STATE OF ISRAEL

UPPER CALLOVIAN AMMONITES AND MIDDLE JURASSIC GEOLOGICAL HISTORY OF THE MIDDLE EAST

Zeev Lewy

GEOLOGICAL SURVEY of ISRAEL

BULLETIN 76

Jerusalem, August 1983

STATE OF ISRAEL
MINISTRY OF ENERGY AND INFRASTRUCTURE
GEOLOGICAL SURVEY OF ISRAEL
BULLETIN
ISSN 0075-1200

GEOLOGICAL SURVEY OF ISRAEL
30 Malkhei Israel St., Jerusalem 95 501, Israel

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UPPER CALLOVIAN AMMONITES AND MIDDLE JURASSIC GEOLOGICAL HISTORY OF THE MIDDLE EAST

ABSTRACT

Ammonites from the Jurassic outcrop at Makhtesh Hatira (Kurnub anticline, Israel) were studied and compared to coeval ammonites recently collected at Gebel Maghara and Gebel El-Minshera (northern Sinai, Egypt). Forty species are distinguished, including a new genus, seven new species and thirteen unnamed ones. The ammonites are divided into two assemblages, both recognizable at Gebel El-Minshera and at Makhtesh Hatira, whereas at Gebel Maghara, only the Upper Assemblage occurs. Both assemblages are attributed to the Upper Callovian; the Upper Assemblage belongs to the Lamberti Zone and part of the Lower possibly ranges into the upper part of the earlier Athleta Zone. Because of the absence of typical cardioceratine ammonites the distinction of the boundary between these two European biozones is quite impossible in southern Tethyan regions. Therefore, both assemblages are attributed to the combined Athleta-Lamberti Zone. Poorly preserved, fragmentary specimens found in the Lower Assemblage which resemble Middle Callovian ammonites are discussed.

On the basis of biostratigraphical and lithofacies considerations, a Late Callovian age is attributed to the whole Upper Zohar Formation in the northern Negev, Israel. The Upper Zohar Formation unconformably overlies the Lower Zohar Formation in whose upper part the *Meyendorffina bathonica* Assemblage Zone occurs. This biozone was previously attributed exclusively to the Late Bathonian, but it is herein suggested that it ranges into the Early Callovian.

An Upper Bathonian-Upper Callovian unconformity is suggested to occur within the Atash Member of the Upper Dhruma Formation in central Saudi Arabia, based on a revision of the Middle Jurassic ammonites and accompanying faunas recorded from there.

Isr. Geol. Surv. , Bull.	No. 76	pp. 1-56, 11 Figs; 8 Pls.	Jerusalem, August, 1983

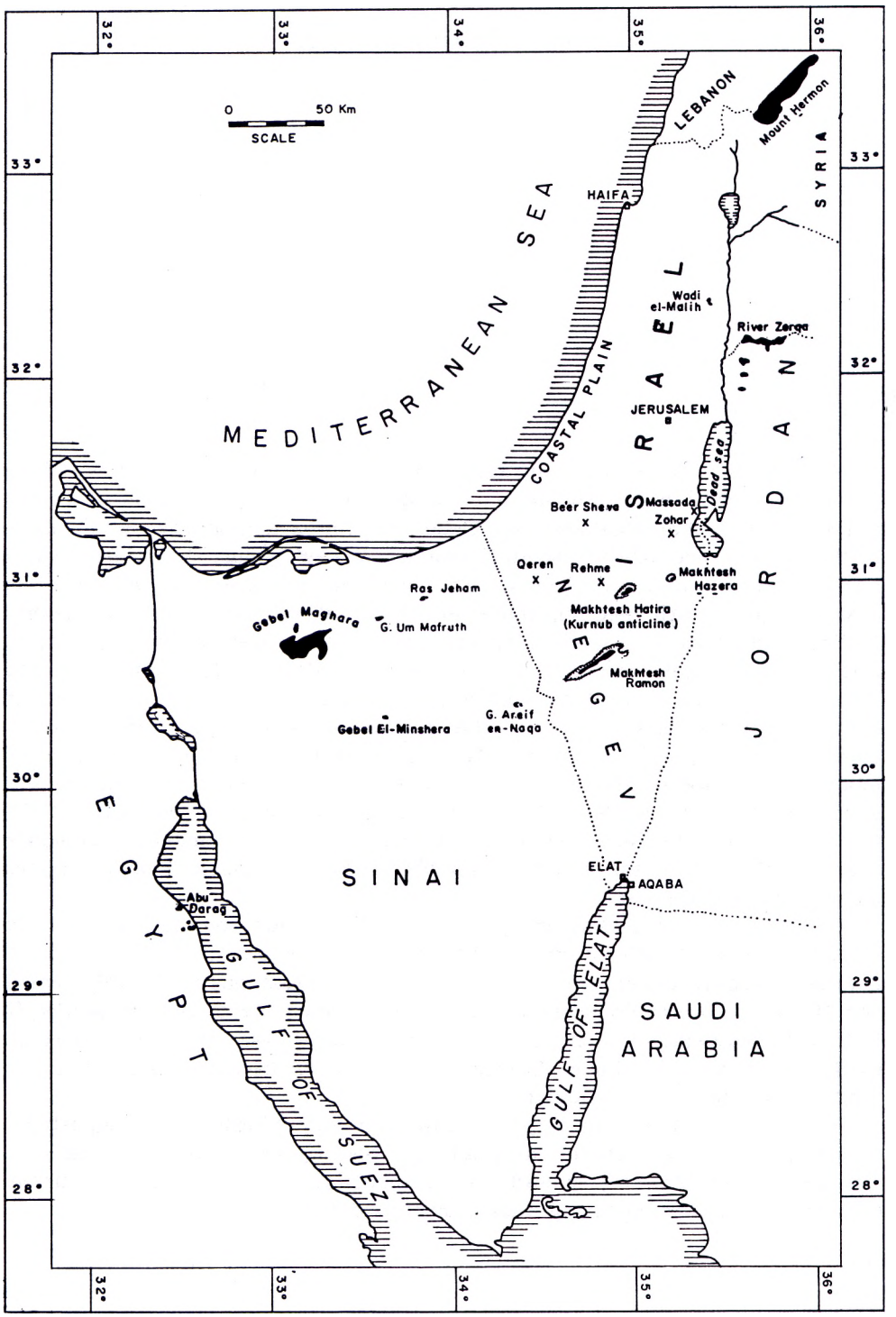

Figure 1. Location map of Jurassic outcrops and selected drillholes which penetrated rocks of this stage in Israel and adjacent countries (modified after Goldberg and Friedman, 1974

INTRODUCTION

The Mid-Jurassic outcrop at Makhtesh Hatira (Kurnub anticline), Israel, is one of a few well-exposed and highly fossiliferous Jurassic rock-sequences in the Middle East, similar in this respect to the exposures at Gebel Maghara, northern Sinai, Egypt and Gebel Tuwaiq, Saudi Arabia. The stratigraphy of these three outcrops has been thoroughly studied by geologists and paleontologists (Gebel Maghara: e.g. Douvillé, 1916; Al-Far, 1966; Goldberg *et al.*, 1971; Gebel Tuwaiq: e.g., Arkell, 1952; Powers *et al.*, 1966; Imlay, 1970; Kier, 1972; Makhtesh Hatira: e.g., Hudson, 1958; Parnes, 1961; Goldberg, 1963; Reiner, 1968; Hirsch, 1980), contributing to the knowledge on the Jurassic stratigraphy and facies changes of the rock-units in which oil reservoirs were discovered in adjacent areas.

In 1975, Gill and Tintant briefly recorded the ammonite biostratigraphy of Makhtesh Hatira, changing the chronostratigraphy of Hudson (1958), which was based on a few ammonites (determined by L.F. Spath), Bivalvia and Gastropoda (determined by L.R. Cox), Brachiopoda (determined by H.M. Muir-Wood), some corals (determined by F. Gosling) and other groups such as Foraminiferida and Stromatoporoidea. In their distribution chart, Gill and Tintant (1975) noted the coexistence of the genera *Thamboceras* (Upper Bajocian), *Erymnoceras* (Middle Callovian) and *Pachyceras* (Upper Callovian). This biostratigraphic discrepancy stimulated the present study of the ammonites of Makhtesh Hatira in the material at the Geological Survey of Israel, collected by M. Raab during the study of the Jurassic sequence by Goldberg (1963). Additional material was found by F. Hirsch, L. Picard and the author. Some Callovian ammonites were recently collected at Gebel Maghara and Gebel El-Minshera, northern Sinai by the author with a few additional specimens by Y. Bartov, Y. Druckman, R. Freund and F. Hirsch. These Callovian ammonites are incorporated into a regional Callovian ammonite biostratigraphy and compared to the assemblages recorded from Saudi Arabia (Arkell, 1952; Imlay, 1970) and Egypt (Abdallah *et al.*, 1965). The chronostratigraphy as based on the ammonites is herein correlated with the ages attributed to the same rock units in Makhtesh Hatira and northern Sinai on the basis of calcareous nannofossils (Moshkovitz and Ehrlich, 1976; 1981), Foraminiferida and Ostracoda (Maync, 1966), Bivalvia and Gastropoda (Reiner, 1968; Hirsch, 1980) and Echinoidea (Parnes, 1961). Similarly, the ammonites collected at Gebel El-Minshara enabled revising the ages given to the Jurassic rocks there by Farag and Shata (1954) and Farag and Omara (1955). The present study resulted in the proposal of a new ammonite biostratigraphy, assigning new ages to the Jurassic rock-units of Makhtesh Hatira, as well as a revision of the Jurassic stratigraphy of Gebel Tuwaiq (Saudi Arabia) and Abu Darag (Egypt).

The present study was conducted parallel to G. Gill, H. Tintant and J. Thierry's work on ammonites from the same section, and presents a different biostratigraphy from that of Gill and Tintant (1975). Preliminary biostratigraphic conclusions of the present study were published by the author (Lewy, 1981, 1981a) and are in part amended herein.

PROVENANCE OF MATERIAL AND DEPOSITION

The ammonites studied were found in the Jurassic outcrop at Makhtesh Hatira (Kurnub anticline) from 9 m above base Tsia Member (subunit 6 of Goldberg, 1963) of the Upper Zohar Formation, throughout the overlying Kidod Formation and in the following 20 m of the Be'er Sheva Formation (Gill and Tintant, 1975, recorded ammonites up to 50 m above the base of this formation). Another single finding was from the top of the Be'er Sheva Formation.

The ammonites at Gebel Maghara occur in a single unit, 1-10 m thick, at the top of the Zohar Formation (subunit 82 of Goldberg *et al.*, 1971). The ammonites at Gebel El-Minshera occur along the upper 17 m of the sequence and accord a litho- and biostratigraphic correlation to both Gebel Maghara and Makhtesh Hatira.

Sample numbers of the ammonites deposited in the collections of the Geological Survey of Israel are prefixed by M-; those from the collections of the Hebrew University of Jerusalem by HU-. The number of specimens within a sample is given in brackets and the individual specimen number within a sample (if more than one) is given after a colon. Forty ammonite species are described and illustrated including a new genus, seven new species and thirteen unnamed ones.

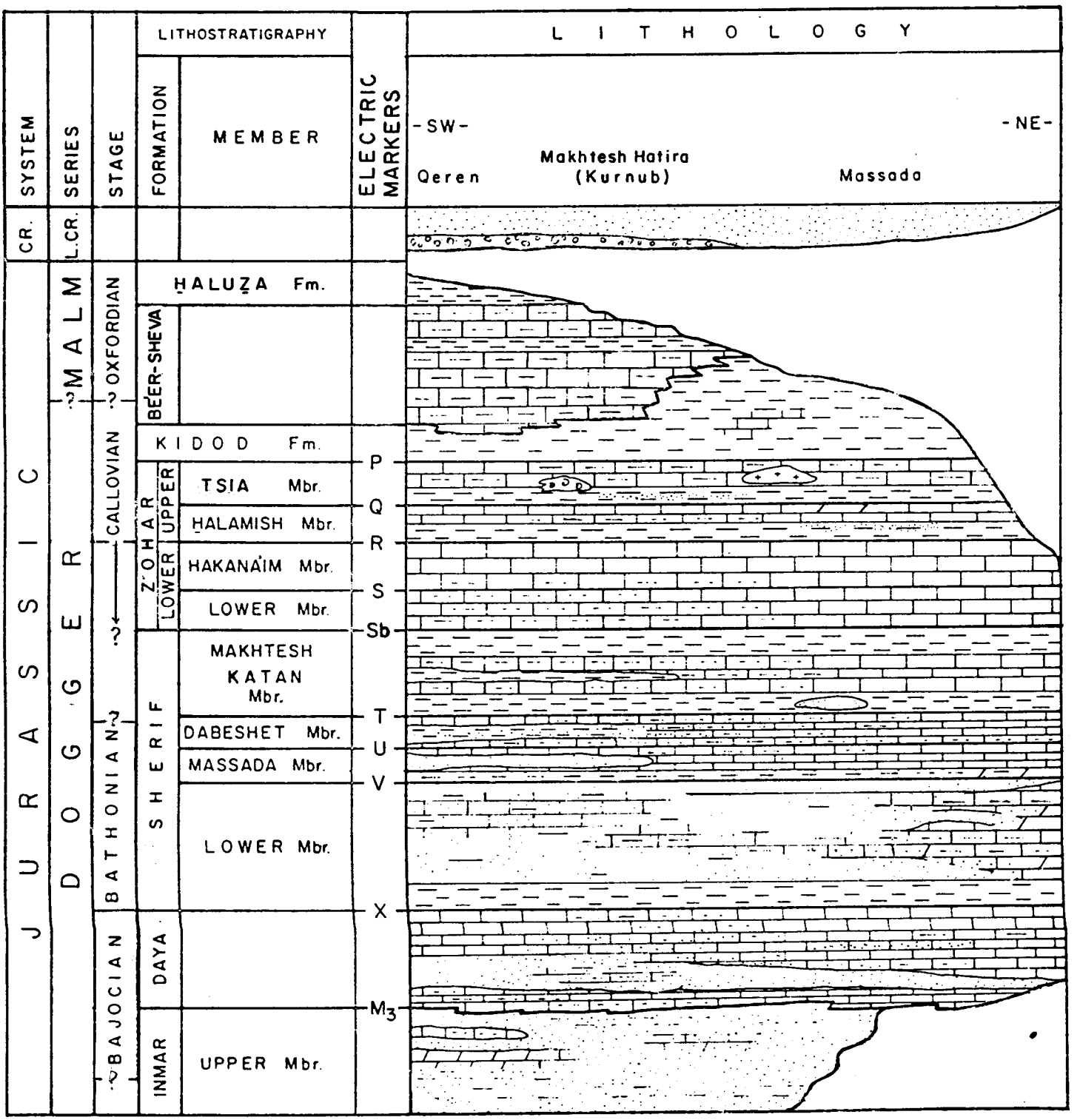

Figure 2. Schematic composite columnar section of the Middle to Upper Jurassic rock sequence in southern Israel (modified after Goldberg, 1970).

STRATIGRAPHY

The stratigraphic position of the ammonites studied is in accordance with the sections measured by Goldberg (1963) at Makhtesh Hatira, Goldberg *et al.* (1971) at Gebel Maghara and by the author (herein) at Gebel El-Minshera. A generalized sketch of these sections is presented in Figures 7, 8 and 10.

The Jurassic stratigraphy and paleogeography of southern Israel was studied mainly by Goldberg (1967, 1970) and Goldberg and Friedman (1974). For an understanding of the stratigraphic descriptions and analysis presented herein, the characteristics of the Middle Jurassic lithostratigraphic units in the Negev (southern Israel; recognizable at Gebel Maghara in addition to the formations recorded by Al-Far, 1966; Fig. 10) are briefly described (Fig. 2), based on Goldberg and Friedman (1974).

The DAYA FORMATION (Eliezri, in Coates *et al.*, 1963) consists mainly of carbonate with some shale and a few sandstone layers, transgressive over fluvial-deltaic sandstones of the INMAR FORMATION (Nevo, 1963, modified by Goldberg, 1964, 1970). The Daya Formation in the subsurface contains Bajocian microfossils (Maync, 1966) and was lithostratigraphically correlated with the MAHMAL FORMATION (Nevo, 1963, emended by Katz, 1968) exposed in Makhtesh Ramon. Parnes (1981) established a biostratigraphic correlation between the Mahmal Formation and the upper part of the Daya Formation and the lower part of the overlying Sherif Formation (as determined by Goldberg *et al*, 1971) exposed at Gebel Maghara, northern Sinai.

The transgressive Daya Formation is followed by the SHERIF FORMATION (Eliezri, in Coates *et al.*, 1963) and has a slight regressive nature as indicated by a greater abundance of clastic material (clays and sandstones) than in the underlying Daya Formation and a northward shift of the occurrence of terrestrial elements (plant remains, especially coal beds). The Sherif Formation was divided in the subsurface into four members on the basis of prominent electric log markers (Fig. 2). As a whole, the Sherif Formation is made up of shale and some sandstone layers alternating with calcareous rocks in varying proportions; the lower part is sandy, the middle calcareous and the upper part, shaly. In its middle part, the Sherif Formation exposed at Gebel Maghara (Fig. 10) contains the Middle Bathonian *Micromphalites* (subunits 57-61 of Goldberg *et al.*, 1971) overlain by the Upper Bathonian *Bullatimorphites bullatus* (d'Orbigny) (Fig. 3) and *Eudesia* species (in subunit 64). The *Eudesia* ranges up to top subunit 64 (Goldberg *et al.*, 1971). The Bathonian/Callovian boundary may be tentatively placed some 40 m above the base of subunit 65, at the occurrence of the foraminiferid *Pseudocyclammina (?) smouti* Banner, which is known from Callovian-Early Oxfordian rocks (Frenkel, 1975). However, 150 m above this foraminiferid, at the middle of the overlying

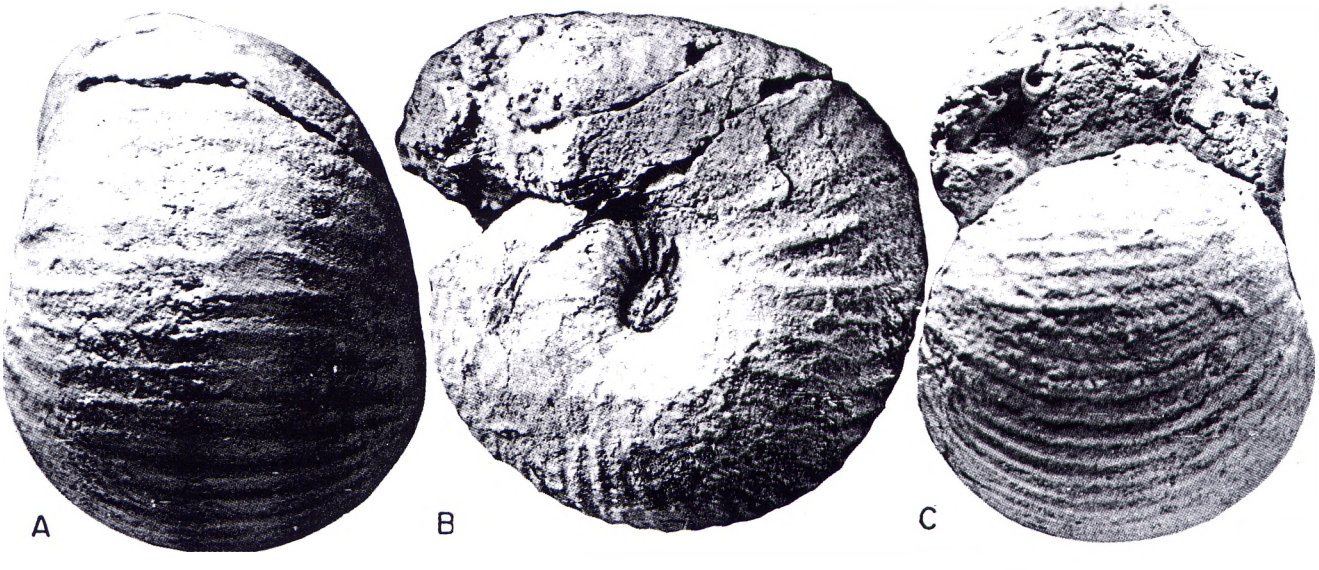

Fig. 3. *Bullatimorphites bullatus* (d'Orbigny), (type 1442), x 1, M-7843, G. Maghara, Sherif Fm., subunit 64 (Goldberg *et al.*, 1971), (Coll. F. Hirsch); U. Bathonian on basis of associated *Eudesia* species.

Zohar Formation (subunit 76), Frenkel (1975) distinguished the *Meyendorffina bathonica* Subzone which is regarded as Late Bathonian in age.

The Sherif Formation is overlain by the ZOHAR FORMATION (Rosenberg, in Coates *et al.*, 1963) which consists mainly of carbonate rocks (108-182 m thick). In the Negev this formation was divided on the basis of electric log markers into four members. The two lower members (the Lower Member overlying the Hakana'im Member) form the Lower Zohar Formation, which is composed of thick calcarenite layers interbedded with thin layers of shale. The shale content tends to decrease toward the NW (seaward in Jurassic time) forming a calcarenite unit in the coastal plain of Israel (BRUR FORMATION, "Brur Calcarenite"; Derin and Reiss, 1966; p. 11, 13; Goldberg, 1970). The lithological change between the Lower Zohar and the Upper Zohar Formation is marked by the electric log marker R (Goldberg, 1970; herein Fig. 2). Near or at the top of the Lower Zohar Formation (or its lithostratigraphic equivalent: Brur Formation; Barzel and Friedman, 1970), *Meyendorffina bathonica* Aurouze and Bizon occurs (e.g., in drillhole Zohar 5). The two upper members, which form the Upper Zohar Formation in the northern Negev (Halamish Member and overlying Tsia Member), consist of limestone with a varying shale content, locally exceeding that of the carbonates. They are quite similar to the lower two members with the general dominance of carbonate characterizing the Zohar Formation as a calcareous unit, and thereby distinguish it from the shaly Kidod Formation above and the rather shaly Sherif Formation below.

The two upper members of the Zohar Formation show remarkable lateral lithofacies variations, as well as indications of local unconformities in the eastern region. Sandy layers and dolostones occur in the Halamish Member and in the lower part of the Tsia Member in the northeastern Negev. Some of the dolostones are regarded as syngenetic (Gill, 1966) and are associated with mud-cracks in Makhtesh Hazera (=Makhtesh Qatan), some of which may have developed into erosion or tidal channels, indicating the subaerial exposure of this region (Gill, 1966; Goldberg, 1967).

The Brur Formation (lithostratigraphic equivalent of the Lower Zohar Formation) is made up of 30-90 m detrital limestone, partly or completely dolomitized in some drilling samples in the coastal plain of Israel (Goldberg and Bogoch, 1978).

The Brur Formation is overlain by the shaly KIDOD FORMATION (Rosenberg, in Coates *et al.*, 1963) which overlies the Upper Zohar Formation in the Negev, Israel. The Kidod shales above the Brur Formation may be coeval to both the Upper Zohar and the Kidod formations, as well as to the lower part of the Be'er Sheva Formation in the Negev, although erosion of a lithostratigraphic equivalent of the Upper Zohar Formation in the coastal plain cannot be excluded (Barzel and Friedman, 1970, p. 188) as indicated by the varying thickness and the dolomitization of the Brur Formation. Moshkovitz and Ehrlich (1981) recorded a biostratigraphic unconformity in the coastal plain of Israel between the Upper Callovian-Oxfordian nannofossil *Watznaueria manivitae* Bukry in the Kidod Formation and the foraminiferid *Meyendorffina bathonica* Assemblage Zone in the Brur Formation below (attributed to the Upper Bathonian).

The Kidod Formation in Makhtesh Hatira contains Upper Callovian ammonites (Gill and Tintant, 1975) whereas at Gebel Maghara (northern Sinai) and Mount Hermon it contains *Creniceras renggeri* (Oppel) of Early Oxfordian age at its base.

An increase in the carbonate content of the shales, probably due to a lowering of the sea level and the development of normal benthic communities (corals and molluscs) resulted in the deposition of the limy-marly BE'ER SHEVA FORMATION (Rosenberg in Coates *et al.*, 1963) which locally interfingers and generally overlies the Kidod Formation (Fig. 2).

Except for a single outcrop in the Samaria region (Wadi El-Malih; Fig. 1), the Jurassic sequence in central and northern Israel was studied only from boreholes (unpublished internal reports of oil companies). Due to remarkable lithofacies changes, some of the formations of the Negev could not be distinguished in the coastal plain of Israel. Therefore, several geographically limited formations were established, some whose precise correlation with those in the northern Negev is unknown. The most comprehensive studies of the Jurassic sequence in the subsurface of Israel were carried out by Maync (1966) and by Derin (1974) and Derin and Reiss (1966).

REVISED MIDDLE JURASSIC STRATIGRAPHY OF THE MIDDLE EAST

I. Ammonite Assemblages

The distribution pattern of the Jurassic ammonites from southern Israel and northern Sinai allows a distinction between two assemblages, defined by the exclusive occurrences of very few taxa in each assemblage.

1) The Lower Assemblage exclusively contains species of *Levanticeras* nov. gen.
2) The Upper Assemblage exclusively contains several members of the Oppeliidae (e.g., species of *Brightia, Pseudobrightia, Kheraites, Lunuloceras* and *Distichoceras)* and probably also exclusively *Sowerbyceras tietzei* (Till).

Both assemblages contain many common ammonites such as *Pachyerymnoceras* and *Pachyceras* species and cf. *Lamberticeras henrici* (R. Douvillé).

The Lower Assemblage is well represented at Makhtesh Hatira within the Tsia Member (Figs. 7, 9, 10) and at Gebel El-Minshera in units 3-6 (Fig. 8). The Upper Assemblage is best represented at Gebel Maghara in the top of the Upper Zohar Formation (upper 10 m of subunit 82 of Goldberg *et al.*, 1971) and occurs in unit 7, top Upper Zohar Formation at Gebel El-Minshera (Figs. 8, 9, 10). At these localities, the Upper Assemblage is overlain by the shaly Kidod Formation, which contains *Creniceras renggeri* (Oppel) of Early Oxfordian age at its base (in Gebel Maghara). The Upper Assemblage may be recognized at Makhtesh Hatira by a few Oppeliidae in the lower part of the Be'er Sheva Formation (herein, and in Gill and Tintant, 1975). "*Paraspidoceras*" sp. and the *Pachyceras* and *Pachyerymnoceras* are also present. A similar oppeliid-*Paraspidoceras* assemblage is recorded by Gill and Tintant (1975), ranging up to 155 m above the base of the Tsia Member.

The argillaceous limestone in which the Upper Assemblage occurs in northern Sinai differs considerably from the reefal limestone below it, which contains the Lower Assemblage at Gebel El-Minshera. At Gebel Maghara, this reefal lithofacies may have been originally barren of ammonites or its hard nature may prevent their recognition in the rock; in any case, to date, the Lower Assemblage has not been discerned at Gebel Maghara.

II. Chronostratigraphy

(a) Previous works

The Jurassic outcrop at Makhtesh Hatira was subdivided by Hudson (1958) into five biostratigraphic units, dating from Middle Callovian to Late Oxfordian with a probable Early Callovian age for the lowermost layers. The Middle Callovian age of the lower part of the exposure was based on the presence of *Erymnoceras* aff. *dorotheae* Spath (determined by L.F. Spath). Instead of relating to the age of the species *dorotheae*, which occurs in the Upper Callovian Athleta Zone in Cutch (Spath, 1927-1931, p. 220), and on the associated *Pachyceras* spp. (Hudson, 1958, p. 418), Hudson (1958) emphasized the genus *Erymnoceras*, which is a European Mid-Callovian index taxon. Due to the rather low chronostratigraphic significance of most invertebrate groups studied for the recognition of substages (e.g., Mollusca: Reiner, 1968; Hirsch, 1976, 1980; Nannofossils: Moshkovitz and Ehrlich, 1976, 1981), Hudson's (1958) chronostratigraphy was used as the basis for all other stratigraphic studies in Israel (e.g., Maync, 1966).

Gill and Tintant (1975) published a short note on the Jurassic ammonite biostratigraphy of Makhtesh Hatira, dividing the lower 155 m of the exposed 205 m into the Middle Callovian Coronatum Zone (from 10 m above base to 60 m) and the Upper Callovian Athleta Zone (from 60 to 155 m). Although the so-called Mid-Callovian *Erymnoceras philbyi* of Gill and Tintant (1975) is associated with *Pachyceras lalandeanum* (d'Orbigny) of Late Callovian age (e.g., Charpy and Thierry, 1977), they (Gill and Tintant, 1975, p. 103) rejected the comment of Zeiss (1974, p. 273) that the Arabian *Erymnoceras philbyi*, as well as *E. dorotheae* Spath from Cutch are actually *Pachyerymnoceras* species.

Intensive microfaunal analyses were carried out on subsurface samples from drillings in the Negev and the coastal plain of Israel in addition to the studies on the large invertebrates from the few outcrops. *Meyendorffina bathonica* Aurouze and Bizon (foraminiferid) at the top of the Lower Zohar Formation (drillhole Zohar 5) dated this level in the Negev as Late Bathonian. It is overlain by the Upper Zohar Formation which contains from its base upward the Callovian-Oxfordian nannofossil *Stephanolithion bigoti* Deflandre (Moshkovitz and Ehrlich, 1976). These stratigraphical relations in the Negev were

regarded conformable in the absence of short ranging fossils. In the coastal plain of Israel the *Meyendorffina bathonica* Assemblage Zone occurs in the upper part of the Brur Formation (=Lower Zohar; Barzel and Friedman, 1970). This formation is overlain by the shaly Kidod Formation which contains the Upper Callovian-Oxfordian nannofossil *Watznaueria manivitae* Bukry, suggesting a biostratigraphic unconformity (Moshkovitz and Ehrlich, 1981).

(b) Revised Middle Jurassic ammonite chronostratigraphy

The ammonite assemblages from the three outcrops studied comprise Upper Callovian taxa such as *Pachyceras, Pachyerymnoceras Alligaticeras* and *Euaspidoceras,* which date as Late Callovian all the associated genera and species of questionable identity. No unequivocally exclusive Lower or Middle Callovian species have been found below the Upper Callovian forms. Similarly, no exclusively Oxfordian species occurs in the upper part of the Be'er Sheva Formation at Makhtesh Hatira, which was lithostratigraphically correlated with Oxfordian limestones in the subsurface (Negev; Goldberg, 1963). However, *Brightia* sp. A from the top of the Be'er Sheva Formation at Makhtesh Hatira, high above the Upper Callovian ammonites at the base of this formation, as well as above those recorded by Gill and Tintant (1975), may already be of Oxfordian age. Such an age for the upper part of the Be'er Sheva Formation is supported by the occurrence of the Early Oxfordian foraminiferid *Flabellocycloitna reissi* Hottinger, 180 m above the base of the Tsia Member (H. Frenkel, in Hirsch, 1980, p. 159). Gill and Tintant (1975) recorded three oppeliid species from the middle part of the Be'er Sheva Formation of this sequence, ranging up to 155 m above the base of the Tsia Member. They are associated with *Paraspidoceras* which is found in a lower bed together with *Pachyerymnoceras* (Fig. 7) and may represent Late Callovian species. Therefore, the Callovian-Oxfordian boundary at Makhtesh Hatira is tentatively inserted (Fig. 7) above the last occurrence of these oppeliids (35 m above the last occurrence of our *Pachyerymnoceras)* and below the recorded Early Oxfordian foraminiferid.

cf. *Erymnoceras coronoides* (Quenstedt) within the Lower Assemblage of Makhtesh Hatira is a poorly preserved fragment resembling the Hungarian specimen of Loczy (1915). Although E. *coronoides* is regarded as a Mid-Callovian species, Lóczy (1915, p. 452) recorded it from the Athleta Zone (his O_1) of western France, Swiss Alps, southern Germany and Poland. Similarly *Kinkeliniceras* sp. cf. *K. kinkelini* (Dacqué) resembles the Upper Callovian form recorded by Collignon (1958, pl. 29, fig. 135) and not the Middle Callovian type species. Another Upper Callovian *Kinkeliniceras* has been recently described by Kanjilal and Singh (1980) supporting the extension of the range of this genus into the Upper Callovian. In both above mentioned examples the Israeli specimens are compared to Upper Callovian forms which Lóczy (1915) and Collignon (1958) named as Middle Callovian species although attributing them to the Upper Callovian. Therefore, the doubtful specific identification, as well as the Mid-Callovian age, is insignificant and the reference is made to a certain recorded specimen and its stratigraphic level.

Both local ammonite assemblages contain *Pachyceras* and *Pachyerymnoceras,* which are regarded as dimorphs *(Pachyceras,* the macroconch of *Pachyerymnoceras;* Callomon, 1963). Accordingly, they must be considered as coeval. *Pachyceras* appeared in Europe at the top of the Athleta Zone (upper Spinosum Subzone of Callomon and Sykes, in Duff, 1980) and became abundant in the Lamberti Zone (Callomon, 1981, pers. comm.; Charpy and Thierry, 1977), characterized by *Pachyceras lalandeanum* (d'Orbigny).

In Makhtesh Hatira and Gebel El-Minshera, *Pachyceras* appears above *Pachyerymnoceras* and becomes abundant in the Upper Assemblage. Gill and Tintant (1975) recorded new Pachyceratidae together with *P. lalandeanum* at Makhtesh Hatira from the lower part of the sequence, from 30 m above the base of the Tsia Member. This shortens the range of *Pachyerymnoceras* without *Pachyceras* to 20 m, which does not necessarily contradict the dimorphic relations of these taxa regarding the general scarcity of ammonites in the sequence.

(c) Remarks on microfaunal chronostratigraphy

Some doubts as to the exclusive Late Bathonian age of *Meyendorffina bathonica* Aurouze and Bizon (1958) have arisen during the present survey of Gebel Maghara, northern Sinai. *M. bathonica* Subzone was distinguished there by Frenkel (1975, p. 52) in the middle part of the Zohar Formation (subunit 76 of Goldberg et al.,

1971). This level is situated approximately 220 m above the ammonite *Bullatimorphites bullatus* (d'Orbigny) (Figs. 3 and 10) known in Europe from the uppermost Bathonian and lowermost Callovian beds (herein attributed to the Upper Bathonian due to its association with *Eudesia*, as well as to its close position above the Middle Bathonian *Micromphalites*; Fig. 10). The Callovian-Oxfordian foraminiferid *Pseudocyclammina (?)smouti* Banner (Frenkel, 1975) occurs 150 m below the *M. bathonica* Subzone. If the *M. bathonica* Subzone was exclusively of Late Bathonian age, a sequence of some 200 m would have to be attributed to the Upper Bathonian, whereas the Upper Callovian ammonites occur 100 m above this subzone (the base of the Upper Callovian is herein tentatively placed 20 m above *M. bathonica* Subzone at the base of the Upper Zohar Formation as suggested for the Negev, Israel).

The foraminiferid *M. bathonica* was first described from the Paris Basin where it is found in a nodular limestone unit (Aurouze *et al.*, 1956), overlying Lower Bathonian rocks and overlain by oolitic limestone followed by dark colored marl of Late Callovian *(Peltoceras athleta)* age (Furrer and Septfontaine, 1977). Therefore, the maximal range of *M. bathonica* could be from the Middle Bathonian to the Middle Callovian. However, in the Jura region (Dôle, France) *M. bathonica* occurs within the middle part of the Late Bathonian *Clydoniceras discus* Range Zone. This is one of very few stratigraphically controlled occurrences of this foraminiferid. According to Furrer and Septfontaine (1977), *M. bathonica* may be missing in Upper Bathonian rocks containing *Clydoniceras discus* of a certain lithofacies. Its absence in similar rocks of Callovian age does not necessarily imply its non-existence during the Callovian. The stratigraphic control of *M. bathonica* (and its accompanying *Kilianina blancheti* Pfender and *Pfenderina* sp.) is rather poor. This is perhaps due to the lithofacies favored by these foraminiferids, i.e., hard rock which is unsuitable for the existence, preservation or recognition of ammonites or other macrofossils. Thus all other levels in question were dated by a few occurrences of *M. bathonica* with Upper Bathonian fauna. Therefore, Furrer and Septfontaine (1977) were careful in dating this so-called Upper Bathonian index fossil, giving it a possible range of Middle-Upper Bathonian to Callovian(?). The occurrence of M. bathonica Subzone at Gebel Maghara more than 200 m above the Upper Bathonian *Bullatimorphites bullatus* and some 150 m above the Callovian-Lower Oxfordian foraminiferid *Pseudocyclammina(?) smouti* Banner (Frenkel, 1975), support the probable existence of *M. bathonica* during Callovian (at least Early) times (Fig. 10).

Vail *et al.*, (1977) recorded a global regression at the Bathonian-Callovian boundary followed by a quick Callovian transgression. *M. bathonica* occurs in Israel in the upper part of a reefal calcarenite (Lower Zohar Formation=Brur Formation) overlying clay, oolitic limestone, marl and silt (Karmon and Sederot formations=Sherif Formation; Fig. 11). This implies that *M. bathonica* already lies high within the transgressive sequence, namely, in Callovian strata according to Vail *et al.* (1977).

(d) The boundary between the Lower and the Upper Zohar Formation

The lower 9 m of the exposed Tsia Member at Makhtesh Hatira and the 25 m of the Halamish Member below it (subsurface) did not yield any ammonites (Fig. 7). The Callovian-Oxfordian nannofossil *Stephanolithion bigoti* Deflandre occurs at the base of the Halamish Member (base Upper Zohar Formation) - (the range of *S. bigoti*, in the sense of Medd, in England is from the base of the Middle Callovian to the Lower Kimmeridgian; Medd, 1982). The Halamish Member overlies the top of the Lower Zohar Formation which contains *Meyendorffina bathonica* (drillhole Zohar 5; Moshkovitz and Ehrlich, 1976). The 34 m barren of ammonites at the base of the Upper Zohar Formation in Makhtesh Hatira are composed of shale, clay, silt and sandy limestone and dolostone layers (Goldberg, 1963). They show a gradual decrease in silt and sand from bottom to top and a transition from dolomite in the lower part of Halamish Member to a sandy oolitic limestone at its top. The lower part of the overlying Tsia Member is sandy-marly becoming limy upwards. Gill (1966) and Goldberg (1967) described syngenetic dolomites and erosion channels in the lower part of the Tsia Member at Makhtesh Hazera (20 km east of Makhtesh Hatira), indicating that this region was shallow marine and partly exposed at the time of deposition. The lower part of the Upper Zohar Formation in the Negev apparently represents a transgressive sequence with a high rate of clastic deposition during a short period rather than a condensed sequence representing the time

span between the Lower Callovian (post *M. bathonica)* and the Upper Callovian. The clastic-enriched lower part of the Upper Zohar Formation overlies fossiliferous calcarenite of the Lower Zohar Formation (Hakana'im Member), forming a lithological break between the Lower and the Upper Zohar Formation. This boundary can be lithostratigraphically and biostratigraphically traced to the coastal plain of Israel, where the Lower Zohar Formation of the Negev is regarded the lithostratigraphic equivalent of the Brur Formation (with *M. bathonica* in its upper part). No limy lithostratigraphic equivalent of the Upper Zohar Formation occurs there (Barzel and Friedman, 1970). The Brur Formation varies in thickness (30-90 m) and shows local dolomitization, mineralization and karstic phenomena (Goldberg and Bogoch, 1978; Buchbinder, 1979) hinting at an unconformity with the Kidod Formation above, as indicated by Foraminiferida and nannofossils (Moshkovitz and Ehrlich, 1981).

The boundary between the Lower and the Upper Zohar Formation at Mount Hermon and Gebel Maghara is less clear. However, it is suggested that it be inserted at the top of the Meyendorffina bathonica Zone, at the top of subunit 3 of the section at Majdal Shams (Mount Hermon; Goldberg, 1969) where dolomitization, silicification and karst phenomena are abundant. At Gebel Maghara this boundary is placed herein at top subunit 77 of Goldberg *et al.* (1971) where silicification is common *(M. bathonica* Subzone recognized at subunit 76); this unit is overlain by shales with limonite concretions.

The boundary between the Lower and the Upper Zohar Formation is herein regarded as indicating a profound paraconformity between the Upper Bathonian (Lower Callovian, as suggested in this study) Lower Zohar Formation (=Brur Formation) and the Upper Callovian Upper Zohar Formation (probably correlative to the lower part of the Kidod Formation of the coastal plain of Israel (Fig. 11).

III. Stratigraphic Correlation With Adjacent Regions

(a) Saudi Arabia

The biostratigraphy and the ages attributed to the lithological units of the Jurassic outcrops at Gebel Tuwaiq (central Saudi Arabia) were based mainly on ammonites (Arkell, 1952; Imlay, 1970). Other studies, such as on foraminiferids (Redmond; 1964a, 1964b, 1965), echinoids (Kier, 1972) and other faunal groups recorded in Powers *et al.* (1966) contributed additional stratigraphic data but generally did not change the ages attributed by Arkell (1952) on the basis of the ammonites.

Ammonites collected by a team of the U.S. Geological Survey and ARAMCO geologists enabled Imlay (1970) to improve Arkell's (1952) ammonite biostratigraphy of the same region. At the base of the Middle Dhruma Formation, Imlay (1970) distinguished a *Spiroceras* unit of Late Bajocian overlain by the *Thambites* and *Dhrumaites* unit of Early Bathonian age, assigning *Clydoniceras pseudodiscus* Arkell to its upper part. The latter unit is overlain by the *Tulites* unit followed by the *Micromphalites* and *Thambites* unit, both of Middle Bathonian age. The succeeding *Dhrumaites* unit contains at its top *Dhrumaites cardioceratoides* Arkell which Arkell (1952) attributed to the Upper Bathonian. Overlying this unit is the Upper Dhruma Formation which is divided into two members: the lower limy 'Atash Member (25 m) and the upper shaly Hisyan Member (Fig. 10). The 'Atash Member is made up of calcarenitic and some aphanitic limestone and contains the Bathonian brachiopods: *Eudesia cardium* (Lam.) and *E. cardioides* Douvillé (Arkell, 1952, p. 247; Powers *et al.*, 1966, Pl. 7). At 11 m above its base a new echinoid assemblage occurs, comprising species different from those in the Middle Dhruma Formation (Kier, 1972). *Pachyceras* cf. *P. schloenbachi* (Roman) and *Grossouvria* sp. also first occur at the same level, whereas several *Pachyerymnoceras* species start to appear (a little higher) below the top of this member. This *Pachyerymnoceras* assemblage (Fig. 10) ranges throughout the upper part of the 'Atash Member into the Hisyan Member and the lower 25-40 m of the lower part of the Tuwaiq Mountain Formation (Imlay, 1970, p. D7). This assemblage comprises *Pachyerymnoceras* and *Pachyceras* species of Late Callovian age which were previously attributed by Arkell (1952) and Imlay (1970) to the Middle Callovian, and later in part redefined and redated by Zeiss (1974). The Bathonian *Eudesia* species recorded by Arkell (1952, p. 247) from the 'Atash Member must have originated from the lower 11 m, i.e., below the beginning of the Upper Callovian ammonite assemblage. Thus a paraconformity is inserted at 11 m above base 'Atash Member, separating Upper Bathonian rocks (with *Eudesia*) from Upper Callovian rocks (Figs. 10, 11). From Arkell's (1952)

assumption that *Dhrumaites* does not range into the Lower Callovian, Imlay (1970, p. D7) noted the absence of Early Callovian ammonites. Kier (1972) suspected such an unconformity on the basis of the complete change in the echinoid assemblages between the Middle and Upper (11 m above base 'Atash Member) Dhruma Formation. Dunnington *et al.* (1959) indicated a similar Bathonian-Callovian unconformity in Iraq.

(b) Lebanon and Syria

The most studied Jurassic outcrops of Lebanon and Syria occur at Mount Hermon. The Jurassic strata at its southern flank were measured and sampled by Goldberg (1969), who assigned Israeli formation names to the lithologic units J1-J7 described by Dubertret (e.g., 1963, 1966). Ponikarov (1967) made a synthesis of litho-, bio- and chronostratigraphic units dividing the sequence into J 1-3 with subdivisions according to stages (e.g., J2bt = Bathonian; J3cl = Callovian). The 717 m of the Callovian J3cl consists of 700 m of limestone attributed to both the Lower and Upper Callovian which contain *Erymnoceras* at the top. The remaining overlying 17 m consists of argillaceous limestone containing Upper Callovian ammonites (Ponikarov, 1967). Dubertret (1955, 1966) recorded *Erymnoceras coronatum* (Bruguière) from this upper unit (14.5 m) and attributed it to the Upper Callovian on the basis of accompanying Upper Callovian ammonite species. This casts some doubt on the identification of *E. coronatum* which is herein suspected to be a *Pachyerymnoceras* species. ?*Quenstedtoceras (Pavloviceras)* ?*mariae* (d'Orbigny) from Mount Hermon (Haas, 1955, p. 120, Pl. 18, Figs. 22-25) is quite a large, limy, natural cast from an unknown precise stratigraphic level within the Callovian-Oxfordian fossiliferous sequence. It differs by its dimensions and limy nature from the pyritized, rather small ammonites of Early Oxfordian age described by Haas (1955) from this locality. This single, corroded ammonite closely resembles the *Pachyceras*-like adult stage of *Pachyerymnoceras* (Late Callovian). Due to its calcareous composition it is thought to originate from the fossiliferous argillaceous limestone (top Zohar Formation) just below the dark shale with the pyritized fauna (Kidod Formation), from which Upper Callovian ammonites were recorded (Dubertret, 1955, 1963; Ponikarov, 1967).

Dubertret (1963) combined the 14.5 m of the fossiliferous argillaceous limestone with the overlying clay (containing the Lower Oxfordian *Creniceras renggeri* (Oppel); Haas, 1955) into the unit J5. Due to the remarkable lithological and faunal change between the clay and the underlying argillaceous limestone, several authors considered the J5 as comprising only the Lower Oxfordian clays, known in Israel as the Kidod Formation. The Meyendorffina bathonica Zone in this section was traced by Derin (in Goldberg, 1969) throughout a biomicritic limestone (subunits 1-3 of Goldberg, 1969) at the upper part of which karstic phenomena and dolomite with chert nodules occur, suggesting a sedimentary omission surface. This surface is herein regarded as the boundary between the Lower and the Upper Zohar Formation where the boundary between the Bathonian (or Lower Callovian) and the Upper Callovian is tentatively inserted.

(c) Abu Darag Region, Eastern Egypt

The ammonites of the Jurassic outcrops in the Abu Darag region (western side of Gulf of Suez) recorded by Abdallah *et al.*, (1965) seem to belong to the Upper Callovian on the basis of *Pachyceras* cf. *lalandei* and the so-called *Erymnoceras* and *Clydoniceras*, recalling the *Pachyerymnoceras* and *Levanticeras* nov. gen. of northern Sinai. *Nubidites omarai* of Wiedmann and Kullmann (1979) from Nubian sandstone near Abu Darag is herein suspected to be a young *Levanticeras levantinense* nov. gen. and sp., and probably the *Clydoniceras* of Abdallah *et al.* (1965). However, due to its very young stage it is difficult to compare it to our advanced growth stages. The Jurassic outcrop at Abu Darag is herein regarded as representing the Late Callovian transgression (Athleta-Lamberti Zone) as in northern Sinai and Israel.

(d) Zerqa River, Jordan

A few outcrops of Jurassic sediments occur in the central Jordan Valley along a segment of the Zerqa River (Yaboq). Most fossils collected there point to Bajocian (?) and Bathonian ages whereas some paleontologists extended their ages to the Callovian and even to the Oxfordian (see in Bender, 1974; Basha, 1980). The lithostratigraphic correlation of the Jurassic strata in the Zerqa River area with those in Israel as suggested by Bandel (1981) lacks the necessary biostratigraphic and chronostratigraphic data for the recognition of the equivalents to the Upper Callovian Zohar and Kidod formations of Makhtesh Hatira in Jordan

(Bandel, 1981, p. 290). The occurrence of *Eudesia* near the top of this sequence indicates a Middle to Late Bathonian age for the upper part of the Jurassic sequence at the Zerqa River area (Delance, 1982, pers. comm.).

THE NATURE OF THE UNCONFORMITY

The local karstic phenomena, dolomitization and mineralization of the Brur Formation (= Lower Zohar Formation) in the coastal plain of Israel (e.g., Buchbinder, 1979), associated with a biostratigraphic unconformity (Moshkovitz and Ehrlich, 1981) is the only clear evidence of an unconformity there between Upper Bathonian (or Lower Callovian, as suggested herein) and Upper Callovian (?Lower Oxfordian) rocks. This unconformity is traced throughout Israel and northern Sinai to central Saudi Arabia. The lithology on both sides of the assumed unconformity plane is quite similar and no change in the bedding plane, no conglomerates or undisputed hardgrounds occur. However, a reevaluation of the minor lithological changes at this level makes it possible to reconsider the presence of a paraconformity between the Lower and the Upper Zohar Formation, for example at Makhtesh Hatira, which was noted by Goldberg (1963). He later ignored this paraconformity due to the excellent lithostratigraphic correlation of the formations and members of the Mid-Jurassic sequence across the Negev (Israel) to northern Sinai, which more or less retain the same nature and thickness (e.g., Goldberg and Friedman, 1974). The hiatus at Gebel Tuwaiq ranges from the latest Bathonian to the Late Callovian. The extent of this hiatus in Israel and Sinai is less clear and would be considerably reduced if *M. bathonica* really did range into the Early Callovian and even more so if it ranged into the Middle Callovian. Nevertheless, the clear biostratigraphic unconformity at Gebel Tuwaiq and in the coastal plain of Israel suggests a similar situation in the Negev (Israel).

Late Callovian ammonites (*Pachyerymnoceras*, as well as *Pachyceras* or *Levanticeras* nov. gen.) are the first marine fossils in the lowermost part of the transgressive sequence, just above the Upper Bathonian (Gebel Tuwaiq) or Bathonian(?) (coastal plain of Israel, Gebel Maghara) assemblages, and at the base of the marine sequence at Abu Darag (Egypt). The beginning of this transgression, which overlies different levels of earlier strata, seems to be well dated (Late Callovian) and isochronous. The similar ammonite assemblages in the lower part of the Late Callovian transgression suggest that it was extensive and rapid. Therefore, the 34 m of mainly clastic sediments (Halamish Member and lower 9 m of the Tsia Member) barren of ammonites, at the base of this transgressive sequence at Makhtesh Hatira (Negev, Israel) are assumed to represent a high rate of sedimentation and unfavorable living conditions for ammonites (although the lack of ammonites even in the exposed basal 9 m of the Tsia Member at Makhtesh Hatira may be due to their general scarcity, as well as to the small dimensions of the exposure). Since this lower part of the Upper Zohar Formation is herein regarded as a rapidly deposited, mainly clastic (sea-marginal to shallow marine) unit at the beginning of the transgression, it is dated as Late Callovian on the basis of similarly dated ammonites or nannofossils at the base of the transgressive sequence in Saudi Arabia and the coastal plain of Israel.

The following environmental development during the late Mid-Jurassic is suggested to have formed the proposed paraconformity with a hiatus of up to 4-5 million years in Saudi Arabia (according to van Hinte's, 1976, time scale). During the Late Bathonian, the present-day regions of northern Sinai, Israel, Lebanon and central Saudi Arabia were part of an almost level, shallow marine shelf environment. The level nature of the bottom was attained following a long period of clastic supply from the continent, which gradually also levelled the nearby terrestrial regions. This terrigenous material intermixed with the marine carbonate particles, mainly skeletons of benthonic organisms, all well-distributed by the currents (demonstrated by the clear and extensive lithostratigraphic correlation of the members of the Sherif Formation). In Early Callovian (as suggested herein) times, a minor transgression resulted in the accumulation of reefal limestone. Thereafter, this shallow marine area was exposed without discernible tilting. This drop in sea level was possibly caused by a regional eustatic event as a result of which the Tethys of the Middle East retreated more than 100 km seawards. The level nature of the exposed shelf bottom and the nearby continent was not affected by the regression, hence resulting in a geographically limited, very minor erosion of the exposed area. Furthermore, during the gradual sea-level drop the unlithified rocks may have been subjected to

lagoonal and sabha-type environments, leading to dolomitization and silicification and thus to hardening of the upper part of the exposed layers, which later resisted destruction by weathering (e.g., top *Meyerdorffina bathonica* Zone, subunit 3 of Goldberg, 1969, at Mount Hermon; middle Zohar Formation, subunit 77 of Goldberg *et al.*, 1971, at Gebel Maghara, northern Sinai).

Tectonic quiescence during the time of exposure prevented the development of relief and the accumulation of terrestrial clastic sediments in the lows. Only in limited regions (e.g., the southern coastal plain of Israel) were the exposed rocks subjected to some erosion and karstic processes, leading to variations in thickness of the Brur Formation (30-90 m), dolomitization and the mineralization of voids and channels by quartz - fluorite- Fe-dolomite (Buchbinder, 1979) and siderite (L. Buchbinder, 1981, pers. comm.).

The upper part of the Lower Zohar Formation (Hakanaiim Member), as well as its lithostratigraphic equivalent in the coastal plain of Israel (Brur Formation), is generally composed of limestone. The overlying lower part of the Upper Zohar Formation (Halamish Member) has a variable lithology in different regions (clay, marl, limestone and dolomite, all with varying amounts of silt), changing upward into a "deeper marine" lithofacies. This transgressive nature characterizes both members of the Upper Zohar Formation, with a gradual increase in marine influence from the lower Halamish Member into the overlying Tsia Member. Therefore, both are herein attributed to the same sedimentary phase, which is assumed to have been rapid and of Late Callovian age, although the first age-indicative ammonites occur 9 m above base Tsia Member (Makhtesh Hatira, Negev, Israel; Fig. 7). Higher in the sequence, the Upper Zohar Formation becomes limy, forming together with the limy Lower Zohar Formation, a calcareous unit clearly distinguished from the shaly Sherif Formation below (or Karmon Formation; Fig. 11) and the Kidod Formation above.

A similar intraformational unconformity occurs in central Saudi Arabia, where the discontinuity plane separates the 'Atash Member (Upper Dhruma Formation) into a lower Late Bathonian sequence of 11 m, overlain by 14 m of aphanitic limestone of Late Callovian age.

GEOLOGICAL HISTORY

The Middle Eastern countries (Egypt, Israel, Jordan, Saudi Arabia, Lebanon and Syria) were part of a broad shelf surrounding the Arabo-Nubian craton in Middle Jurassic times. Sea-level oscillations, as well as varying rates of supply of clastic material from the continent, were the main factors which determined the nature of the Middle Jurassic rocks (see: Goldberg and Friedman, 1974).

The rather dry tropical conditions during the Lower Liassic (evaporites of the Ardon Formation in southern Israel) were followed by a humid tropical climate from Mid-Liassic times onward. This is indicated by the accumulation of thick fluviatile and deltaic clastic sediments partly intermixing with shallow marine ones, all rich in iron-oxides and plant remains (Inmar Formation in Israel, Marrat Formation in Saudi Arabia), resulting from a high rate of clastic supply from the continent. A late Mid-Bajocian transgression penetrated landward and reached Makhtesh Ramon in southern Israel (Daya Formation = Mahmal Formation). The marine environments during the Middle and Upper Bajocian are well represented by fossiliferous marl and limestone in northern Sinai (Bir Maghara Formation = Daya Formation) and Saudi Arabia (Lower Dhruma Formation). This Bajocian transgression is followed by a slight regression at the beginning of the Bathonian, which deposited sandstone and shale with plant remains in northern Sinai (lower part of Safa Formation of Al-Far, 1966, lithostratigraphic equivalent of the Sherif Formation in Israel). The marine influence increased during the Middle and Upper Bathonian although generally, the whole region was under a very shallow sea and even temporarily affected by terrestrial conditions (Mid-Bathonian coal bed at Gebel Maghara). The Middle and Upper Bathonian sediments were enriched in fine clastics forming shale layers interbedded with limestones in northern Sinai, in the northern Negev (Israel) and in the coastal plain of Israel (Karmon Formation; Fig. 11). The Bathonian-Callovian boundary may lie within this shaly lithofacies as proposed herein. Towards the upper part of this shaly unit, sandstone beds, iron-oxide concretions, oncolites and gypsum occur and macrofossils become rare. This clastic sequence indicates a period of great influx of terrigenous material from the continent into the broad, shallow marine environment, leading to a leveling of the sea bottom, as well as of the nearby continent, accompanied by sea shallowing. Thereafter a rather rapid subsidence of the shelf region (approximately 20-40 m) occurred, resulting in the sedimentation of aphanitic and calcarenitic

limestone containing corals, stromatoporoids with some molluscs and brachiopods in northern Sinai and the coastal plain of Israel (Brur Formation = Lower Zohar Formation). This limy lithofacies contains the *Meyendorffina bathonica* Assemblage mainly in its upper part, herein assumed to range into the Lower Callovian.

In Early Callovian times (post *Meyendorffina bathonica* Assemblage Zone), a regional eustatic drop in sea level occurred. Due to the rather level relief of the former broad, shallow shelf-region, this regression exposed large areas of the present-day Middle East. The gradually exposed level topography was subjected to minor erosion or non-deposition due to a lack of tectonism during this period. However, meteoric water may have affected the exposed rocks (karstic phenomena; Buchbinder, 1979). The lacuna increases landwards up to an interval from the Late Bathonian to the Late Callovian at Gebel Tuwaiq, Saudi Arabia.

The Late Callovian (Athleta-Lamberti Zone) sediments represent a rapid transgression in the southern Tethyan regions, distributing European fauna into the Eritrean-Indian region (e.g., *Pachyceras* and *Pachyerymnoceras* in Eritrea, Somalia and Cutch).

The accumulation of residual clay minerals which were carried seawards during the Late Callovian transgression may have resulted from the pre-Upper Callovian aereal exposure and minor erosion. These fine clastics were distributed by currents, forming a shaly unit (Kidod Formation) overlying the Brur Formation, whereas in the shallow marine environments these clays intermixed with the calcareous bioclastics forming the marl and argillaceous limestone of the Upper Zohar Formation in the Negev, Israel (Fig. 11). Although the entire region (present-day Sinai, Lebanon, central Saudi Arabia) was a shallow shelf, various sedimentary environments prevailed due to the position of river-mouths, current pattern and bathymetry. These factors controlled the development of coral reefs and other faunal niches, as well as the dispersal of fine clastics and the formation of dolomite in lagoons. Thus from the Late Callovian onward, limestone and marl (Upper Zohar and lower part of Be'er-Sheva Formation) or pure limestone (partly dolomitized; Nir'am Formation) accumulated, interfingering and intermixing with clays (Kidod Formation).

With the beginning of the Lower Oxfordian, the region seems to have subsided during another eustatic (?) pulse, shifting the belt of benthic productivity southeastward (landward). Bioclastic carbonate supply into the newly formed "deep" marine regions was drastically reduced, whereas fine clastics accumulated, forming a thick shale unit (Kidod Formation, which started to accumulate elsewhere already from the Upper Callovian; 155 m at Mount Hermon, J5; 64 m at Gebel Maghara). These shales contain very few benthonic faunas, mainly small, mud-dwelling bivalves (e.g., *Nucula)* whereas plankton (foraminiferids and nannofossils e.g., Moshkovitz and Ehrlich, 1976) and nekton (ammonites; e.g., Haas, 1955) are abundant in the lower part of the shaly unit. All originally aragonitic skeletons formed pyritic internal moulds before dissolving. The biota and the diagenetic processes indicate that the surface water was normal marine whereas at the bottom, reducing conditions prevailed, perhaps due to oxygen consumption by the decomposition of the organic matter within the shales. The high rate of deposition resulted in the rapid burial of the undamaged skeletons in a non-bioturbated sediment. The rather small dimensions of the fauna (as well as the fine-grained sediments) point to a low energy environment, apparently with minor vertical intermixing (during the same times, a similar facies prevailed in Europe, known in England as the Oxford Clay; e.g., Duff, 1975). Upwards in the shaly section fossils decrease in number and the environmental conditions seem to be unfavorable even for nekton and plankton. This may be due to the closure of the area by a barrier reef (Nir'am Formation) which developed more or less along the present-day Mediterranean coastline of southern Israel, partly sealing the eastern (landward) basin from the open sea.

This paleoenvironmental reconstruction generally agrees with that suggested by Derin and Gerry (1972, Fig. 4a), which differs from the present scheme in the timing and in the pre-Upper Callovian lacuna. However, both schemes suffer from lack of precise age determination of the Kidod Formation, overlying the Brur Formation in the coastal plain of Israel (suggested here to be of Late Callovian age, coeval to the Upper Zohar Formation - see: Barzel and Friedman, 1970) which bears directly on the geological history of the area.

SYSTEMATIC PALEONTOLOGY

The systematic order of the descriptions of the ammonites is based on Arkell (1957) with some emendations according to Donovan *et al.* (1981). The small number of specimens, as well as their state of preservation precluded relating them to the suggested dimorphic connections between *Pachyceras* and *Pachyerymnoceras* or between *Peltoceras* and *Rursiceras* (e.g., Charpy and Thierry, 1977; Callomon, 1963; Callomon, pers. comm., 1981). Hence these taxa are herein described as separate genera.

The morphological features measured are diameter (D), height of whorl (H), its width (W) and the diameter of the umbilicus (U); all measurements are in millimeters.

All illustrations are in natural size unless otherwise marked. Arrows indicate the last septal suture and the beginning of the body-chamber.

Family PHYLLOCERATIDAE Zittel, 1884
Genus and Subgenus PHYLLOCERAS Suess, 1865

Type species: *Am. heterophyllus* J. Sowerby, 1820

Phylloceras (Phylloceras) plicatum Neumayr
Pl. 1, fig. 5

1887 *Phylloceras plicatum* Neumayr, Noetling, p. 14; Pl. 2, fig. 2.
1915 *Phylloceras plicatum* Neumayr, Lóczy, p. 283; text-fig. 6.
1955 *Phylloceras (Phylloceras) plicatum* Neumayr, Haas, p. 14; Pl. 1, figs. 1-5, 8-13.

DESCRIPTION: Involutely coiled, whorl section compressed, ovate with subparallel flanks in the inner whorls, becoming with growth more rounded and inflated in the middle of the flanks. W/H increases with growth from 12.1/20.6 = 0.59 to 29/44 = 0.66. The shell is ornamented by fine, flexuous striae, superimposed on very low, similarly flexuous lateral ribs. Each stria may be traced from the umbilical seam across the venter without furcating. Therefore, the striae are very fine and dense near the umbilicus, becoming relatively broader and more widely spaced towards the venter which they cross with a gentle adorally convex flexure. Sutures not preserved.

DISCUSSION: The compressed, ovate whorl section and the striae superimposed on low ribs characterize this species. Therefore, the broad form of Haas (1955, Pl. 1, figs. 6-7) is excluded herein from the synonymy. The main saddles in the suture of *P. plicatum* are diphylloid, so that this species should have been assigned to *Hypophylloceras* rather than to *Phylloceras* s. str. according to the criteria suggested by Wiedmann (1962). However, *Hypophylloceras* is attributed to the Cretaceous only, therefore, for the time being the species *plicatum* is still included in *Phylloceras*.

AGE: Lóczy (1915, p. 450) recorded *P. plicatum* from the Lower Bathonian to Upper Oxfordian strata in south-central Europe. The specimens of Noetling (1887) and Haas (1955) originate from Lower Oxfordian shales (Kidod Formation; Renggeri-Zone) at Mount Hermon, whereas our specimens occur in the underlying Zohar Formation.

MATERIAL AND OCCURRENCE: (Type No. 1231) M-6046, 5384 (coll. M. Goldberg and M. Raab), Makhtesh Hatira, Upper Zohar Formation (Tsia Member); M-7745(6) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation; M-7852 (coll. Z. Lewy), Gebel El-Minshera, top Zohar Formation (Unit 7).

Genus SOWERBYCERAS Parona and Bonarelli, 1895

Type species: *Ammonites tortisulcatus* d'Orbigny, 1849

Sowerbyceras tietzei Till
Pl. 1, figs. 1-3

1915 *Phylloceras tietzei* Till, Lóczy, p. 305; Pl. 3, figs. 2-3, text-figs. 28-29.

DESCRIPTION: Involutely coiled, compressed conch with flattened flanks and an almost flat venter. The umbilicus is small with a low rounded wall. The dimensions of the best preserved specimen (M-7745) are: D = 36.0, H = 18.3(0.50), W = 14.3(0.40), W/H = 0.78, U = 5.6(0.16). The internal mould is smooth, with strongly prorsiradiate constrictions, five per volution (D = 36 mm) which vary in strength but keep the ventral rib-like pre-constrictional labial ridges in all specimens (Pl. 1, fig. 3). The constrictions are sygmoidal with a strong labial, adapical curvature. Sutures not preseved.

DISCUSSION: The strongly prorsiradiate constrictions and the whorl section are similar tothose of *Sowerbyceras tietzei* Till of Lóczy (1915). Our material, as well as the Hungarian, differs from that of Jeannet (1951, Pl. 5, fig. 10) under the name *S.* cf. *tietzei* Till, by the larger umbilicus of the latter. *S. helios* (Noetling) from the Lower Oxfordian of Mt. Hermon (Haas, 1955) and northern Sinai is broader than our specimens, which stratigraphically occur below *S. helios*.

AGE: The Hungarian material was recorded from the Lower and Middle Callovian (Lóczy, 1915, p. 437) whereas Jeannet's (1951, p. 29) is restricted to the Upper Callovian (Athleta-Zone).

MATERIAL AND OCCURRENCE: (Type No. 1378) M-7745(1), 7746(2) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation; M-6006(1) (coll. M. Goldberg and M. Raab), Makhtesh Hatira, 5 m above base Be'er-Sheva Formation.

Sowerbyceras sp.
Pl. 1, fig. 4

DESCRIPTION: Platycone, compressed, rather involute conchs.

MEASUREMENTS:

	D	H	W	W/H	U
M-7746:1	19.2	9.8(0.50)	8.0(0.41)	0.81	3.5(0.18)
M-7745:1	21.8	12.0(0.50)	10.3(0.49)	0.86	6.6(0.30)
M-7746:2	39.0	19.4(0.50)	15.7(0.40)	0.80	8.0(0.20)

The umbilicus is generally a fifth of the diameter ranging to nearly a third in a few specimens. The flanks are flattened and the venter gently rounded. The conch is completely smooth except for a few, widely spaced ventral labial ridges which mark the position of the very shallow, almost invisible constrictions (thereby differing from the smooth Jurassic Haploceratidae). Sutures not preserved.

DISCUSSION: This form differs from the more involute and clearly constricted *Sowerbyceras tietzei* Till. The single well-preserved specimen (in addition to fragments) does not enable deciding whether this form completely lacks the constrictions and is thus meanwhile undeterminable.

MATERIAL AND OCCURRENCE: (Type No. 1379) M-7745(6), 7746(5) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

Family LYTOCERATIDAE Neumayr, 1875
Genus LYTOCERAS Suess, 1865

Type species: *Ammonites fimbriatus* J. Sowerby, 1817

Lytoceras sp. cf. *L. adelae* (d'Orbigny)
Pl. 1, figs. 13-14

cf. 1844 *Ammonites adelae* d'Orbigny, p. 429; Pl. 1, figs. 10-11.
cf. 1964 *Lytoceras adelae* (A. d'Orbigny), Pugin, p. 13; Pl. 1, fig. 2.

DESCRIPTION: The poorly preserved fragment has a circular whorl section. The outer volution is ornamented with annular riblets, more or less evenly spaced, with shorter and finer secondary ones occasionally in between the primaries. The riblets are slightly flexuous, rursiradiate on the umbilical wall, prorsiradiate on the flanks becoming rursiradiate towards the venter which they cross with a gentle adapically convex curvature. No flares or constrictions occur on the fragment.

DISCUSSION: Our poorly preserved fragment does not permit definitive species identification.

AGE: Pugin (1964) revised the definition of d'Orbigny's (1844, 1849) *Am. adelae* and attributed this species to the Upper Bajocian-uppermost Callovian.

MATERIAL AND OCCURRENCE: (Type No. 1376) M-7745 (coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

Family OPPELIDAE Bonarelli, 1894
Subfamily HECTICOCERATINAE Spath, 1923
Genus LUNULOCERAS Bonarelli, 1893

Type species: *Nautilus lunula* Reinecke, 1818

Lunuloceras sp. cf. *L. lunuloides* (Kilian)
Pl. 1, fig. 6

cf. 1932 *Hecticoceras lunuloides* Kilian, Corroy, p. 91; Pl. 3, fig. 3.
cf. 1951 *Lunuloceras lunuloides* Kilian sp., Jeannet, p. 58; Pl. 12, figs. 10-11; Pl. 13, figs. 3-6, text-fig. 128.
?1951 *Lunuloceras* cf. *grossouvrei* Par. and Bon. sp., Jeannet, p. 59; Pl. 13, figs. 7-8.
?1975 *Sublunuloceras discoides* Spath, Gill and Tintant, p. 103.

DESCRIPTION: A small (D = 26 mm) half specimen, slightly corroded, rather involutely coiled (U/D approximately 0.29); whorl section high and narrow (W/H = 7/13 = 0.54) with a fastigate, unicarinate venter, subparallel flanks, angular, umbilical shoulder and a steep, low umbilical wall.

The shell is ornamented by low, gently falcoid ribs which are very weak or even absent at the dorsal part of the flanks, strengthening ventrally although remaining low. Some ribs bifurcate at the middle of the flank, thereby, changing slightly from prorsiradiate to radiate. The venter and the umbilical wall are smooth. Sutures not preserved.

DISCUSSION: Our specimen is very similar to the other recorded *lunuloides* specimens but its poor state of preservation does not enable undoubtable specific identification. Among the specimens attributed by Jeannet (1951) to *lunuloides* are some quite evolute (U/D = 0.37) and broad (W/H = 0.63) ones which stratigraphically occur above the typical forms. *Lunuloceras* cf. *grossouvrei* Par. and Bon. in Jeannet (1951, p. 59; Pl. 13, figs. 7-8) are rather involute and compressed with weak to almost no ornament on the dorsal half of the flanks. Thus our specimen, like that of Corroy (1932), is close to some of the morphological varieties included by Jeannet under *lunuloides* and cf. *grossouvrei*. *Orbignyceras paulowi* Tsytovitch of Jeannet (1951) comprises a variety of morphotypes, ranging from Middle Callovian to the Lower Oxfordian. Some of these specimens resemble our fragment, although most have well developed concave ventral shoulders, forming a biconcave venter. Gill and Tintant (1975) recorded (without figuring) *Sublunuloceras discoides* Spath, from the same stratigraphic level in Makhtesh Hatira where our specimen originates; therefore, it is possible that it represents the same form.

AGE: Jeannet (1951, p. 58) recorded this species from lowermost Callovian, Middle Callovian to Lower Oxfordian rocks.

MATERIAL AND OCCURRENCE: (Type No. 1366) M-7810 (coll. F. Hirsch), Makhtesh Hatira, lower part of Be'er Sheva Formation.

genus KHERAITES Spath, 1925

Type species: *Harpoceras crassefalcatum* Waagen, 1875

Kheraites ferrugineus Spath
Pl. 1, figs. 9-12

1928 *Kheraites ferrugineus* Spath, p. 110; Pl. 9, figs. 6 a-c.

1951 *Kheraites ferrugineus* Spath, Jeannet, p. 51; Pl. 11, figs. 5-7, text-figs. 111-112.

DESCRIPTION: Evolutely coiled, planulate conch. The whorl section is almost quadrangular with sub-parallel flanks and a broad, low fastigate venter.

MEASUREMENTS:

	D	H	W. max.	W/H	U
M-7745:1	30.5	14.6(0.48)	11.3(0.37)	0.77	8.3(0.27)
M-7745:1	41.5	19.3(0.46)	14.0(0.33)	0.72	11.2(0.27)

The young ontogenetic stage is smooth up to a diameter of 6-7 mm, where ribs appear, becoming stronger with growth. Over a diameter of 15 mm, it attains the characteristic ornament of falcoid primary ribs, some of which bifurcate at the middle of the flanks. The primaries are intercalated by short ventrolateral secondaries which may approach the primaries looking as if they furcate from them. All ribs become broader and stronger on the venter in the form of prorsiradiate bullae, joining the more elevated siphonal keel. The keel is slightly crenulate with lows in-between consequent ventral ribs. The dorsolateral parts of the primary ribs appear as bullae due to some weakening and thinning of the ribs at the middle of the flanks of the young stage. Sutures not preserved.

DISCUSSION: Our specimens closely resemble those from Cutch and Switzerland, although our single complete specimen has a smaller umbilicus and narrower whorl sections.

AGE: Spath's (1928) type material originates from the Middle Callovian of Cutch. The Swiss specimen of Jeannet (1951, p. 51) is attributed to the uppermost Callovian (Lamberti-Zone).

MATERIAL AND OCCURRENCE: (Type No. 1381) M-7745(6) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

Kheraites intermedium (Spath)
Pl. 1, figs. 15, 16

1928 *Putealiceras intermedium* Spath, p. 112; Pl. 11, figs. 9a, b.

1928 *Putealiceras intermedium* samatrense Spath, p. 112; Pl. 14, fig. 4.

cf. 1951 *Rossiensiceras* cf. *rossiense* Teisseyre, Jeannet, p. 49; Pl. 11, figs. 1-2 (not 3), text-figs. 106 b,c, 107a.

? 1975 *Putealiceras intermedium* Spath, Gill and Tintant, p. 108.

DESCRIPTION: Evolutely, coiled, planulate, compressed conchs. Whorl section high (W/H = 0.62), trapezoidal with a fastigate unicarinate venter. The ornament consists of falcoid primary ribs with a shorter secondary one in between each pair of primaries, starting near the middle of the flank as if the primaries bifurcate. The umbilicolateral part of the ribs tends to weaken and disappear in advanced growth stages whereas the ventrolateral part becomes broader and lower, forming the ventrolateral shoulder. Generally, ornament weakens with growth (Pl. 1, fig. 16). The venter is smooth, fastigate and unicarinate throughout ontogeny.

DISCUSSION: This species has a more compressed whorl section, lower and less fluxuous ribbing and a higher fastigate venter than *K. ferrugineus*. It is herein attributed to *Kheraites* rather than *Putealiceras* due to its unicarinate venter and quite coarse ribbing in early ontogenetic stages. Some of the specimens attributed by Jeannet (1951) to *Rossiensiceras* cf. *rossiense* resemble *K. intermedium* in whorl section and ornament, especially those with the widely-spaced ribbing from the Late Callovian. Gill and Tintant (1975) recorded *Putealiceras intermedium* from the lower part of the Be'er Sheva Formation of Makhtesh Hatira (Israel), the herein assumed biostratigraphic equivalent of top Zohar Formation of Gebel Maghara. *P. intermedium samatrense* Spath (1928, Pl. 14, fig. 4) is identical in ribbing, whorl section and weakening of ornament in advanced growth stages to our specimens, all being similar to the typical *intermedium* (Spath, 1928, Pl. 11, figs. 9a,b) in mode of ornament and whorl section. The coarsely ornamented subspecies *intermedium robusta* Spath (1928, Pl. 12, figs. 9a,b) has a quite similar whorl section, but differs by its very coarse ribbing even in advanced growth stages and therefore it is not included herein in the synonymy. *Putealiceras intermedium* and *P. intermedium irregularis* of Collignon (1958; Pl. 33, figs. 158, 159) have a broad whorl section with a broad, low venter, especially in the young stage, whereas the advanced growth stage of *P. intermedium irregularis* Collignon tends to approach the shape of the unicarinate *intermedium* Spath.

AGE: *K. intermedium* occurs in Cutch together with *Pachyceras indicum* Spath in uppermost Callovian rocks (Duncani to Lamberti Zones; Spath, 1928, p. 113).

MATERIAL AND OCCURRENCE: (Type No. 1382) M-7745(11) coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

Genus BRIGHTIA Rollier, 1922

Type species: *Hecticoceras nodosum* Bonarelli, 1893

REMARKS: Most authors attribute to species of *Brightia* a broad range of intraspecific morphological variations, some of which resemble other species. To reach an undoubtable identification, several well-preserved specimens are needed. Due to the fragmentary, corroded state of our material, the specific identifications are very tentative.

Brightia sp. A
Pl. 1, figs. 17, 18

DESCRIPTION: Small (D = 34.5 mm), broken and partly corroded specimens.

MEASUREMENTS:

M-7670	D	H	W	W/H	U
	34.5	14.1(0.40)	9.7(0.27)	0.68	12(0.35)

Strong prorsidradiate, bullate, dorsolateral ribs bifurcate at the dorsal third of the flank. They continue for a short distance as very low prorsiradiate ribs, which turn back strongly at the dorsal 2/5 of the flank, forming an angle of approx. 125 . The ribs weaken near the fastigate and smooth venter. At the angular turning-point of the ribs, they may be low so that it seems as if a furrow occurs between the dorsolateral, strong bullae and the ventrolateral ribs (Pl. 1, fig. 17). The bullae and the ribs are as broad as their interspaces, thus forming a similar pattern in the dorsal and ventral regions of the flanks. Sutures not preserved.

DISCUSSION: The whorl section, the fastigate, unicarinate venter and the ornament are of *Brightia*. Our specimen is an internal mould and has broad, low, rather widely-spaced ribs which occur in some *Putealiceras* and *Campylites* species (e.g., *P. schummacheri* (Noetling) in Haas, 1955; Pl. 9, figs. 38-40). The venter of our specimen neither has ventrolateral keels in addition to the siphonal one, nor faint ribs, so that a relation to species of the above mentioned genera is excluded. Some *Brightia* species in Jeannet (1951) and Lominadze (1975) have a broad range of morphological variations in respect to ribbing density and mode of involute coiling, e.g., *Brightia svevum* (Bonarelli), *B. metomphala* (Bonarelli). Our single fragment shows some similarity to a number of specimens attributed to these species; however, for an undoubtable specific identification more material from the same stratigraphic level is needed.

MATERIAL AND OCCURRENCE: (Type No. 1232A) M-7670 (coll. F. Hirsch), Makhtesh Hatira, upper part of Be'er Sheva Formation, probably of Early Oxfordian age.

Brightia sp. B
Pl. 1, fig. 19

DESCRIPTION: Two poorly-preserved fragments of an evolutely coiled planulate, unicarinate Brightia. U/D = 11.3/31.4 = 0.36. The ornament consists of broad, bullate, prorsiradiate umbilicolateral ribs which bifurcate at the dorsal third of the flank into adorally concave, rursiradiate ribs, finer than the umbilicolateral ones. Sutures not preserved.

DISCUSSION: This form is quite similar to *Brightia* sp. A from Makhtesh Hatira (Israel), differing from it by finer ribbing. The broad ribs of *Brightia* sp. A may be due to its state of preservation so that both forms from Israel and northern Sinai may be conspecific. Meanwhile, they are regarded separately and neither can be undoubtedly related to any recorded species.

MATERIAL AND OCCURRENCE: (Type No. 1232 B) M-7745(2) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

Brightia metomphala (Bonarelli)
Pl. 1, fig. 20

1919 *Hecticoceras (Lunuloceras) metomphalum* Bonarelli, Couffon, p. 187; Pl. 14, fig. 7, text-fig. 29.

1951 *Brightia metomphala* Bonarelli, Jeannet, p. 64; Pl. 14, figs. 2-4, text-figs. 143-145.

1961 *Hecticoceras metomphalum* Bonarelli, Rangheard, p. 154; Pl. 3, figs. 6-7, text-fig. 9.

1975 *Putealiceras (Putealiceras) metomphalum* (Bonarelli), Lominadze, p. 34; Pl. 1, figs. 5-7; Pl. 2, figs. 1-5; text-fig. 6.

1975 *Putealiceras (Putealiceras) metomphalum multicostatum* (Tsytovitch), Lominadze, p. 37; Pl. 2, figs. 6-7.

DESCRIPTION: Evolutely coiled, compressed conchs. Whorl section high (W/H = 0.67, 0.76), oval with the maximum width at the dorsal third. The flanks converge towards the venter, which is rounded and unicarinate. The conch is ornamented with umbilicolateral, short and weak prorsiradiate ribs which strengthen at the dorsal third of the flank in the form of tubercles or bullae. Some bi- or trifurcate there into rursiradiate curved ribs turning adorally near the venter where they disappear, leaving a smooth venter. Sutures not preserved.

DISCUSSION: This species is characterized by the tubercle-like umbilicolateral ribs which bi- or trifurcate into finer, more densely spaced ribs. *B. svevum* is quite similar, differing by its non tubercle-like umbilicolateral ribs. *B. metomphala* is common in the Middle-Upper Callovian of Europe and Iran (Assereto *et al.*, 1968) and only a few references are given herein in the synonymy (see: Lominadze, 1975). Lominadze (1975) included in this species forms which develop long umbilicolateral ribs (ibid., Pl. 2, figs. 2, 4), as well as variations in the ribbing density. He distinguished some of these variations as separate subspecies, following Tsytovitch (1911, in Lominadze, 1975). According to the broad morphological range within *metomphala* s. st., there seems no justification for a separate subspecies *metomphalum multicostatum* Tsytovitch. *Hecticoceras metomphalum* in Loczy (1915) has tubercle-like dorsolateral short bullae at the dorsal third of the flank, leaving the dorsal part of the adult stage smooth. Each such bulla corresponds to 3-4 ribs, thus differing from our material.

AGE: *B. metomphala* was recorded from Middle to uppermost Callovian beds (e.g., Jeannet, 1951, p. 64; Lominadze, 1975, p. 37).

MATERIAL AND OCCURRENCE: (Type No. 1385) M-7745(3) (coll. Z. Lewy), Gebel maghara, top Zohar Formation.

Brightia sp. cf. *B. taeniolata* (Bonarelli)
Pl. 1, figs. 23, 24

cf. 1975 *Lunuloceras (Lunuloceras) taeniolatum* (Bonarelli, 1894), Lominadze, p. 79; Pl. 8, figs. 1-3, text-figs. 35-36.

DESCRIPTION: Two poorly preserved fragments of a compressed unicarinate conch with an umbilicus of approximately a quarter of the conch's diameter. The ornament consists of ventrolateral, curved, rursiradiate ribs terminating at the ventrolateral shoulder. The dorsolateral region of the flanks is smooth or irregularly ornamented by short rudimentary ribs, very few of which are strong and discernible as true ribs. Sutures not preserved.

DISCUSSION: Several *Brightia* species tend to shorten the dorsolateral ribs and, around the umbilicus, form a smooth band which may be slightly concave ("taeniola" of Jeannet, 1951). The present fragments clearly show the absence of some umbilicolateral ribs, as well as the occurrence of relics of such ribbing. By this ribbing pattern, as well as by the whorl section, our forms resemble Lominadze's (1975) *Lunuloceras taeniolatum*. Unfortunately, their state of preservation does not enable a precise determination.

AGE: *B. taeniolata* is recorded by Lominadze (1975, p. 80) from Lower Callovian to Lower Oxfordian strata.

MATERIAL AND OCCURRENCE: (Type No. 1391) M-7745(2) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

genus PSEUDOBRIGHTIA Spath, 1928

Type species: *P. dhosaensis* Spath, 1928

Pseudobrightia sp.
Pl. 1, figs. 7, 8

? 1958 *Orbignyceras trezeense* Gérard and Contaut, Collignon, Pl. 33, fig. 160.

DESCRIPTION: Evolutely coiled, planulate, with rather broad subquadrate adult whorl sections. The flanks are slightly rounded and subparallel and the venter is rounded and tricarinate.

MEASUREMENTS:

	D	H	W	W/H	U
M-7745:1	16.0	5.5(0.34)	5.1(0.32)	0.93	6.4(0.4)
M-7745:1	25.5	11.0(0.43)	8.1(0.31)	0.74	10.0(0.4)
M-7745:2	-	10.8	9.3	0.86	-
M-7745:2	27.6	9.6(0.35)	-	-	11.0(0.4)
M-7745:3	-	12.9	11.4	0.88	-

The umbilicus is large (U/D = 0.4). The whorl height is normally a little larger than its width (W/H = 0.93-0.86) and a third of the diameter.

The ornament consists of falcoid ribs which are strong and prorsiradiate near the umbilical shoulder, where some bifurcate. They weaken at the dorsal third of the flank where they turn back and become stronger again, forming a curve concave adorally. The weakening of the ribs at their turning-point gives an impression of a pseudo-furrow.

DISCUSSION: Our tricarinate specimens have a subangular whorl section thus differing from the high triangular section of *Campylites*. Jeannet (1951) indicated with a question mark the broad, tricarinate *Putealiceras* which are quite similar to his *Pseudobrightia*. The specimens from Sinai are more evolute than those from Switzerland (Jeannet, 1951) and originate from an earlier biozone than the European ones and the specimens from Cutch (Spath, 1928). Our material has the affinities of *Pseudobrightia* but because of the fragmentary nature of the rather young ontogenetic stages, no new species is established here. For the same reason, the relations between our material and the 6 cm large *Orbignyceras trezeense* Gérard and Contaut of Collignon (1958) are not clear, although the partly exposed inner volutions of the Madagascan species closely resemble our fragments. However, the holotype in Gérard and Contaut (1936; Pl. 16, figs. 2,2a) has finer ribs than our specimen at the same stage.

AGE: Collignon's (1958) specimens originate from the Upper Callovian Athleta-Zone.

MATERIAL AND OCCURRENCE: (Type No. 1383) M-7745(3) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

Subfamily DISTICHOCERATINAE Hyatt, 1900
Genus DISTICHOCERAS Munier-Chalmas, 1892

Type species: *Ammonites bicostatus* Stahl, 1824 (= *bipartitus* Zieten, 1830)

Distichoceras bicostatum (Stahl)
Pl. 1, figs. 21, 22

1847 *Ammonites bipartitus* Zieten, d'Orbigny, p. 443; Pl. 158, figs. 1, 2, 4.
1928 *Bonarellia bicostata* (Stahl), Spath, p. 95; Pl. 15, figs. 4 a-c.
1928 *Bonarellia* sp. indet., Spath, p. 95; Pl. 14, figs. 2 a-c.
1939 *Distichoceras bicostatum* (Stahl), Arkell, Pl. 8, figs. 19 a-b..
1951 *Bonarellia bicostata* Stahl, Jeannet, p. 36; Pl. 8, figs. 1-5, text-figs. 81-82.
1967 *Distichoceras bicostatum* (Stahl), Palframan, p. 62; Pl. 9, figs. 1, 7, 8; Pl. 11, figs. 3-5, 7, 8; Pl. 12, figs. 3, 5-9; Pl. 13, figs. 1-3; text-figs. 1-5, 7-9.

DESCRIPTION: A small fragment of an involutely coiled compressed conch. The venter is concave, bordered by ventrolateral clavi in alternating position. A siphonal keel occurs, lower than the two rows of clavi.

The ornament is very weak and is discernible on the ventrolateral part of the flanks only. It consists of low ribs which bifurcate from the clavi dorsally, being slightly prorsiradiate. The pair of ribs emerging from each clavi almost form a complete loop, but most of them fade and disappear before reaching the middle of the flank.

DISCUSSION: Spath (1928) and Jeannet (1951) recognized the priority of the name *bicostatum* Stahl, 1824, for the same species commonly recorded as *bipartitus* Zieten, 1830, both established on material from Wuttemberg, Germany. Being common, only a few references are herein given in the synonymy. Our specimen is the female type of Palframan (1967) who gave a broad synonymy for both dimorphs.

AGE: This species seems to be restricted to the Upper Callovian Athleta and Lamberti Zones (Palframan, 1967, p. 92).

MATERIAL AND OCCURRENCE: (Type No. 1384) M-7745 (coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

Superfamily STEPHANOCERATACEAE Neumayr, 1875
Family THAMBOCERATIDAE Arkell, 1952

DESCRIPTION: The Thamboceratidae are characterized by oxycone unicarinate and bicarinate conchs, having simple to very digitated sutures according to a basic pattern common to all of them. This pattern consists of a large first lateral saddle of a rather bifid main part and an external accessory saddle. The first lateral lobe is narrow, followed by a bifid, narrow second lateral saddle. The following three saddles up to the umbilical seam are broad and low, separated by narrow lobes.

This pattern differs considerably from that of the Clydoniceratidae, which may have a very broad first lateral lobe e.g., in *Clydoniceras* and *Dhrumaites* and a very broad second lateral saddle e.g., in *Clydoniceras*, *Clydomphalites* and *Micromphalites*.

Within the Thamboceratidae a new genus, *Levanticeras*, is here designated. Thereby, the range of the family is extended to the Upper Callovian.

Genus LEVANTICERAS nov. gen.

HOLOTYPE: *Levanticeras levantinense* nov. gen. and sp. M-7813, (Type No. 1205), Makhtesh Hatira (Israel, coord. 1490/0384), Upper Zohar Formation (middle Tsia Member), Pl. 2, figs. 1-3.

DERIVATION OF GENERIC NAME: Distribution area.

STRATIGRAPHIC LEVEL: Upper Callovian

DIAGNOSIS: Involute, compressed, oxycone with acute venter. Low, falcoid narrow or broad ribs, slightly rursiradiate in the ventral half of the flanks, where bifurcation or short secondaries may occur. Suture as described for the family.

Levanticeras levantinense nov. gen. and sp.
Pl. 1, figs. 25-30;
Pl. 2, figs. 1, 3, 4; Fig. 6 I, J.

? 1965 *Clydoniceras* sp., Abdallah, Adindani and Fahmy, p. 12.
1975 *Thamboceras* sp., Gill and Tintant, p. 103.
? 1979 *Nubidites omarai* Wiedmann and Kullmann, p. 249; figs. 2,3.

HOLOTYPE AND STRATIGRAPHIC LEVEL: as for the genus.

DERIVATION OF SPECIFIC NAME: Distribution area.

DESCRIPTION: Involute, very compressed, discoidal conch. Whorl section lanceolate with an acute venter throughout ontogeny (Pl. 2, fig. 3). The maximum width is usually near the umbilicus, but in specimen M-5385, it occurs at mid-height. The flanks converge ventrally without forming any ventrolateral shoulder, except in the very young stage. The umbilicus in young stages is small (at D = 18, U = 2 mm; Pl. 1, figs. 29, 30) but with growth it is occluded by the dorsal part of the shell (Pl. 2, fig. 3).

MEASUREMENTS:

	D	H	W	W/H	U
M-7814	-	4.0	2.8	0.70	-
M-7814	13.8	8.0(0.58)	3.8(0.28)	0.47	1.8(0.13)
M-7814	18.3	10.4(0.57)	4.8(0.26)	0.46	2.0(0.11)
M-7813:1	47.5	28.2(0.59)	7.6(0.16)	0.27	-
M-7813:1	-	86.0	30.0	0.35	-

The young conch (D = 20 mm, Pl. 1, figs. 29, 30) has ventrolateral radiate to slightly rursiradiate ribs, which weaken dorsally; with growth (D = 4-5 cm; Pl. 1, fig. 25), the ribs broaden, being adorally convex and rursiradiate on the ventral margins. There a few secondaries seem to intercalate whereas some of the primaries bifurcate (inconclusive observations due to the state of preservation). This ventrolateral ribbing is very weak and easily affected by corrosion. Moreover, also the broad, lateral, rursiradiate ribs occur on well-preserved specimens only (Pl. 1, fig. 26).

The sutures (Fig. 6 I,J) have open (quadrangular) elements as in *Thambites* but a few specimens may have "tree"-shaped first and second lateral saddles and the lobe in between with narrow necks, resembling the suture of *L. sinaiense* nov. gen. and sp. (Fig. 6 F).

DISCUSSION: Our oxycone specimens have a typical thamboceratid suture with narrow first lateral lobe and second lateral saddle, and broad umbilical saddles. Thereby *Levanticeras* nov. gen. as well as *Clydoniceras pseudodiscus* Arkell (Bathonian of central Saudi Arabia) differs from typical *Clydoniceras* which tends to a very broad first lateral lobe.

Levanticeras nov. gen. is a weakly ribbed ammonite found together with Upper Callovian forms (e.g., *Pachyerymnoceras*). Therefore, it is distinguished from the Bathonian (associated with *Thambites*), smooth (Arkell, 1952, p. 282) *Clydoniceras pseudodiscus* Arkell, although both exhibit a remarkable homoeomorphy (therefore Lewy, 1981, recorded the Israeli specimen as *Levanticeras pseudodiscus* (Arkell) nov. gen.).

Arkell (1952, p. 282) noticed the similarity of the sutures of *C. pseudodiscus* to those of *Thambites* forms which "seem to be inseparable from *Clydoniceras*" (Arkell, 1952, p. 279). These close relations led Arkell (1952, p. 283) to suggest that the "Clydoniceratidae are derived from *Thambites* and the Bajocian *Thamboceras*." However, the thamboceratid suture of *Levanticeras* nov. gen. strengthens the characteristics of this pattern, clearly differing from typical *Clydoniceras*, and extends the range of the Thamboceratidae to the Upper Callovian.

Collignon (1958; Pl. 25, fig. 102) recorded a Lower Callovian, oxycone, young ammonite under *Pseudoclydoniceras besairiei*, having simple suture lines. However, the lack of a precise suture pattern does not enable placing it conclusively as a forerunner of the Upper Callovian thamboceratid *Levanticeras* nov. gen., or as a post-Bathonian clydoniceratid.

Gill and Tintant (1975) mentioned *Thamboceras* sp. from the type locality of *Levanticeras* nov. gen., which seems to be nothing else but the latter new genus. Abdallah *et al.* (1965) recorded from Jurassic outcrops at Abu Darag, western side of Gulf of Suez, Egypt, *Clydoniceras* with *Erymnoceras* and nearby *Pachyceras*, recalling assemblages of northern Sinai and Makhtesh Hatira. Wiedmann and Kullmann (1979) described a very young oxycone ammonite from within the Nubian Sandstone sequence a few kilometers east of Abu Darag. They attributed it to a new genus and species, *Nubidites omarai* of Cretaceous affinities. The suture of this early ontogenetic stage (D = 11 mm) closely resembles the Thamboceratid pattern of the young *Levanticeras* nov. gen. (Fig. 6 J), suggesting that *Nubidites omarai* and most probably the *Clydoniceras* of the Abu Darag region are the present Upper Callovian *Levanticeras* nov. gen. However, additional specimens and stratigraphic data of the Egyptian material are needed to prove this identity.

MATERIAL AND OCCURRENCE: Holotype (Type No. 1205) M-7813:1 and specimens M-7813(2), 5362(2), 5385, 5375, 7814 (coll. M. Goldberg, M. Raab, F. Hirsch, Z. Lewy) Makhtesh Hatira Upper Zohar Formation (upper part of Tsin Member). M-7621(10), 7663 (coll. Z. Lewy), Gebel El-Minshera, (units 5, 6).

Levanticeras sinaiense nov. gen. and sp.
Pl. 2, figs. 5, 6; Fig. 6F

HOLOTYPE: M-7261:1 (Type No. 1206), Gebel El-Minshera coord. 9690/0219); Pl. 2, figs. 5-6; Fig. 6F.

DERIVATION OF NAME: Type area, Sinai.

STRATIGRAPHIC LEVEL: Upper part of Zohar Formation at Gebel El-Minshera, unit 5, the lithostratigraphic equivalent of the Tsia Member of Upper Zohar Formation in Israel, Upper Callovian.

DIAGNOSIS: *Levanticeras* with low, fine and dense ribbing, rather digitated sutures, with "tree"-shaped elements.

DESCRIPTION: Involute, compressed, discoidal; whorl section high, oxycone with a sharp venter (fragmentary specimen).

MEASUREMENTS:

	D	H	W	W/H	U
M-7261:1	-	15.7	6.3	0.40	-
M-7261:1	44.0	31.0(0.70)	11.5(0.26)	0.37	2.3(0.05)

The shell is ornamented by very low, slightly falcoid, radiate fine ribs which fade and are almost invisible at the dorsal region of the flanks. The partly preserved ribbing pattern seems to be of long primaries with one or two shorter secondaries in between, some of which probably furcate from the primaries.

The sutures (Pl. 2, fig. 5, Fig. 6 F) comprise rather denticulated elements. The first lateral saddle is broad with an external accessory saddle. The first lateral lobe is deep and almost closed by the adjacent tree-shaped second lateral saddle. The second lateral lobe is similar to the first one, but smaller. The following three saddles up to the umbilical seam are broad and bifid.

DISCUSSION: *L. sinaiense* nov. gen. and sp. has fine, dense ribs in contrast to the broad, widely spaced ribs in *L. levantinense* nov. gen. and sp.

MATERIAL AND OCCURRENCE: M-7621(3) (coll. Z. Lewy), Gebel El-Minshera, Upper Zohar Formation, unit 5.

Family PACHYCERATIDAE Buckman, 1918

The Pachyceratidae comprise forms which are thought to be the macroconch and the microconch of the same "biological" species. Callomon (1963; and pers. comm., 1981) regards *Pacherymnoceras* as the microconch of *Pachyceras*. However, Charpy and Thierry (1977) distinguished in each of the taxa *Pachyceras* and *Pachyerymnoceras* a pair of micro- and macroconchs although they regarded *Pachyerymnoceras* as a subgenus of *Pachyceras*.

No definite dimorphic relations in the sense of Callomon or Charpy and Thierry could be attributed to our specimens, although both *Pachyceras* and *Pachyerymnoceras* forms usually occur together in Israel and Sinai. Likewise, no *Pachyceras lalandeanum* (d'Orbigny) microconchs of Charpy and Thierry (1977) have been found with our "macroconchs." Our small number of specimens of a rather high variability permitted grouping them into several morphotypes only, without defining intraspecific variations or dimorphism. If dimorphism occurs among our Pachyceratidae, it would most likely be between *Pachyerymnoceras philbyi* (Arkell) as the macroconch and *Pachyerymnoceras levantinense* nov. sp. as the microconch. However, due to the state of preservation of our material, each morphotype is herein distinguished as a species of one of the two genera, either *Pachyceras* or *Pachyerymnoceras*.

Genus PACHYERYMNOCERAS Breistroffer, 1947

Type species: *Pachyceras jarryi* R. Douvillé, 1912

REMARKS: R. Douvillé (1912, p. 37) distinguished a globose *Pachyceras*-like, tuberculated Upper Callovian form as *Pachyceras jarryi*, discussing in detail its relations to both the Middle Callovian *Erymnoceras* and the Upper Callovian *Pachyceras*. The young stage resembles *Erymnoceras* by the cadicone whorl section and tuberculated umbilical shoulder, whereas advanced growth stages attain whorl sections greater in height than width, with a weakening of the tuberculation, thus resembling *Pachyceras*. On the basis of these affinities, Breistroffer (1947, in Arkell, 1957) regarded this Late Callovian taxon as a subgenus of the Middle Callovian *Erymnoceras* which, in the evolutionary sense, is unnecessary and stratigraphically misleading. This may have influenced Imlay (1970) to attribute his *Erymnoceras (Pachyerymnoceras)* cf. *E. (P.) jarryi* to the Middle Callovian, although it occurs together with *Pachyceras* (similar biostratigraphic mixture in Gill and Tintant, 1975).

Zeiss (1974) discussed the ages of the

undoubtable *Pachyceras* and *Pachyerymnoceras* species, some of which are accompanied by so-called *Erymnoceras*-like ammonites. Attributing Arkell's (1952) *Erymnoceras philbyi* to *Pachyerymnoceras*, he suggested that the Middle Callovian ammonite assemblages of Jebel Tuwaiq, Saudi Arabia (and thus its biostratigraphic equivalent in Israel described herein) are of Late Callovian age.

Pachyerymnoceras philbyi (Arkell)
Pl. 2, figs. 2, 7; Pl. 3, fig. 10; Fig. 4 E

1952 *Erymnoceras philbyi* Arkell, p. 290; Pl. 29, figs. 1-3.
1952 *Erymnoceras* cf. *jarryi* R. Douvillé, p. 290; Pl. 29, fig. 4.
1958 *Erymnoceras* aff. *dorothea* Spath, Hudson, p. 418.
1970 *Erymnoceras* cf. *E. philbyi* Arkell, Imlay, p. D12; Pl. 2, figs. 12-13.

DESCRIPTION: Large to moderately sized conchs, with three different types of morphology changing rather suddenly at various diameters. The first morphotype, which resembles *Erymnoceras*, comprises the whole phragmocone of the adult stage in most samples. The second is characterized by quite a high rounded whorl section, densely ribbed like the preceding morphotype. In the third morphotype the ribs become widely spaced and simple near the gerontic aperture.

The first (young) morphotype is involute, cadicone and coronate. The venter and the flanks form a complete arch (curved stronger than in *P. levantinense* nov. sp.) with W/H ratio of 1.5 (Fig. 4 E). The umbilical wall is steep, slightly rounded and quite smooth, except for low undulations near the umbilical tubercles. The umbilical shoulder is almost angular at the tubercles and rounded in between them. The tangents at the umbilical region form nearly a straight angle between the umbilical wall and the umbilicolateral part of the flank. Low ribs bi- or trifurcate from prominent umbilical tubercles. With growth, the tubercles become lower and fuse with the ribs emerging from them, forming short, broad ribs (or bullae).

The second (mature) morphotype comprises at least half a volution of the body-chamber. It has a rather high whorl section due to a decrease in growth rate of the whorl's width relative to an increase in its height, causing uncoiling (Pl. 3, fig. 10). Ribbing continues more or less in the same width and spacing as in the preceding stage, giving the impression of dense ribbing on the large body-chamber.

The third morphotype comprises the gerontic part of the body-chamber. A sudden coarsening in ornament occurs there, forming simple or bifurcating, widely-spaced, strong and broad ribs (Pl. 2, fig. 7, the most complete specimen from Saudi Arabia, refigured from Imlay, 1970).

The dimensions of the shell at which each morphological change occurs, as well as the dimensions of the complete adult conch, vary from specimen to specimen. Variations similarly occur in whorl width to height ratio.

A large fragmentary specimen from Gebel El-Minshera, (M-7809), is more than twice as wide as the complete *Erymnoceras* cf. *E. philbyi* Arkell, from Saudi Arabia (Imlay, 1970; refigured herein in Pl. 2, fig. 7) and its reconstruction makes it twice as large. The sutures are not well preserved.

DISCUSSION: This species differs from *P. levantinense* nov. sp., mainly by the densely ribbed *Pachyceras*-like adult body-chamber. The *Erymnoceras*-like phragmocones of both species may look similar, although that of *P. levantinense* nov. sp. has a higher W/H ratios (1.8-2) with a flatter venter and a sharper umbilical shoulder than in *P. philbyi* (W/H = 1.5), especially in advanced growth stages.

Spath (in Hudson, 1958) may have compared the Israeli *P. philbyi* to his *Erymnoceras dorotheae*, which occurs in Cutch in Upper Callovian strata. Because of its shape and the high stratigraphic position, Zeiss (1974) attributed the species *dorotheae* to *Pachyerymnoceras*.

P. dorotheae (Spath, 1928, Pl. 18, fig. 4) is a small (young?) specimen which exhibits the *Erymnoceras*-like morphology and has a constricted aperture. Because of its small dimensions, it is impossible to decide whether this constriction indicates the gerontic stage or the beginning of the mature one. The young stage of *P. dorotheae* is similar to *P. philbyi* in whorl section and ornament and only the doubtful morphology of the adult *P. dorotheae* impedes clarifying their relations.

Arkell (1952, p. 284) and Imlay (1970, p. D12) pointed out the remarkable homoeomorphy between their Middle Callovian *Erymnoceras* (herein Late Callovian *Pachyerymnoceras*) and Bathonian *Tulites* of central Arabia. Even the

bifid second lateral lobe by which Arkell (1952, p. 15, fig. 7) distinguished *Tulites* from *Erymnoceras* does not seem to be a stable feature. Such bifid-like lobes occur in *Erymnoceras* (e.g., Jeannet, 1951, p. 116, figs. 263, 267) and in some of our *Pachyerymnoceras*. It seems that the Arabian *Tulites* forms need further study on better preserved material that is stratigraphically more precisely sampled.

Erymnoceras philbyi in the sense of Lominadze (1970) seems to be a true Middle Callovian *Erymnoceras* sp.

MATERIAL AND OCCURRENCE: (Type No. 1208) M-5340, 5362, 5313, 5346, ?6067 (coll. M. Goldberg and M. Raab), Makhtesh Hatira; HU 30980 (coll. E. Nevo), Makhtesh Hazera; M-7809, 7621(3), 7909 (coll. Z. Lewy), Gebel El-Minshera. All samples from Upper Zohar Formation (Tsia Member).

Pachyerymnoceras levantinense nov. sp.
Pl. 3, figs. 1-9; Figs. 4A-D, F, 6G

1970 *Erymnoceras philbyi* Arkell, Imlay, p. D12; Pl. 2, figs. 3-9.
1970 *Erymnoceras (Pachyerymnoceras)* cf. *E. (P.) jarryi* (R. Douvillé), Imlay, p. D13; Pl. 2, figs. 1-2.
1974 *Pachyerymnoceras imlayi* Zeiss, p. 273; Pl. 37, figs. 5, 8-9.
?1974 *Pachyerymnoceras jarryi* (R. Douville) *ethiopicum* Zeiss, p. 275; Pl. 37, figs. 1, 6-7.

HOLOTYPE: (Type No. 1207) M-53621 (coll. M. Goldberg and M. Raab), Makhtesh Hatira, Zohar Formation (Tsia Member, subunit 43 of Goldberg, 1963); Pl. 3, figs. 1-3.

DERIVATION OF NAME: Levantine distribution area.

STRATIGRAPHIC LEVEL: Upper Callovian.

DIAGNOSIS: Young stage, involute, very depressed cadicone and coronate. Prominent umbilicolateral tubercles from which low ribs bi- or trifurcate and cross the venter. The adult stage is characterized by a sudden decrease or cessation in width growth with an increase in the rate of height growth, resulting in uncoiling and a high *Pachyceras*-like whorl section. The adult and gerontic stages bear coarse and widely spaced bifurcating or simple ribs.

MEASUREMENTS:

	D	H	W	W/H	U
M-5362	-	25.5	47.3	1.8	-
"	91.2	37.7(0.41)	43.8(0.46)	1.2	29.8(0.32)
"	113.1	39.4(0.34)	42.5(0.37)	1.1	40.5(0.35)
M-7663	-	24.0	40.6	1.7	-
"	95.0	35.2(0.37)	43.3(0.45)	1.2	38.1(0.40)
"	98.0	32.5(0.33)	45.8(0.47)	1.4	42.2(0.43)
M-5328	-	19.2	38.6	2.0	-
"	-	33.8	56.4	1.6	-
"	-	43.0	58.0	1.3	-
"	-	55.0	55.0	1.0	-

DESCRIPTION: Inner whorls up to D = 6 mm are smooth with a rounded umbilical shoulder. With growth low umbilical bullae develop, which at D = 16 mm become spinose and form the angular umbilical edge of the depressed cadicone (*Teloceras*-like) .whorl section. The conch is evolutely coiled, each volution embracing the ventral part of the former volution nearly up to the umbilical shoulder. The venter of each volution forms a gentle curve, all being more or less parallel in cross-section (Fig. 4F).

The umbilical wall is steep, straight and quite smooth except for low undulations according to the position of the umbilical tubercules. The tangents to the umbilical wall and the umbilicolateral part of the flanks form a sharp angle of approximately 60 -65 (Pl. 3, figs. 6, 8). The ribs bi- or trifurcate from the prominent umbilical tubercles situated on the almost sharp angular umbilical shoulder. The ribs are gently prorsiradiate, as broad as the interspace and rather low, so that in some specimens, they are nearly erased on the middle of the venter.

A sudden morphological change occurs nearly at the end of the phragmocone and the beginning of the body-chamber of the mature stage (at diameters over 5-8 cm). The height of the whorl increases while the width may remain constant or even decrease slightly at the region of morphologic change (Pl. 3, fig. 2). The conch thus uncoils, becoming evolute (Pl. 3, fig. 1). The adult stage has a high *Pachyceras*-like whorl section of variable W/H ratios. The umbilical shoulder becomes rounded and the umbilical tubercles fuse with the ribs and disappear. Ribbing becomes widely spaced and stronger, tending to a simple pattern toward single primaries on the gerontic body-chamber. The largest preserved diameter is

nearly 12 cm whereas reconstructed conchs are estimated to reach 15-16 cm.

The sutures preserved on two specimens show very broad, quadrangular (open) first and second lateral saddles and rather narrow first lateral and umbilicolateral lobes (Fig. 6G).

DISCUSSION: This species is the most common among the *Erymnoceras*-like ammonites in the lower part of the outcrop of Makhtesh Hataira. However, its undoubtable distinction from young stages of *P. philbye* is sometimes impossible. The young stage of *P. levantinense* nov. sp. has a more depressed cadicone conch than *P. philbyi*, but towards the adult stage, the whorl height of *P. levantinense* nov. sp. increases more rapidly than its width, thus becoming similar to *P. philbyi*. The adult *P. levantinense* nov. sp. lacks the intermediate morphotype of *P. philbyi* with the densely ribbed, high Pachyceras-like whorls.

Erymnoceras species recorded from the western side of the Gulf of Suez (Egypt; Abdallah *et al.*, 1965) and from Makhtesh Hatira, Israel (Gill and Tintant, 1975) could not be undubitably attributed or compared to any of the *Pachyerymnoceras* species described here because no description or figure was presented.

P. jarryi (according to R. Douvillé, 1912) does not show the sudden morphological change in whorl section and ornament as does *P. levantinense* nov. sp., but rather a gradual increase in whorl height toward a *Pachyceras*-like section without uncoiling.

P. jarryi ethiopicum Zeiss (1974) has a compressed cadicone conch like *P. levantinense* nov. sp., with rather fine umbilicolateral tubercles and ribbing which may occur in *P. levantinense* nov. sp. Also similar in shape is *P.* sp. cf. *P. jarryi* of Imlay (1970) which differs from *levantinense* nov. sp. only in the adult stage by its gradually forming the triangular whorl section. *P. imlayi* Zeiss seems to represent the adult, coarsely ornamented stage of *P. jarryi ethiopicum* so that both Ethiopian forms are believed to belong to *P. levantinense* nov. sp. The present new species is based on well- preserved, complete conchs from Israel which the fragmentary material from elsewhere only partly resembles. Therefore, a new name was designated to avoid possible misinterpretation of the foreign species not in hand.

MATERIAL AND OCCURRENCES: (Type No. 1207) At Makhtesh Hatira, M-5302(2), 5304, 5324, 5326, 5328, 5333, 5362, 5371, 5372, 5375, 5384, 5394, 5393, 6067 (coll. M. Goldberg, M. Raab and Z. Lewy), throughout the Tsia Member of the Zohar Formation; M-5416, ?6149 (coll. M. Goldberg and M. Raab) at the base of the Be'er Sheva Formation (Matmor Member). At Gebel El-Minshera, units 5, 6: M-7621(10), 7663 (coll. R. Freund, Z. Lewy).

Pachyerymnoceras sp. cf. *P. jarryi* (R. Douvillé)
Pl. 4, fig. 3; Pl. 5, fig. 1; Figs. 6B, H

aff. 1912 *Pachyceras jarryi* E. Eudes Deslongchamps, R. Douvillé, p. 37; Pl. 1, figs. 3, 4, 5, 7, 8, 10; text-figs. 37-43.

aff. 1977 *Pachyceras (Pachyerymnoceras) jarryi* (Douvillé) - Formemicroconque, Charpy and Thierry, p. 206; Pl. 5, figs. 2, 3; text-fig. 4d.

DESCRIPTION: Involutely coiled, coronate, depressed, globose conchs. In the adult stage the height of the whorls increases more rapidly than its width towards a *Pachyceras*-like section.

The edge of the umbilical shoulder bears tubercles from which low, rounded ribs bi- or trifurcate, being slightly prorsiradiate. The ribs are as broad as their interspacing and cross the venter almost without any flexure. The growth angle of the whorl's width is large in the young stages and decreases in the adult stage towards an almost constant width, while the height increases. The largest specimen developed a triangular adult whorl section without any change in ornament.

Sutures (Fig. 6H) with a narrow bifid external lobe, a broad first lateral saddle followed by the small second lateral bifid lobe on the middle of the flank and the similarly wide second lateral bifid saddle. The umbilical lobe is just on the umbilical shoulder and its wall.

DISCUSSION: Our specimens are closely related to *P. jarryi* (R. Douvillé). The adult holotype of this species (Douville, 1912, Pl. 1, fig. 10) is more compressed and reaches the *Pachyceras*-like stage in smaller diameters than in our material, whereas the young stages of R. Douville (1912, Pl. 1, figs. 3-5, 7-6, 12) are very depressed and more finely ribbed than our specimens. These young stages, as well as the young Ethiopian *P. jarryi ethiopicum* Zeiss (1974), resemble the young depressed conchs of *levantinense* nov. sp. This latter species is characterized by a sudden change in morphology in the adult stage in contrast to the gradual change in *P. jarryi*. Our

Pachyerymnoceras sp. aff. *P. jarryi* does not show any change in ornament while forming the *Pachyceras*-like whorl section as does *P. levantinense* nov. sp. from Makhtesh Hatira (Israel), which can also be attributed to the present described species. Charpy and Thierry (1977) regarded these forms of *jarryi* in Douvillé (1912) as microconchs of a larger, more compressed macroconch of the same species. Our few specimens do not confirm their suggestion of dimorphism in this species.

AGE: *P. jarryi*, the type species of *Pachyerymnoceras* is known from the Upper Callovian only (e.g., Arkell, 1957, p. L. 297).

MATERIAL AND OCCURRENCE: (Type No. 1380) M-7745(4) (coll. M. Goldberg), Gebel Maghara, top Zohar Formation.

cf. *"Erymnoceras" coronoides* (Quenstedt)
Pl. 4, figs. 1-2

cf. 1848 *Ammonites coronatus* Bruguière, d'Orbigny, p. 465 (part); Pl. 168, figs. 3, 6, 7.

cf. 1915 *Stepheoceras coronoides* Quenstedt, Lóczy, p. 347; Pl. 14, fig. 8.

DESCRIPTION: A single fragment of the last volution (part of the phragmocone and body-chamber) of a large, depressed cadicone conch. The width to height (approximate height) ratio is 119/58 = 2.0. The venter is gently curved with rounded ventrolateral shoulders. Prominent umbilicolateral bullae stretch dorsally and weaken on the umbilical wall. These bullae furcate on the venter into two or three low and narrow, radiate to slightly prorsiradiate ribs. The ribs cross the venter and at least two of them join the opposite bullae. Occasionally, one rib of a bundle weakens before reaching the opposite ventrolateral shoulder.

The poorly-preserved sutures exhibit broad, open, quadrangular elements, with saddles more than twice as broad as the dorsally adjacent lobes.

DISCUSSION: This Middle to Early Late Callovian form described and illustrated by Lóczy (1915) is based on specimens attributed by d'Orbigny (1848, Pl. 168, figs. 3, 6, 7) to the Middle Callovian species *coronatus* Bruguière. Under the same specific name, d'Orbigny (1848, Pls. 168-169) presented a variety of morphotypes which later were attributed to different species and genera of Middle Callovian to Late Callovian age. This taxonomical process (e.g., R. Douvillé, 1912; Lóczy, 1915; Spath, 1928, p. 219; Arkell, 1957) overlooked the existence of cadicone *Erymnoceras*-like species ranging into the Late Callovian, such as the present cf. *coronoides* Quenstedt. Lóczy (1915) has attributed it to *Stepheoceras* Buckman (1898, synonym of *Stephanoceras* Waagen, 1869, in Arkell, 1957), Lominadze (1970) included it in *Erymnoceras*, whereas the restriction of *Erymnoceras* to the Middle Callovian only left this form without a suitable generic name in Arkell's (1957) systematics. This form is well known in Europe and now probably also in the Middle East, but it seems that no proper genus has been established for it. Although it resembles early stages of *Pachyerymnoceras*, it is distinguished (at least for the time being) by the lack of any ontogenetic polymorphism in large specimens. Meanwhile, this partly known form is left under the generic name *"Erymnoceras"* in spite of the possible stratigraphic misinterpretation.

Our fragment seems to be the largest one recorded. This may be the reason for the abundance of the trifurcating ribs in contrast to their rare occurrence on the small conchs of d'Orbigny (1848) and Lóczy (1915).

AGE: Typical *E. coronoides* Quenstedt are of a Middle Callovian age, whereas the Hungarian specimen occurs in the Upper Callovian of Hungary (Lóczy, 1915).

MATERIAL AND OCCURRENCE: (Type No. 1204) M-5302, (coll. M. Goldberg and M. Raab), Makhtesh Hatira (Israel), Upper Zohar Formation, lower part of Tsia Member.

Genus PACHYCERAS Bayle, 1878

Type species: *Am. lalandeanus* d'Orbigny, 1848

DESCRIPTION: R. Douvillé (1912) described the ontogenetic polymorphism in *P. lalandeanum*. Recently, Charpy and Thierry (1977) gave a detailed description and illustrated the polymorphism, regarding this large form as the macroconch of a smaller, different-looking dimorph. This microconch shows gradual coarsening of ornamentation on the gerontic body-chamber whereas the macroconch has three completely differing morphotypes during ontogeny. Our sparse and fragmentary material lacks Charpy and

Thierry's (1977) "microconch" of *P. lalandeanum*; moreover, it does not show any dimorphism between *Pachyceras* and *Pachyerymnoceras* as suggested by Callomon (1963). Thus these forms are regarded herein as separate genera.

Pachyceras spathi nov. sp.
Pl. 5, figs. 2-4; Fig. 4 G

HOLOTYPE: Type No. 1249, M-7691:1 (coll. M. Raab), Makhtesh Hatira, base Be'er Sheva Formation, Pl. 5, figs. 2-4, Fig. 4 G.

DERIVATION OF NAME: In honour of L.F. Spath who studied the ammonites of Makhtesh Hatira (in Hudson, 1958).

STRATIGRAPHIC LEVEL: Upper Callovian.

DIAGNOSIS: Large (D = 20 cm) *Pachyceras*, involute, rather compressed, having three shapes throughout ontogeny. The young conch has a broad, oval section with a rounded venter ornamented by strong ribs. The adult stage develops a high lanceolate whorl section ornamented by low, dense ribs; the gerontic body-chamber uncoils and returns to subparallel flanks with a broad rounded venter ornamented by coarse, widely spaced ribs which fade and disappear adorally, leaving a smooth shell near the gerontic aperture.

DESCRIPTION: Involutely coiled, large, rather compressed conchs, attaining diameters over 20 cm. The gerontic-body chamber uncoils considerably.

MEASUREMENTS:

	D	H	W	W/H	U
M-7811	-	40.5	37	0.91	-
M-7691	114	55.0(0.48)	47(0.41)	0.85	23(0.20)
"	160	74.0(0.46)	60(0.37)	0.80	28(0.17)
"	180	77.0(0.42)	62(0.34)	0.80	34(0.19)
"	213	80.0(0.37)	64(0.30)*	0.80*	55(0.26)

*reconstructed

The young conch is rounded to oval in section, becoming discoidal-oval with growth due to a more rapid increase in the height than in the width of the whorls (Fig. 4G). The flanks are rounded, converging towards a broad, rounded venter. The umbilicus is narrow and deep with steep walls and rounded umbilical shoulders.

Over a diameter of 8-9 cm, the flanks converge towards an angular venter developing with growth a lanceolate (or cordate) whorl section. In this adult stage (the gerontic phragmocone) the shell attains a discoidal shape (resembling Cardioceratidae) with a very narrow, rounded to nearly acute venter (in the internal mould).

The whorl section of the gerontic body-chamber changes from lanceolate to sub-quadrate with subparallel flattened flanks and a broad rounded venter accompanied by uncoiling. The gerontic aperture is slightly constricted. The ribbing pattern of the shell changes step by step with the change in whorl section and coiling. The young conch has strong, slightly prorsiradiate ribs which bi- or trifurcate at the umbilical shoulder from short bullae. Occasionally, they are intercalated by shorter secondaries. The ribs are as broad as their interspaces and cross the venter uninterrupted as strongly as on the flanks.

With growth, the ribs become lower but retain their width and interspaces as in the earlier stage, giving an impression of dense ribbing on the large discoidal conch. The ribs weaken before the narrow venter and do not cross it.

At the beginning of the gerontic body chamber, the ribs suddenly coarsen and turn into broad, low, simple ribs. Others unsuccessfully start to bifurcate, forming a broad triangular rib near the venter. The ribs cross the venter forming low, broad undulations. Near the gerontic aperture, the conch tends to constrict and the ornament disappears leaving a smooth shell along 5 cm (or more) before the aperture (Pl. 5, fig. 2). The sutures are poorly preserved but show broad, open first lateral and second lateral saddles and narrow, open first and second lateral lobes.

DISCUSSION: *Pachyceras spathi* nov. sp. is more compressed than *P. indicum* Spath whose gerontic body-chamber is unknown. *P. lalandeanum* (d'Orbigny) attains its lanceolate section at larger diameters than in *P. spathi* nov. sp., with a more inflated whorl section with rounded flanks, differing from the rather triangular section in *P. spathi* nov. sp. *P. lalandeanum* usually differs from *P. spathi* by its rather weak dorsolateral ribs, becoming stronger ventrally.

The reexamination of *Obtusicostites* of Spath (in Hudson, 1958) from the Eligmus-Grossouvria unit at Makhtesh Hatira (sample C-71700, British Museum) suggests it to be a fragment of the inner whorls of *P. spathi* nov. sp.

Charpy and Thierry (1977) attributed to their *P. lalandeanum* d'Orbigny) macroconch a broad range of morphological variations. Although not figured, it seems that they would have included *P. spathi* nov. sp. in *P. lalandeanum* (Thierry, 1981, pers. comm.). In the same sense, Gill and Tintant (1975) may have included it in their P. *lalandeanum* from Makhtesh Hatira (30 m above base Tsia Member into the lower 20 m of the Be'er Sheva Formation).

MATERIAL AND OCCURRENCE: Holotype M-7691 (Type No. 1249) and specimens M-6003, 5382, 5993, 6022 (coll. M. Goldberg and M. Raab) and M-7811 (coll. F. Hirsch and M. Goldberg), Makhtesh Hatira; all except M-5382, 5993 are from the base of the Be'er Sheva Formation (M-5382, 5993 not in situ in the upper part of the Zohar Formation).

Pachyceras lalandeanum (d'Orbigny)
Pl. 4, fig. 4; Fig. 5A

1848 *Ammonites lalandeanum* d'Orbigny, p. 477; Pl. 175, figs. 1-3, non 4-5.

1912 *Pachyceras lalandei* d'Orbigny, R. Douvillé, p. 44; Pl. 2, figs. 2, 3, 5, non 1; text-figs. 32, 47-51.

1977 *Pachyceras (Pachyceras) lalandeanum* (d'Orbigny) - Forme macroconque, Charpy and Thierry, p. 204; Pl. 1; Pl. 2, fig. 2; Pl. 4, fig. 2; text-fig. 4c.

DESCRIPTION: Involutely coiled, lense-shaped large conchs. The young stage has a broad and rather circular whorl section becoming higher than wide with growth (Fig. 5A). The flanks converge gradually toward the rounded venter which becomes narrower and almost acute in the adult stage with weak ventral shoulders, thus attaining a lanceolate whorl section.

The ornament of the young stage consists of prorsiradiate ribs which tend to fade and become narrower dorsally, leaving a smooth umbilical shoulder. Most ribs are primaries, but secondaries may occur, all crossing the venter with an adorally convex arch. In the adult stage the ribs end before the acute venter and contribute thereby to the formation of the ventral shoulder. The umbilicus is rather small with a deep, steep, smooth umbilical wall in all stages. In a few specimens the ribs start from the umbilical shoulder but they do not form tubercles or bullae-like inflations there.

DISCUSSION: This species (the macroconch in the sense of Charpy and Thierry, 1977) is characterized by a compressed, lense-shaped conch without any umbilical tuberculation. It thereby differs from *Pachyerymnoceras* which possesses umbilical tubercles and has depressed whorl sections in the young stages, becoming higher with growth into *Pachyceras*-like whorls. Therefore, the *Pachyceras lalandei* of R. Douvillé (1912, Pl. 2, fig. 1) is herein excluded from this species due to its compressed young whorls, probably with umbilical tubercles. This specimen is thought to represent a *Pachyerymnoceras*, perhaps an advanced growth stage of *P. jarryi* (R. Douvillé).

It is quite impossible to relate to the fragmentary young stage of cf. *P. lalandeanum* (d'Orbigny) of Zeiss (1974) or to the unfigured *P. lalandeanum* recorded from Makhtesh Hatira (Israel) by Gill and Tintant (1975). This latter form, as well as the herein described new species *P. spathi* or the *Pachyceras* sp., may be from the same locality. As Spath (1928) stated, his *Pachyceras indicum* is closely related to the European *P. lalandeanum*. *P. indicum* has less rounded flanks and thus a triangular whorl section without an acute venter. *P. spathi* nov. sp. already attains a lanceolate section in smaller diameters than *P. lalandeanum* and thereafter recoils and forms the gerontic body-chamber with the broad, rounded venter. The ribs of *P. spathi* nov. sp. are less prorsiradiate than in *P. lalandeanum* and tend to start at the umbilical shoulder, whereas the ribs of *P. lalandeanum* weaken and usually disappear before reaching the umbilical shoulder.

AGE: *Pachyceras lalandeanum* (d'Orbigny) appears in Europe in the upper part of the Athleta-Zone and is most abundant in the Lamberti-Zone, both of Late Callovian age (e.g., Charpy and Thierry, 1977).

MATERIAL AND OCCURRENCE: (Type No. 1386) M-7745(6), 7746 (coll. M. Goldberg and Z. Lewy), Gebel Mághara; M-7852 (coll. Z. Lewy), Gebel El-Minshera, top Zohar Formation.

Pachyceras magharense nov. sp.
Pl. 6, fig. 12; Fig. 5B

cf. 1977 *Pachyceras (Pachyceras) lalandeanum* (d'Orbigny) - Forme macroconque, Charpy and Thierry, p. 204; Pl. 2, fig. 1.

HOLOTYPE: M-7745 (Type No. 1392), Gebel Maghara, northern Sinai (coll. M. Goldberg *et al.*, 1971, at their subunit 82), Pl. 6, fig. 12, Fig. 5B.

DERIVATION OF NAME: Type locality.

STRATIGRAPHIC LEVEL: Top Zohar Formation, Upper Callovian.

DIAGNOSIS: Involute, recoiling in the gerontic stage. Adult conch lenticular, whorl section lanceolate with an acute venter, becoming rounded in the gerontic stage with an inflated whorl section. Strong, coarse prorsiradiate ribs, weak or absent on the ubilical region, forming chevrons on the gerontic venter.

DESCRIPTION: A single, almost complete specimen of an involutely coiled, lenticular conch exposing the adult and gerontic stages only. The adult stage has a lanceolate whorl section with a high, acute venter and differentiated ventrolateral shoulders at the endings of the strong ribs. The umbilicus is small (U/D = 30/170 = 0.17) with rounded shoulders and a steep wall. The gerontic stage is marked by recoiling (U/D = 48/210 = 0.23) and by the inflating of the whorl section forming a broad, rounded venter. The gerontic aperture is constricted. The adult and gerontic stages are ornamented by coarse, prorsiradiate ribs, as broad as their interspaces. They are weak or completely absent near the umbilicus, becoming stronger ventrally. At the ventrolateral region they are most pronounced and weaken on the venter so that a ventrolateral shoulder is formed. The ribs on the gerontic body-chamber cross the rounded venter forming chevrons there. Sutures not preserved.

DISCUSSION: The shape of the early stages of this form is unknown. Although the adult stage has a lanceolate whorl section reminiscent of a *Pachycardioceras*, this species is attributed to *Pachyceras* on the basis of the morphological development of this latter genus as well as because of our lack of records on such large, coarsely ornamented *Pachycardioceras* species from Late Callovian or even Early Oxfordian rocks.

P. magharense nov. sp. differs from all other *Pachyceras* species by its lanceolate adult whorl section with the high acute venter and the coarse ornament. The gerontic body-chamber may resemble that of *P. spathi* nov. sp., although the latter has bifurcating ribs forming triangular broad inflations because both branches are close to each other. Charpy and Thierry (1977) included in *P. lalandeanum* (macroconch) a coarsely ribbed variety which very much resembles our specimen although the French one does not show the high acute keel of the lanceolate phragmocone seen in our material.

MATERIAL AND OCCURRENCE: (Type No. 1392) M-7745 (coll. M. Goldberg), Gebel Maghara, top Zohar Formation.

Pachyceras crassum R. douvillé
Pl. 4, fig. 5; Fig. 6A

? 1848 *Ammonites lalandeanum* d'Orbigny, p. 477; Pl. 175, figs. 4-5.
? 1912 *Pachyceras crassum* R. Douvillé, p. 42; Pl. 1, figs. 1-2, 9, 11; Pl. 2, fig. 4, text-figs. 45-46.
? 1916 *Pachyceras* cf. *lalandei* d'Orbigny, H. Douvillé, p. 70; Pl. 8, figs. 4-5.
1977 *Pachyceras (Pachyceras) lalandeanum* (d'Orbigny) - Forme microconque, Charpy and Thierry, p. 202; Pl. 5, fig. 1, text-fig. 4b.

DESCRIPTION: Involutely coiled, globose and depressed section in the young stage, increasing the growth rate of the height relative to the width toward an oval section. The umbilicus is small and very deep with steep and smooth umbilical walls and rounded shoulders (Fig. 6A). The conch is ornamented with rounded ribs as broad as their interspacing. These are narrow and rather weak near the umbilicus becoming broader and stronger toward the venter in a slightly prorsiradiate pattern. Shorter secondaries sometimes intercalate the primaries. No umbilical tuberculation occurs superimposed on the ribs, which begin on the umbilical shoulder. The spacing of the ribs increases gradually with growth but the ribs remain rather low and rounded throughout ontogeny. The gerontic stage is missing in our specimens.

DISCUSSION: Our material closely resembles that of R. Douvillé (1912) in its whorl sections and ornament. The weak umbilical tuberculation discernible in his Pl. 2, fig. 4, may be the starting points of the ribs. The umbilical region of *P. lalandei* in R. Douvillé (1912) in Pl. 2, fig. 1 is not clear. If the tubercle-like structures are really superimposed on the ribs this specimen should be attributed to *Pachyerymnoceras*; but if these are only the starting points of the ribs then this globose form is a *P. crassum*. Similarly there is a question of identity of the depressed

fragment of *P.* cf. *P. lalandei* of H. Douvillé (1916). This globose *Pachyceras* species of an unknown gerontic conch has been attributed by Charpy and Thierry to the microconch of *P. lalandeanum*. Our material reaches diameters over 11 cm without any sign of senility as seen in the French specimens, which do not exceed 10 cm. It seems that globose *Pachyceras* macroconchs in the sense of Charpy and Thierry (1977) occur alongside the globose microconchs which may look similar in the young ontogenetic stages. This assumption is supported by the triangular whorl section of our large specimen which characterizes the second ontogenetic stage of *Pachyceras* ("macroconchs"). Due to the unknown gerontic body-chamber of this globose form it is herein distinguished from wide *P. lalandeanum*.

AGE: *Pachyceras crassum* (R. Douvillé (1912) is an Upper Callovian species.

MATERIAL AND OCCURRENCE: (Type No. 1387) M-7745(2), 7746 (coll. Z. Lewy), Gebel Maghara region, top Zohar Formation.

Pachyceras sp.
Pl. 6, fig. 2; Fig. 6C

DESCRIPTION: Two young specimens (D = 14, 30 mm), partly corroded. Moderately evolute. The whorl section of the inner volutions is rounded (H = W) becoming cordate with growth with the width slightly greater than the height (Fig. 6C).

The young stage is smooth with sproadic constrictions and irregular, prorsiradiate, weak ribs. Ribbing strengthens with growth especially on the venter and ventrolateral region, weakening dorsally towards a smooth umbilical shoulder (D = 30 mm). Suture not preserved.

DISCUSSION: The mode of coiling, whorl section and ornament suggest that this young form belongs to *Pachyceras* rather than to the involute, coronate *Pachyerymnoceras*. However, due to the lack of adult forms an undoubtable generic identification is impossible as is its relations to other *Pachyceras* species.

MATERIAL AND OCCURRENCE: (Type No. 1367) M-5339, 5351 (coll. M. Goldberg and M. Raab), Makhtesh Hatira, upper part of the Zohar Formation (middle Tsia Member).

Pachyceras robustum nov. sp.
Pl. 5, figs. 5, 6; Pl. 6, fig. 1

HOLOTYPE: Type No. 1390, M-7745, Gebel Maghara, northern Sinai (coll. Z. Lewy); Pl. 5, fig. 6; Pl. 6, fig. 1.

DERIVATION OF NAME: Morphological affinity.

STRATIGRAPHIC LEVEL: Top Zohar Formation, Upper Callovian.

DIAGNOSIS: Involute, globose, cadicone conchs, whorl height increases more rapidly than the width forming a triangular whorl section. Strongly prorsiradiate ribs furcate from low umbilical tubercles, forming chevrons on the venter.

DESCRIPTION: Involutely coiled, globose conchs. The flanks are gently rounded and converge towards the rounded venter forming together a triangular whorl section. The umbilical shoulder is sharp and angular and the umbilical wall is steep. The umbilicus is cone-shaped and deep.

MEASUREMENTS:

	D	H	W	W/H	U
M-7745:1	48.5	23.0(0.48)	37.0(0.76)	1.6	13(0.27)
M-7745;1	121.0	62.0(0.50)	80.0(0.66)	1.3	28(0.23)

The umbilical shoulder is damaged in most specimens, but in one fragment it bears tubercles from which weak and narrow prorsiradiate ribs furcate. They become broader and stronger ventrally, intercalated occasionally by secondaries. The ribs curve adorally, forming rounded chevrons on the venter. Sutures not preserved.

DISCUSSION: This form resembles some globose *Goliathites* or *Herznachites* species of the Cardioceratinae by the triangular whorl section and the strongly prorsiradiate ribs, forming chevrons on the venter. However, the ribs are quite straight and not falcoid, and the young stages of our specimens have no sign of an acute venter as in most Cardioceratinae. On the other hand, it differs from the recorded *Pachyerymnoceras* species by the strongly prorsiradiate ribs and by the absence of any morphological changes up to its largest diameter of 13 cm. The whorl section and the ribbing resembles those found in some *Pachyceras*, but this latter genus usually lacks umbilical tubercles, which occur in our material. Similar tuberculation and prorsiradiate ribbing occur in *Pachyceras lalandei* of R. Douvillé (1912, Pl. 2, fig. 1) which

is more compressed than our large specimen. Our largest specimen shows some of the affinities of the Pachyceratidae, however, there is some doubt as to whether it is a large, young specimen which would have undergone the same morphological changes that are typical to *Pachyceras* ("macroconch").

A fragment (M-5450) from the upper part of the Zohar Formation at Makhtesh Hatira (not in situ) resembles this species in whorl section and strongly prorsiradiate ribbing. Because of its bad state of preservation, it is only tentatively attributed to this species.

MATERIAL AND OCCURRENCE: (Type No. 1390) M-7745(4) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation and probably M-5450, Makhtesh Hatira, upper Upper Zohar Formation.

Family CARDIOCERATIDAE Siemiradzki, 1891

REMARKS: Several of the ammonites studied show morphological affinities of the Cardioceratidae. None of the recorded genera in the available literature completely fits the description of our material. However, the specimens may be compared to quite similar looking genera to avoid the definition of new taxa based on incomplete material (e.g., lack of sutures). Both Thierry and Callomon (pers. comm., 1981) suggested regarding these forms as new genera (or dimorphs of known genera) to avoid any relations with the European *Quenstedtoceras*, *Lamberticeras* and *Prorsiceras*, hitherto unknown from the southern Tethyan region, due to which the Lamberti Zone could not be recognized there (Callomon, 1962, p. 274). However, the remarkable similarity of our specimens to these European genera, as well as their suitable stratigraphic level led to the usage, with appropriate caution, of these Boreal generic names. Better preserved specimens of these Cardioceratid-like ammonites will clarify their identity as well as their correlation to European genera.

Genus QUENSTEDTOCERAS Hyatt, 1877

Type species: *Am. leachi* J. Sowerby, 1819

"Quenstedtoceras" sp.
Pl. 7, fig. 7; Fig. 6D

DESCRIPTION: Two small fragments of an evolute conch with a cordate whorl section. The imprint of the inner volution shows a broad venter (dorsum of the present fragment in Fig. 6D). W/H decreases with growth and the venter becomes carinate.

MEASUREMENTS:

	H	W	W/H
M-7261:1	7.3	7.8	1.7
M-7261:1	8.7	7.8	0.9

Ornament of prorsiradiate, slightly sigmoidal, bifurcating low ribs forming chevrons on the sharp venter. Sutures not preserved.

DISCUSSION: The cordate whorl section of the small fragment and the mode of ornament resemble those occurring in some *Quenstedtoceras*. However, they do not even enable undoubtable generic identification.

MATERIAL AND OCCURRENCE: (Type No. 1305) M-7621(2) (coll. Z. Lewy), Gebel El-Minshera, unit 5, Upper Zohar Formation.

Genus LAMBERTICERAS Buckman, 1920

Type species: *Am. lamberti* J. Sowerby, 1819

cf. *Lamberticeras henrici* (R. Douvillé)
Pl. 7, figs. 1-6

cf. 1912 *Quenstedticeras henrici* R. Douvillé, p. 55; Pl. 4, figs. 24-33.
cf. 1972 *Quenstedtoceras henrici* (R. Douvillé), Reyment, p. 20; Pl. 2.

DESCRIPTION: Moderately evolute, planulate small (D < 5 cm) conchs. The exposed volutions, D > 2 cm, have flanks converging gently towards a low, acute venter.

MEASUREMENTS:

	D	H	W	W/H	U
M-5397	30.0	12.0(0.4)	9.3(0.31)	0.77	9.1(0.33)
M-5346	32.5	13.0(0.4)	8.1(0.25)	0.62	10.6(0.32)

The ornament (over a diameter of 2 cm) consists of prorsiradiate bifurcating ribs becoming more widely spaced with growth. They are rather weak near the umbilicus and the middle of the flanks, become stronger and arch forward near the venter. The ribs cross the acute venter forming chevrons with a lower pseudocarina in between them. Sutures not preserved.

DISCUSSION: *Lamberticeras henrici* R. Douvillé (1912) is characterized by bifurcating ribs with occasionally a single secondary in between the primaries. Thereby it differs from *L. lamberti* which usually has two or three secondary ribs between the simple or bifurcating primaries. The whorl section of *L. lamberti* and *L. praelamberti* (R. Douvillé) is highly cordate with a sharp venter at diameters of 3-5 cm, thus differing from *henrici* which tends to rounding of the venter with growth.

Our specimens resemble *L. henrici* in whorl section and ornament, although differ from some of the specimens from France and Scandinavia (Reyment, 1972) and British Columbia (Frebold and Tipper, 1975) by weaker dorsolateral ribbing in addition to the following features: M-5397 tends to coarse and widely spaced ribbing at D > 25 mm (early maturity?); M-5346 is flattened like the French *L. praelamberti*, but is more coarsely ribbed. Due to the intraspecific variability seen in the material figured by R. Douvillé (1912, Pl. 4), more well-preserved material is needed to clarify the identity of the Israeli specimens, which have meanwhile been attributed to the closest-looking form.

AGE: *L. henrici* R. Douvillé characterized the lower subzone of the Late Callovian Lamberti-Zone (Callomon and Sykes, in: Duff, 1980).

MATERIAL AND OCCURRENCE: Specimens (Type No. 1209) M-5346, 5397 (coll. M. Goldberg and M. Raab), Makhtesh Hatira, Upper Zohar Formation (Tsia Member); at Gebel El-Minshera (coll. Z. Lewy), M-7621(2) unit 5, and M-7852 unit 7 uppermost part of Zohar Formation.

Genus PRORSICERAS Buckman, 1918

Type species: *Ammonites gregarius* Leckenby, 1859

"*Prorsiceras*" *hatirae* sp. nov.
Pl. 6, figs. 7-11

HOLOTYPE: (Type No. 1210) M-6089 (coll. M. Goldberg and M. Raab), Makhtesh Hatira, top Zohar Formation. Pl. 6, figs. 7-9.

DERIVATION OF NAME: Type locality: Makhtesh Hatira.

STRATIGRAPHIC LEVEL: Upper Callovian.

DIAGNOSIS: Small (D < 3 cm), quite evolute, planulate conch. Young stage smooth attaining with growth strongly prorsiradiate bifurcating ribs, which become coarser with age and form chevrons on the gerontic venter. Straight projecting ventral rostrum.

DESCRIPTION: The mature holotype has a diameter (before the rostrum) of 23 mm and the largest, almost complete specimen (M-5384) has a diameter of 30 mm. The whorl section has sub-parallel flanks and a rounded venter which may be fastigate in the young ontogenetic stage.

MEASUREMENTS:

	D	H	W	W/H	U
M-6089 Holotype	23.0	7.5(0.32)	6.0(0.26)	0.80	7.7(0.33)
M-5384	25.0	8.8(0.35)	7.3(0.29)	0.83	9.2(0.37)
"	30.0	10.2(0.34)	8.0(0.27)	0.78	11.8(0.39)

The conch becomes evolute with growth (U/D = 0.33-0.39) whereas the W/H ratios slightly decrease. The venter is relatively obtuse and even rounded in the mature stage, but it may be fastigate, with a pseudo-carina in between the strongly prorsiradiate ribs which converge towards the venter. The gerontic complete specimen (D = 23 mm) has a straight, projecting ventral rostrum in the form of a smooth scoop characteristic to *Quenstedtoceras*. The young conch is smooth up to a diameter of 9-12 mm, where it starts to develop weak, broad, prorsiradiate ribs. Some of the ribs bifurcate at the dorsal third of the flank, but most of them are singles with a shorter secondary one in between. All ribs cross the venter forming chevrons. Ribbing becomes coarser near the gerontic aperture, strengthening the chevrons on the venter (Pl. 6, figs. 8, 10). Sutures not preserved.

DISCUSSION: "*P.*" *hatirae* sp. nov. comprises small specimens with a simple ribbing pattern of bifurcating or alternating primary and a single secondary rib, thus differing from the larger, more complexly ribbed *P. gregarium* (Leckenby, 1859 in Arkell, 1957). The Israeli material shows the presence of a rostrum such as known from *Quenstedtoceras* s. str., supporting its relations to the cardioceratids with a questionable identitfication with *Prorsiceras*.

MATERIAL AND OCCURRENCE: Holotype (Type No. 1210) M-6089, specimens M-5400, 5384, 5451

(coll. M. Goldberg and M. Raab), Makhtesh Hatira, uppermost part of the Zohar Formation.

Family REINECKEIIDAE Hyatt, 1900
Genus REINECKEITES Buckman, 1924

Type species: *Reineckeites duplex* Buckman, 1924

Reineckeites sp. cf. *R. douvillei* Steinmann
Pl. 7, figs. 8-10

cf. 1932 *Reineckeia stuebeli* Steinmann, var. *douvillei* Steinmann, Corroy, p. 121; Pl. 14, fig. 4, non 3, 5-6.
cf. 1951 *Reineckeites douvillei* Steinm. sp., Jeannet, p. 141; Pl. 49, fig. 7; Pl. 57, fig. 1.
cf. 1968 *Reineckeites douvillei* Steinmann, Bourquin, p. 54; Pl. I, 2-5; Pl. IV, 2; Pl. X, 2; Pl. 5, figs. 1-4.

DESCRIPTION: A small fragment of the whorl of a planulate conch. The subparallel flanks are ornamented by irregularly spaced primary, simple or bifurcating ribs. The secondaries tend to approach and join some of the primaries but weaken and disappear just before converging. All ribs are prorsiradiate, especially near the venter, where they become stronger on the ventrolateral shoulder. They weaken suddenly on the venter leaving a siphonal furrow.

DISCUSSION: The small fragment exhibits the characteristics of *Reineckeites*, similar in nature to the compressed *R. douvillei* Steinmann, with the irregularly spaced, ribbing (not the regular bifurcating pattern in Corroy, 1932; Pl. 14, figs. 3, 5-6). This species was recorded from the Middle (?) and Upper Callovian. However, the present small fragment does not enable undoubtable specific identification.

AGE: *R. douvillei* is recorded from the Middle Callovian and the Upper Callovian Athleta-Zone of Switzerland (Jeannet, 1951, p. 141).

MATERIAL AND OCCURRENCE: (Type No. 1365) M-5371(2) (coll. Z. Lewy), Makhtesh Hatira, Upper Zohar Formation (middle Tsia Member).

Genus COLLOTIA de Grossouvre, 1917

Type species: *Ammonites fraasi* Oppel, 1957

Collotia sp.
Pl. 7, figs. 11, 12

DESCRIPTION: A poorly preserved fragment of a ventral part of the whorl, with coarse, widely spaced lateral ribs, bearing a ventrolateral tubercle (dorsal part damaged). Ventral short, prorsiradiate ribs become stronger in the form of bullae and terminate before the siphonal region, where they form a shallow groove. The ventral ribs do not furcate from the ventrolateral tubercles.

DISCUSSION: Our fragment has the ornament pattern of the adult stage of *Collotites* (= *Collotia) odysseus* Mayer-Eymar (Jeannet, Pl. 67) which has a high whorl section. *Collotia* aff. *angustilobata* (Brasil, in Spath, 1928, Pl. 33, fig. 10) also has a similar coarse ornament and a broad whorl section. However, due to the fragmentary nature of our specimen, no specific identification is possible.

AGE: *Collotia* ranges from the Middle into the Upper Callovian Athleta-Zone and has been recorded as relatively rare from the Upper Callovian Lamberti-Zone (Arkell, 1939; Callomon and Sykes in Duff, 1980).

MATERIAL AND OCCURRENCE: (Type No. 1377) M-7746 (coll. Z. Lewy), Gebel Maghara (G. Hamir, coord. 9838/0102), top Zohar Formation.

Family PERISPHINCTIDAE Steinmann, 1890
Subfamily PROPLANULITINAE Buckman, 1921
Genus KINKELINICERAS Buckman, 1921

Type species: *Proplanulites kinkelini* Dacqué, 1910

Kinkeliniceras sp. cf. *K. kinkelini* (Dacqué)
Pl. 6, figs. 3, 4

cf. 1931 *Kinkeliniceras kinkelini* (Dacqué), Spath, p. 307; Pl. 62, fig. 7.
cf. 1958 *Obtusicostites devi* Spath, Collignon, Pl. 31, fig. 144.

DESCRIPTION: Moderately evolute (U/D = 0.36), planulate conch. Whorl section trapezoidal with the maximum width at the umbilical shoulder and a slightly, narrow, rounded venter. W/H decreases with growth, especially in the young stage, forming the planulate coiling pattern. The umbilical wall is quite steep with rounded shoulders.

MEASUREMENTS:

	D	H	W	W/H	U
M-7671	-	11.5	18.3	1.6	-
"	-	18.5	18.0	0.96	-
"	49	19.5(0.40)	19.0(0.39)	0.97	17.5(0.36)

The young stage has a short, prominent umbilicolateral ribs resembling bullae, which bifurcate into prorsiradiate ribs. With growth, a shorter secondary rib appears in between the pair of primaries, weakening dorsally in the middle of the flank. All ribs strengthen ventrally, become very prominent on the ventrolateral shoulder and weaken on the siphonal region, resembling somewhat Proplanulites, which has a smooth band on the siphonal region. Generally, the ribs cross the venter with a gentle adorally convex curvature. The sutures are not preserved.

DISCUSSION: Our single specimen is poorly preserved. However, its mode of coiling and ornament is that of the Planulitinae, among which it most resembles *Kinkeliniceras kinkelini* (Dacqué) of Spath (1931, Pl. 62, fig. 7) from the Upper Callovian (Athleta beds) of Cutch. *Obtusicostites devi* Spath, from the Upper Callovian of Madagascar (Collignon, 1958), resembles our specimen in mode of ribbing. This Madagascan specimen is larger than our one and shows a more advanced growth stage than obtained by our specimen. Therefore, an undoubtable identity could not be established. Arkell (1957, p. L317) noticed the great similarity of some *Obtusicostites* species to those of *Kinkeliniceras*, both genera attributed by him to the Middle Callovian. However, the Late Callovian age of the two above mentioned species of *Kinkeliniceras* and *Obtusicostites* and the Upper Callovian *Kinkeliniceras oppeli* Kanjilal and Singh (1980) from Cutch, suggest an extension of the range of these genera into the Upper Callovian.

AGE: Our specimen is compared to Upper Callovian (Athleta-Zone) forms although the typical *K. kinkelini* (Dacqué) is a Middle Callovian taxon.

MATERIAL AND OCCURRENCE: (Type No. 1223) M-7671 (coll. M. Goldberg and M. Raab), Makhtesh Hatira, Upper Zohar Formation (middle Tsia Member).

Subfamily PSEUDOPERISPHINCTINAE Schindewolf, 1925
Genus GROSSOUVRIA Siemiradzki, 1898

Type species: *Perisphinctes subtilis*, 1870

Grossouvria sp.
Pl. 7, fig. 15

DISCUSSION: The fragmentary single specimen forms a quarter of a volution. It differs from the two *Grossouvria* sp. from Saudi Arabia (Imlay, 1970, p. D14; Pl. 3, figs. 1-4) by its strongly prorsiradiate (not falcoid) primary ribs, all bifurcating at the ventrolateral margins and by its higher than wide whorl section. *Grossouvria* sp. of Spath (in Hudson, 1958; British Museum No. e71701) has alternating simple and bifurcating radiating ribs and may be close (or identical to our "*Perisphinctes*" sp.

MATERIAL AND OCCURRENCE: (Type No. 1368) M-7815 (coll. M. Goldberg and M. Raab), Makhtesh Hatira, base Be'er Sheva Formation.

Subfamily PERISPHINCTINAE Steinmann, 1890

"*Perisphinctes*" (s.l.) sp.
Pl. 7, figs. 23, 24

? 1958 *Grossouvria* sp., Hudson, p. 420.

DESCRIPTION: Evolutely coiled, planulate, quadrangular whorl section higher than wide (W/H = 7.5/8.6 = 0.87). Flanks flattened and subparallel, rounded umbilical shoulder and an almost tabulate to slightly rounded venter. Fine, sharp ribs radiate from the umbilical seam, pass over the umbilical wall onto the flanks. Most ribs bifurcate at the middle of the flanks from where they tend to bend forward, crossing the venter with a gentle adorally convex curvature. Ribbing is very fine and dense on the young volutions and coarsens gradually with growth. No constrictions are discernible. The suture is only generally represented by the surface of a septum showing a large first lateral saddle, a narrow first lateral lobe at the middle of the flank, and three, small gradually decreasing umbilical saddles.

DISCUSSION: Our fragment is similar to the Oxfordian *Perisphinctes* s. str., differing only by the rather low point of rib-bifurcation in our specimen (thereby differing from *Dichotomosphinctes* and *Dichotomoceras* and from

the constricted *Orthosphinctes)*. A great variety of Callovian perisphinctids was attributed to the genus *Grossouvria*, perhaps to avoid the extension of the ranges of well-known Oxfordian genera or the establishment of new ones.

MATERIAL AND OCCURRENCE: (Type No. 1369) HU-17780 (coll. L. Picard) and M-6062 (coll. M. Goldberg and M. Raab), Makhtesh Hatira. HU-17880 is attributed to the Eligmus-Grossouvria unit of Hudson (1958), from the middle part of the unit yielding M-6062 (Upper Zohar Formation).

Genus SUBGROSSOUVRIA spath, 1924

Type species: *Perisphinctes aberrans* Waagen, 1875

Subgrossouvria sp.

Pl. 7, figs. 13, 14

DESCRIPTION: Evolutely coiled, whorl section wider than high (W/H = 15.3/12.0 = 1.27; 26.4/23.5 = 1.12) with rounded flanks and venter. The young stage is ornamented with fine and dense prorsiradiate ribs which bifurcate ventrolaterally into finer ribs than the primaries and cross the venter with an adorally convex curvature. Ornament coarsens with growth, becoming more widely spaced but keeping the regular dichotomous pattern. The primary ribs may be radiate or slightly rursiradiate on the flanks, turning stronger forwards ventrolaterally. No constrictions occur on the fragments. Sutures are not preserved.

DISCUSSION: The broad rounded whorl section and the regular ornament pattern are those of *Subgrossouvria*. Although all three fragments represent different ontogenetic stages, they are assumed to belong to the same species. Most of the *Subgrossouvria* species from Cutch (Spath, 1928) have constrictions or coarser and more numerous ventral ribs. The constricted *Subgrossouvria*(?) sp. (Spath, 1928, Pl. 68, fig. 1) is most similar to our material, which cannot be undoubtably identified due to its fragmentary nature.

MATERIAL AND OCCURRENCE: (Type No. 1380) M-7745(2), 7746 (coll. Z. Lewy), Gebel Maghara region (Gebel Hamir), top Zohar Formation.

Genus ALLIGATICERAS Buckman, 1923

Type species: *Ammonites alligatus* Leckenby,1859

Alligaticeras sp. cf. *A. raguini* (Gérard and Contaut)

Pl. 7, fig. 22; Pl. 8, figs. 1, 2

cf. 1936 *Orionoides raguini* Gérard and Contaut, p. 60; Pl. 12, fig. 1a,b.

DESCRIPTION: Evolutely coiled planulate conch.

MEASUREMENTS:

	D	H	W	W/H	U
M-7745:1	100.0	25.8(0.26)	24.2(0.24)	0.93	54.0(0.54)
M-7852:1	139.0	35.3(0.25)	32.0(0.23)	0.91	76.0(0.55)

The ornament consists of prorsiradiate ribs, being fine and densely spaced in the young stage, becoming gradually more widely spaced with growth. Near the venter, they bi- or trifurcate into narrower and weaker ribs, crossing the venter with an adapical (convex) flexure. Two or three constrictions per volution occur throughout ontogeny. Sutures not preserved.

DISCUSSION: Our evolute, planulate specimens are characterized by a gradual coarsening of ornament of mainly bifurcating ribs with occasionally trifurcating ones. Several fragments show slight variations in W/H ratios and ribbing density, but the specific significance of these variations is yet unknown due to the poor state of preservation. The two most complete specimens resemble *A. raguini* in mode of ornament, slightly differing from the French specimen which has a narrower whorl section (W/H = 0.86) and larger umbilicus (0.58). However, these small morphological differences from the French holotype may merely represent its intraspecific variations. Other species of Gérard and Contaut (1936), such as *A. cayeuxi* and *A. piveteaui* have widely spaced ribs at the early ontogenetic stage in contrast to the fine and dense ribs in our material. Although our specimens are closely related to *A. raguini*, an undoubtable identity could not be proven. Our specimens are quite large for typical *Alligaticeras*, but no more suitable taxon was found in the literature.

AGE: *A. raguini* originates from the Upper Callovian Athleta-Zone (Gérard and Contaut, 1936).

MATERIAL AND OCCURRENCE: (Type No. 1389) M-7745(4) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation; M-7621 unit 5, 7852 unit '7 (coll. Z. Lewy), Gebel El-Minshera.

Family ASPIDOCERATIDAE Zittel, 1895
Subfamily PELTOCERATINAE Spath, 1924
Genus PELTOCERAS Waagen, 1871

Type species: *Am. athleta* Phillips, 1829

Peltoceras trifidum (Quenstedt)
Pl. 7, figs. 16-21

1931 *Peltoceras trifidum* (Quenstedt), spath, p. 562; Pl. 110, fig. 5.
1951 *Peltoceras trifidum* Q. sp., Jeannet, p. 167; Pl. 72, fig. 4; Pl. 73, figs. 1-4; text-figs. 394-396.
cf. 1959 *Peltoceras trifidum* Q., collignon, Pl. 36, fig. 192.
1975 *Peltoceras trifidum* (Quenstedt), Gill and Tintant, p. 102.

DESCRIPTION: A complete, young specimen (M-5451, Pl. 7, figs. 19-21; D = 35 mm) and two fragmentary ones (M-6046, 7664) from a narrow stratigraphic interval at Makhtesh Hatira and two corroded fragments from Gebel El-Minshera, northern Sinai (M-7663); all are regarded as of the same species although minor variations do occur, perhaps because of the various ontogentic stages, as well as their state of preservation. Evolute, sub-quadrate whorl section with the width greater than the height up to a diameter of 5 cm. The maximum width is at the umbilicolateral margins even in between the tubercles. Each whorl section is almost twice as high and wide as that of the preceding one. The umbilical wall rounded.

MEASUREMENTS:

	D	H	W	W/H	U
M-5451	25.6	8.5(0.33)	10.1(0.39)	1.18	1.7(0.45)
M-7664	-	17.0	18.0	1.06	-
"	-	19.3	18.8	0.97	-

The young stage has fine, densely-spaced, radiate ribs which bifurcate at the ventrolateral margins and form loops on the venter. With growth (D > 16 mm) the ribs become coarser and more widely spaced, mainly on the flanks. They develop umbilicolateral rounded projections which in later stages, when the ribs weaken on the flanks, form the umbilicolateral bullate tubercles. Spinose ventrolateral tubercles start to appear at several ventrolateral bifurcation points, developing with growth into a regular pattern. The tubercles which evolved as dorsolateral projections superimposed on the ribs become with growth the dominant feature, while the lateral ribs disappear and the ventral ones weaken considerably. These latter ribs form an irregularly spaced pattern due to variations in the number of ribs furcating from the tubercles and the occurrence of intercalatory ventral ribs not connected to any tubercle.

The suture is characterized by a very narrow asymmetric first lateral lobe (Pl. 7, fig. 16).

DISCUSSION: *Peltoceras trifidum* is quite similar to *P. athleta* Phillips in mode of coiling and ornament. The only feature which may differentiate between them is the very long and narrow asymmetric first lateral lobe in *trifidum*. *P. trifidum* of Collignon (1959) loses its ribs on the flanks and venter at earlier stages than our material. It does not show the sutures well and thus may only be compared to our specimens. Gill and Tintant (1975) recorded from the Makhtesh Hatira *P.* aff. *antiquum* (Lóczy) in addition to *P. trifidum*, which is the only species identified within the framework of this study.

AGE: *P. trifidum* is known from the Middle (?) and mainly from the Athleta-Zone of the Upper Callovian of Switzerland (Jeannet, 1951, p. 169) and the Upper Callovian Lamberti-Zone of Madagascar (Collignon, 1959, Pl. 36, fig. 1).

MATERIAL AND OCCURRENCE: (Type No. 1224) M-5451, 6046(2), 7664 (coll. M. Goldberg and M. Raab; F. Hirsch) Makhtesh Hatira, Upper Zohar Formation (Tsia Member; some of the specimens of Gill and Tintant were collected also at the base of the Be'er Sheva Formation). M-7663(2) (coll. Y. Druckman) Gebel El-Minshera, Upper Zohar Formation, unit 6.

Subgenus RURSICERAS Buckman, 1919

Type species: *Am. reversus* Leckenby, 1859

REMARKS: Callomon (1981, pers. comm.) regards *Rursiceras* as the microconch of its dimorph *Peltoceras*, so that *Rursiceras* should be assigned at least as a subgenus of *Peltoceras*.

A small fragment from Gebel Maghara and a diagenetically compressed badly preserved specimen from Makhtesh Hatira show rursiradiate ribbing characterizing *Rursiceras*. Their poor state of preservation hinders any attempt at a specific identification as well as preventing comparison between them, so that meanwhile they are described herein as separate undeterminable species.

Rursiceras sp. A.
Pl. 6, figs. 5, 6

DESCRIPTION: A poorly preserved specimen, evolutely coiled, planulate (partly diagenetically compressed; W/H = 66/125 = 0.53) attaining a diameter of 38 mm. The last volution is ornamented by slightly falcoid, rursiradiate to radiate ribs, which bifurcate at the middle of the flank and become strongly rursiradiate towards the venter, crossing it without weakening. Ribbing coarsens and becomes more widely spaced with growth. Sutures not preserved.

MATERIAL AND OCCURRENCE: (Type No. 1307) M-6065 (coll. M. Goldberg and M. Raab), Makhtesh Hatira, Upper Zohar Formation (middle Tsia Member).

Rursiceras sp. B
Pl. 8, fig. 3

DESCRIPTION: A small fragment of an evolutely coiled planulate conch, subparallel flanks and a rounded venter (W/H = 17.4/18.3 = 0.95). A slight increase in width and height marks the adoral direction on which the generic identification is based. Strong, sharp rursiradiate primaries bifurcate at the middle of the flanks into sharp, strongly rursiradiate ribs which cross the venter. Sutures not preserved.

MATERIAL AND OCCURRENCE: (Type No. 1445), M-7746 (coll. Z. Lewy), Gebel Maghara region (G. Hamir), top Zohar Formation.

Genus EUASPIDOCERAS Spath, 1931

Type species: *Ammonites perarmatus* J. Sowerby, 1882

Euaspidoceras ferrugineum Jeannet
Pl. 8, figs. 4-6

1916 *Aspidoceras babeaui* d'Orbigny, Douvillé, p. 70; Pl. 8, fig. 6a,b.
1951 *Euaspidoceras ferrugineum* Jeannet, p. 202; Pl. 92, fig. 1; Pl. 93, fig. 1.
?1951 *Euaspidoceras spinigerum* Rollier, Jeannet, p. 205; Pl. 94, fig. 3, text-fig. 484.

DESCRIPTION: Moderately large, evolute coiling with a wide whorl section (W/H = 47/42 = 1.12 in between the ribs). The widely-spaced, strong umbilicolateral and ventrolateral horny tubercles give it a broader appearance and a trapezoidal whorl section due to the more protruding umbilicolateral ones. The venter and the flanks in between the tubercles form an almost circular section, truncated dorsally by the strongly rounded umbilical shoulder and the gently concave dorsum (Pl. 8, fig. 4). The fragment of the adult conch has very low ribs connecting between the pair of lateral tubercles. The ribs weaken and tend to disappear near the ventrolateral tubercle. The venter is almost smooth except for low rib-like undulations, some connecting between the pairs of the ventrolateral tubercles. The poorly preserved sutures show a narrow bifid external lobe, a broad bifid first lateral saddle and a smaller similar second lateral one, reaching the umbilical shoulder. The narrow and deep first lateral lobe lies in the middle of the flank and is as long as the external lobe.

DISCUSSION: Douvillé (1916) attributed the specimens from Gebel Maghara to *E. babeanus* (d'Orbigny) on the basis of the broad whorl section and the horn-like pair of lateral tubercles of the young ontogenetic stage. However, according to the drawings in d'Orbigny (1847, Pl. 181, fig. 1), the ventrolateral tubercles weaken and disappear at a diameter over 85 mm, thus differing from the coarsely tuberculated large fragment from Sinai (Pl. 8, figs. 4-6). Two species described by Jeannet (1951) resemble our fragments: *E. spinigerum* Rollier and *E. ferrugineum* Jeannet. The refigured holotype of *E. spinigerum* shows morphological similarity with *E. ferrugineum*. This latter species is represented by several specimens (e.g., var. A) of a broad variability in whorl height (H/D = 0.32-0.29), width (W/D = 0.42-0.31) and umbilical ratio (U/D = 0.50-0.46) which include the pattern of the holotype of *E. spinigerum* Rollier. *E. ferrugineum* occurs in Switzerland from the lower Athleta-Zone to the lower Lamberti-Zone, whereas the single specimen of Rollier is known from the upper Athleta-Zone. It seems that Jeannet (1951) assigned to his species *ferrugineum* a broad, morphological and stratigraphical range which may include *E. spinigerum* Rollier. Therefore, here it is preferred to attribute the material from Sinai to *E. ferrugineum*, although it may be a junior synonym of *E. spinigerum* Rollier.

AGE: Aspidoceratinae appear in Europe from the Upper Callovian Lamberti-Zone (Callomon, 1981, pers. comm.); *E. ferrugineum* occurs in Switzerland in the Athleta-Zone and base Lamberti-Zone of

the Upper Callovian (Jeannet, 1951).

MATERIAL AND OCCURRENCE: M-7745(3) (coll. Z. Lewy), Gebel Maghara, top Zohar Formation.

Subfamily ASPIDOCERATINAE Zittel, 1895
Genus PARASPIDOCERAS Spath, 1925

Type species: *Am. meriani* Oppel, 1863

"Paraspidoceras" sp.
Fig. 6E

1975 *Paraspidoceras* sp. nov., Gill and Tintant, p. 103.

DESCRIPTION: Evolutely coiled, large conchs. The whorl section of the adult fragment in between the tubercles is circular, whereas the robust ventrolateral tubercles give it a trapezoidal (or even triangular) shape (Fig. 6E). The reconstruction of the conch according to the fragments shows a broad, slightly rounded, smooth venter and rounded flanks in between the tubercles. The prominent horn-like triangular ventrolateral tubercles may stretch dorsally as pseudo-ribs mainly in whorls up to 4 cm in height, whereas in H > 5 cm, they weaken and disappear ventrally to the middle of the flank. No ribs or dorsolateral tubercles occur. Sutures only partly preserved.

DISCUSSION: Our fragmentary specimens have horn-like ventrolateral widely spaced tubercles, resembling the ornament of *Paraspidoceras* from the Upper Oxfordian. Usually, *Paraspidoceras* (=*Extranodites* Jeannet, 1951) has rather long and narrow horny tubercles from the young ontogenetic stages, tending to depressed sections with clavate horns. Our specimens are adult stages which bear broad, coarse, horn-like short tubercles resembling the ventrolateral row of some *Euaspidoceras*, but lack the dorsolateral tubercles. Better material is needed to decide whether it is a new form.

Gill and Tintant (1975) have recorded from the same locality and stratigraphic level *Paraspidoceras* sp. nov. Although not described or figured, it is reasonable to assume that it is identical to our material. In the absence of any ventral ribbing on our fragment, no relations could be established with *Peltoceras* (?) *antiquum* (Lóczy, 1915, Pl. 26, figs. 1-2).

MATERIAL AND OCCURRENCE: M-6149(2), 6025(7) (coll. M. Goldberg and M. Raab; Z. Lewy), Makhtesh Hatira, lower part of Be'er Sheva Formation, attributed to the Late Callovian on the basis of its association with *Pachyerymnoceras levantinense* Lewy nov. sp. (Type No. 1306).

ACKNOWLEDGEMENTS

This study is based mainly on ammonites collected at Makhtesh Hatira (Kurnub anticline), Israel, by M. Goldberg and M. Raab. A few additional specimens were found by L. Picard, F. Hirsch and the author. The specimens from Gebel Maghara and Gebel El-Minshera (northern Sinai) were collected mainly by the author and some specimens by Y. Bartov, Y. Druckman and the late R. Freund.

The lithostratigraphy of the Jurassic sequences in the Negev, Israel, northern Sinai and Mount Hermon has been worked out by M. Goldberg and used herein with his kind permission.

L. Buchbinder, B.H. Conway, A. Ehrlich, H. Frenkel, F. Hirsch, S. Moshkovitz, A. Parnes and especially M. Goldberg (Geological Survey of Israel), J. Thierry (University of Dijon, France) and J.H. Callomon (University College, London) contributed to this study through discussions, criticism and data from their own work on the Jurassic stratigraphy.

R. Imlay (Smithonian Institution, Washington D.C.) sent me the photos of an ammonite from Saudi Arabia, described by him in 1970, with the kind permission to refigure it.

Great technical assistance has been offered by C. Alafi, R. Bogoch, M. Dvoracheck, B. Katz, R. Knafo, S. Levy, Y. Levy, A. Pe'er and N. Shragai. To all of them the author is greatly indebted.

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Figure 4. A-D, F: *Pachyerymnoceras levantinense* nov. sp., (type 1207); A-D: various ontogenetic stages of the same specimen, x 1, (coll. M. Goldberg and M. Raab); E: *Pachyerymnoceras philbyi* (Arkell), (type 1208), x 1, HU-30980, Makhtesh Hazera, Tsia Mbr., Upper Zohar Fm., (coll. E. Nevo); compare the rounded whorl section to the depressed ones of *P. levantinense* in Fig. 4 F; F: HU-30979, x 1, Makhtesh Hatira, lower part of Tsia Mbr.; G: *Pachyceras spathi* nov. sp., (type 1249), x 1, M-7691, holotype, Makhtesh Hatira, base Be'er-Sheva Fm., (coll. M. Goldberg and M. Raab).

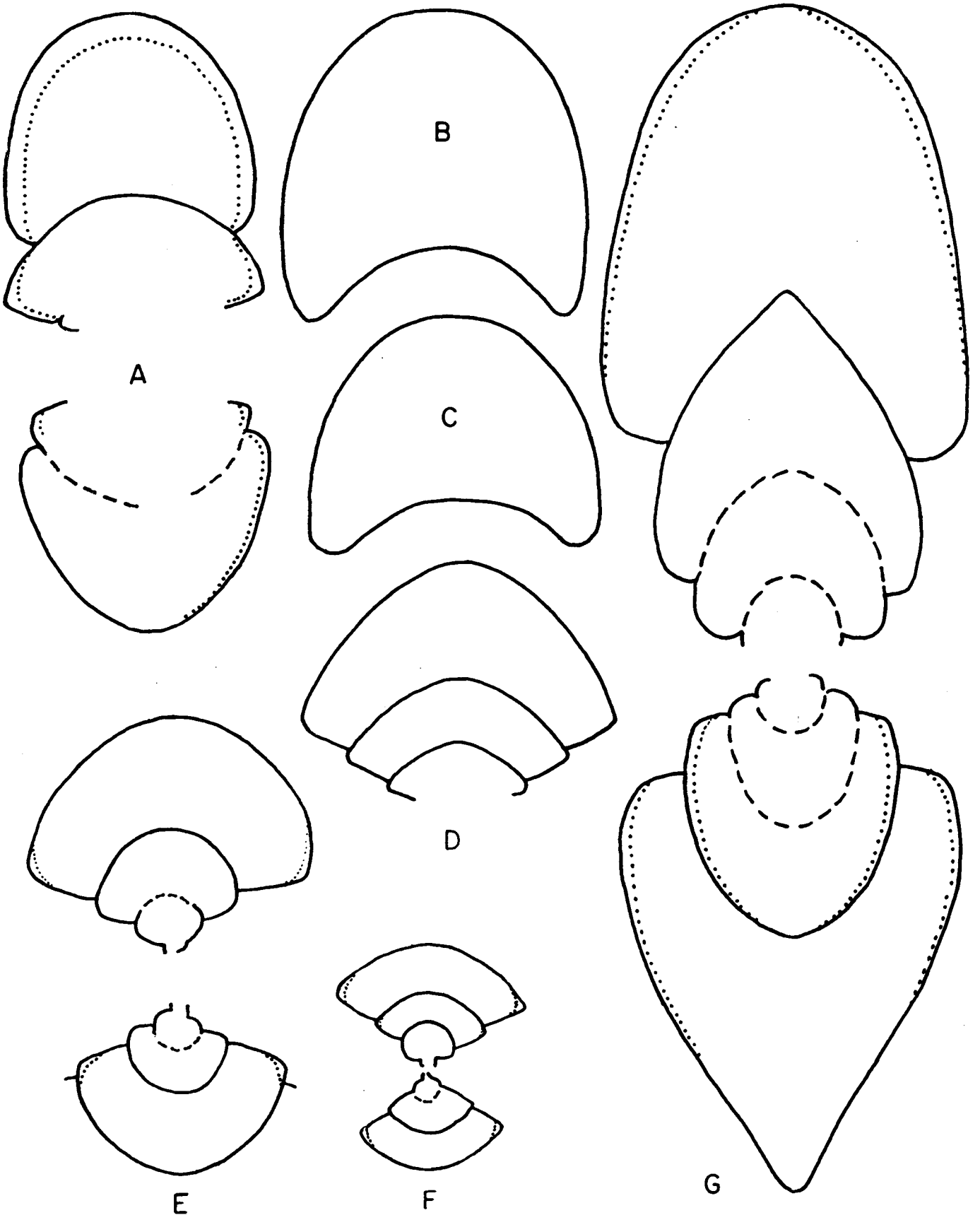
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Figure 5 A: *Pachyceras lalandeanum* (d'Orbigny), (type 1386), x 1, M-7745, G. Maghara, top Zohar Fm., (coll. M. Goldberg); B: *Pachyceras magharense* nov. sp., (type 1392), x 1, M-7745, holotype, G. Maghara, top Zohar Fm., (coll. M. Goldberg).

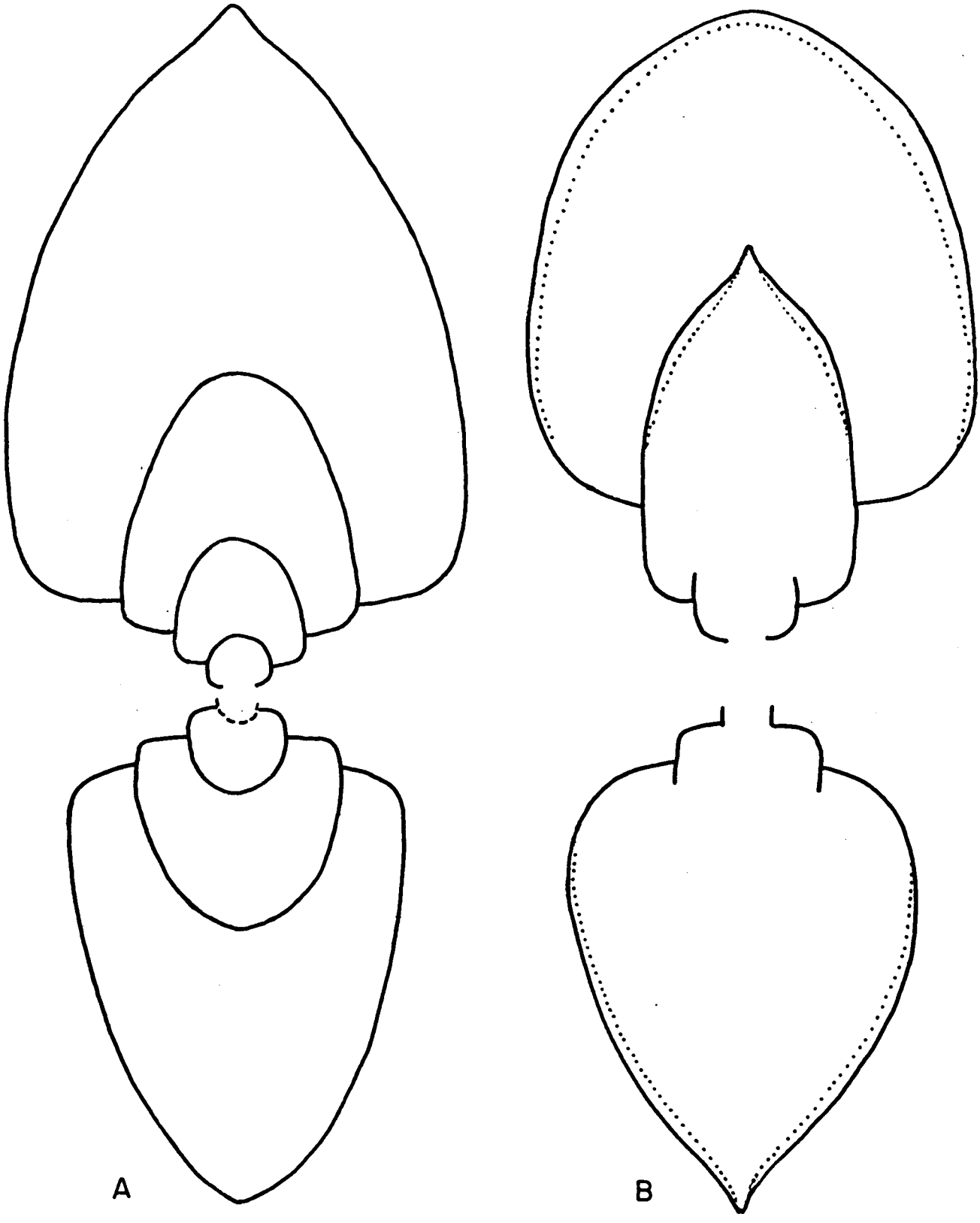
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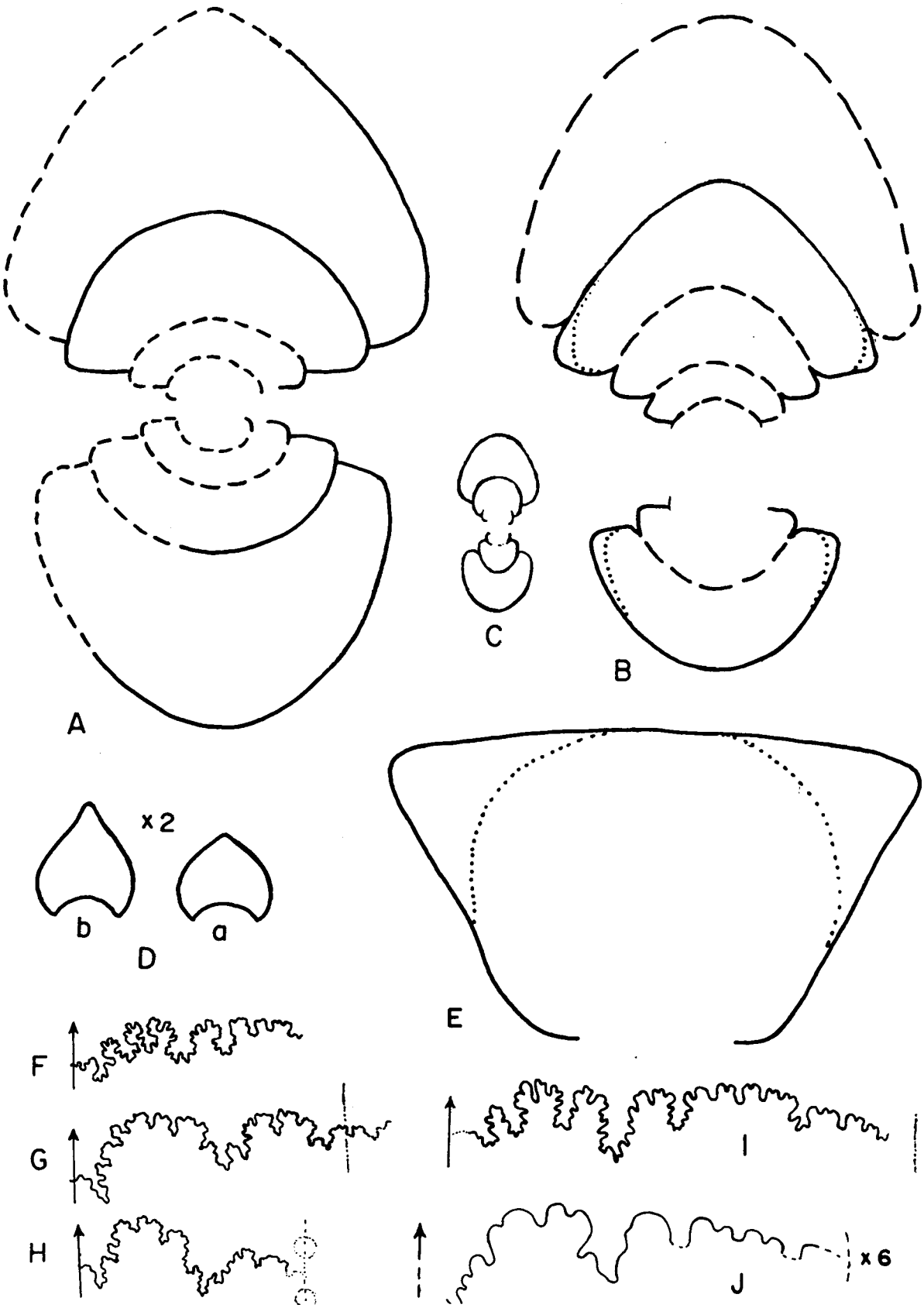
Figure 6 A: *Pachyceras crassum* R. Douvillé, (type 1387), x 1, M-7745, G. Maghara, top Zohar Fm., (coll. Z. Lewy); B: *Pachyerymnoceras* sp. cf. *P. jarryi* (R. Douvillé), (type 1380), x 1, M-7745, G. Maghara, top Zohar Fm., (coll. M. Goldberg); C: *Pachyceras* sp., (type 1367), x 1, M-5339, Makhtesh Hatira, middle Tsia Mbr., Upper Zohar Fm., (coll. M. Goldberg and M. Raab); D: cf. *"Quenstdtoceras"* sp., (type 1305), x 2, M-7261, G. El-Minshera, Upper Zohar Fm., unit 5, (coll. Z. Lewy); E: *"Paraspidoceras"* sp., (type 1306), x 1, M-6025, Makhtesh Hatira, lower part of Be'er-Sheva Fm., (coll. Z. Lewy); F: *Levanticeras sinaiense* nov. gen. and sp., (type 1206), x 1, M-7261, G. El-Minshera, Upper Zohar Fm., unit 5, (coll. Z. Lewy); G: *Pachyerymnoceras levantinense* nov. sp., (type 1207), x 1, M-5328, Makhtesh Hatira, upper part of Tsia Mbr., Upper Zohar Fm., (coll. M. Goldberg and M. Raab); H: *Pachyerymnoceras* sp. cf. *P. jaryyi* (R. Douvillé), (type 1388), x 1, M-7745, G. Maghara, top Zohar Fm., (coll. M. Goldberg); I,J: *Levanticeras levantinense* nov. gen. and sp., (type 1205), Tsia Mbr., Upper Zohar Fm., (coll. Z. Lewy); I: M-7261, G. El-Minshera, x 1; J: M-7814, Makhtesh Hatira, x 6.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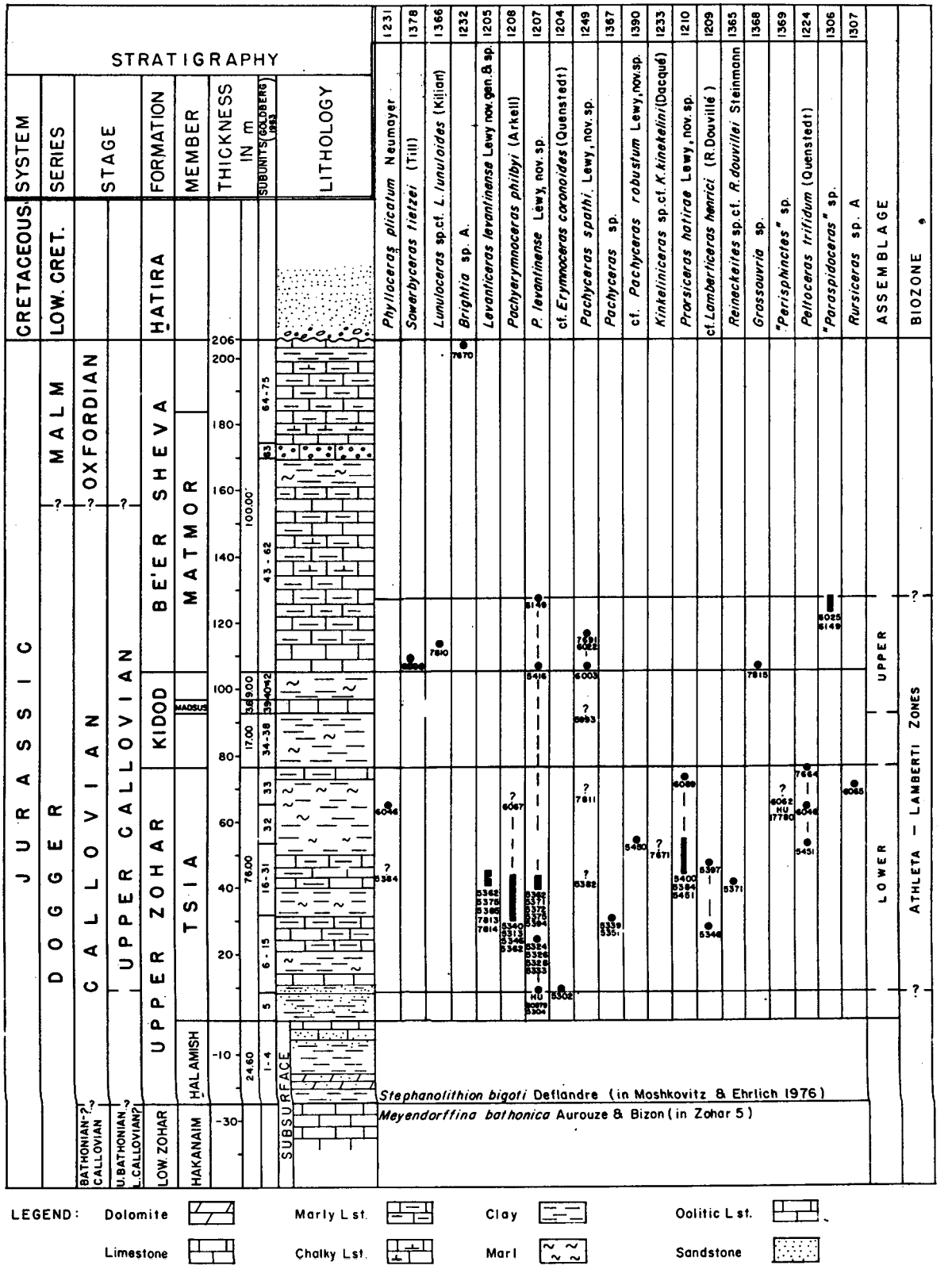


Figure 7. Distribution chart of the Jurassic ammonites at Makhtesh Hatira (Kurnub anticline), southern Israel (measured and sampled by M. Goldberg and M. Raab; Goldberg, 1963).

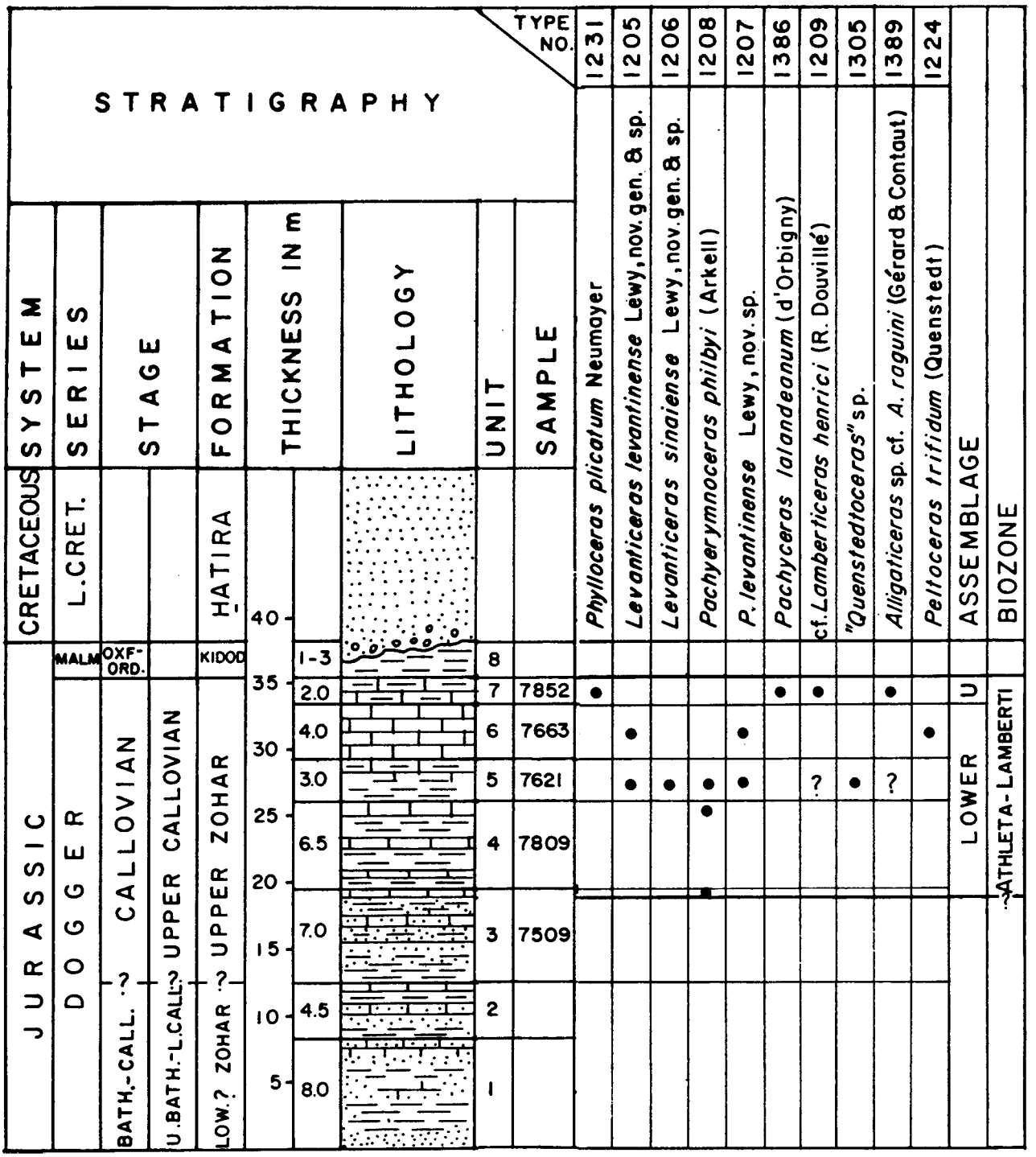


Figure 8. Distribution chart of the Jurassic ammonites at Gebel El-Minshera, northern Sinai (Israeli grid 9690/0219; measured and sampled by Z. Lewy).

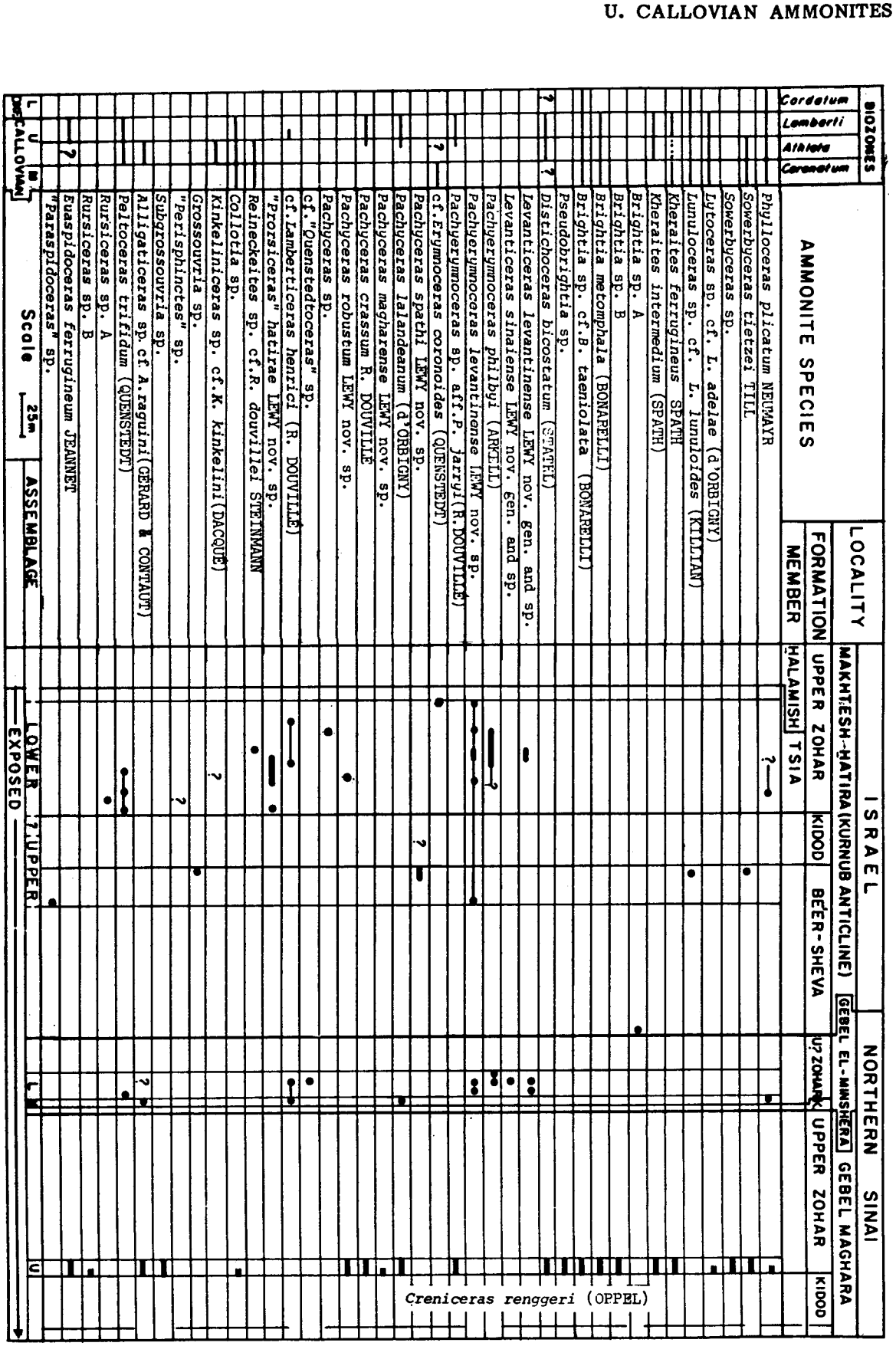


Figure 9. Distribution chart of Middle Jurassic ammonites in southern Israel and northern Sinai and the recorded ranges of some of the species elsewhere.

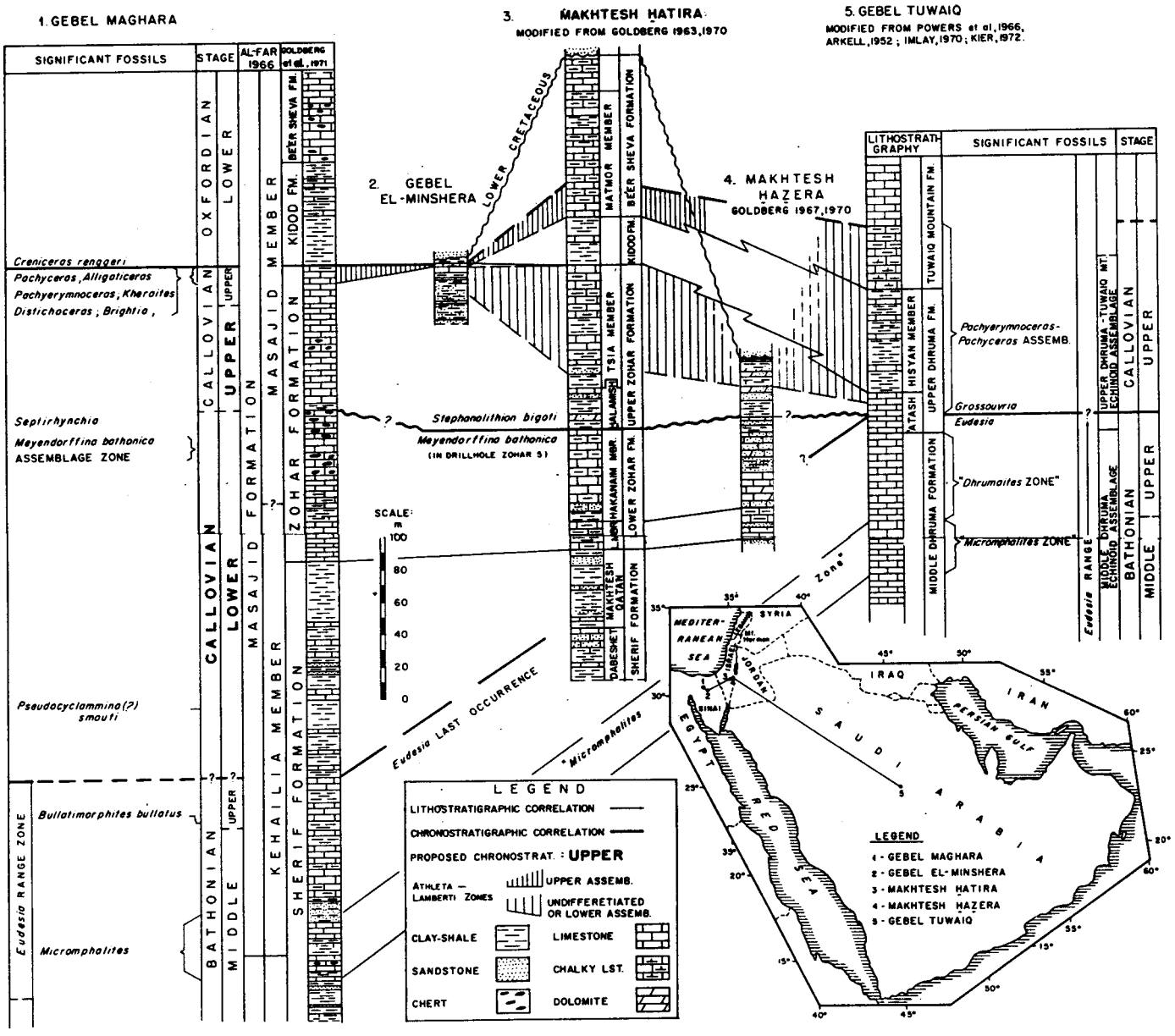


Figure 10. Stratigraphic correlation of Jurassic formations between northern Sinai, southern Israel and central Saudi Arabia.

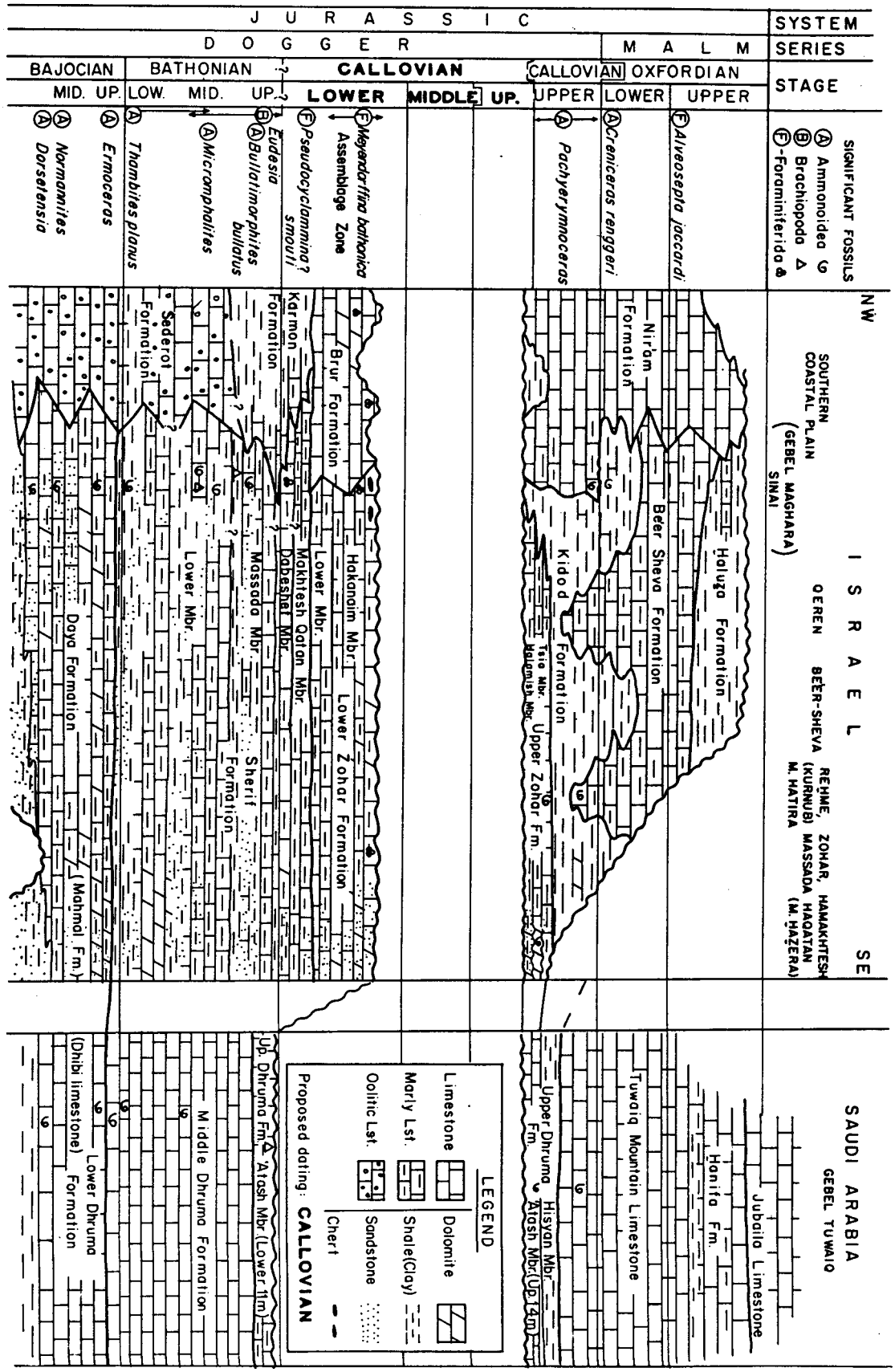


Figure 11. Generalized lithostratigraphic and revised chronostratigraphic correlation of Middle to Upper Jurassic formations in southern Israel and central Saudi Arabia.

PLATES 1-8

EXPLANATION OF PLATE 1

Figures

1-3 *Sowerbyceras tietzei* (Till), (type 1378), x 1, top Zohar Fm., Up. Callovian.
1. M-7746:1 strongly constricted; G.Maghara region (G. Hamir).
2-3. M-7745:1 weakly constricted; G. Maghara.

4 *Sowerbyceras* sp., (type 1379), M-7745:1, x 1, G. Maghara, top Zohar Fm., Up. Callovian.

5 *Phylloceras plicatum* Neumayr, (type 1231), M-6046, x 1, Makhtesh Hatira, upper part of Tsia Mbr., Upper Zohar Fm., Up. Callovian.

6 *Lunuloceras* sp. cf. *L. lunuloides* (Kilian), (type 1366), M-7810, x 1, Makhtesh Hatira, lower part of Be'er-Sheva Fm., Up. Callovian.

7-8 *Pseudobrightia* sp., (type 1383), M-7745:1, x 1, G. Maghara, top Zohar Fm., Up. Callovian. 7: tricarinate venter.

9-12 *Kheraites ferrugineus* Spath, (type 1381), x 1, G. Maghara, top Zohar Fm., Up. Callovian. 9-10: M-7745:1; 11-12: M-7745:3 coarsely ornamented adult stage.

13-14 *Lytoceras* sp. cf. *L. adelae* (d'Orbigny), (type 1376), M-7745. x 1, G. Maghara, top Zohar Fm., Up. Callovian.

15-16 *Kheraites intermedium* (Spath), (type 1382), x 1, G. Maghara, top Zohar Fm., Up. Callovian. 15: M-7745:2; 16: M-7745:1, ornament weakens with growth.

17-18 *Brightia* sp. A, (type 1232A), M-7670, x 1, Makhtesh Hatira, upper part of Be'er-Sheva Fm., Lower (?) Oxfordian.

19 *Brightia* sp. B, (type 1232B), M-7745, x 1, G. Maghara, top Zohar Fm., Up. Callovian.

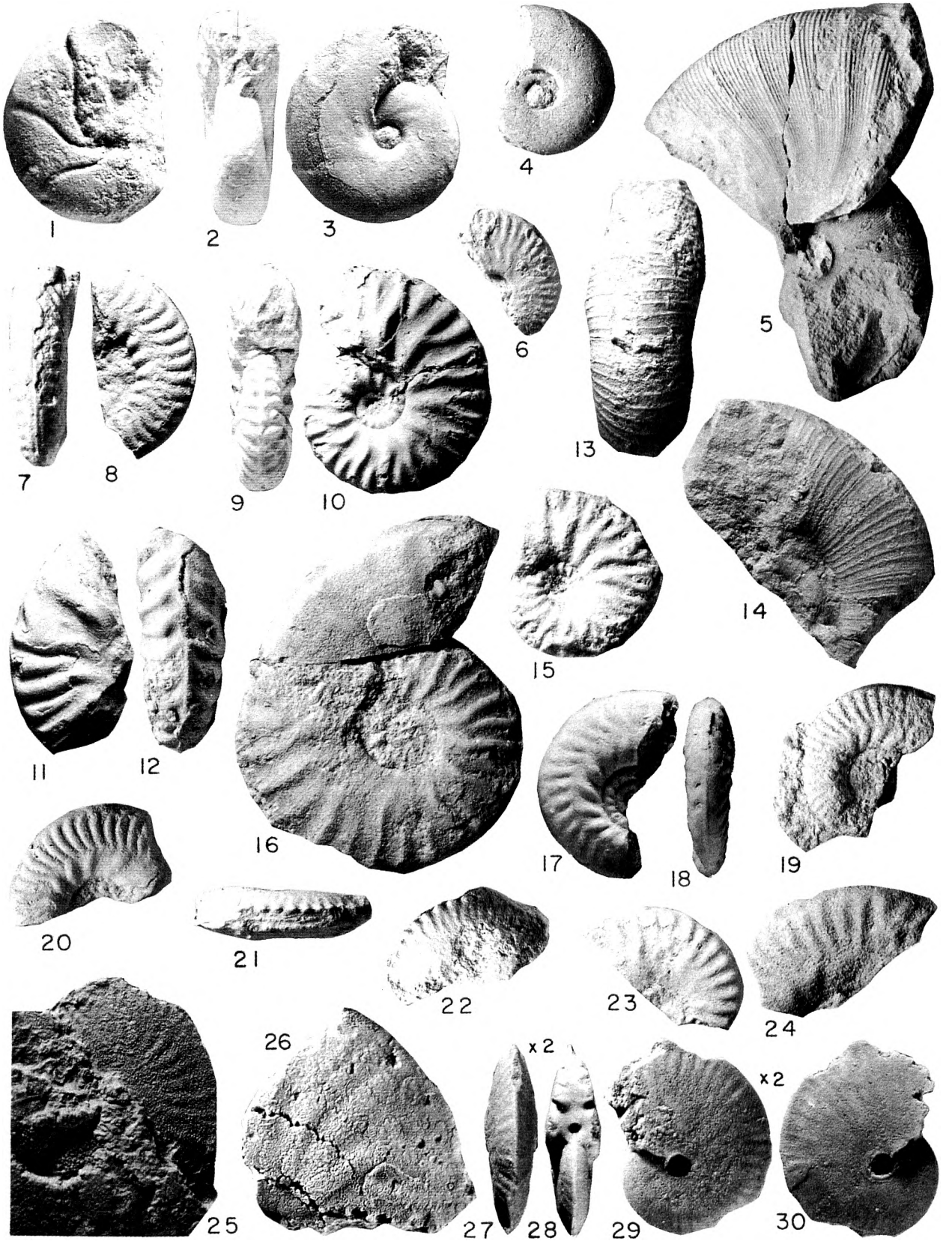
20 *Brightia metomphala* (Bonarelli), (type 1385), M-7745:1. x 1, G. Maghara, top Zohar Fm., Up. Callovian.

21-22 *Distichoceras bicostatum* (Stahl), (type 1384), M-7745, x 1, G. Maghara, top Zohar Fm., Up. Callovian.

23-24 *Bightia* sp. cf. *B. taeniolata* (Bonarelli), (type 1391), M-7745:1, x 1, G. Maghara, top Zohar Fm., Up. Callovian.

25-30 *Levanticeras levantinense* nov. gen. and sp. (type 1205), Up. Callovian.
25. M-5362, Makhtesh Hatira, middle part of Tsia Mbr., upper Zohar Fm., x 1, ornament of inner volution.
26. M-7261, x 1, coarse ribbing of the adult stage, G. El-Minshera, upper Zohar Fm., unit 5.
27-30. M-7814, same provenance as Figure 25, x 2, young stage with weak ventrolateral shoulders and an open umbilicus.

PLATE 1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EXPLANATION OF PLATE 2

Figures

1, 3-4 *Levanticeras levantinense* nov. gen. and sp., (type 1205), Makhtesh Hatira, middle Tsia Mbr., upper Zohar Fm., Up. Callovian.
1. M-7813, holotype, x 2/3; low, broad ribs on phragmocone.
3. M-7813, holotype, x 1; cross-section of inner volutions with an acute venter.
4. M-5385, x 1, like Figure 3.

2 *Pachyerymnoceras philbyi* (Arkell), (type 1208), x 1, HU-30980, Makhtesh Hazera, upper Zohar Fm., Up. Callovian (coll. E. Nevo); part of the specimen in Pl. 3, Fig. 10.

5-6 *Levanticeras sinaiense* nov. gen. and sp., (type 1206), x 1, M-7261, holotype, G. El-Minshera, upper Zohar Fm., unit 5 (coll. Z. lewy); note fine, low ribbing and denticulated sutures.

7 *Pachyerymnoceras philbyi* (Arkell), (type 1208), x 1, USNM-163618, Aramco locality L-942, top Dhruma Fm., Jebel Tuwaiq, central Saudi Arabia (refigured from Imlay, 1970, pl. 2, fig. 12); the most complete *P. philbyi* showing the morphological changes between the adult and the gerontic stages. Up. Callovian.

PLATE 2

EXPLANATION OF PLATE 3

Figures

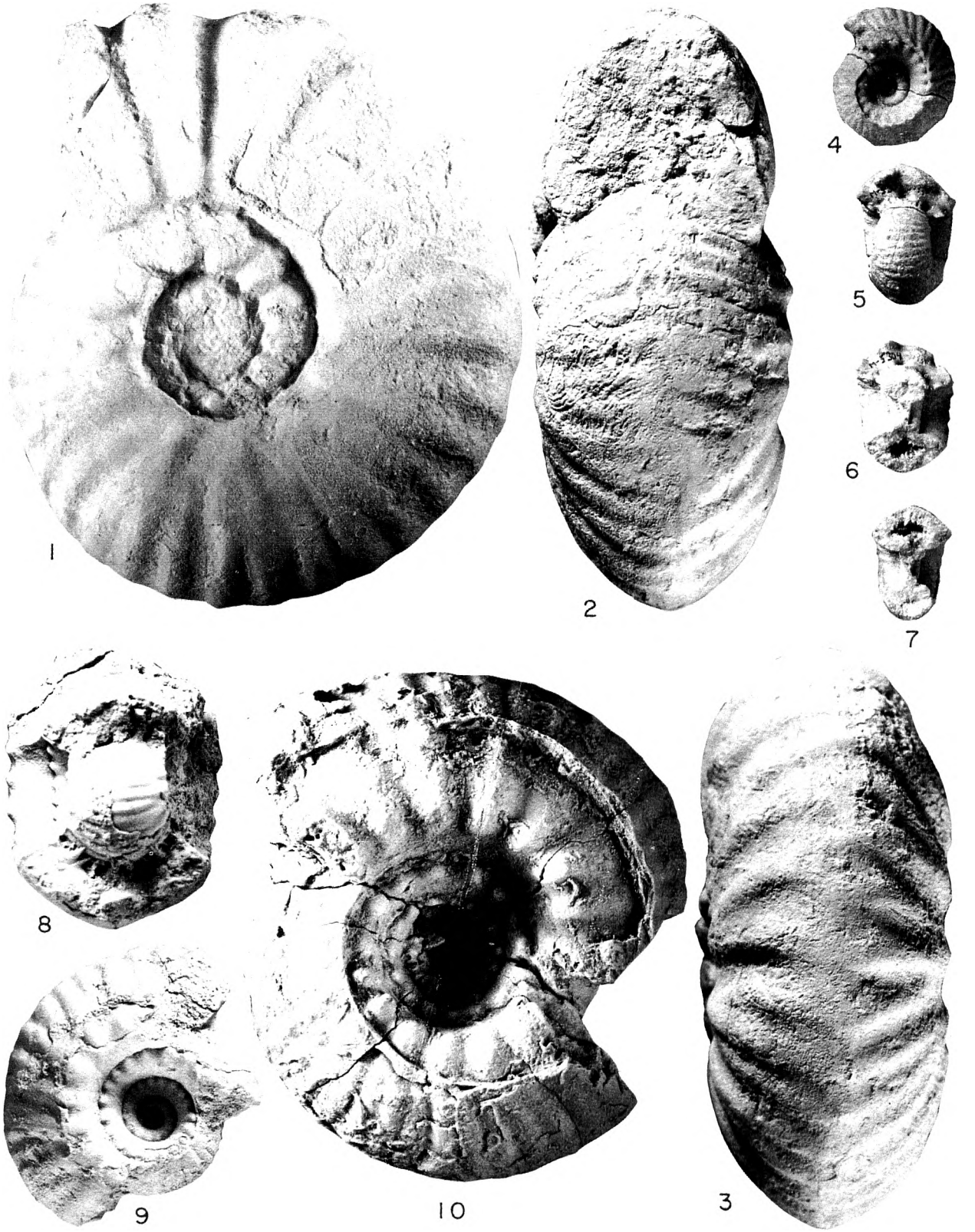
1-3 *Pachyerymnoceras levantinense* nov. sp., (type 1207), M-5362, holotype, Makhtesh Hatira, middle part of Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab); x 1, complete gerontic specimen with an Erymnoceras-like phragmocone and a *Pachyceras*-like gerontic body-chamber.

4-7 *Pachyerymnoceras levantinense* nov. sp., (type 1207), M-5304, Makhtesh Hatira, lower part of Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab); x 1, several views of a young stage.

8-9 *Pachyerymnoceras levantinense* nov. sp., (type 1207), HU-30979, Makhtesh Hatira, lower part of Tsia Mbr., upper Zohar Fm., Up. Callovian.

10 *Pachyerymnoceras philbyi* (Arkell), (type 1208), HU-30980, Makhtesh Hazera, upper Zohar Fm., Up. Callovian, (coll. E. Nevo); see cross-section of the younger fragment in Pl. 2, Fig. 2.

PLATE 3



EXPLANATION OF PLATE 4

Figures

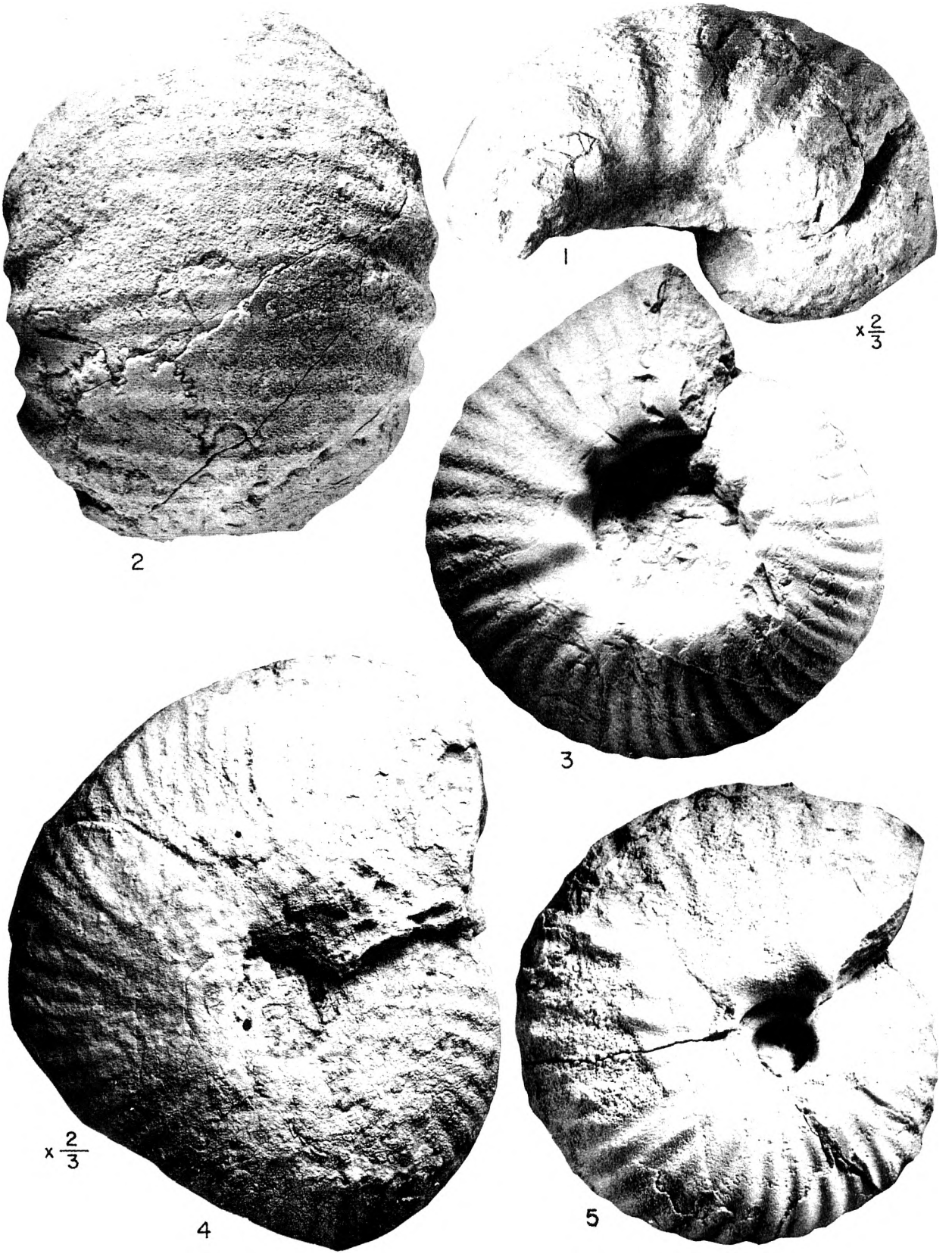
1-2 cf. "*Erymnoceras*" *coronoides* (Quenstedt), (type 1204), M-5302, Makhtesh Hatira, lower part of Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab); end of phragmocone and begining of body-chamber, x 2/3.

3 *Pachyerymnoceras* sp. cf. *P. jarryi* (R. Douvillé), (type 1380), M-7745, G. Maghara, top Zohar Fm., Up. Callovian, (coll. M. Goldberg); same specimen as in Pl.5, Fig.1; x 1.

4 *Pachyceras lalandeanum* (d'Orbigny), (type 1386), M-7745:1, G. Maghara, top Zohar Fm., Up. Callovian, (coll. M.Goldberg); x 2/3.

5 *Pachyceras crassum* R. Douvillé, (type 1387), M-7745, G.Maghara, top Zohar Fm., Up. Callovian, (coll. Z. Lewy).

PLATE 4



EXPLANATION OF PLATE 5

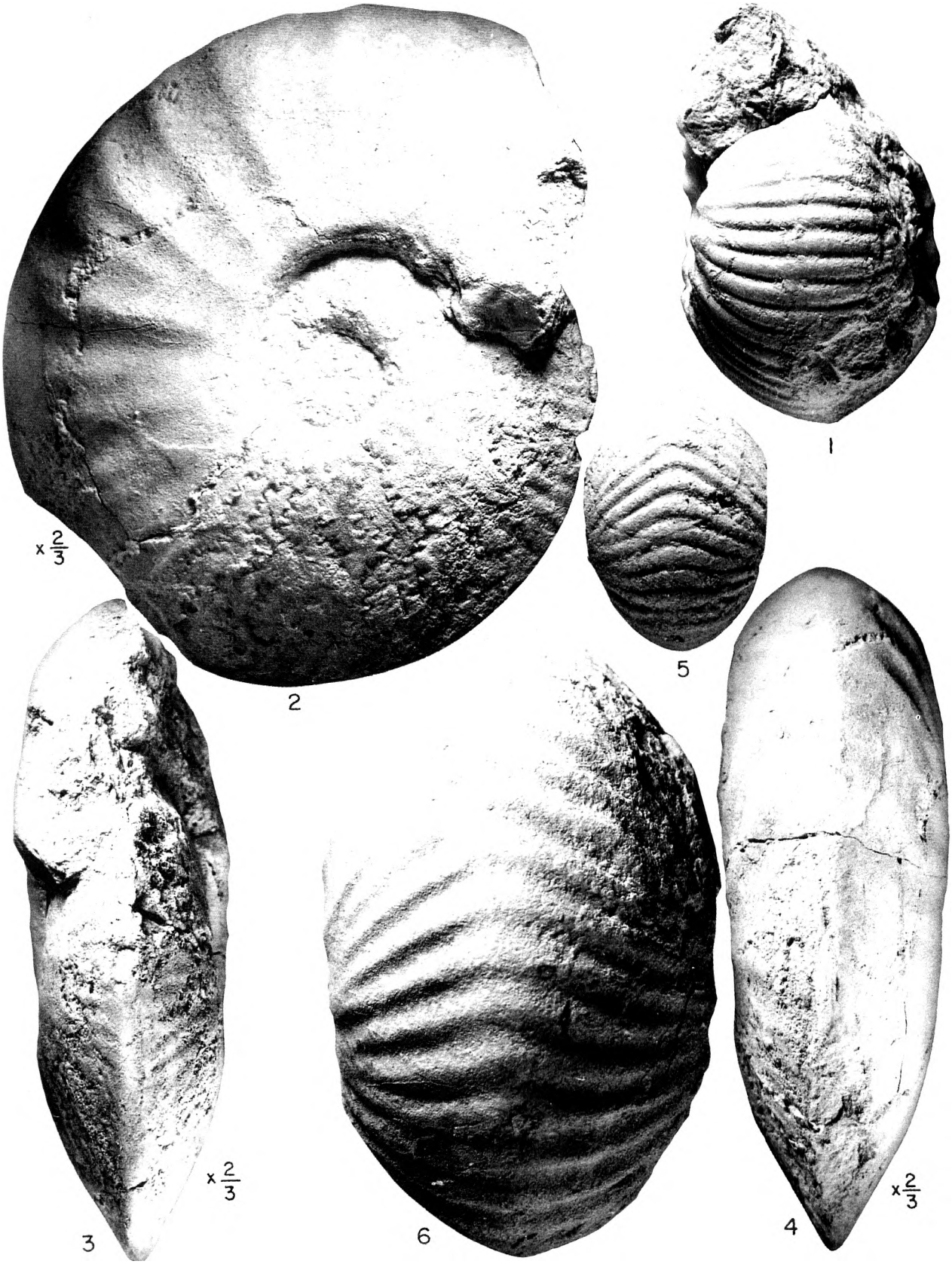
Figures

1 *Pachyerymnoceras* sp. cf. *P. jarryi* R. Douvillé, (type 1380), M-7745, G. Maghara, top Zohar Fm., Up. Callovian, (coll. M. Goldberg); x 1.

2-4 *Pachyceras spathi* nov. sp., (type 1249), M-7691, holoype, Makhtesh Hatira, base Be'er-Sheva Fm., Up. Callovian, (coll. M. Goldberg and M. raab); x 2/3, change in ornament and whorl-section between the adult and the gerontic stages.

5-6 *Pachyceras robustum* nov. sp., (type 1390), M-7745:1, G. Maghara, top Zohar Fm., Up. callovian, (coll. Z. Lewy); x 1, prorsiradiate ribs forming a V-shaped projection on the venter (compare to *Pachyerymnoceas* in Fig. 1). 5: holotype.

PLATE 5



EXPLANATION OF PLATE 6

Figures

1 *Pachyceras robustum* nov. sp., (type 1390), same specimen as in Pl. 5, Fig. 6, holotype, x 2/3.

2 *Pachyceras* sp., (type 1367), M-5339, Makhtesh Hatira, middle Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab), x 2.

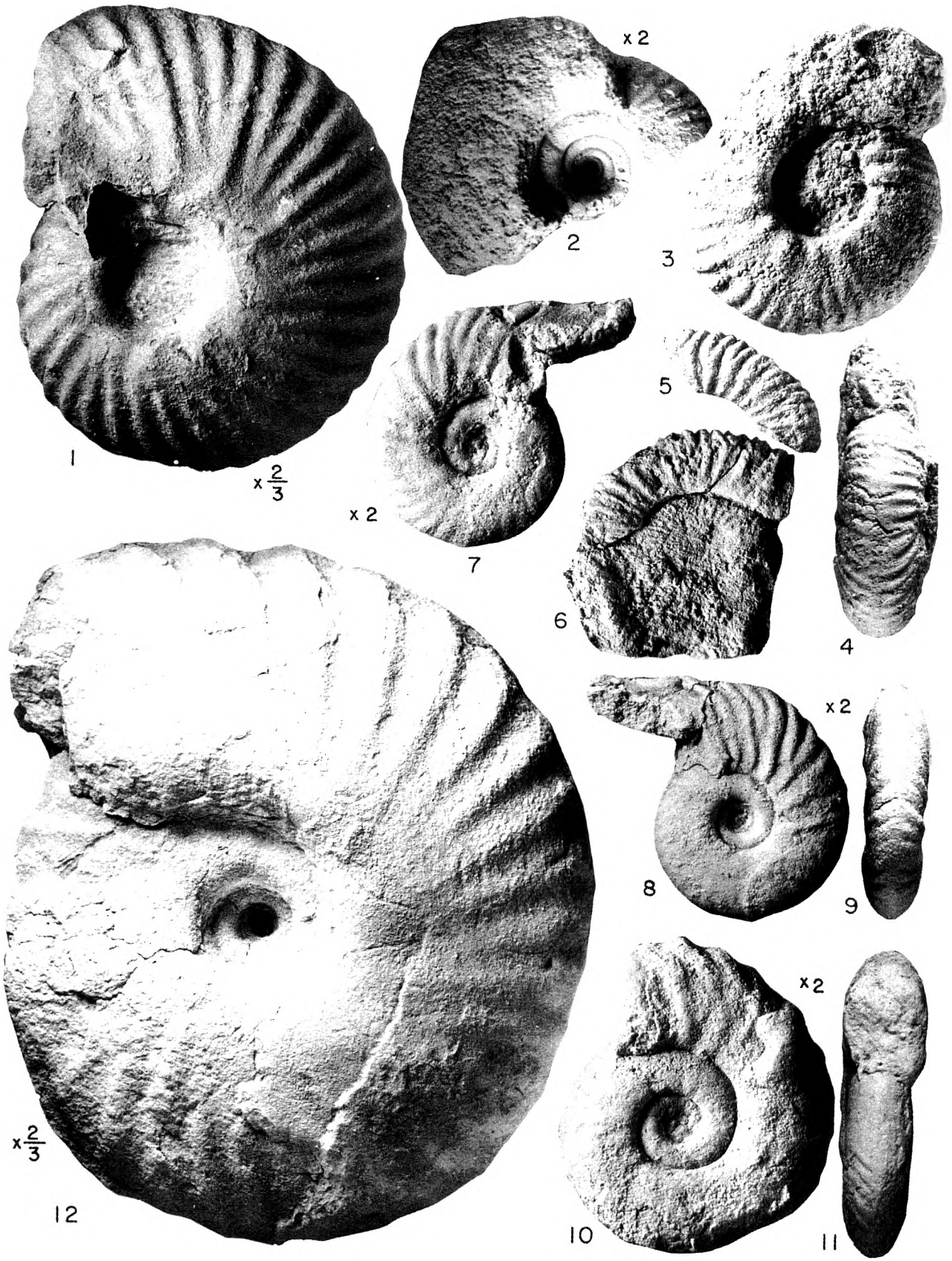
3-4 *Kinkeliniceras* sp. cf. *K. kinkelini* (Dacqué), (type 1223), M-7671, Makhtesh Hatira, upper Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab); strong ventrolateral ribs weakening on the siphonal region.

5-6 *Rursiceras* sp.A, (type 1307), M-6065, Makhtesh Hatira, middle Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab); 5: right side of a fragment from Fig. 6.

7-11 "*Prorsiceras*" hatirae nov. sp., (type 1210), Makhtesh Hatira, upper part of Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab), x 2;
7-9: M-6089, holotype, with preserved rostrum
10-11: M-5384, larger dimensions of a gerontic stage.

12 *Pachyceras magharense* nov. sp., (type 1392), M-7745, holotype, x 2/3, G. Maghara, top Zohar Fm., Up. Callovian, (coll. M. Goldberg).

PLATE 6



Z. LEWY

EXPLANATION OF PLATE 7

Figures

1-6 cf. *Lamberticeras henrici* (R. Douvillé), (type 1209), Makhtesh Hatira, Tsia mbr., uppr Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab), x 1; 1-3: M-5397; 4-6: M-5346.

7 cf. *"Quenstedtoceras"* sp., (type 1306), M-7261, G. El-Minshera, upper Zohar Fm., unit 5, Up. Callovian (coll. Z. Lewy), x 2.

8-10 *Reineckeites* sp. cf. *R. douvillei* Steinmann, (type 1365), M-5397, Makhtesh Hatira, lower Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. Z. Lewy), x 1; 10: corroded specimen associated with the fragment in Figs. 8-9 and attributed to the same species.

11-12 *Collotia* sp., (type 1377), M-7746, Maghara region (G. Hamir), top Zohar Fm., Up. Callovian, (coll. Z. Lewy); x 1;
11: cross-section;
12: ventral view.

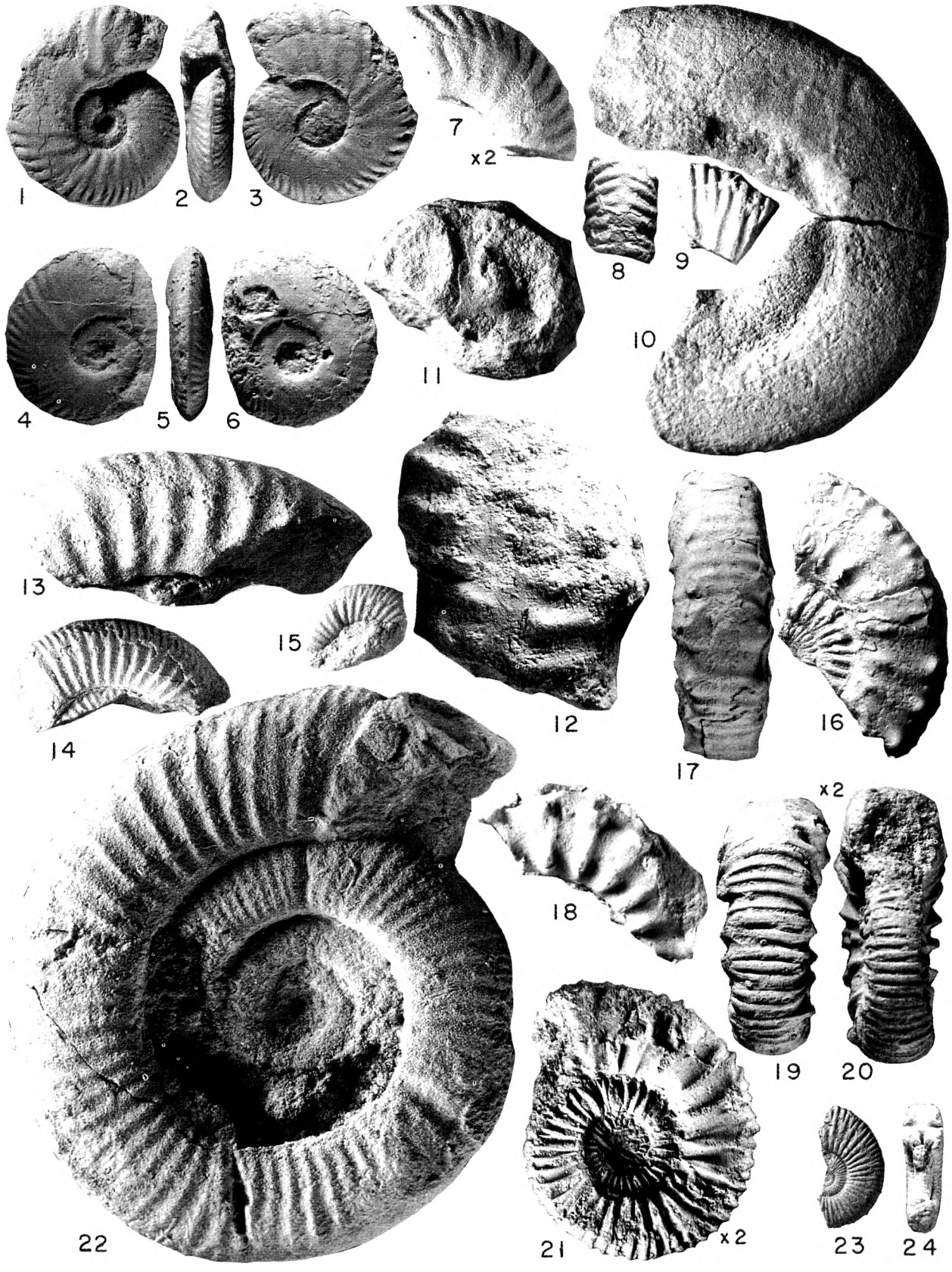
13-14 *Subgrossouvria* sp. (type 1380), top Zohar Fm., Up. Callovian, (coll. Z. Lewy), x 1;
13: M-7746, G. Maghara region (G. Hamir);
14: M-7745, G. Maghara.

15 *Grossouvria* sp., (type 1368), M-7815, Makhtesh Hatira, lower part of Be'er-Sheva Fm., Up. Callovian, (coll. M. Goldberg and M.Raab), x 1.

16-21 *Peltoceras trifidum* (Quenstedt), (type 1224), Makhtesh Hatira, upper Tsia Mbr., upper Zohar Fm., Up. Callovian, (coll. M. Goldberg and M. Raab);
16-17: M-7664, x 1, note narrow, assymmetric first lateral lobe;
18 : rubber cast of M-6046, x 1; 19-21: M-5451, x 2.

22 *Alligaticeras* sp. cf. *A. raguini* (Gérard and Contant), (type 1389), M-7745, G. Maghara, top Zohar Fm., Up. Callovian, (coll. Z. Lewy).

PLATE 7



EXPLANATION OF PLATE 8

Figures

1-2 *Alligaticeras sp. cf. A. raguini* (Gérard and Contant), (type 1389), top Zohar Fm., Up. Callovian, (coll. Z. Lewy);
1: M-7852, G. El-Minshera, x 8/9;
2: M-7745:1, x 1 .

3 *Rursiceras* sp. B, (type 1445), M-7746, G. Maghara region, (G. Hamir), top Zohar Fm., Up. Callovian, (coll. Z. Lewy); x 1.

4-6 *Euaspidoceras ferrugineum* Jeannet, (type 1375), M-7745, G. Maghara, top Zohar Fm., Up. Callovian (coll. Z. Lewy); and of phragmocone and begining of body-chamber, x 1.

7 *"Paraspidoceras"* sp., (type 1306), M-6025, Makhtesh Hatira, lower part of Be'er-Sheva Fm., attributed to the Up. Callovian, (coll. Z. Lewy); see whorl-section in Fig. 6E.

PLATE 8

מדינת ישראל

אמוניטים מהקלוביאן המאוחר במזרח התיכון וההיסטוריה הגיאולוגית של אזור זה ביורה התיכון

זאב לוי

המכון הגיאולוגי

בולטין 76

ירושלים , אלול תשמ"ג