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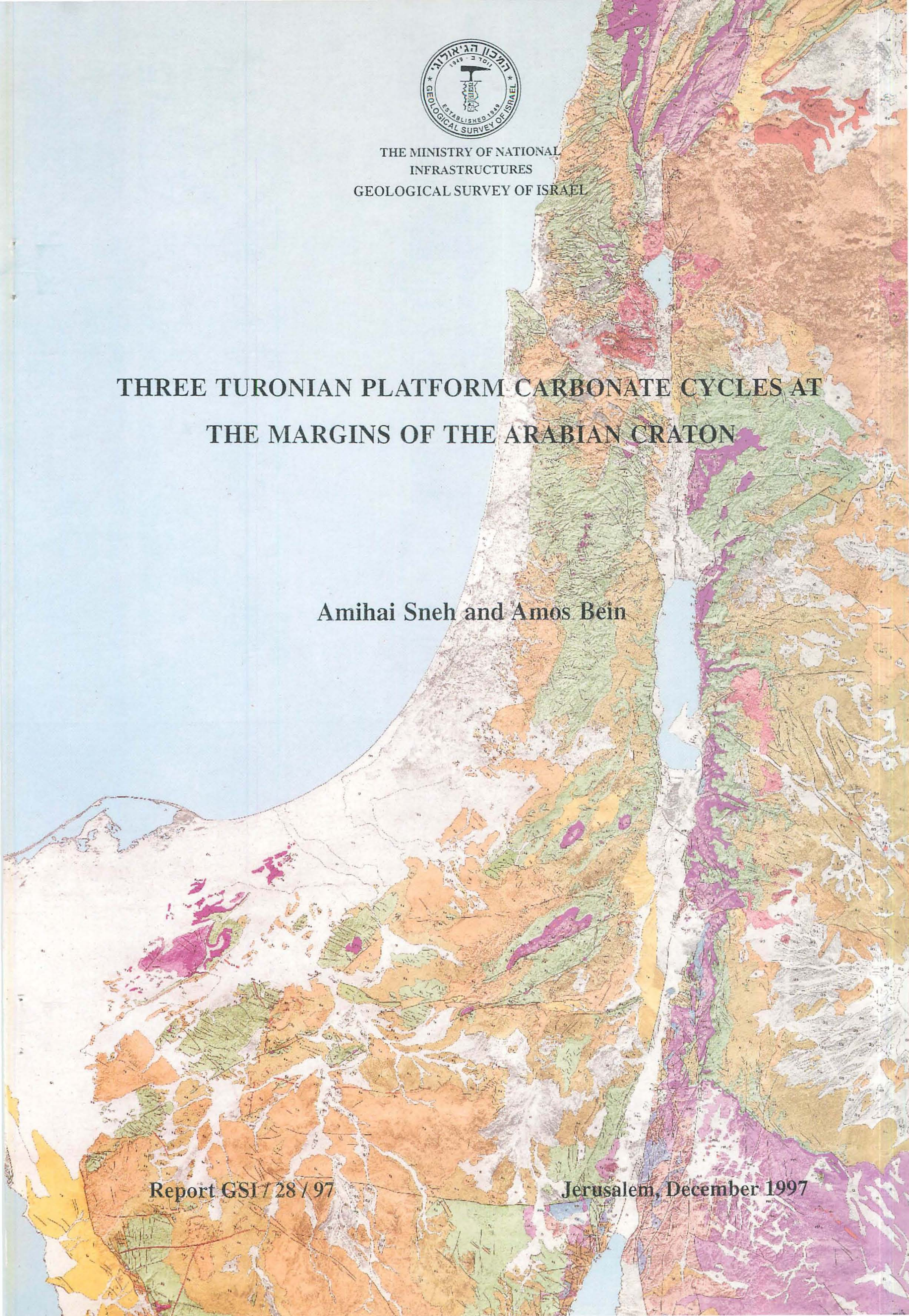
GEOLOGICAL SURVEY OF ISRAEL

THREE TURONIAN PLATFORM CARBONATE CYCLES AT THE MARGINS OF THE ARABIAN CRATON

Amihai Sneh and Amos Bein



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Abstract

The Turonian transgression over the platform of the margins of the Arabian Craton within the area of Israel is portrayed by three depositional cycles, each demonstrating sea-level rise to sea-level fall facies trends. Lithostratigraphically, the rising trend in each cycle is represented by the lower parts of the Derorim, Upper Ora and "Clastic" units and their correlatives, respectively, whose dominant lithologies are marls and clays and sands. The falling trend terminus in each cycle coincides with the top of the Shivta, Lower Kishk and Upper Kishk, limestone, units and their correlatives, respectively.

תקציר

ההצפה הטורונית על גבי מדף היבשה הערבי מיוצגת בשטח ישראל בשלושה מחזורי השקעה שכל אחד מהם מאופיין על ידי מגמות של שינויים פציאליים המייצגים עלייה ובעקבותיה ירידה של מפלס פני הים. ליתוסטרטיגרפית, מגמות העלייה בכל מחזור מיוצגות בחלקים התחתונים של תצורת דרורים, בפרט אורה עליון וביחידה הקלסטית וביחידות הקורלטיביות להן בהתאמה, כאשר הליתולוגיות השולטות הן חוארים, חרסיות וחולות. השלב המסיים את מגמות הירידה של פני הים בכל מחזור מיוצג על ידי גירים בגג תצורת שבטה, בגג פרט קישק תחתון ובגג פרט קישק עליון והיחידות הקורלטיביות להן בהתאמה.

1. Introduction

Turonian platform carbonate cycles developed at the margins of the Arabian Craton; their fingerprints in the area of the Middle East are well displayed in Israel where the turonian strata build an important part of its mountain backbone (Fig. 1).

Previous regional correlations, throughout Israel, were presented in the 1965` 1:250000 geological map of Israel, northern sheet by Picard and Golani and southern sheet by Bentor, Vroman and Zak, and in various correlation charts that were prepared by Arkin and Braun (1967), Arkin and Hamaoui (1967), Bartov et. al., (1972), Bartov et. al., (1981), Flexer et. al., (1981), Cohen et. al., (1987), Braun et. al., (1987) and Sandler (1996). Comprehensive paleogeographical reconstructions were proposed by Sass and Bein (1982) and by Lewy (1989).

The current study unravels stratigraphic issues raised in former studies and presents a new outlook on the depositional history of the platform during the Turonian based on new correlations and on genetic stratigraphical concepts.

During the Turonian, carbonate deposition - 90 to 280 m thick sequences - were controlled by the existing of a wide platform adjacent to the Arabian craton. The edge of the platform lies close to the present-day Mediterranean coastline (Bein, 1976; Bein and Weiler 1976). Beyond the platform edge and along the continental slope, deposition of hemipelagic sediments occurred, forming a sedimentary prism, which comprise the Talme Yafe Formation (Bein and Gvirtzman, 1977).

2. Lithostratigraphy and correlations

The depositional setting at the margin of the craton and the differential subsidence and minor folding during the Turonian resulted in a complex framework of facies and stratigraphic units. Nevertheless, the present regional correlations (Fig. 2) show three distinctive eustatic controlled cycles, probably corresponding to the three global Turonian 3rd order cycles, 2.5, 2.6 and 2.7 of Haq et. al., (1988). However, in the absence of well established time markers this assumption remains highly hypothetic.

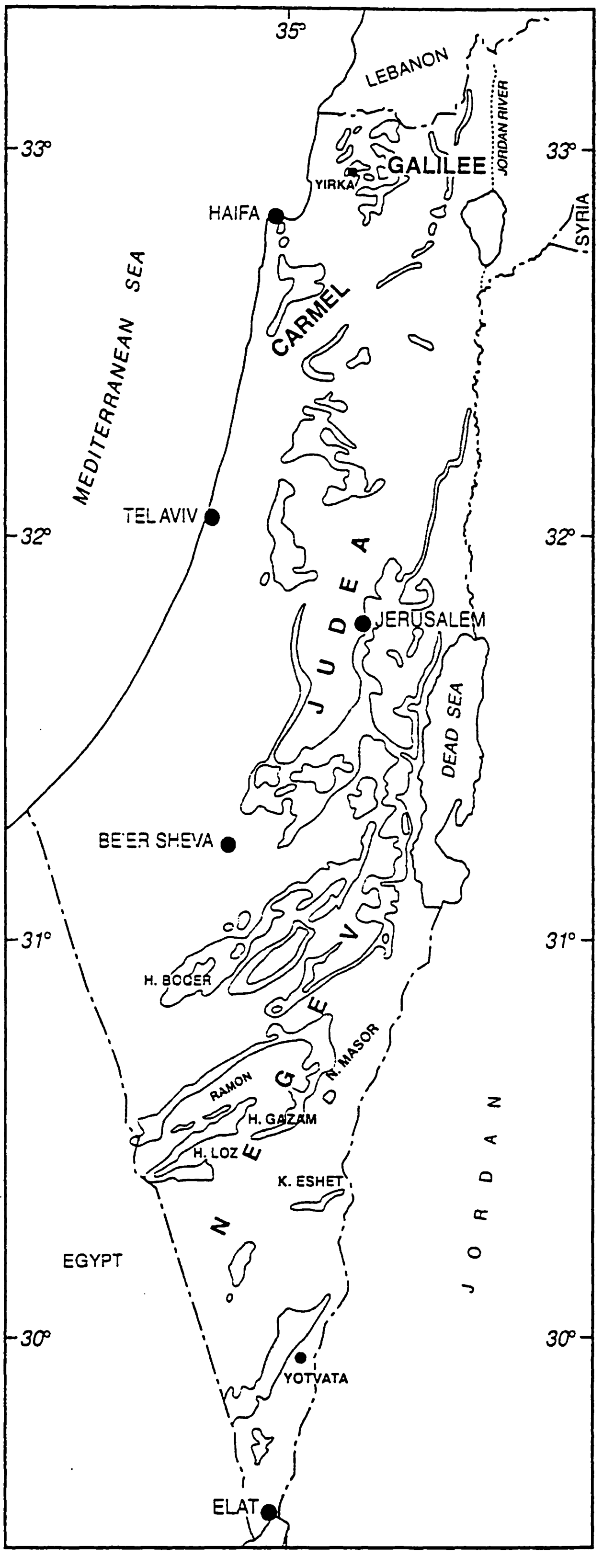


Figure 1 - Location map, showing distribution of Turonian outcrops in Israel.

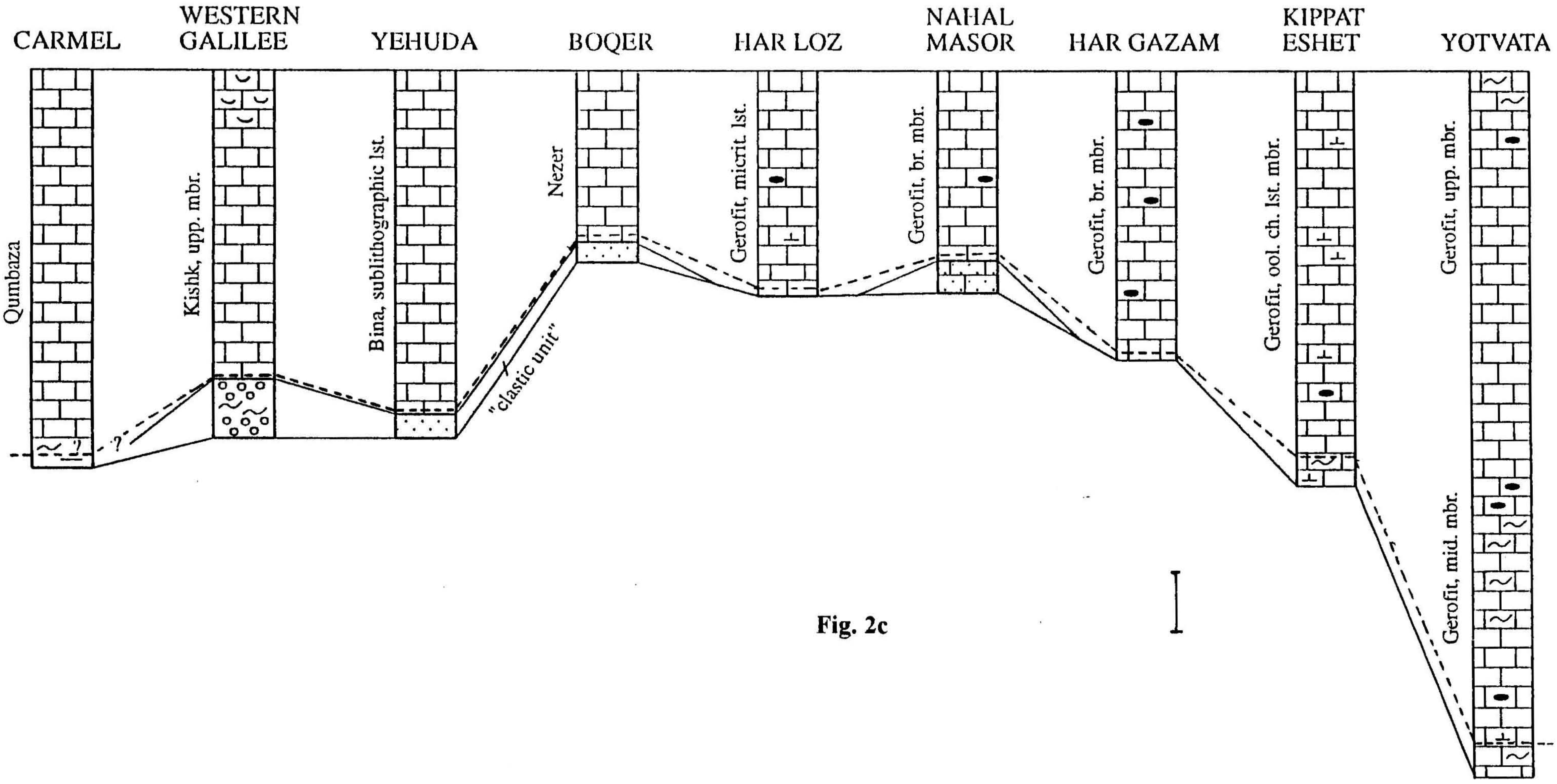


Fig. 2c

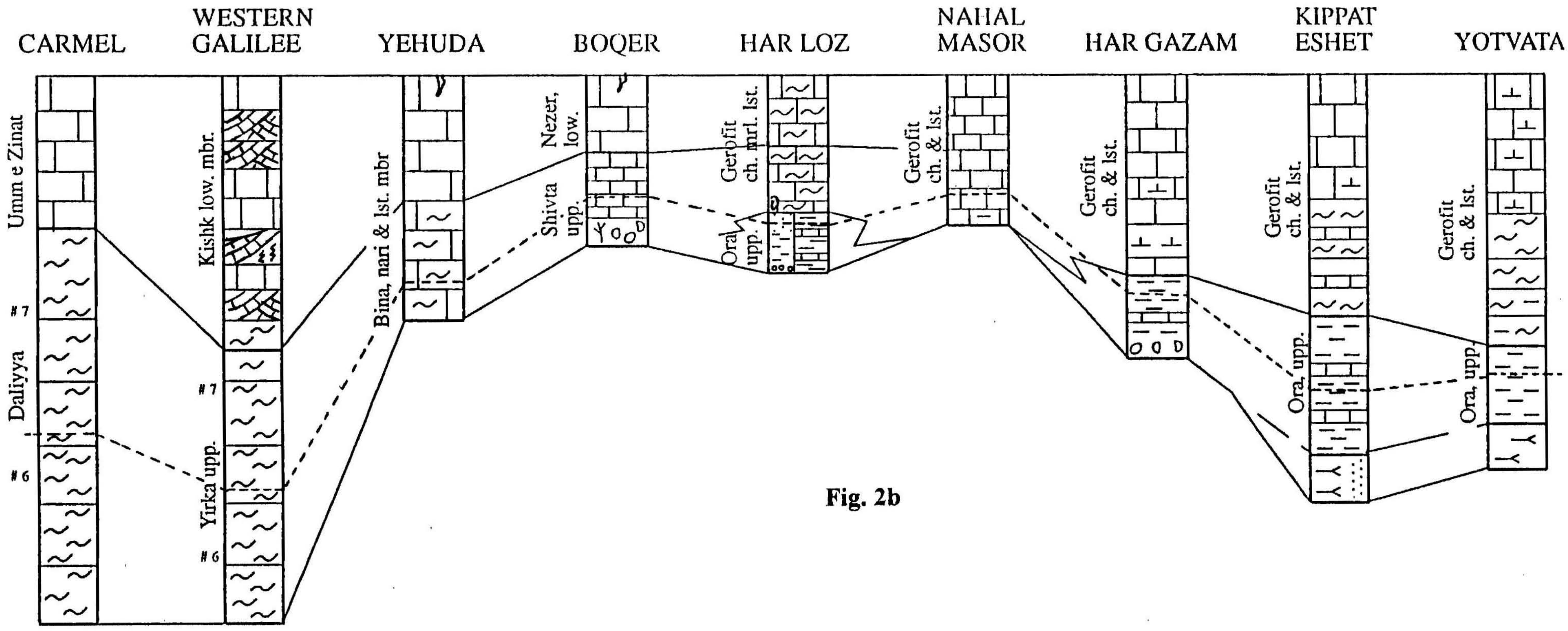


Fig. 2b

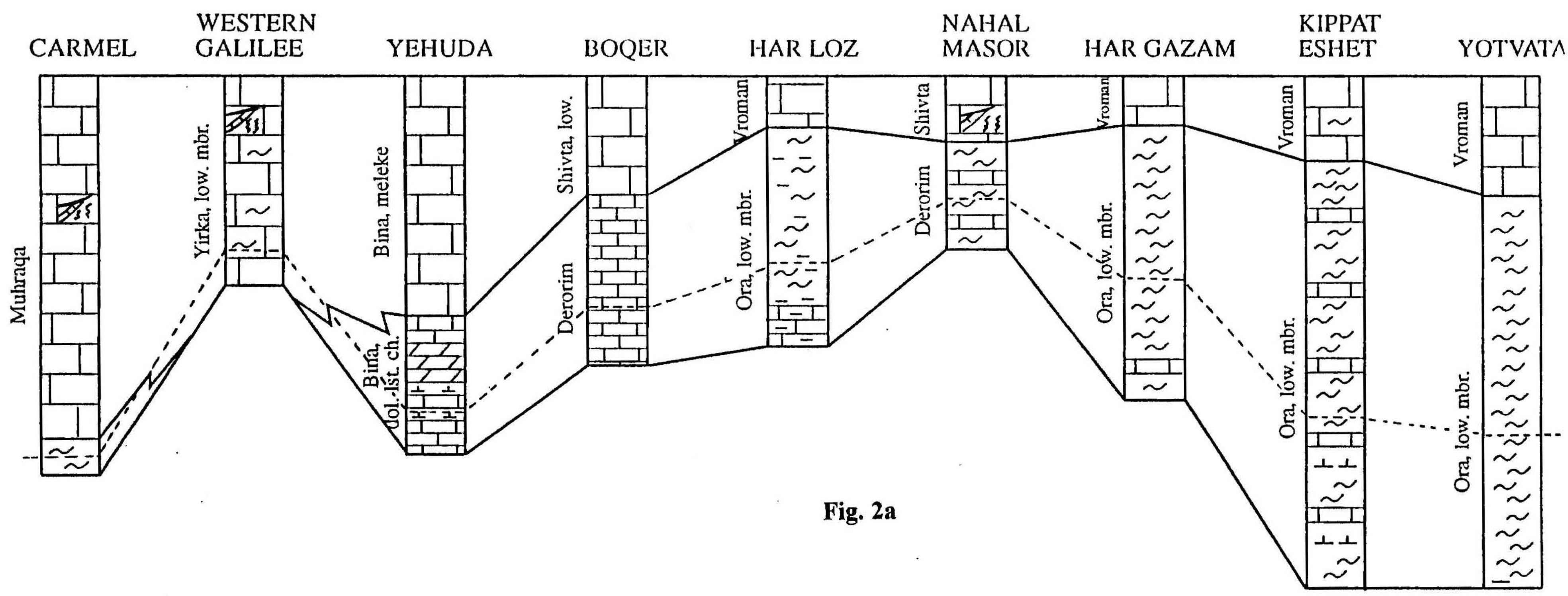
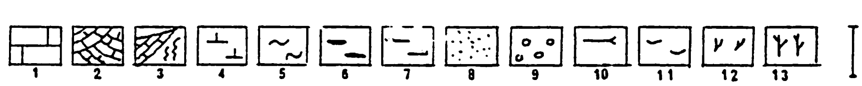


Fig. 2a

Figure 2 - North-South stratigraphic cross sections of the Turonian cycles. A) Lower cycle. B) Middle cycle. C) Upper cycle. For explanations see text.

Sources: Mt. Carmel - Karcz, 1959; Kashai, 1966; Bein, 1977. Western Galilee - Freund, 1959, 1960; Kafri, 1972; Yehuda (Judea Mountains) - Arkin and Hamaoui, 1967; Boqer Ridge and Har Zavo'a - Braun, 1964; Arkin and Braun, 1965; Wdowinski, 1985; Avni and Sass, 1987; Avni, 1989; Har Loz - Avni, 1989; Nahal Masor - Eyal, 1984; Har Gazam - Baer, 1981; Kippat Eshet - Sakal, 1967; Yotvata - Ginat, 1991.

Legend:



1 - limestone, 2 - cross stratification, 3 - reef talus; reef core, 4 - chalk, 5 - marl, 6 - chert, 7 - clay, 8 - sand, 9 - gravel, 10 - gypsum, 11 - mud cracks, 12 - karstic cavities, 13 - plant remains. Dashed line - maximum flooding surface. Vertical scale: length of bar = 10 m

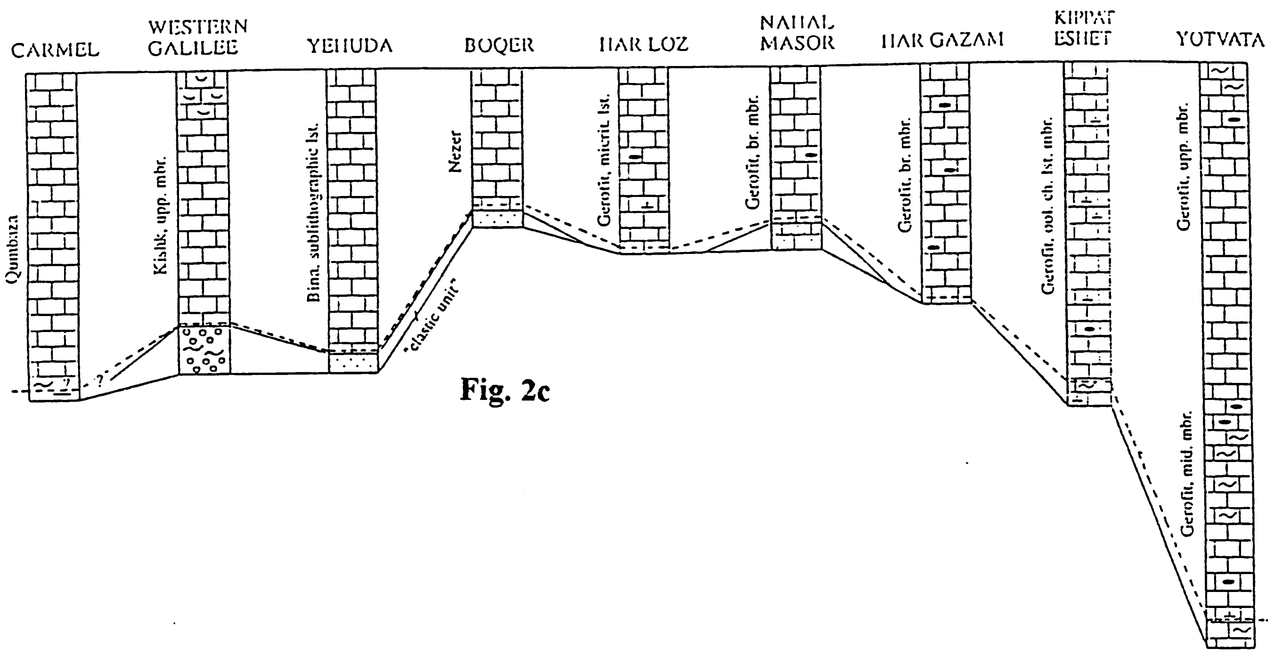


Fig. 2c

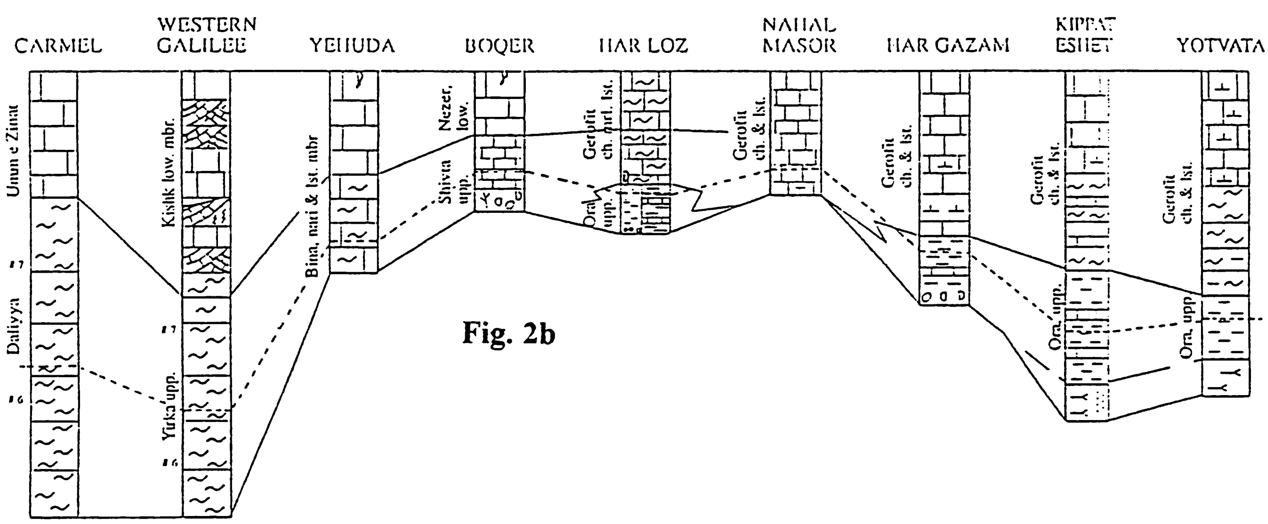


Fig. 2b

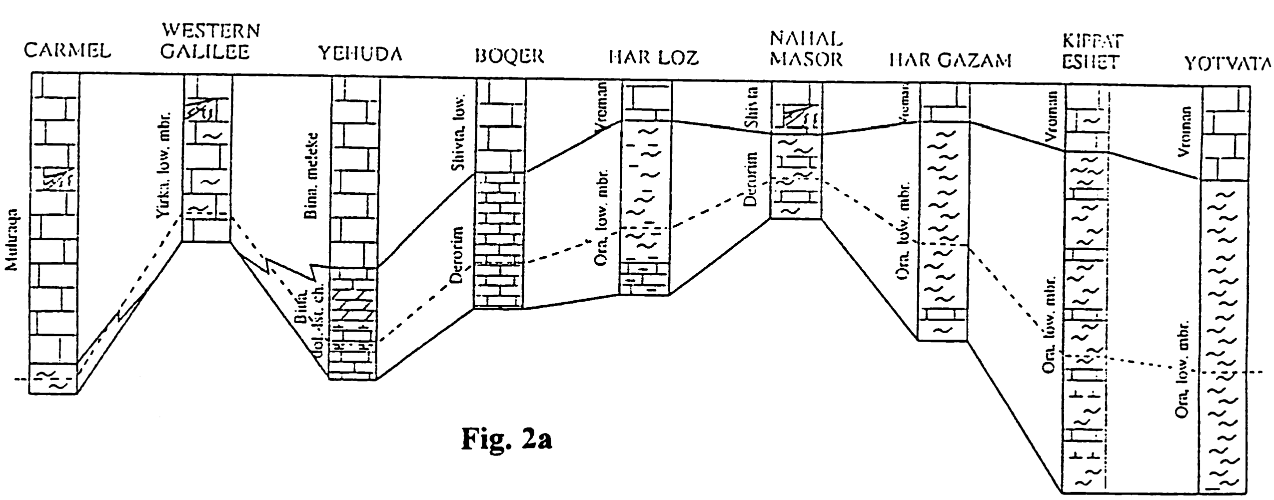


Fig. 2a

2.1. The lower cycle (Fig. 2a)

The lithostratigraphical lower boundary of the lower cycle is a sharp marker at the top of Cenomanian dolostone sections: the Tamar Formation in the Negev, Weradim Formation in Judea and Samaria and Sakhnin Formation in the Galilee. This marker is suggestive of a very shallow water platform environment; large mud cracks were observed in the Tamar Formation; Lewy and Avni (1988) identified a bored surface and limonitic crust at the top of the formation in the Negev and Bogoch et. al., (1994) described an iron-stained calcrete crust suggestive of subareal exposure at the top of the Sakhnin Formation in the Galilee. Locally, though, dolomitization, particularly that adjacent to and associated with the formation of the Dead Sea Rift, obliterates this marker and its distinction from the overlying units is impossible.

The Cenomanian - Turonian transition on the Israeli platform was marked by Lewy (1996), and its exact position is in the lowermost part of the lower cycle section, slightly above the top of the Cenomanian dolostone section; the lower part of the lower cycle is thus still of a Cenomanian age.

The newly established, transgressive facies system over the platform is built mostly of marl with limestone alternations at the lower parts of the sequence, including the lower Ora Shales in the southern Negev (Yotvata), the Derorim Formation in the northern Negev (Har Boqer) and the Bina Formation - Dolomite, Limestone and Chalk Member in Judea (Yehuda). The following unit in the respective geographic provinces consists of skeletal limestones (rudists and other molluscs) of the "Vroman Bank", the Shivta Formation and the Bina Formation - Biosparite Member. Facies changes between the two units, e.g., Derorim and Shivta, were reported by Agnon (1983) from the Judean Desert. The lower cycle in the Carmel is represented by a few meters of marls, part of the Daliyya marls which dominate the more western, offshore, sections (in the subsurface), and by the Muhraqa skeletal limestones which exhibit similar petrographic characteristics to those of the Shivta Formation in the Negev (Bein 1977). Bogoch et. al. (1994) described an 8 m sequence of tidalites, desiccation features and algal stromatolites, from the eastern Galilee, overlying the calcrete crust at the top of the Sakhnin dolostones.

Sedimentation in the western Galilee was affected by the development of the platform, northeast - southwest, Yirka Basin already during the Cenomanian. Freund, (1965) described reef complexes from the margins of this narrow basin. (According to

Freund, reefs were developed in two stratigraphic levels, at first during the upper Cenomanian and again during the Turonian. The former were assigned to the Yanuh Formation. The reef cores, surrounded by talus forset beds, developed rapidly, as claimed by Freund, forming a relief of several tens of meters with almost no penecontemporaneous sedimentation around them.). During Early Turonian (beginning perhaps already in the uppermost Cenomanian) the Cenomanian reef complex was buried by the marls and limestones of the Yirka Formation lower member. These units which are restricted to the platform Yirka basin, constitute the lower cycle in the Galilee. Outside the Yirka Basin, the equivalent units are perhaps the lowermost rock units of the Bina Formation which display platform carbonates but are not distinctive from the upper two cycles.

2.2. The middle cycle (Fig. 2b)

This cycle comprises clays and marls and limestones of the upper Ora Shales and the overlying Chalk and Limestone Member of the Gerofit Formation in the southern Negev, the upper part of the Shivta Formation and the lower part of the Nezer Formation in the northern Negev and the Limestone and Nari Member of the Bina Formation in the Judea Mountains.

Correlations with the Galilee and with the Carmel are more problematic, mainly because of the complicated paleogeographic configuration there, i.e., the existense of the narrow NE-SW Yirka Basin with biosiltite and marl, rich in quartz grains - the upper part of the Yirka Formation - in its deeper parts and reef complex lithologies at the margins (Freund, 1965). These strata are overlain by the limestones of the lower member of the Kishk Formation. The correlative units in the Carmel are the Daliyya Marls (or the En Haud Chalk of Karcz, 1959) and the overlying Umm el Zinat biosparites ("Meleke") of Kashai (1966), respectively.

Based on the ammonite biozones set by Freund and Raab (1969), the part of the Daliyya marl section, which was correlated with the upper Ora Shales, corresponds also to the upper marly part of the Yirka Formation which is confined to the Yirka Basin in the western Galilee (zones #6 and #7; zone 6b and 7 of Lewy, 1989). Lipson-Benitah et. al., (1988) attributed a middle Turonian age to this section.

The lower member of the Kishk Formation (t2 of Freund, 1959; 1961) consists of thick beds of coarse crystalline, skeletal and pelletal limestones, which are frequently cross bedded. Bioherms, mainly made of rudists and gastropods, are common and reef complexes, reef core and reef foresets included, occur as well; the deeper parts of the Yirka Basin comprise bio-siltite and pellet limestones. The reef structures are mostly obliterated by boring organisms such as sponges and algae (Freund, 1965). According to Freund (1965), the Kishk lower member is quite confined to the Yirka Basin, although some patch reefs developed also on the platform, outside the basin.

2.3. The upper cycle (Fig. 2c)

A relatively rapid subsidence of the platform in the southern Negev during Late Turonian resulted in a very thick limestone and marl section that comprises the Gerofit Formation (Sakal, 1967; Ginat, 1991), characterizing the upper cycle. The basic types of lithofacies in the Gerofit Formation are biomicritic, biosparitic and, in places, oolitic limestones. Chalks and marls are common in the lower member. Fossils are abundant and rudist reefs occur as well, and burrows are common. Siliceous rocks form thin chert layers, small nodules and quartzolites (local name for coarsely to medium crystalline silicified rocks). Stromatolites, quartz geodes and plant remains were found at the top of the formation. Cross bedding in skeletal limestones was also reported by Ginat (1991).

Correlative stratigraphic units are the Nezer Formation in the northern Negev and the Sublithographic Limestone Member of the Bina Formation in the Judea Mountains. The correlatives in the Carmel and in the Galilee are the Qumbaza sub-lithographic biomiocrites ("Mizi hilu") of Kashai (1966) and the upper member of the Kishk Formation (t3 of Freund, 1965), respectively. The latter consists of thin, well-bedded, fine crystalline ("Mizi hilu") "lithographic" limestones. Laminated, slightly undulated limestones and fossiliferous limestones in thin discontinuous beds (bioherms) occur as well. Quartzoliteswere found close to its top (Shadmon, 1959; Levy, 1983). Burrows, ripples and mudcracks, mainly in the uppermost layers, are common. Some chalk beds are found particularly at the base of the upper Kishk and in the lower parts of correlative sequences elsewhere, however, they are not as common as the marls and chalks at the base of the former cycles. Much more conspiceous at this stratigraphic position is the appearance of sands designated "clastic unit" (see discussion below). Exposures were studied in the Judea Mountains (Avnimelech, 1950; Weiler and Sass, 1972), in the northern Negev (Sandler, 1996) and in the Galilee (Kafri, 1972 ; Kafri and Sandler, 1992).

The relatively rapid subsidence of the platform in the southern Negev continued during Coniacian and resulted in a sequence of marls and limestones with abundant megafossils comprising the Zihor Formation (Lewy, 1975; Sakal, 1967; Ginat, 1991), which is not recognized in the central and northern parts of the country. According to Lewy, (1989) the Zihor is time equivalent of the Nezer Formation of the northern Negev, and therefore, it is not clear whether it constitutes a separate cycle. The boundary between the Gerofit Formation and the Zihor Formation is not always that distinct.

3. Environmental synthesis

The three cycles described reflect sea level fluctuations that dictate the basic facies evolutionary distribution trends, yet in each point in time facies changes are controlled by differential subsidence and minor folding.

Rapid transgression at the onset of the Turonian is generally manifested by the marly lithofacies associated with open marine fauna, which are suggestive of relatively "deep" water platform environments. Locally though, the changes in facies are frequent. In the southern Negev the marly (lower Ora Shales) environments predominate; in the northern Negev, Judea and Samaria, marls are less abundant (Derorim Fm.), unit thickness decreases, and water depth over the platform, as a result of differential subsidence, seems lower. In the Carmel and in the Galilee, equivalent marls barely exist, except for a few meters in the Carmel and perhaps several marly horizons at the base of the Yirka Formation which are found only within the Yirka Basin. The next stage (Muhraka Fm.; Shivta Fm.) witnessed deposition over a shallower platform, development of patch reefs and cross bedded structures of skeletal debris thereof. The boundary with the overlying unit is generally sharp (it should be noted, however, that some facies change relations between the Shivta and the overlying Limestone and Nari units in the northern Negev, were locally proposed by Wdowinski 1984), evidently the result of sea level drop (resulting in an omission surface, according to Lewy and Avni, 1988). In structurally high regions, e.g., around the Ramon (e.g. Har Loz section), conglomerates accumulated (Avni, 1989). This was followed by a new transgressive systems tract.

The transgression advanced rapidly southeastwards so that shallow lagoons (represented by marine evaporites, sands and shales in the upper Ora Shales) were mostly restricted to the Negev. Limestone and marl lithofacies prevailed in Judea and Samaria and in the Negev (base Gerofit). Inner platform and open outer shelf-basin marls (Daliyya and Yirka marls) were deposited in the Carmel and in the western Galilee. At this stage the whole platform is flooded, defining the maximum flooding surface of the second cycle. In the northwest, and to a certain degree in Samaria, Judea and the Negev, deposition continued in winnowing high energy environments where water depth was within the influence of tidal currents, as indicated by the predominance of the biosparitic limestone lithofacies (Kishk Fm. lower member, Umm el Zinat Fm., units at the base of the Nezer Fm. and in the Gerofit Fm. lower Member). Reefs developed in patches and at the margins of shallow platform channels (Kishk reef complex) and planar cross stratified skeletal and pelletal limestones (in the Kishk Fm.) represent highly tidal (ebb?) dominated intra platform basins. Water depth by the end of this stage is remarkably shallow; certain areas emerge and karst (Weiler and Sass, 1972) and other pedogenic processes (Sandler, 1996) dominate.

The third cycle transgressive stage is also perhaps the shortest. It is represented by the subtidal gravels at the base of the upper member of the Kishk Formation in the Galilee and by the shallow marine sands (of the "clastic" unit) elsewhere in Judea and as far as in the central Negev. Differential subsidence accounts for the thick marine sections - middle parts of the Gerofit Formation - in the south. The attribution of a marine origin to the sands of the "clastic" unit needs to be discussed; see next paragraph.

Mid Turonian sandstone bodies occurring in discontinuous layers, a few meters in thickness, and in karstic pockets and cavities, were studied by Weiler and Sass (1972), who attributed them to a shallow marine depositional environment. Supporting evidence for this is the continuity of a marine realm below and above the sands without any faunistic break (op. cit), and the absence of any channel system or characteristic sedimentary structures that might be indicative of a continental terrain. The layered sandstones are argillaceous with the mud fraction constituting the major part of the grain population. The marine origin of the sandstones was challenged by Sandler and Zilberman (1985) and Sandler (1996), who argued for a fluvial origin instead, mainly as a consequence of new findings of pedogenic features, e.g., paleosols, calcrete nodules, etc. Accordingly, an extensive unconformity surface was established, dividing the Turonian into two subcycles (see also Lewy, 1989). Such a fluvial system, however, raises some disturbing questions. The sands which are described from the middle of the platform, are neither thicker where they originate, (in the southeast, according to Sandler, 1996) nor do they thicken in the direction of their transport, i.e., northwestwards. Moreover, well-sorted channel sands were not reported from anywhere over the platform. Considering these reservations, it is more plausible to postulate a marine origin for the sands. This event was probably related to a short-lived, regional drop in sea level, which resulted in an influx of sands into the shallow sea elsewhere, perhaps in northern Egypt. From there, as explained by Weiler and Sass (1972), the sands were transported by the longshore currents which deposited their load over the platform, during the following rise in sea level.

The main bulk of the third cycle comprises the well-bedded biomicrites (Nezer Fm., "Sublithographic" Limestone Member; Kishk Fm. upper member), which are the most prominent and continuous units, attesting to the extreme flatness of the platform. Laminated limestones, burrows and ripple cross laminations are intertidal and occurrences of mudcracks (top of Kishk Fm.) are indicative of desiccation events. The appearance of stromatolites and plant remains at the top of the Gerofit Formation, is similarly interpreted. Yet, continuous subsidence in the southern Negev during the lower Coniacian resulted in the deposition of the marly fossiliferous limestones of the Zihor Formation and in a conformable relationship with the underlying Gerofit Formation. As the Zihor Formation (studied in detail by Sakal, 1967, and by Lewy, 1975) is restricted to the Negev, it is not elaborated in the present study and is not shown in Fig. 2.

4. Summary

The worldwide Turonian transgression is represented in Israel by 90 to 280 m of sediments that accumulated over the platform at the margins of the Arabo-Nubian craton. Deposition on the platform took place in three cycles, reflecting sea-level fluctuations and local tectonics, superimposed on the global transgressive trend. Each of the three depositional cycles, is portrayed by base-level rise to base-level fall facies trends.

The Lower Turonian transgression began with deposition of marls - Lower Ora, Derorim and lower part of Daliyya -, reached maximum flooding and continued with high-energy calcarenites and reefs of the Shivta Formation in the Negev, the Muhraka Formation in the Carmel, and the Yirka Formation (lower parts) in the Galilee.

Another cycle comprises the marls with quartz grains of the upper Yirka or Daliyya formations, particularly in the intra-platform Yirka Basin in the Galilee (Freund, 1965), reflecting a base-level rise hemicycle. They are followed by a shoaling upward sequence of calcarenites, reefs, and basin margin foresets of the lower Kishk Formation, representing a base-level fall hemicycle. Likewise, the upper Ora marls are replaced upward with the chalk and limestone beds of the lower part of the Gerofit or Nezer formations in the Negev. Build-up to sea-level at this point in time, resulted in partial exposure (Sandler 1996).

Transgressive, shallow marine sands (Weiler and Sass, 1972), the "clastic unit", followed, replaced upward by the Upper Turonian, highstand system of facies; the limestones of the upper part of the Bina Formation and its correlatives, the Nezer Formation (Lewy, 1989), and the upper parts of the Kishk Formation, which are well-bedded, and homogeneously and most widely distributed. They display desiccation features, attesting to the final stages of aggradation.

Another, Turonian, local platform basin developed in the southern Negev. In this area, sedimentation continues uninterruptedly to the Coniacian. In the rest of the country top Turonian strata are eroded, forming an unconformity surface, recognized and interpreted (Flexer et. al. 1986;) as the result of a regional sea-level drop (Harris et. al., (1984).

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