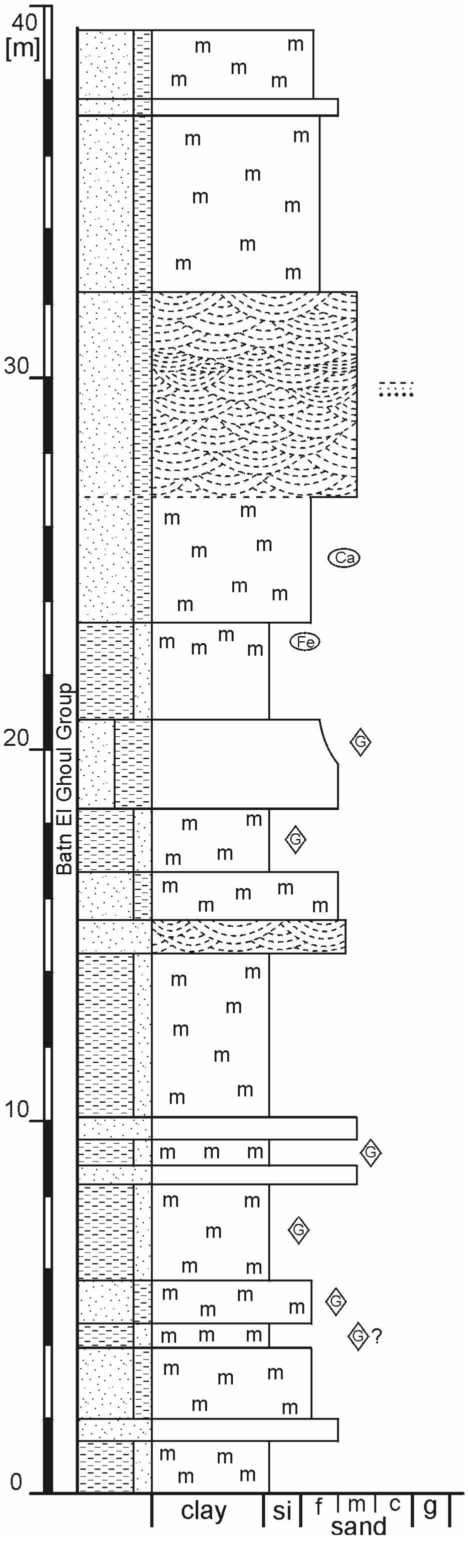
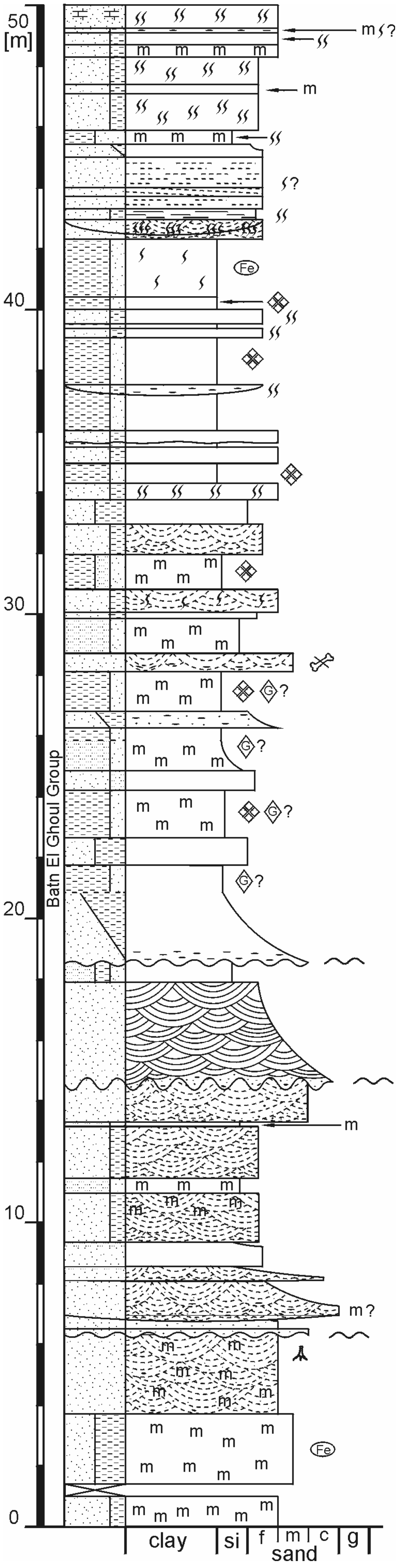
Section 13



Section 14

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Section 15

Composition of associations from the Upper Cretaceous Ajlun Group of southern Jordan

(A) *Aphrodina dutrugei – Paraesa* sp. association

(8 samples with 498 individuals)

species	relative abundance (%)	presence percentage (%)
1. *Aphrodina dutrugei*	10.2	75
2. *Paraesa* sp.	10.0	62.5
3. *Afrogyra africana "typica"*	6.6	50
4. ?*Toucasia matheroni*	5.3	25
5. *Pholadomya vignesi*	4.2	37.5
6. *Neithea shawi*	3.8	50
7. "*Dosinia*" *delettrei*	3.8	50
8. *Ceratostreon flabellatum*	3.4	50
9. *Curvostrea* cf. *rouvillei*	3.4	62.5
10. *Plicatula auressensis*	3.2	37.5
11. *Mecaster* cf. *luynesi*	2.9	12.5
12. *Globiconcha rotundata*	2.9	37.5
13. ?*Schedotrapezium acclivis*	2.3	62.5
14. "*Nerinea*" *pauli*	2.3	37.5
15. *Rhynchostreon mermeti*	2.3	12.5
16. "*Strombus*" *incertus*	2.0	25
17. *Afrogyra africana* "*crassa*"	2.0	37.5
18. *Trachycardium mermeti*	2.0	37.5
19. *Trigonarca diceras*	1.8	50
20. *Granocardium carolinum*	1.8	37.5
21. *Plicatula fourneli*	1.4	12.5
22. *Pterodonta deffisi*	1.4	37.5
23. *Costagyra olisiponensis*	1.2	25
24. *Tetragramma variolare*	1.2	12.5
25. *Goniopygus menardi*	1.2	50
26. *Arctica cordata*	1.2	25
27. *Granocardium productum*	1.2	12.5
28. *Laevigyra dhondtae*	1.2	12.5
29. *Ambigostrea cf. dominici*	1.0	12.5
30. *Pterodonticeras germeri*	0.8	25
31. "*Aporrhais*" *turriculoides*	0.8	12.5
32. "*Radiolites*" sp.	0.8	25
33. *Granocardium* cf. *desvauxi*	0.6	12.5
34. *Arctica*? sp.	0.6	12.5
35. heterodont bivalve sp. B	0.6	12.5
36. "*Nerinea*" *gemmifera*	0.6	12.5
37. "*Nerinea*" *subaequalis*	0.6	25
38. *Heterodiadema libycum*	0.6	25
39. *Mecaster* cf. *batnensis*	0.6	12.5
40. *Protocardia coquandi*	0.4	12.5
41. heterodont bivalve sp. A	0.4	12.5
42. *Micropedina olisiponensis*	0.4	25
43. *Coenholectypus larteti*	0.4	12.5
44. *Camptonectes* sp.	0.4	12.5
45. *Brachidontes* aff. *fulpensis*	0.4	12.5
46. *Trigonia* cf. *ethra*	0.2	12.5
47. *Mecaster syriacus*	0.2	12.5
48. "*Dosinia*" sp.	0.2	12.5

49. heterodont bivalve sp. C	0.2	12.5
50. *Tylostoma globosum*	0.2	12.5
51. *Torinia animi*	0.2	12.5
52. *Veniella*? *Trapezoidalis*	0.2	12.5
53. *Pholadomya* cf. *pedernalis*	0.2	12.5
54. *Coronatica ornata*	0.2	12.5
55. *Pyrazus* cf. *valeriae*	0.2	12.5
56. *Pterodonta subinflata*	0.2	12.5

(B) *Exogyra* (*Costagyra*) *olisiponensis* – *Ilymatogyra* (*Afrogyra*) *africana* association

(5 samples with 227 individuals)

species	relative abundance (%)	presence percentage (%)
1. *Costagyra olisiponensis*	47.6	100
2. *Afrogyra africana* “*crassa*“	27.3	80
3. *Astraeofungia* sp.	6.2	60
4. *Exogyra italica*	4.4	20
5. *Plicatula fourneli*	4.0	60
6. *Rhynchostreon mermeti*	3.5	40
7. *Goniopygus menardi*	2.6	20
8. *Mecaster* cf. *batnensis*	2.2	20
9. *Micropedina olisiponensis*	0.9	20
10. *Columnocoenia* sp.	0.9	20
11. *Tetragramma variolare*	0.4	20

(C) *Ilymatogyra* (*Afrogyra*) *africana* association

(3 samples with 173 individuals)

species	relative abundance (%)	presence percentage (%)
1. *Afrogyra africana* “*typica*“	65.3	100
2. *Aphrodina dutrugei*	4.7	100
3. “*Dosinia*“ *delettrei*	2.4	66.7
4. *Trigonarca diceras*	2.4	33.3
5. ?*Schedotrapezium acclivis*	1.8	33.3
6. *Plicatula fourneli*	1.8	66.7
7. *Ceratostreon flabellatum*	1.8	33.3
8. *Costagyra olisiponensis*	1.8	66.7
9. *Curvostrea* cf. *rouvillei*	1.1	33.3
10. *Tylostoma globosum*	1.1	33.3
11. *Phelopteria* cf. *dalli*	1.1	33.3
12. *Granocardium carolinum*	1.1	66.7
13. heterodont bivalve sp. B	1.1	33.3
14. *Neithea shawi*	1.1	33.3
15. *Micropedina olisiponensis*	1.1	66.7
16. *Mecaster* cf. *luynesi*	1.1	33.3
17. *Veniella*? *trapezoidalis*	1.1	33.3
18. *Granocardium productum*	1.1	33.3
19. *Pholadomya vignesi*	1.1	66.7
20. *Plagiostoma* sp.	0.6	33.3

21. *Plagiostoma tithensis*	0.6	33.3
22. *Pterodonta deffisi*	0.6	33.3
23. *Tylostoma cossoni*	0.6	33.3
24. *Heterodiadema libycum*	0.6	33.3
25. *Mecaster syriacus*	0.6	33.3
26. *Pycnodonte vesiculosum*	0.6	33.3
27. *Laevigyra dhondtae*	0.6	33.3

(D) Carditid bivalve sp. A – *Anthonya jordanica* association

(4 samples with 464 individuals)

species	relative abundance (%)	presence percentage (%)
1. Carditid bivalve sp. B	20.3	75
2. *Anthonya jordanica*	20	75
3. *Geltena* cf. *mactraeformis*	1	75
4. *Mesosaccella* cf. *subacuta*	7.9	100
5. *Barbatia* sp.	7.1	50
6. *Anthonya dayi*	5.4	25
7. *Brachidontes* aff. *fulpensis*	5.4	50
8. Carditid bivalve sp. A	5.4	50
9. *Parmicorbula?* aff. *tapuchii*	2.5	50
10. Gastropod sp. C	1.7	25
11. *Mesosaccella* sp.	1.5	25
12. *Corbulomima*? sp.	1.3	25
13. *Nemodon* (*Nemodon*) sp.	1.3	25
14. *Camptonectes* sp.	1.3	50
15. *Lucina* sp.	0.9	25
16. „*Turritella*“ *amotzi*	0.9	50
17. heterodont bivalve sp. D	0.5	25
18. *Linearia* sp.	0.5	25
19. *Noetia* (*Icanopsis*?) sp.	0.5	25
20. “*Tellina*“ sp.	0.5	25
21. Gastropod sp. B	0.2	25
22. *Nuculana* aff. *perdita*	0.2	25
23. *Paraesa* sp.	0.2	25
24. *Trigonia* sp.	0.2	25
25. “*Crassatella*“ sp.	0.2	25

(E) Gastropod sp. C – *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* association

(4 samples with 369 individuals)

species	relative abundance (%)	presence percentage (%)
1. Gastropod sp. B	14.9	100
2. *Parmicorbula eretzisraelensis*	14.1	75
3. *Curvostrea* cf. *rouvillei*	11.7	100
4. *Musculus* sp.	7.9	50
5. heterodont bivalve sp. D	7.6	25

6. *Parmicorbula?* aff. *tapuchii*	7.1	75
7. Decapod sp. A	5.5	50
8. *Paraesa* sp.	4.2	25
9. Oyster indet.	3.8	25
10. Carditid bivalve sp. B	3.6	50
11. heterodont bivalve sp. E	3.3	75
12. *Mesosaccella* cf. *subacuta*	2.2	25
13. *Camptonectes* sp.	1.4	25
14. *Camptonectes* aff. *curvatus*	1.1	25
15. *Periplomya* sp.	1.1	25
16. *Anthonya jordanica*	0.8	25
17. *Plicatula fourneli*	0.8	25
18. *Ilymatogyra africana „typica“*	0.8	25
19. *Barbatia* sp.	0.8	25
20. *Mecaster* cf. *batnensis*	0.8	25
21. “*Tellina*“ sp.	0.5	25
22. *Pholadomya vignesi*	0.5	25
23. *Rhynchostreon mermeti*	0.5	25
24. *Nucula* (*Nucula*) sp.	0.5	25
25. *Phelopteria* sp.	0.3	25
26. *Pseudoptera* sp.	0.3	25
27. *Modiolus* sp.	0.3	25
28. *Linearia* sp.	0.3	25
29. „*Crassatella*“ sp.	0.3	25
30. Decapod sp. B	0.3	25
31. „*Turritella*“ *amotzi*	0.3	25

(F) *Rhynchostreon mermeti* – *Curvostrea* cf. *rouvillei* association
(3 samples with 149 individuals)

species	relative abundance (%)	presence percentage (%)
1. *Rhynchostreon mermeti*	29.5	100
2. *Curvostrea* cf. *rouvillei*	24.8	66.7
3. *Parmicorbula eretzisraelensis*	23.5	100
4. *Ilymatogyra africana „crassa“*	8.7	33.3
5. *Parmicorbula*? aff. *tapuchii*	7.4	66.7
6. *Paraesa* sp.	6	33.3

(G) *Rhynchostreon mermeti* – gastropod sp. C association
(3 samples with 216 individuals)

species	relative abundance (%)	presence percentage (%)
1. *Rhynchostreon mermeti*	52.8	100
2. Gastropod sp. C	24.8	66.7
3. *Parmicorbula*? aff. *tapuchii*	23.5	66.7
4. *Curvostrea* cf. *rouvillei*	8.7	33.3

5. *Parmicorbula eretzisraelensis*	6	33.3
6. *Brachidontes* sp.	3.7	66.7
7. „*Turritella*“ *amotzi*	1.4	33.3
8. *Anthonya jordanica*	0.9	33.3
9. *Camptonectes* sp.	0.9	33.3
10. *Mesosaccella* sp.	0.5	33.3
11. *Nemodon* (*Pleurogrammatodon*) sp.	0.5	33.3
12. heterodont bivalve sp. E	0.5	33.3

(H) *Brachidontes* sp. – *Parmicorbula* aff. *tapuchii* association

(2 samples with 111 individuals)

species	relative abundance (%)	presence percentage (%)
1. *Brachidontes* sp	32.4	100
2. *Parmicorbula*? aff. *tapuchii*	25.2	100
3. “*Lingula*“ sp.	16.2	100
4. heterodont bivalve sp. E	9.9	50
5. *Cercomya*? *jettei*	7.2	50
6. Decapod sp. B	4.5	50
7. heterodont bivalve sp. D	2.7	50
8. *Corbula sp.*	1.8	50

(I) *Parmicorbula* (*Caestocorbula*) *eretzisraelensis* – *Parmicorbula* aff. *tapuchii* association

(6 samples with 346 individuals)

species	relative abundance (%)	presence percentage (%)
1. *Parmicorbula eretzisraelensis*	49.4	100
2. *Parmicorbula*? aff. *tapuchii*	28.6	100
3. *Mesosaccella* cf. *subacuta*	5.2	66.7
4. heterodont bivalve sp.	4.9	16.7
5. *Rhynchostreon mermeti*	4.8	33.3
6. *Paraesa* sp.	2.9	33.3
7. *Geltena*? cf. *mactraeformis*	1.7	16.7
8. *Corbula sp.*	1.4	16.7
9. *Inoperna* cf. *transjordanica*	0.6	16.7
10. aff. *Pseudoliva ambigua*	0.3	16.7

Composition of assemblages from the Upper Cretaceous Ajlun Group of southern Jordan

(K) *Eomiodon* cf. *libanoticus* assemblage

(1 sample, 130 individuals)

species	relative abundance (%)
1. *Eomiodon* cf. *libanoticus*	57.7
2. *Paraesa* sp.	8.4
3. “*Turritella*“ *amotzi*	7.7

4. *Pholadomya vignesi*	6.2
5. *Parmicorbula*? aff. *tapuchii*	4.7
6. Gastropod sp. C	4.7
7. *Protocardia judaica*	3.5
8. *Rhynchostreon mermeti*	2.6
9. *Mesosaccella* cf. *subacuta*	2.6
10. heterodont bivalve sp. E	0.3
11. "*Tellina*" sp.	0.3

(L) *Mecaster* cf. *batnensis* – *Nerinea pauli* assemblage
(1 sample, 71 individuals)

species	**relative abundance (%)**
1. *Mecaster* cf. *batnensis*	56.3
2. *Nerinea pauli*	21.1
3. heterodont bivalve sp.	9.9
4. *Dosinia delettrei*	2.8
5. *Tylostoma globosum*	2.8
6. *Micropedina olisiponensis*	2.8
7. *Ilymatogyra africana* „*crassa*“	1.4
8. *Pterodonta deffisi*	1.4
9. *Heterodiadema libycum*	1.4

(M) *Crassostrea* sp. – Decapod sp. B assemblage
(1 sample, 51 individuals)

species	**relative abundance (%)**
1. *Crassostrea* sp.	52.9
2. Decapod sp. B	27.5
3. *Courvostrea* cf. *rouvillei*	19.6

Distribution of the macrobenthos in southern Jordan

	J1-3B	J1-5	J1-5A	J1-5B	J2-1	J2-2	J2-3A	J2-3	J3-8A	J3-9	J3-10	J4-1	J5-18	J5-36	J5-37
Nucula (*Nucula*) sp.															
Nuculana aff. *perdita*															
Mesosaccella cf. *subacuta*														3	
Mesosaccella sp.															
Barbatia sp.															
Nemodon (*Nemodon*) sp.															
Nemodon (*Pleurogrammatodon*) sp.															
Noetia (*Icanopsis*?) sp.															
Trigonarca diceras	3		2					4		1		3			
Brachidontes aff. *fulpensis*					1										
Musculus (*Musculus*) sp.															
Inoperna cf. *transjordanica*															
Modiolus (*Modiolus*?) sp.															
Phelopteria cf. *dalli*								2							
Phelopteria sp.															
Pseudoptera sp.															
Camptonectes sp.												1			
Camptonectes aff. *curvatus*															
Neithea shawi	2						1			3		8	6		
Neithea (*Neitheops*) *syriaca*															
Plicatula auressensis		6	8								1				
Plicatula fourneli							3	3				7			
Plagiostoma tithensis								1							
Plagiostoma sp.								1							
Ceratostreon flabellatum	2						3			4	2		9		
Afrogyra africana „typica“			4		16		51	18	44	8	3		4		
Afrogyra africana „crassa“						1				4		2			
Laevigyra dhondtae		2					4						4		
Rhynchostreon mermeti				8									11	3	
Exogyra italica				10											
Costagyra olisiponensis				31			3	1		5	1				
Pycnodonte vesiculosum								1							
Crassostrea sp.															
Curvostrea cf. *rouvillei*	1	2	12								1				
Ambigostrea cf. *dominici*													4		
Oyster indet.															
Trigonia cf. *ethra*										1					
Trigonia sp.															
Lucina sp.															
Carditid bivalve A															
Carditid bivalve B															
Opis? sp.															
"Crassatella" sp.															
Anthonya dayi															
Anthonya jordanica															
Granocardium productum								1			2	7			
Granocardium cf. *desvauxi*										3					
Granocardium carolinum								2		7	1	1			
Trachycardium mermeti	5									3	2				
Protocardia cf. *judaica*														4	
Protocardia coquandi													2		
Geltena cf. *mactraeformis*															
“Tellina“ sp.														1	
Linearia sp.															
Arctica cordata											5	3			
Arctica? sp.			3												
Schedotrapezium? *acclivis*	1	2	5				3				3				
Veniella? *trapezoidalis*								1							
Venilicardia? *cordiformis*												4			
Eomiodon cf. *libanoticus*														75	
Aphrodina dutrugei		7	31		2		6	2		1	13	1			
“Dosinia“ delettrei	1	4	13			2	4					1			
"Dosinia" sp.												1			
Paraesa sp.	4	30	16		1					1				12	
Corbula sp.															
Corbulomima? sp.															
Parmicorbula? aff. *tapuchii*														6	23
Parmicorbula eretzisraelensis															45
Toucasia? *matheroni*					24										
“Radiolites“ sp.													5		
heterodont bivalve sp. A			2												
heterodont bivalve sp. B			3			7		4							
heterodont bivalve sp. C			1												
heterodont bivalve sp. D															
heterodont bivalve sp. E														1	

	J1-3B	J1-5	J1-5A	J1-5B	J2-1	J2-2	J2-3A	J2-3	J3-8A	J3-9	J3-10	J4-1	J5-18	J5-36	J5-37
Pholadomya vignesi	16				2					3				8	
Pholadomya cf. *pedernalis*															
Pholadomya sp.								1				5			
Cercomya? Jettei															
Periplomya sp.															
Torinia animi											1				
Pyrazus cf. *valeriae*															
Tylostoma globosum					3	2		1			11	3			
Tylostoma cossoni								2			1				
Coronatica ornata															
Pterodonta deffisi	5				1	1		1		1		4			
Pterodonta cf. *subinflata*															
"Apporhais" turriculoides															
Pterodonticeras germeri										1		3			
“Strombus“ incertus					1							9			
“*Nerinea*“ *gemmifera*												1			
“*Nerinea*“ *pauli*					8	15					1		1		
“*Nerinea*“ *subaequalis*					2						3				
Globiconcha rotundata															
Pseudoliva ambigua															
„Turritella“ amotzi														11	
Gastropod sp. A												1			
Gastropod sp. B															
Gastropod sp. C														6	
Lingula sp.															
Astraeofungia sp.															
Meandraraea sp.															
Columnocoenia sp.															
Aspidiscus cristatus															
Heterodiadema libycum						1		1			2	1			
Tetragramma variolare								1			6				
Goniopygus menardi		1								1	3				
Micropedina olisiponensis						2	1				2				
Coenholectypus larteti											2				
Mecaster syriacus									1						
Mecaster cf. *batnensis*		1				40				3					
Mecaster cf. *luynesi*							1			3	14				
Archiacia sp.				5											
Decapod sp. A															
Decapod sp. B															

	J5-42	J5-45	J5-46	J5-68B	J6-10	J6-24	J6-26A	J6-29	J6-32	J6-33	J6-34	J6-52	J7-2
Nucula (*Nucula*) sp.													
Nuculana aff. *perdita*													
Mesosaccella cf. *subacuta*					12	4							6
Mesosaccella sp.													7
Barbatia sp.													
Nemodon (*Nemodon*) sp.													
Nemodon (*Pleurogrammatodon*) sp.													
Noetia (*Icanopsis*?) sp.													2
Trigonarca diceras													
Brachidontes aff. *fulpensis*				34									
Musculus (*Musculus*) sp.		27											
Inoperna cf. *transjordanica*													
Modiolus (*Modiolus*?) sp.		1											
Phelopteria cf. *dalli*													
Phelopteria sp.		1											
Pseudoptera sp.		1											
Camptonectes sp.													2
Camptonectes aff. *curvatus*		4											
Neithea shawi													
Neithea (*Neitheops*) *syriaca*													
Plicatula auressensis													
Plicatula fourneli	1	3								6	2		
Plagiostoma tithensis													
Plagiostoma sp.													
Ceratostreon flabellatum													
Afrogyra africana „typica“													
Afrogyra africana „crassa“	8		17					13		24	15		
Laevigyra dhondtae													
Rhynchostreon mermeti							18	5	22	1			
Exogyra italica													
Costagyra olisiponensis	16	1	23							17	21		
Pycnodonte vesiculosum													
Crassostrea sp.													
Curvostrea cf. *rouvillei*		24						14	23				
Ambigostrea cf. *dominici*													
Oyster indet.													
Trigonia cf. *ethra*													
Trigonia sp.													1
Lucina sp.													
Carditid bivalve A													21
Carditid bivalve B		10			2								
Opis? sp.													
"Crassatella" sp.													
Anthonya dayi													
Anthonya jordanica					15								1
Granocardium productum													
Granocardium cf. *desvauxi*													
Granocardium carolinum													
Trachycardium mermeti													
Protocardia cf. *judaica*													
Protocardia coquandi													
Geltena cf. *mactraeformis*					19								12
“Tellina“ sp.		2											
Linearia sp.													
Arctica cordata													
Arctica? sp.													
Schedotrapezium? *acclivis*													
Veniella? *trapezoidalis*													
Venilicardia? *cordiformis*													
Eomiodon cf. *libanoticus*													
Aphrodina dutrugei													
“Dosinia“ delettrei													
"Dosinia" sp.													
Paraesa sp.						4	9					6	1
Corbula sp.				2								5	
Corbulomima? sp.													
Parmicorbula? aff. *tapuchii*		10		22	1	12		1	10			14	
Parmicorbula eretzisraelensis						31	14	8	12			33	
Toucasia? *matheroni*													
“Radiolites“ sp.													
heterodont bivalve sp. A													
heterodont bivalve sp. B													
heterodont bivalve sp. C													
heterodont bivalve sp. D													
heterodont bivalve sp. E		12		11									

	J5-42	J5-45	J5-46	J5-68B	J6-10	J6-24	J6-26A	J6-29	J6-32	J6-33	J6-34	J6-52	J7-2	J7-6
Pholadomya vignesi														
Pholadomya cf. *pedernalis*														
Pholadomya sp.														
Cercomya? Jettei														
Periplomya sp.														
Torinia animi														
Pyrazus cf. *valeriae*														
Tylostoma globosum														
Tylostoma cossoni														
Coronatica ornata														
Pterodonta deffisi														
Pterodonta cf. *subinflata*														
"Apporhais" turriculoides														
Pterodonticeras germeri														
“Strombus“ incertus														
“*Nerinea*“ *gemmifera*														
“*Nerinea*“ *pauli*														
“*Nerinea*“ *subaequalis*														
Globiconcha rotundata														
Pseudoliva ambigua														
„Turritella“ amotzi					2								2	
Gastropod sp. A														
Gastropod sp. B														
Gastropod sp. C		2											8	
Lingula sp.														
Astraeofungia sp.	8									1	5			
Meandraraea sp.														
Columnocoenia sp.	2													
Aspidiscus cristatus														
Heterodiadema libycum														
Tetragramma variolare											1			
Goniopygus menardi	6													
Micropedina olisiponensis											2			
Coenholectypus larteti														
Mecaster syriacus														
Mecaster cf. *batnensis*		3												
Mecaster cf. *luynesi*														
Archiacia sp.														
Decapod sp. A														
Decapod sp. B														

	J7-16	J7-20	J8-12	J8-16	J8-18	J9-12	J9-18	J9-20	J9-21	J9-26B	J10-6	J10-17
Nucula (*Nucula*) sp.							3					
Nuculana aff. *perdita*						1						
Mesosaccella cf. *subacuta*		3				4	8	3			15	
Mesosaccella sp.												1
Barbatia sp.											33	
Nemodon (*Nemodon*) sp.						6						
Nemodon (*Pleurogrammatodon*) sp.									1			
Noetia (*Icanopsis*?) sp.												
Trigonarca diceras												
Brachidontes aff. *fulpensis*									3	2	27	5
Musculus (*Musculus*) sp.	2											
Inoperna cf. *transjordanica*								2				
Modiolus (*Modiolus*?) sp.												
Phelopteria cf. *dalli*												
Phelopteria sp.												
Pseudoptera sp.												
Camptonectes sp.						4			2			
Camptonectes aff. *curvatus*												
Neithea shawi												
Neithea (*Neitheops*) *syriaca*												
Plicatula auressensis												
Plicatula fourneli												
Plagiostoma tithensis												
Plagiostoma sp.												
Ceratostreon flabellatum												
Afrogyra africana „typica“			3									
Afrogyra africana „crassa“												
Laevigyra dhondtae												
Rhynchostreon mermeti		12	2	23			2	5	47			44
Exogyra italica												
Costagyra olisiponensis												
Pycnodonte vesiculosum												
Crassostrea sp.					23							
Curvostrea cf. *rouvillei*	2		14	17			5					
Ambigostrea cf. *dominici*												
Oyster indet.					8		14					
Trigonia cf. *ethra*												
Trigonia sp.											1	
Lucina sp.											4	
Carditid bivalve A											5	
Carditid bivalve B						52	3				40	
Opis? sp.												
"Crassatella" sp.			2									
Anthonya dayi											25	
Anthonya jordanica			3						2		77	
Granocardium productum												
Granocardium cf. *desvauxi*												
Granocardium carolinum												
Trachycardium mermeti												
Protocardia cf. *judaica*												
Protocardia coquandi												
Geltena cf. *mactraeformis*						34		6				
“Tellina“ sp.						3						
Linearia sp.	1										2	
Arctica cordata												
Arctica? sp.												
Schedotrapezium? *acclivis*												
Veniella? *trapezoidalis*												
Venilicardia? *cordiformis*												
Eomiodon cf. *libanoticus*												
Aphrodina dutrugei												
“Dosinia“ delettrei												
"Dosinia" sp.												
Paraesa sp.	15						3					
Corbula sp.												
Corbulomima? sp.											6	
Parmicorbula? aff. *tapuchii*		12	2			10	14	24	22	6		
Parmicorbula eretzisraelensis	34	13					18	30				13
Toucasia? *matheroni*												
“Radiolites“ sp.												
heterodont bivalve sp. A												
heterodont bivalve sp. B												
heterodont bivalve sp. C												
heterodont bivalve sp. D	12						26			3		
heterodont bivalve sp. E	1			1				17				

	J7-16	J7-20	J8-12	J8-16	J8-18	J9-12	J9-18	J9-20	J9-21	J9-26B	J10-6	J10-17
Pholadomya vignesi							2					
Pholadomya cf. *pedernalis*												
Pholadomya sp.												
Cercomya? Jettei										8		
Periplomya sp.							4					
Torinia animi												
Pyrazus cf. *valeriae*												
Tylostoma globosum												
Tylostoma cossoni												
Coronatica ornata												
Pterodonta deffisi												
Pterodonta cf. *subinflata*												
"Apporhais" turriculoides												
Pterodonticeras germeri												
“Strombus“ incertus												
“*Nerinea*“ *gemmifera*												
“*Nerinea*“ *pauli*												
“*Nerinea*“ *subaequalis*												
Globiconcha rotundata												
Pseudoliva ambigua								1				
„Turritella“ amotzi				1					3			
Gastropod sp. A												
Gastropod sp. B						1						
Gastropod sp. C	22		11	2			20		31			
Lingula sp.										18		
Astraeofungia sp.												
Meandraraea sp.												
Columnocoenia sp.												
Aspidiscus cristatus												
Heterodiadema libycum												
Tetragramma variolare												
Goniopygus menardi												
Micropedina olisiponensis												
Coenholectypus larteti												
Mecaster syriacus												
Mecaster cf. *batnensis*												
Mecaster cf. *luynesi*												
Archiacia sp.												
Decapod sp. A			4				15					
Decapod sp. B					11		1			5		