Mid Cretaceous (Albian-Cenomanian) carbonate platforms in Israel

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ABSTRACT

The Middle Cretaceous (Albian-Cenomanian) carbonate platform sediments of the Judea Group in Israel consist of bank facies, rudistid bioherms (Albian), marly chalks (Early Cenomanian), bioherms and backreef lagoons (Late Cenomanian). Towards the west (Levant coast) they pass laterally into the Talme Yafe basinal chalks, shales and limestones. Southeastwards they gradually onlap the Nubia-type clastics of the Kurnub Group, characterising the peri-Arabian belt.

The Middle Cretaceous carbonates of the Judea Group are delimited by the Early Albian «Yavne» global drop in sea level at the base and a Late Cenomanian event at the top. They are further controlled by the Early Cenomanian «Kesalon» and «Moza» events. The Middle Cretaceous regressive and transgressive oscillations in Israel are correlatable with Middle Eastern (Arabian Peninsula) and western Mediterranean regions (Iberian Peninsula).

Key-words: Albian, Cenomanian, Judea Group, Israel, Carbonate Platform, Kesalon, Sea Level Changes.

RESUMEN

Los sedimentos de plataforma carbonatada del Cretácico medio (Albiense-Cenomaniense) del Grupo de Judea (Israel) consisten en facies de banco

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y de biohermo con rudistas (Albiense), calizas margosas (Cenomaniense inferior), de biohermos y de lagunas arrecifales internas (Cenomaniense superior). Hacia el Oeste (Llanura de la Costa del Levante), se observa el paso lateral de las facies de plataforma de Judea a las cretas, margas y calizas de cuenca de Talme Yafe. Al Sureste, se observa una transgresión gradual del Grupo de Judea encima de las areniscas de tipo Nubia del Grupo de Kurnub, que caracteriza el cinturón peri-Arábico.

Las rocas carbonatadas medio-Cretácicas del Grupo de Judea están delimitadas por las caídas globales del nivel del mar de «Yavne» (Albiense inferior) y del Cenomaniense superior. Están también controladas por los eventos de «Kesalon» y «Moza» (Cenomaniense inferior). Las oscillaciones regresivas y transgresivas del Cretácico medio en Israel son correlacionables con las del Medio Oriente (Península Arábica) y las de las regiones del Mediterráneo occidental (Península Ibérica).

Palabras clave: Albiense, Cenomaniense, Grupo de Judea, Israel, Plataforma carbonatada, Kesalon, Cambio de Nivel del Mar.

INTRODUCTION

The Cretaceous sequence of the African-Arabian platform (Fig. 1) is well represented in the traverse of Israel (Fig. 2).

The Judea Group (Calcari a Radioliti of Shalem, 1925; Judean Limestone of Wellings, 1944; Ball and Ball, 1953; emend. by Arkin *et. al.*, 1965) includes Albian-Coniacian carbonates, which are bounded by the Kurnub Group clastics (Wellings, 1944) and the chalks and cherts of the Mount Scopus Group (Flexer, 1968).

The Judea Group onlaps the Arabian subplate diachronously. Its base is Early Albian from Galilee to the Judean hills and is Late Albian-Cenomanian in the Negev. To the west, in the subsurface of the coastal plain of Israel, the platform is bordered by the more basinal facies of the Talme Yafe Group (Hirsch, 1990).

The facies of the Judea Group extends over most of the Arabian subplate. In the Tauro-Zagrid autochthonous terrains (S. Turkey) and part of Saudi Arabia, Cenomanian laterites interrupted the accumulation of the platform-carbonates (Harris *et. al.*, 1983; Monod, 1977). Comparable facies and transgressive-regressive sequences occur on both sides of the Tethys, in particular in the Western Mediterranean Iberian and Catalonian ranges (Vilas *et. al.*, 1982; Salas, 1984).

The truncation of the Judea Group is due to the post-Turonian embryonic folding of the Syrian Arc as the result of the peri-Arabian alpine thrusting (Flexer *et. al.*, 1989).

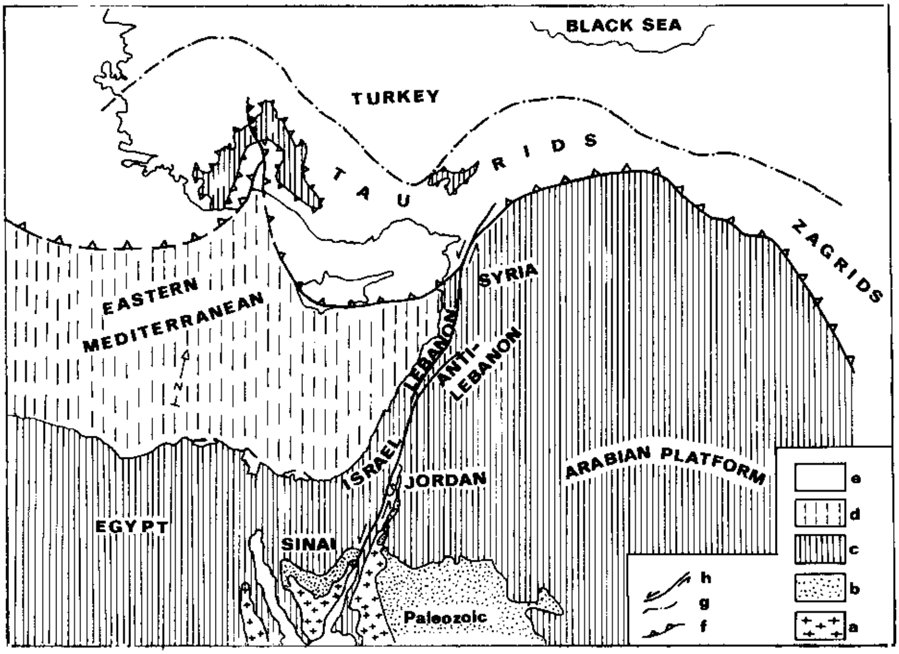

Fig. 1A.—*The African-Arabian Platform in the Levant:* a. Precambrian Basement; b. Paleozoics; c. Mesozoic-Cenozoic of the African Arabian-platform; d. its continuation in the Eastern Mediterranean; e. thrusted Tethyan terrains; f. thrust; g. northern edge of African-Arabian Plate; h. Syrian-African transform.

BIOSTRATIGRAPHY

The oldest Cretaceous deposits of Israel occur in the subsurface of the coastal plain, which extends into northern Sinai, where a predominantly clastic sequence, corresponding to the Gevar-Am Group (Hirsch, 1990) is exposed, yielding Hauterivian-Aptian ammonoids and ostracods (Rosenfeld and Raab, 1985). Albian ammonoids (Lewy, 1981) occur in the lowest marine intercalation of the Hatira Formation, in the Qatana Formation, and in the Hevyon Formation (Hirsch, 1988). The Albian-Cenomanian boundary, placed in the middle of the Kefira Formation by Hamaoui (1965) is now placed by Lewy and Raab (1976) near the top of the Kesalon Formation. This is based on the evidence of Albian ammonoids in the Hevyon Formation and of Early Cenomanian ammonoids in the En Yorqeam Formation.

Late Cenomanian ammonoids date the chalks and shales of the Kefar Shaul Formation. The upper part of the Judea Group is dated by Turonian and Coniacian ammonoids.

The existence of a faunal break towards the end of the Cenomanian in the marls of the Daliya, Ora and Derorim Formations has been related with an anoxic event by Flexer *et. al.* (1986).

MIDDLE-LATE CRETACEOUS LITHOFACIES AND ENVIRONMENT OF DEPOSITION

EARLY ALBIAN

Above the coastal plain subsurface Aptian carbonates of the Telamim Formation, known in the Galilee and in Samaria, where they are exposed, as the Nabi Said and En Al-Asad formations (Eliezri, 1965), follow the Early Albian Yavne shale, Hydra Formation (Eliezri, 1965) or «Couches à *Orbitolines*» in the Galilee and Tammun Formation (Mimran, 1969) in Samaria and Judea. They consist of shales, sands and iron oolites, 300 m thick in the Moza-1 wildcat (Jerusalem) and 100 m in Halhul wildcat (Hebron). This Yavne event appears to correspond to a global drop in sea level (Flexer *et. al.*, 1986).

The carbonate En Qiniya Formation (Shachnay, 1968) of Samaria and Judea, the calcaire de Zumoffen of Lebanon, or Asfuri Formation (Eliezri, 1965) of Galilee, consists of small rudistid patch-reefs. It is followed by the marly Qatana Formation (Bentor, 1945), the couches à *Knemiceras*» or Rama Formation of Galilee, and is coeval to Early Albian marine intercallations within the Hatira Formation (Kurnub Group) of the Negev.

LATE ALBIAN

In the Galilee and coastal plain the Yagur Formation consists of monotonous dolostones. In Samaria and Judea these consist of pene-contemporaneous dolomuds, that collected within tidal flats and the supratidal zone (the Givat Yearim and Soreq Formations). These alternate with normal marine limestones (the Kefira and Kesalon Formations) and reach a thickness of up to 350 m (Itzhaki *et. al.*, 1964).

A shallowing is reflected in the more terrestrial facies of the Negev Hevyon Formation (Arkin & Braun, 1965, emend. Hirsch, 1988). The latter corresponds to the Naur Formation in Jordan. The sedimentary break at the top of the Hevyon, Kesalon and Yagur formations (Hirsch, 1985; Kafri, 1986; Braun and Hirsch, 1987) is also recognized in Jordan (Abed, 1985; Babinot et Basha, 1985).

Northwest of Hebron, the sequence of the upper Givat Yearim, Soreq and Kesalon formations consists of oyster-and rudist biostromes (which now form small limestone cliffs) alternating with interbedded oolites, marls and algal dolomites. Elsewhere the Soreq Formation consists of bedded dolostones, dolosiltites and dolomuds with yellowish marl interbeds, suggesting tidal flat deposition. Dinosaur tracks have been found in these at Bet Zeit near Jerusalem (Avnimelech, 1966). The deposition and setting of these rocks matches those of the New York State Early Ordovician Tribes Hill Formation (Braun and Friedman, 1969). The supratidal penecontemporaneous dolomud intraclasts formed under humid climatic conditions (Armstrong, 1969), similar to those of the recent Bahama and Florida Key tidal flats, and are devoid of evaporites (Shinn *et. al.*, 1965).

Early Cenomanian

In Judea and Samaria the Albian sequence is topped by up to 30 m. of dolomitic to fossiliferous limestone. This generally forms an escarpment: the Kesalon Formation (Itzhaki *et. al.*, 1964). This limestone is overlain by the chalks and limestones of the En Yorqeam Formation (Arkin and Braun, 1965; Begin, 1974), yielding Early Cenomanian ammonoids (Avnimelech and Shoresh, 1962; Lewy and Raab, *op. cit.*).

The base of the En Yorqeam Formation consists of an oyster-lumachelle that penetrates the underlying karstified Kesalon limestone. The chalks yield bivalves, echinoderms and ostracodes. The marly uppermost part of the En Yorqeam Formation is equivalent to the Moza marl (Picard, 1938).

Tidal flat facies of pene-contemporaneous dolostones and marlstones often replace the limestones and chalks of the En Yorqeam Formation. As a result the latter have been attributed to the Bet Meir Formation (Itzhaki *et. al.*, 1964). Near Jericho as well as west of Hebron, limey oyster and rudist biostromes replace the upper Bet Meir dolomites. The top beds of the Kesalon and Bet Meir formations are often strongly limonitized, suggesting periods of non-deposition. The clays and limestones of the Moza Formation reflect again normal shallow open marine conditions. They yield abundant bivalves, echinoderms, ostracodes and foraminifers. In western Samaria, a restricted environment prevailed, as indicated by the occurence of dolomite and the wedging out of the Moza marl. These Early Cenomanian rocks reach a thickness of 60 m.

LATE CENOMANIAN

Rapid lateral variations from massive dolomites to more basinal chalks and limestones, named respectively Sakhnin and Deir Hanna formations (Golani, 1961) in the Galilee, correspond in Samaria and Judea to the dolomitic Amminadav, chalky Kefar Shaul-and dolomitic Weradim formations (Itzhaki *et. al., op. cit.*). In the Negev these units are coeval to the Zafit, Avnon and Tamar Formations (Arkin & Braun, 1965; emend. Begin, 1974; emend. Hirsch, 1988).

At the base of the Amminadav Formation, platey limestones contain the remains of fish and snakes, which can be seen in the quarries of Beitin and En Yabrud north and east of Ramallah. The marly chalk and limestones with ammonoids (*Acanthoceras* beds, Blanckenhorn, 1905) of the Kefar Shaul Formation also contain platey limestones with fishes (Deir-Yasini facies of Blanckenhorn, 1905).

A normal open marine setting with rudistid-reefs prevailed during the deposition of the massively bedded Amminadav, Weradim and Sakhnin formations that consist of dolomite with irregular lenses of limestone with

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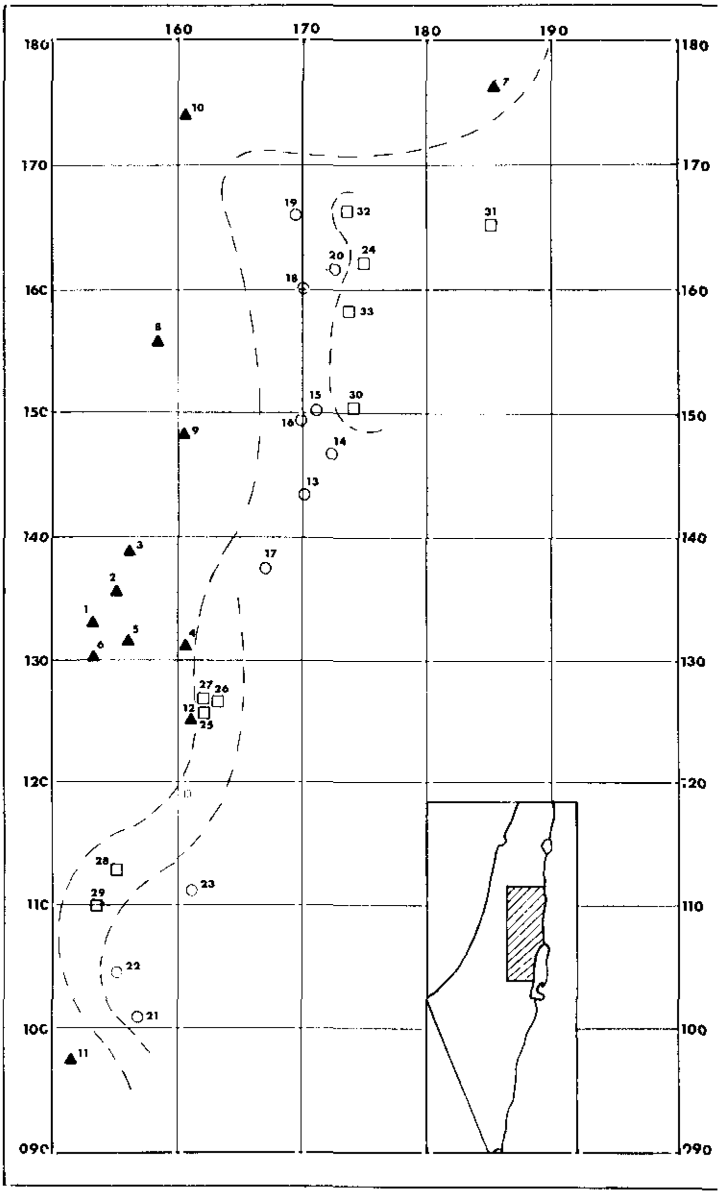
Fig. 1B.–*Facies and Location Map of Sections mentioned in text.* Dolomite Cliff Unit: (Coordinates are Israel Grid E/N): 1. Nahal Kesalon, coord. 1536/1320; 2. Wadi Ilan Section, Coord. 1550/1357; 3. Nahal Somer, Coord. 1567/1387; 4. Near Sataf, Coord. 1610/1314; 5. Ramat Raziel, Coord. 1563/1312; 6. Nahal Soreq, Coord. 1534/1302; 7. Gebel Tammun, Coord. 1857/1765; 8. Nebi Zalach-Bittilu road, Coord. 1538/1561; 9. Road En Arik-El Geneya, Coord. 1614/1486; 10. Wadi Kina, Coord. 1619/1742; 11. Wadi Harsa, Coord. 1505/0996; 12. The Kubi hill, Coord. 1619/1262; Cyclic Unit: 13. Ramallah Nursing School («Hilton»), Coord. 1707/1440; 13A. Bitunya, Coord. 1668/1435; 14. Wadi Shiban Coord. 1726/1464; 15. Gelasun Quarry, Coord. 1710/1504; 16. Ramalla-Bir el Zeit Quarry, Coord. 1703/1490; 17. Nebi Samuel, Coord. 1677/1373; 18. Juljulia Coord. 1709/1533; 19. Salfit-Issakka road, Coord. 1699/1660; 20. Gebel Batin, Coord. 1731/1624; 21. West of Dura, Coord. 1563/1012; 22. Road to Tapuach (coord. 1554/1052) ; 23. East of Halhul, Coord. 1611/1109; Limestone Cliff Unit: 24. Wadi el Maasal, Coord. 1753/1627; 25. Beitir, Coord. 1633/1267; 26. En Karem, Coord. 1658/1309; 27. En Gama, Coord. 1627/1254; 28. Halhul-Haras road, Coord. 1558/1133; 29. Wadi Izha, Coord. 1543/1100; 30. En Yabrud, Coord. 1730/1503; 31. Magdal Banai Fadail, Coord. 1845/1653; 32. Kuzra-Talpit road, Coord. 1735/1669; 33. Mazra'a Sharkiye, Coord. 1746/1570; 34. Gush Etzion, Coord. 1610/1180.

LOCATION MAP



▲ Dolomite section
○ Cyclicunit
□ Limestone section

leached remnants of silicified rudists and oysters, for which the name «quartzolite» has been coined by Bentor (1945). In some restricted areas, brines formed, which resulted in the penecontemporaneous dolomitization of the reefs. These reefs were separated by channels in which the Kefar Shaul (Deir Hanna) chalks and marls were deposited. The thickness of the Late Cenomanian may reach 250 m. Flexer *et. al.* (*op. cit.*) related shallowing at the top of this sequence and the faunal break that occurs, to a falling sea-level.

Latest Cenomanian-Turonian-Early Coniacian

The Carmel Daliya and the Negev Derorim and Ora shales and chalks yield latest Cenomanian to Turonian ammonoids. These rocks pass laterally into the limestones of the cliff-forming commonly biohermal Shivta- (Arkin and Braun, *op. cit.*) or bedded Bi'na Formation (Shadmon 1959). The Shivta facies passes vertically as well as laterally into the sublithographic limestones of the Nezer Formation. A clastic sand-unit, has been described as an unconformity by Avnimelech (1950). it possibly corresponds to a major Late Turonian regional drop of sea-level. The top of the Judea Group is truncated as a result of the folding of the Syrian Arc.

Analysis of the Late Albian facies of the Kesalon sea level drop

(Numbers in text refer to locations on the Facies and Location Map of sections of the Kesalon Formation Fig. 1-b)

Wide areas of the region were covered by normal marine waters, resulting in the growth of rudistid- and ostreid patch-reefs in the northeastern and western parts of the region. In the eastern parts, alternations of limestone and chalk were deposited, while in the central area, dolomite formed. Brines in the central area caused later reefal dolomitization.

The Kesalon Formation is well exposed in the cores of the Hebron, Ramallah and Faria anticlines (Braun, 1970), that form the mountains of Judea. Starting with a transitional unit, passages from limestone to dolomite facies and from massive beds to a well-bedded cyclic unit of alternating marls, dolomite and limestone characterize the Kesalon Formation.

The top of the Kesalon Formation represents an erosional surface. It may be topped by a thin fossiliferous oyster-ledge (22), or, by a conglomerate of limestone and dolomite pebbles as well as intraformational dolomite breccia (25, 27).

Silicified lenses (so-called «Quartzolite», Bentor, 1945) are the result of a differential weathering process, leaching out the carbonate content of silica-rich dolomites, particular abundant in the Jerusalem and Ramallah areas.

1. *The transitional unit:* Above the Soreq Formation the base of the Kesalon Formation consists of the transitional unit, represented by a 7.50-10 m thick cliff, formed by white gray, porous dolomite, that contains rudist and gastropod fragments (1, 6, 10, 7), algal lamination (8, 10), intraformational conglomerate beds with limonitic staining as well as fossil molds with limonitic infills (3). Well bedded dolosiltite also occur (11, 26, 29) with poikilotopes and laminated algal mats (Plate Fig. 7), limonitic staining, interbedded chert concretions, marls, dolomitic pebbles and blocks. Dedolomite contains quartz spherulites, birds eyes, algal mats and stromatolites. Arenitic bioclasts in the formation are derived mainly from rudistid fragments, foraminifers and ostracods. Truncation features and channel-fillings are evident in the lower part of the unit. The predominant microfacies in the transitional unit is an intraclastic pelletal dolostone (Plate Fig. 1). The intraclasts and pellets consist of dolomud and the matrix is mostly dolosiltite. In places poikilotopes and porphyrotopes of dolomite up to 0.15 mm in diameter are embedded in the matrix. The porphyrotopic and poikilotopic dolomite crystals are subhedral to euhedral; locally they occur as pore fillings. By and large the intraclasts and pellets are mud-supported and only a few specimens are grain-supported. Intraclasts and pellets range in diameter from about 0,5 mm to 3 cm and are identical in color and grain size to the matrix. Intraclasts, including allochthonic constituents, are well rounded. Pellets are of oval to irregular shape. Dolomud is inequigranular subhedral. The limit between intraclasts and matrix is sharp. Pellets often show micritic envelopes. Recrystallization and abundant transitions from dolomud to dolositite can be observed. Bioclasts are partly silicified.

Leaching of bioclasts seems to be responsible for the porosity in this lithofacies. In many samples quartz or chert grains are abundant, and appear to have been formed at the expense of dolomite crystals. Idiotopic quartz is abundant. Diagenetically, algal encrustations are found in vugs, pores and cracks, and are mostly calcitic. Intraformational conglomerates have the same matrix as the surrounding dolostone. Boundaries between pebbles and matrix are mottled. The intraformational conglomerates, formed by subaerial desiccation, are often stained with large patches of limonite, and are the source of dolomite intraclasts and pellets. The rounded shape of the intraclasts and pellets was the result of short transportation by occasional floods. These dolomite flats, devoid of any terrestrial detrital material, were distant from any landmass. The rare quartz and chert grains are penecontemporaneous replacements of dolomite crystals. The origin of much of the matrix seems to be algal. Most of those calcitic algae encrust voids related to flooding of the tidal flats by normal marine waters, later filled by dolosiltite when the system turned hypersaline.

The Kesalon Formation may consist only of the transitional unit as the characteristic dolomite cliff may locally wedge out (11).

2. *Dolomite Cliff Unit:* This cliff forming main part of the Kesalon Formation varies in thickness from 2 m (2, 5) to 6 m (4) and up to 33 m (6). Rudist and Nerinea molds are especially preserved in dark brown silicified patches and lenses in the dark gray, originaly bioclastic dolostone. These fossils are rarely in growing position, except near the type locality (1, 3) where they form a bioherm. The entire Kesalon Formation passes lateraly from a terrace-like morphology of bedded dolomites (8, 9) to reef-talus (pseudobreccia), devoid of bedding (7).

Microfacies consists of silicified bioclasts as *Orbitolina*, rudist fragments (Plate fig. 2), mosaic diagenetic dolostone, which is inequigranular, 0.03-0.2 mm, subhedral or anhedral and only occasionally euhedral. High porosity is mainly due to leached bioclasts. The rudist walls are replaced by dolosiltite whereas toward the canals of the walls the crystals consist of large mosaic dolomite. Calcite occurs as large pore fillings (Plate fig. 3). The ghosts of biogenic constituents (Plate fig. 2) suggest that they were originally aragonite or calcite. Dolomitization took place in a late stage. The fact that most bioclasts were leached and not filled with dolomite shows that leaching of the calcitic or aragonitic bioclasts occurred in a later stage as well. The difference in texture and size of the dolomite that replaces the matrix and that fills the leached

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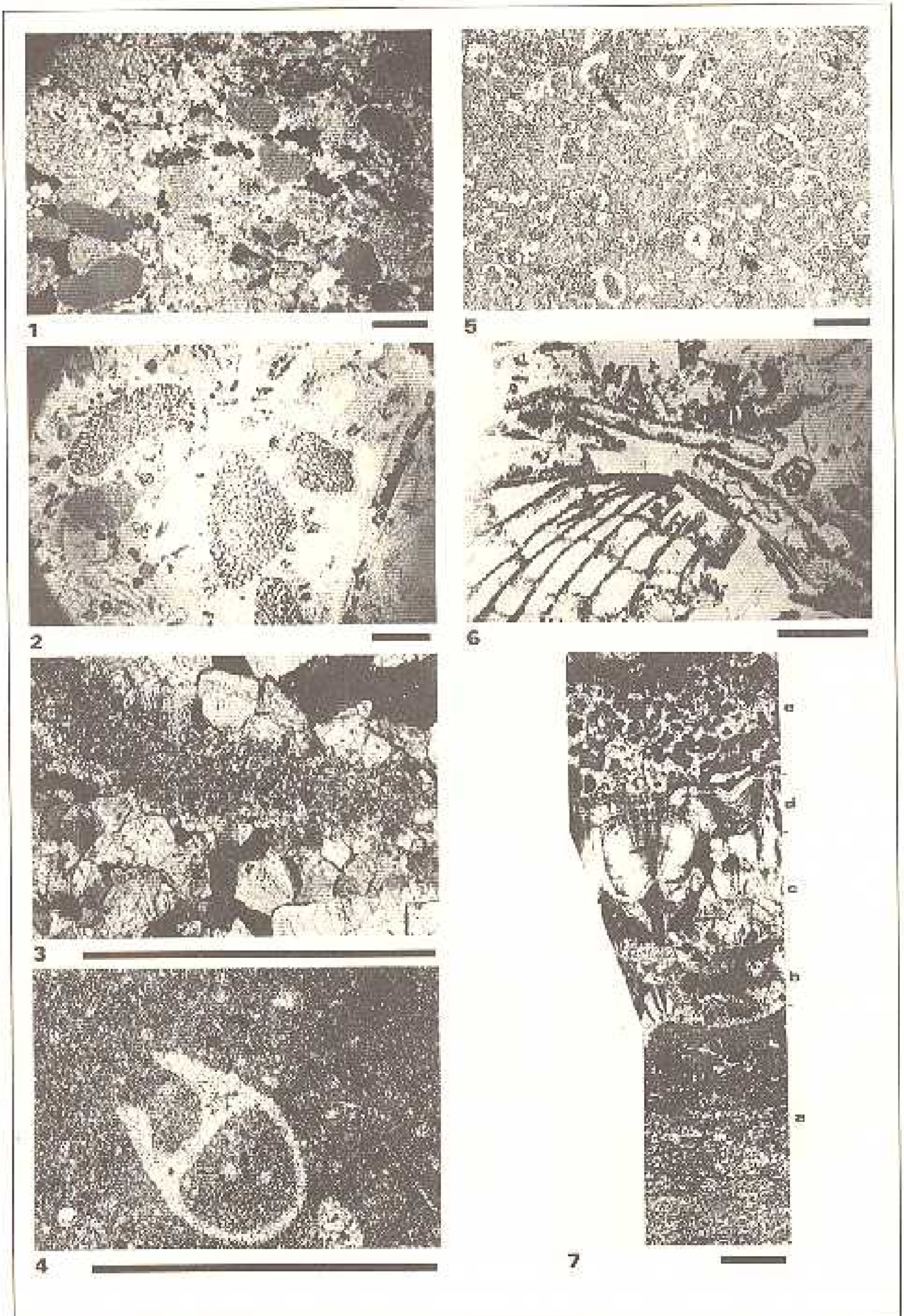
PLATE (Scale = 0.5 mm) Fig. 1.–Mud-supported biomicrite, sparite-filled foraminifera. Locality: Juljulia (18), Sample MB 1275. Fig. 2.–«Quartzolite» consisting mainly of orbitolinid and rudist fragments. Locality: Bittilu-Nebi Zalach road (8), Sample MB 1372. Fig. 3.–Dolomitized rudist, note wall replaced by dolomud, canals infilled by anhedral to subhedal coarse dolomite. Locality: Type Kesalon (1), Sample 61/7/45. Fig. 4.–Dolomud with gastropods, with shells replaced by coarser anhedral dolomite. Locality: Sample. Fig. 5.–Dedolomitized rhomb with dark rims and some cases with empty cores. Location: Gelasun Quarry (15), Sample MB 1333. Fig. 6.–«Quartzolite» consisting of rudist fragments and foraminifers. The walls of the rudists still contain carbonate material. The canals are filled with coarse quartz crystals. Locality: Bituniya (13A), sample MB 1238. Fig. 7.–Algal coating (c) on a laminated dolosiltite consisting of four different textures from bottom to top: a) micritic calcite brownish and almost opaque, highly porous; the pores have a microsparry coat. b) Concentric sparry calcite with irregular patches of the micritic material. c) Concentric sparry calcite stromatolitic structure. d) Micitic pellets with sparry cemment, porous. Locality: Wadi Kina (10), sample MB 1391.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bioclasts shows that they were formed in different stages and under different conditions. In most cases the pores of the leached bioclasts are lined with larger dolomite crystals towards their center, suggesting that these crystals were formed in a later stage when the pores were empty, and under different dolomitization potential (Sass, 1965). The fact that some pores are filled with large anhedral to subhedral crystals suggests that a late phase of pore filling under low dolomitization potential might be related to the calcite filling in some pores. Where calcite fills the pores, most dolomite crystals are euhedral or subhedral and their size is of a tenth of a mm (Plate fig. 3). Porphyrotopes might be of the same origin as other pore filling. Rudist dolomitization is different from that of gastropods. The canals of the rudists are filled with coarse dolomite, the pores remaining mostly empty, whereas gastropod-shells are entirely replaced by coarse dolomite (Plate fig. 4).

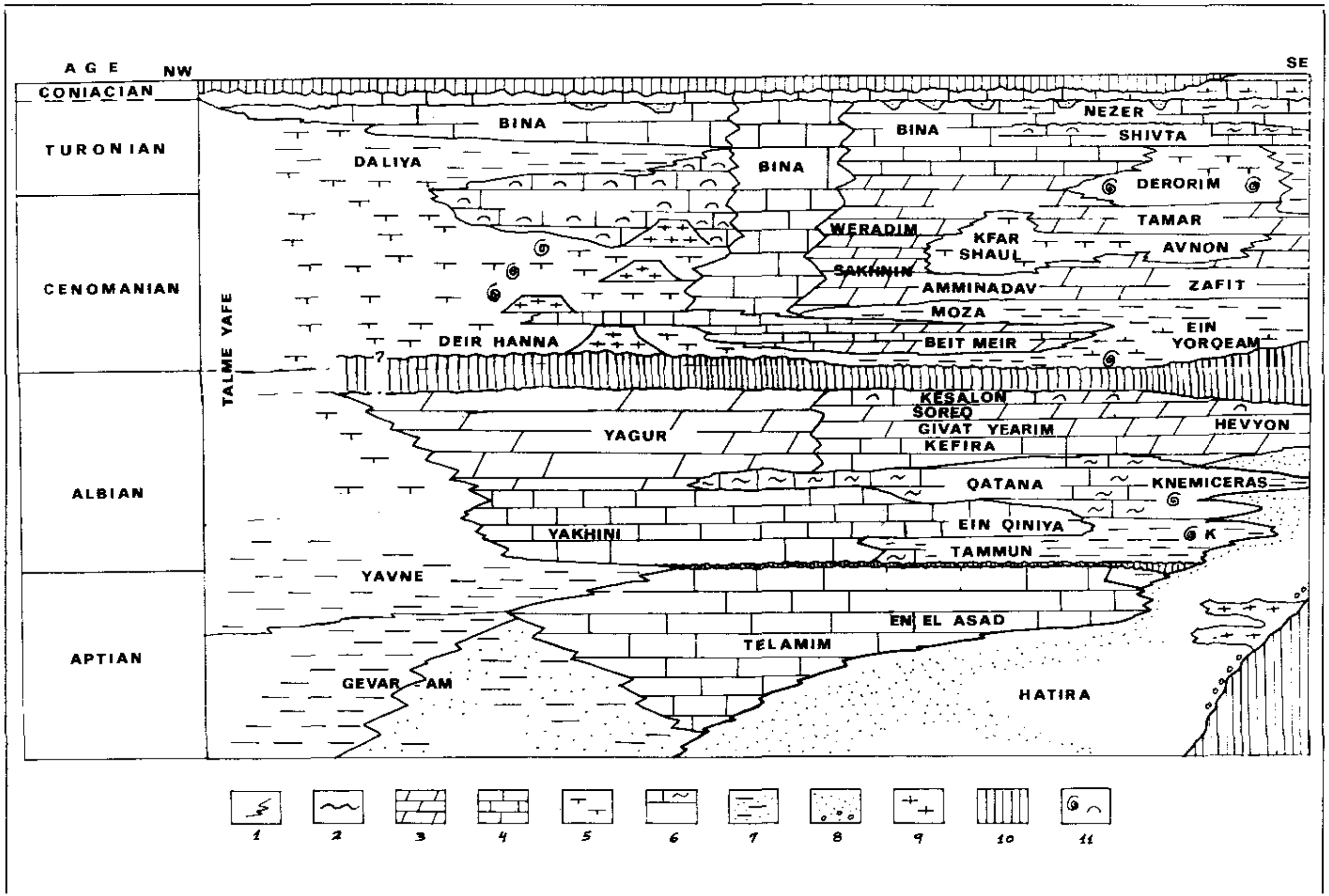
3. *Limestone Cliff Unit:* The limestone facies of the Kesalon Formation builds almost a vertical cliff, devoid of bedding, except in its uppermost part (25, 26, 27, 29, 30). It consists mainly of mud-supported biomicrite, biosparite and some poorly sorted, grain-supported biopelsparite. The arenitic bioclasts derive from rudists, gastropods, oysters, foraminifers (mostly orbitolinids, miliolids), ostracods and algae. Large bioclasts are silicified in patches. Porosity is high. Stylolites are abundant. Abundant bioclasts, whole rudists and annelid-borings are common towards the uppermost limonitized layer of the cliff unit. Silicified algal structures are found in thinly bedded dolomite with flint concretions (30). Mud cracks occur (31). Fast facies change from cliff to cyclic unit is accompanied by a conglomeratic facies (27).

The top of the cliff often consists of an oyster bed with occasional corals (25) in a pseudoconcretional limestone.

4. *Cyclic Unit:* Lateral passages from the dolomitic and limestone cliff units to the cyclic unit are manifold. Morphologically the cyclic unit consists of well-bedded terraces. Its sequence of alternating dolostone, laminated dolomitic algal mats, marls, and dolomitized biomicrite, becomes occasionally massive on top, with whole rudists, abundant karstic features and limonite stains. The cyclic unit varies in thickness from 20 m (13, 16) to 10 m (21). The cliff of the Kesalon Formation wedges out entirely in the southern part of the Hebron Mts. (11, 21).

Spherulites of milky quartz, geodes and chert concretions along the bedding planes are particularly abundant (14, 17, 18). Bioclasts are mainly mollusc fragments, algae, echinoid-spines, orbitolinids and miliolids. Leached bioclasts are filled with sparry calcite. Cross-bedded and truncated laminae, disturbed by intraclasts, with rippled boundaries, bioclasts parallel to the bedding plane and channels with reddish fillings occur (15, 20).

High moldic porosity is due to leaching out of the abundant rudists and nerineas. NW of Hebron, up to eight sedimentary cycles replace the Soreq and Kesalon formations, each topped by a small cliff of well-bedded limestone with abundant rudists, the uppermost one covered by oysters and dolomitized burrows filled with bioclasts unaffected by dolomitization (28). The biomicrite is mud-supported, yielding foraminifera, especially large miliolids, fragments of algae and few thick valved ostracods, pointing to a very shallow environment. Dolomitization is irregular in patches or along lamina. Size of bioclasts, though uniform in the same layer, vary from fine to coarser arenitic from layer to layer. Larger bioclasts are silicified in small patches, without affecting the matrix. Most bioclasts of finer sand size are replaced by sparry calcite. Calcarenitic biopelmicrites have hardly any cement. The pellets are suboval. Dedolomites have a micritic texture containing small quartz or chert grains with large calcite crystals filling birds eyes. As noted above, at the top of the unit, thinly bedded limestones with silicified rudist bioclasts are covered by oyster bioclasts, ranging from fine sand size to whole oysters and rudists, miliolids, orbitolinids and algae being abundant. Laterally, any trace of a limestone cliff disappears and the whole section becomes chalky. Dedolomites occur (23) as very coarse sparry calcite with ghosts of small rhombs, or with rhombs of dolomite in the calcite crystals (Plate fig. 5), or as micritic or microsparry calcite with rhomb ghosts, which can only be observed in peels with crossed nicols. The chalk is a mud-supported biomicrite, in which the bioclasts are very fine mollusc fragments infilled with sparry calcite, but foraminifera and some ostracoda occur as well. Some of the chalk contain dolomite rhombs. Ghosts of the rhombs are filled with microsparry calcite and a rim of limonitic dolomite rhombs. This type of penecontemporaneous dedolomitization (Braun and Friedman, 1970) occurs along a seem between calcite and dolomite that ends frontlike where the dolomitization potential gets too low. Crossbedding alterates laminae in the biomicrite. Dolomitization has not affected the bioclasts and intraclasts. Bioclasts are rudist and foraminifera fragments. The dolomite has a good moldic porosity. Pores are filled with dolomite crystals. Laminae contain pelletic dolomud. Towards the uppermost part of the unit pores are coated with calcitic algae, which caused dedolomitization along the walls. Dolosiltite to dolomicrite with few dolomud pellets gradually pass to dolomitized biomicrite with scattered calcitic bioclasts, sand size rudist fragments, grain-or mud-supported. Lenses of silicified biomicrite include large rudist, gastropod and foraminifer bioclasts; a thin carbonatic lining remained preserved along the walls of rudist «septa» (Plate fig. 6). Poikilotopic dolosiltite is very porous due to leached bioclasts.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The early Cenomanian onlap of the En Yorqeam Formation

The top of the cliff is stained by limonite, covered in places by a conglomerate of well rounded limestone and dolomite pebbles derived from the cliffy upper beds. The top bed of the cyclic unit is very limonitic and covered by an oyster lumachelle that penetrates in cracks and «neptunian dikes» within the underlying limestone (22). The Limestone Cliff Unit as well as the Cyclic Unit of the Kesalon Formation are generally covered by the soft marly yellow chalks of the En Yorqeam Formation. The Dolomite Cliff Unit is topped by bedded dolostones of the Bet Meir Formation.

The En Yorqeam Formation consists of chalk and soft dolomite, interbedded with biomicrite and occasional dolosiltite, passing laterally to intraformational conglomerates with limestone pebbles and blocks of dolomud in a very soft dolomite matrix, in which interbedded pseudoconcretional, slightly dolomitic micrite contain ostracod-bioclasts. The micritic chalk yields rare small sparry intraclasts, foraminifers, echinoids spines and ostracodes (21). A mud-supported oyster lummachelle at the base of the unit fills cracks in the underlying unit (22). The lower part of the En Yorqeam chalk yields ammonoids (29, 34). Bioclasts are leached and filled with sparry calcite (25). In the uppermost layer, bioclasts lie parallel to bedding plane. West of Dura (21) abundant bivalves and echinoids occur. The En Yorqeam chalk is characterized by limonitic staining. Chert and phosphate grains are scattered in the chalk.

Model of deposition (Figs. 2, 3)

The monotonous Yagur-type bank-and reef-upbuildings in the north and west of the country passes towards the south and east to the highly diversified lagoonal infra-, intra- and rarely supratidal facies of Judea and Samaria. The latter passes towards the Negev and Jordan into the intra and supra-tidal Hevyon facies.

Towards the end of the Albian and in the Early Cenomanian a number of sea-level drops resulted in a new paleogeography of partly emerged platforms, shallow lagoons and reef belts. The shallowing of the Soreq-Kesalon transition zone was followed by the transgressive cyclic unit that passes la-

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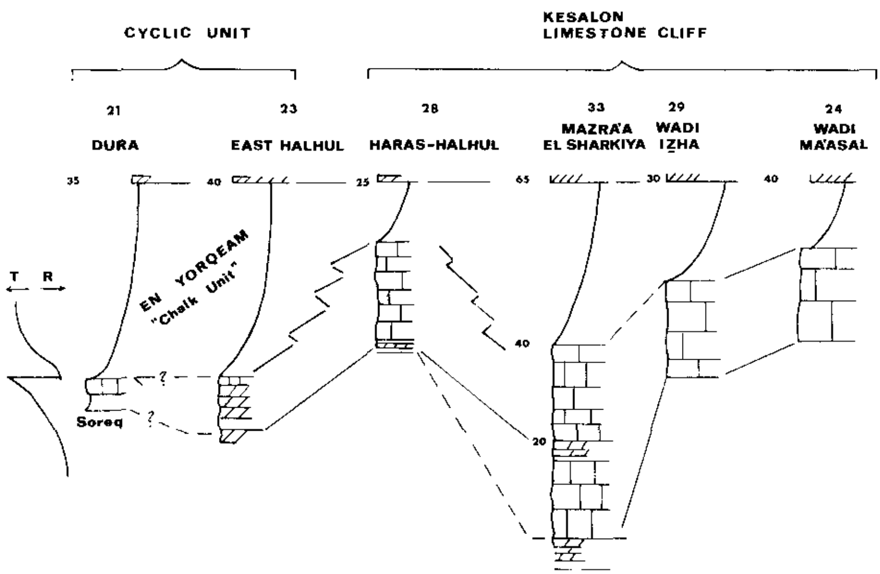
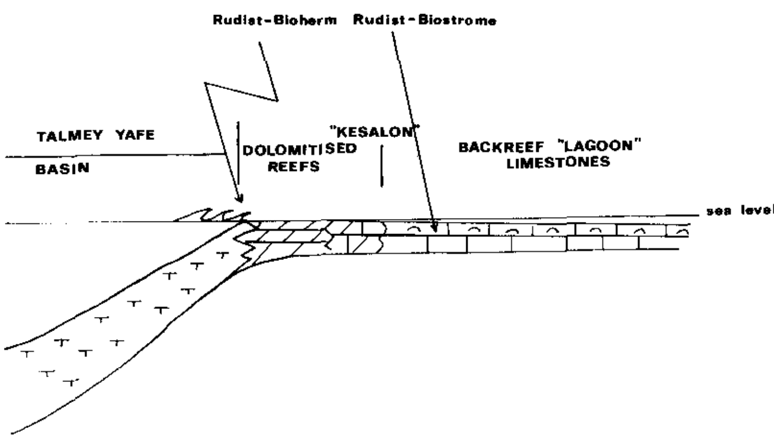
Fig. 2.—*The Cretaceous Stratigraphy of the Arabian Subplate in the traverse of Israel:* 1. lateral facies change; 2. unconformity; 3. dolomite; 4. limestone; 5. chalk; 6. marl; 7. shale; 8. conglomerate and sandstone; 9. volcanics; 10. hiatus; 11. fossils.


CYCLIC UNIT
KESALON
LIMESTONE CLIFF
21
DURA
23
EAST HALHUL
28
HARAS-HALHUL
33
MAZRA'A
EL SHARKIYA
29
WADI
IZHA
24
WADI
MA'ASAL
35
40
25
65
30
40
T
R
EN YORQEAM
"Chalk Unit"
?
?
Soreq
40
20


Rudist-Bioherm
Rudist-Biostrome
TALMEY YAFE
BASIN
DOLOMITISED
REEFS
"KESALON"
BACKREEF "LAGOON"
LIMESTONES
sea level

terally into the reef belt of the Kesalon cliff unit. Renewed emersion, accompanied by karst-activity occurred at the end of the Kesalon deposition. At the top of the Yagur Formation, Kafri (1986) observed a number of phenomena that match our findings, *e.g.* conglomerates, silification, dedolomitization, iron crusts, limonitization and calcrete pisoliths.

The occasional formation of primary dolomite, during the time of deposition of the transitional unit and cyclic units may be related to more restricted setting within the lagoons. Dolomitizition of the cliff unit as well as that of the «chalk unit» (so called Bet Meir facies) is secondary, effected through percolation, and may have occurred as a marine diagenetic process during the Early Cenomanian sea level rise (Kendall and Schlager, 1981).

Distribution of rudist biostromes and reefs in the cliff and cyclic units suggests prevailing normal marine intratidal conditions alternating in the shallow lagoon with supratidal algal mats.

Recent models of deposition suggest conditions varying from near mainland to mid ocean platform, partly covered by a very shallow sea, as in the Bahamas (Skinner, 1963; Deffeyes *et. al.*, 1965; Illing *et. al.*, 1965; Shinn *et. al.*, 1963). Judea and Samaria occupied an intermediate epicontinental position in Late Albian-Early Cenomanian. Its distance from a mainland, inferred from the zero line of Cenomanian deposition beyond Ras Muhamad in southern Sinai (Shata, 1959), from reduced Cenomanian sediments near A Tur (Suez Gulf) and from Cenomanian sandstone with plant remains east of Ras A Naqib in southeast Jordan (Bender, 1968), amounts to several hundreds of kilometers. Marine sandstone, marl and gypsiferous clay near Gebel Raqaba (central Sinai) are the Albian time-equivalent of the Hevyon Formation in the northern Negev.

COMPARISON WITH OTHER AREAS (Figs. 4, 5.)

In the *Arabian Peninsula* (Harris *et al.*, 1983) the Early Cretaceous (Berriasian-Middle Aptian) Thammama Group is overlain by the Late Aptian-Cenomanian Wasia Group, topped by the Coniacian-Maastrichtian Aruma Group. Delimited by equivalents of the Yavne and Kesalon events, the Burgan and Nahr Um Formations represent an Early Albian cycle, followed by the Mauddud Formation, representing a Late Albian cycle; sedimentation

Fig. 3A.–*Columnar Sections of Kesalon Cliff and Cyclic Unit.*

Fig. 3B.–Late Albian Depositional Model prior to Kesalon Event.

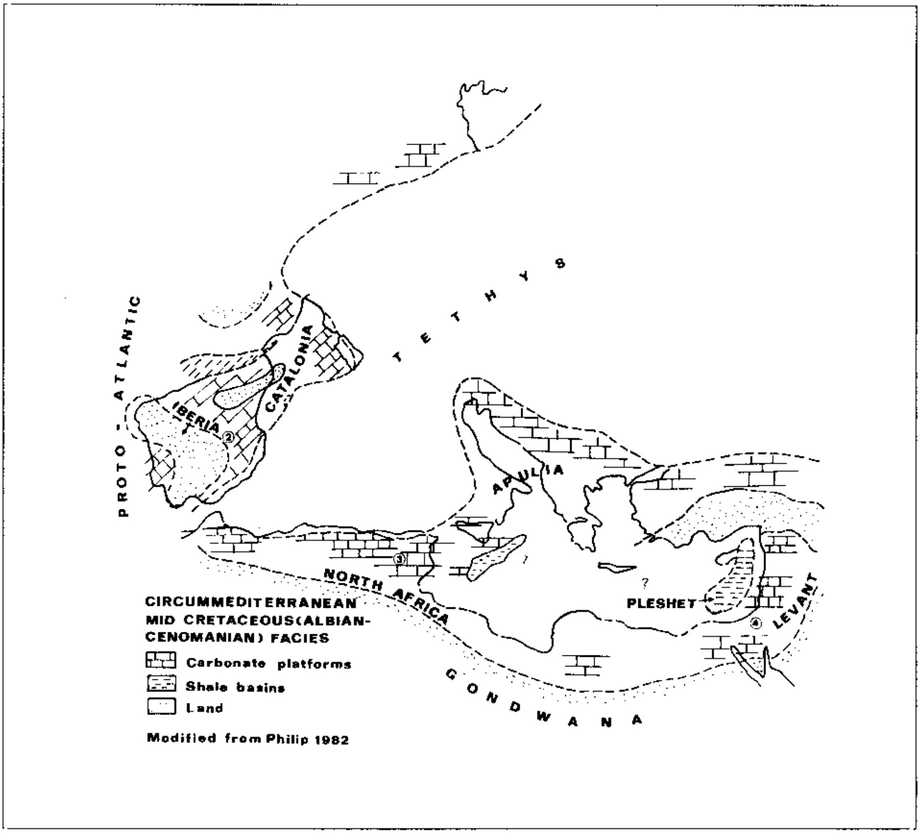


Fig. 4.—*Circum-mediterranean Mid Cretaceous (Albian-Cenomanian) Facies* (modified after Philip, 1982).

was not clearly resumed before the Late Cenomanian Mishrif Formation, followed by a nondeposition in the Turonian.

Similar conditions are found in *Southern Turkey* (Monod, 1977) where the Middle Cretaceous of the autochthonous backbone of the Taurus range is characterised by a Cenomanian-Turonian emersion, with the formation of bauxites.

In *Northwestern Iraq* (Kaddouri, 1982) the Late Cenomanian Tel Hajar Conglomerate unconformably overlies the Albian Qamchuga Formation.

In *North Africa* (Burollet and Busson, 1983), particularly in *Tunisia* (Bismuth *et. al.*, 1981), the Albian Selloum and Cenomanian Ben Younes Formations are delimited by Late Aptian (Yavne), Late Albian (Kesalon) and Late Cenomanian emersions with hardgrounds, similar to the Levant (Israel).

In the *western Mediterranean Iberian Peninsula* the Middle Cretaceous of the Iberian and Catalonian ranges (Vilas *et. al.*, 1982; Salas, 1985) is characterized by the Albian cycles of the Sacaras and Bicuerca Formations, overlying the Aptian cycle of the El Caroch Formation and unconformably overlain by the Early Cenomanian Chera marls and Alatroz limestones and marls, topped by the carbonates of the Late Cenomanian Villa de Vez Formation.

CONCLUSIONS

The domain occupied by the Judea Group in central Israel and the Galilee seems to form a belt, separating the Talme Yafe open sea facies from the more continental Negev facies (*e.g.* Hevyon Fm.). The En Yorqeam and Moza onlaps on partly eroded surfaces are due to Early Cenomanian global events. These are correlative with the circum-Mediterranean «Tethys» sea-level rises.

The deposition of Middle Cretaceous carbonates of the Judea Group is controlled by the Aptian-Albian (LZB 4/UZA 1) global sea level drop at base (Yavne event) and a Late Cenomanian event at top (UZA-2.3/UZA-2.4 ?). They are further controlled by the Albian-Cenomanian «double event» (Kesalon and Moza events), corresponding to Vail *et al.'s* (1977) Ka-Kb or Haq *et. al.'s* (1987) UZA-1.5/UZA-2.2 Global Sea-Level Changes. The Middle Cretaceous regressive and transgressive events in Israel are correlatable with Middle Eastern (Arabian Peninsula) and western Mediterranean regions (Iberian Peninsula).

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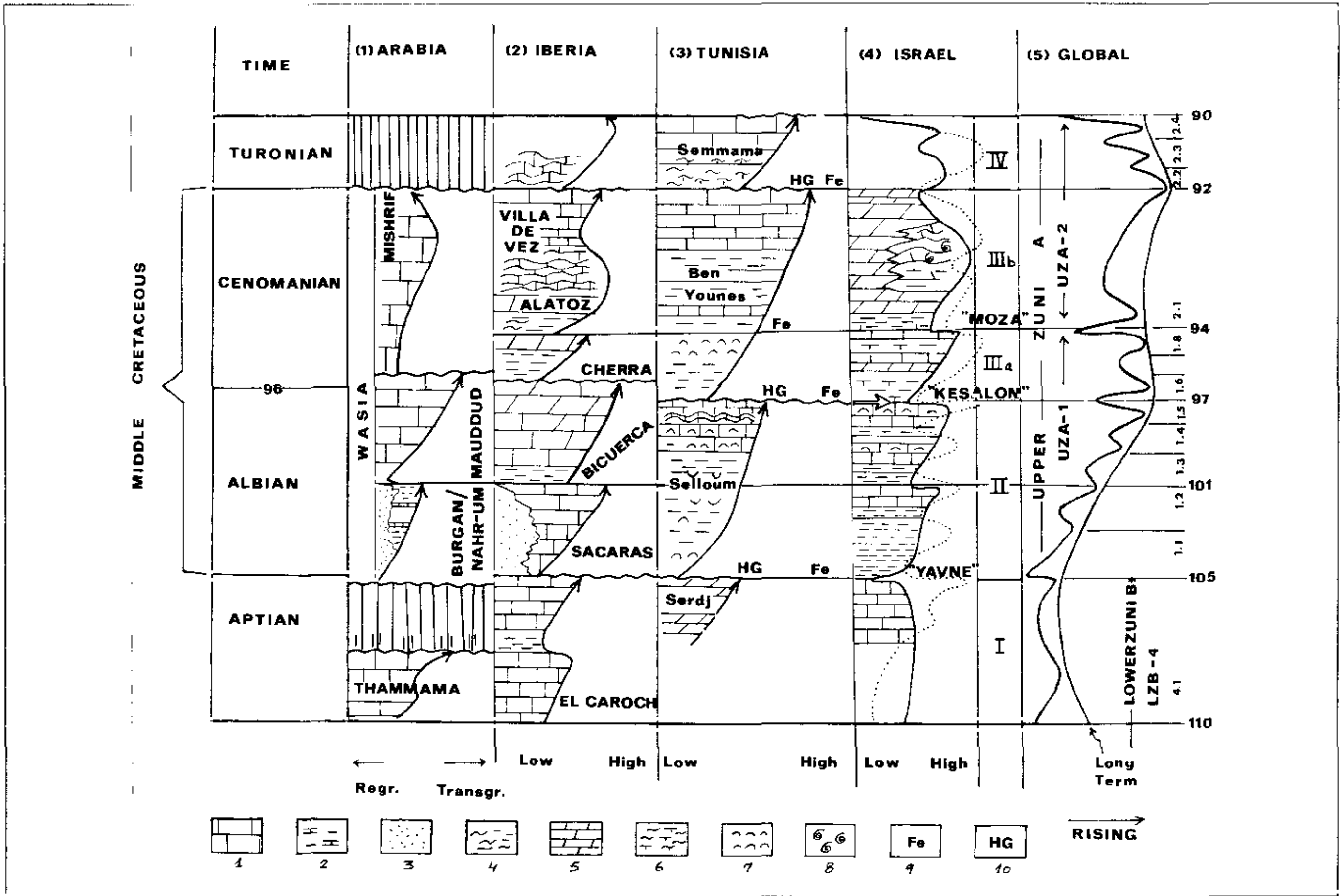
TIME
(1) ARABIA
(2) IBERIA
(3) TUNISIA
(4) ISRAEL
(5) GLOBAL
MIDDLE CRETACEOUS
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
96
MISHRIF
WASIA
MAUDDUD
BURGAN/NAHR-UM
THAMMAMA
VILLA DE VEZ
ALATOZ
CHERRA
BICUERCA
SACARAS
EL CAROCH
Semmama
HG Fe
Ben Younes
Fe
Selloum
Serdj
"MOZA"
"KESALON"
"YAVNE"
IV
IIIb
IIIa
II
I
UPPER ZUNI A
UZA-2
UZA-1
LOWERZUNI B
LZB-4
90
92
94
97
101
105
110
Regr.
Transgr.
Low
High
Long Term
RISING
Fe
HG

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Fig. 5.—*Comparison of the Middle Cretaceous of Arabia, Iberia, Tunisia and Israel with Global Sea Level Changes* (modified after Harris *et al.,* 1984; Monod, 1977; Bismuth *et. al.,* 1981; Vilas *et. al.,* 1982; Salas, 1985; Lewy, 1987; Flexer *et. al.,* 1986; Haq *et. al.,* 1987). 1. limestone; 2. marly shale; 3. sandstone; 5. dolomite; 6. marly chalk; 7. fossiliferous; 8. hiatus; 9. iron crust; 10. Hardground.

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