Triassic Paleogeography of Southern Israel and the Sinai Peninsula

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2 figs.

Abstract

The Triassic sequence in Israel is represented by approximately 1000 m of sediments. This sequence was divided into five formations from the bottom as follows: the Zafir Formation of Scythian age, consisting of alternating shale, fossiliferous limestone and sandstone; the Ra'af Formation of Upper Scythian-Lower Anisian age, consisting mainly of fossiliferous limestones; the Gevanim Formation, of Anisian age, consisting of sandstone, siltstone and shale with minor amounts of limestone; the Saharonim Formation, of Upper Anisian-Carnian age, consisting of fossiliferous limestone, dolomite, marlstone and sparse gypsum and anhydrite layers; the Mohilla Formation of Carnian-Norian age, consisting of anhydrite and dolomite.

In southwestern and central Sinai the Triassic sequence is represented by a clastic sequence of continental origin (Budra Formation).

The paleogeography during the Triassic, over southern Israel and Sinai, was essentially controlled by transgressive and regressive cycles of the Tethys Sea situated north and northwest of the region.

During the Scythian times, regression resulted in deposition of fluvial sediments in southern Sinai, deltaic sediments in southern Israel and western Jordan and shallow marine sediments in the Central and Northern Negev.

During Late Scythian-Early Anisian time the influx of clastics from the Arabo-Nubian massif, situated in the south, was replaced by accumulation of shallow-water carbonates over large parts of northern Sinai and southern Israel. Later, regression led to the deposition of fluvial and deltaic sediments and a shift of the shoreline some 80 to 100 km northwards.

During the Late Anisian-Carnian a large scale transgression brought the shoreline to its southernmost Triassic extent.

The shallow marine sedimentation of this phase was replaced gradually by tidal and sabkha conditions. During the Late Triassic supratidal sabkhas and very shallow lagoons became dominant. This was accompanied by differential subsidence, evaporite accumulation taking place in the subsiding basins and supratidal dolomitization on the surrounding "highs".

The Triassic ended with subareal exposure, slight erosion and development of lateritic soils.

Introduction

Triassic rocks were first described near the northeastern end of the Dead Sea (Wadi Hisban and Zarqa Main) (Fig. 1) by Cox (1924, 1932). Later another Triassic outcrop (Wadi Zarqa) was described by BLAKE (1936). In western Sinai (Gebel Araif e-Naqa) Middle Triassic rocks were studied by AWAD (1946).

In Israel the first indication of a Triassic sequence was given by BROWN, GWIN and NASR (1940) from Har Arif. The most complete and continuous section of exposed Triassic was given by GWIN and NASR (1940) from the exposed core of the Makhtesh Ramon anticline. However, they considered this section as of Jurassic age. The section in Makhtesh Ramon was described in detail by BENTOR and VROMAN (1951) and ZAK (1957).

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Drilling operation during the nineteen-fifties and sixties penetrated Triassic sequences in eighteen deep boreholes. By correlation between the wells and the fragmentary Triassic exposures (Fig. 1) a complete stratigraphic picture of the whole Triassic sequence could be constructed (DRUCKMAN, 1966, 1967).

Petrographic and environmental study on the Middle Triassic section was carried out by DRUCKMAN (1969). Biostratigraphic and chronostratigraphic aspects were dealt with by PARNES (1956, 1962, 1965), BROTZEN (1956), AVNIMELECH (1958), LERMAN (1960), GLICKSON (1964), SOHN (1966), GERRY (1966, 1967a, 1967b), HUDDLE (1970), HOROWITZ (1970), HIRSCH (1972 and in press).

In southwestern Sinai a Triassic sandstone sequence was identified.

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Paleogeography

Sedimentation of the uppermost Yamin Formation (Fig. 2) started probably during the Scythian (HIRSCH, in press) but the main sedimentation during this time interval is represented by the Zafir Formation (WEISSBROD, 1969).

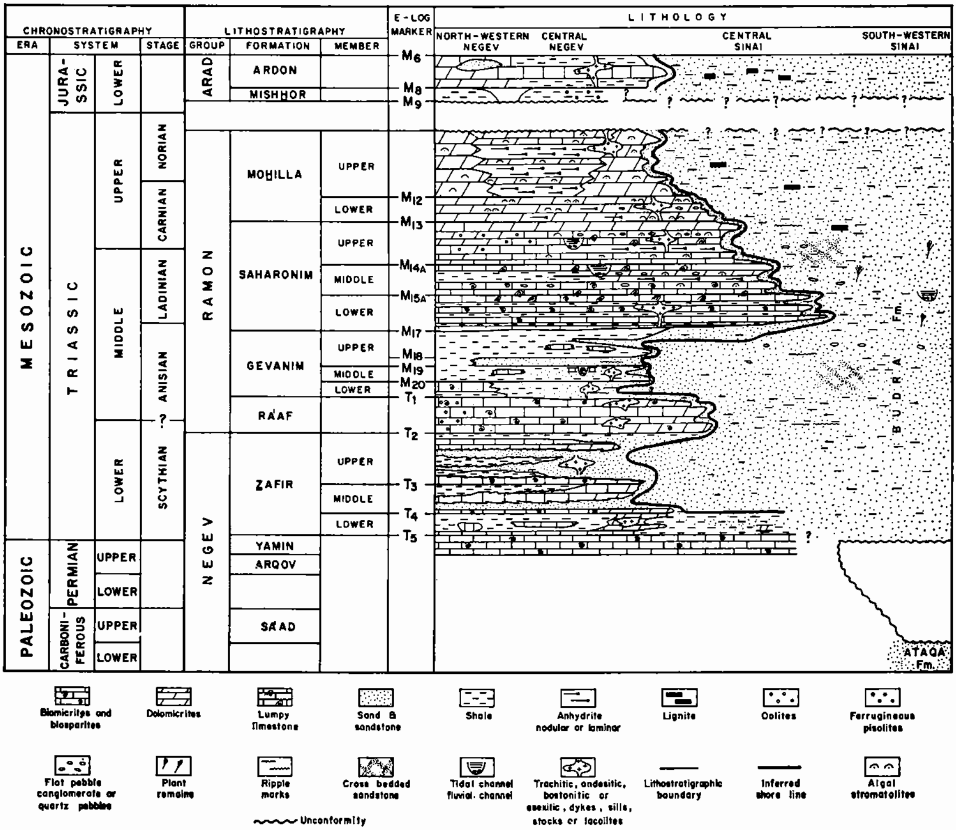

Figure 1. Columnar section of the Triassic sequence in the Ramon area (outcrop and subsurface) and its correlation to neighboring outcrops (underlined on reference map).

The age of this formation is based on the occurrence of *Claraia aurita*, several species of *Pachycladina* and *Hadrodontina* as well as the sporomorph *Endosporites papillatus* (Cox, 1932; Bender, 1968; Hirsch, in press; Glickson, 1964).

The Zafir formation consists mainly of dark gray and brown shale and fossiliferous limestone. The limestones contain mollusk, echinoid fragments and agglutinant foraminifera, conodonts and ostracodes (Hamaui, in Weissbrod 1969; Gerry, 1967, and Hirsch, in press) as well as oncolites, thus indicating a shallow marine environment. The limestones change gradually southwards into dolomites, probably of the Sabkha type.

Sandstones become increasingly abundant in the upper part of the formation, as well as laterally towards its source area in the south and southeast.

The time equivalent rock unit of the Zafir Formation on the eastern bank of the Dead Sea—the Humrat Main Formation (Druckman, Hirsch and Weissbrod, in press) consists mainly of multicolored sandstones and was thought to have been deposited under deltaic conditions (Wetzel and Morton, 1959).

The Zafir Formation demonstrates thickness variations ranging from 190 m in Lot 1 well to 280 m at Zavoa' 1 well, with a local thickening in Ramon 1 well, indicating a differential subsidence. These might be the first expressions of Late Triassic and Early Jurassic fold movements.

A complete termination of the clastic influx from the Arabo-Nubian massif occurred during the deposition of the Ra'af Formation (Zak, in Druckman, 1967). The age of this lithostratigraphic unit ranges from Upper Scythian to Lower Anisian, although a Lower Anisian for the entire unit is still possible. Faunal content of the upper part includes *Hungarites arifensis*, *Costatoria costata*, "*Kellnerites*" nov. gen. nov. sp. (Parnes, 1962 and personal communication), and *Beneckeia* sp. (Avnimelech, 1958), and is overlain by the *Beneckeia levantina* zone. This leaves a range of Upper Scythian-Lower Anisian. The appearance of the sporomorph *Endosporites papillatus* in the lower part of the formation indicates a Scythian age for this part (Dunay, in preparation). On the other hand the occurrence of *Glomospira densa* (det. L. Zaninetti, personal communication) found within and below the Ra'af Formation, is so far known to occur in the Anisian only.

The occurrence of *Beneckeia* cf. *tenuis* in the upper half of the formation at Wadi Hisban indicates, according to Wagner (1934); also an Anisian age.

It is therefore concluded that the upper part of the formation should be regarded as Lower Anisian, whereas the lower part ranges from Upper Scythian to Lower Anisian.

The Ra'af Formation consists mainly of biomicrites and biosparites with echinoid, brachiopod, mollusk and foraminifera fragments. Toward the sea on the northwest oolitic shoals developed, while supratidal dolomicrites and dolosparites developed to the south. The Ra'af transgression did not reach far southwards, thinning from 128 m at Makhtesh Qatan 2 to only 30 m at its southern most occurrence in Har Arif and Hameishar 1 borehole. In central Sinai it does not appear (Druckman, Weissbrod and Horowitz, 1970). There, its time equivalent is the clastic Budra Formation.

Following the shallow marine ingression of the Ra'af Formation the sea regressed during Lower Anisian times some 80—100 km northward, depositing along the way the Gevanim Formation (Zak, 1963). The age of this formation is based mainly on the occurrence of *Beneckeia levantina* Parnes, indicating according to Parnes (1962) a Lower Anisian age.

The lower part of the Gevanim Formation consists mainly of coarse to medium, white, brown and variegated sandstone with abundant plant remains, changing northwards to dark gray shale with minor sandstone intercalations, and further northwards into sandy biomicrites.

The southern part is interpreted as deltaic whereas the northern extent as near-shore marine. The upper part of the Gevanim Formation consists mainly of dark shale with minor sandstone and fossiliferous limestone intercalations. This part of the section contains *Beneckeia levantina*, *Trigonodus tenuidentatus*, *Myalina ramanensis*, *Lingula* sp., Nautilidae, "*Nothosaurus*", *Psephosaurus mosis* and several other pelecypods and brachiopods (Brotzen, 1956; Lerman, 1960; Parnes, 1962).

Within this part of the Gevanim Formation tidal channels and Flasser structures were observed, indicating a clastic tidal environment. The Gevanim Formation wedges significantly northward, thinning from 270 m in Ramon 1 to only 55 m in Zavoa 1.

Towards the end of the Anisian the main transgression of the Triassic took place, lasting till the Carnian depositing the Saharonim Formation (Zak, 1963). Its lower part contains cyclic alternations of fossiliferous limestones and marls, with ammonites, nautiloids, pelecypods, brachiopods, echinoid fragments, miliolids, ostracods, conodonts and reptile remains. In the upper parts the amounts and diversity of the fauna are strongly reduced (Lerman, 1960; Druckman, 1969). Dolomites and gypsum layers occur, as do algal stromatolites, flat pebble conglomerates, lumpy limestones and tidal channels. This represents the change from shallow marine, subtidal conditions to even shallower, intertidal conditions. Minor fluctuations may be detected on the basis of rare marine fossil occurrences.

The Ladinian age of the lower part of the formation was based mainly on the rich ammonite fauna: *Hungarites ramonensis*, *Protrachyceras wahrmani*, *P. curionii* and "*Ceratites*" nov. gen. nov. sp. (Parnes, 1962, and personal communication), and the conodonts *Pseudofurnishius murcianus* (Hirsch, 1972) and *Epigondolella mungoensis* (Huddle, 1970). The Carnian age of the upper part was based on *Clionites rarecostatus* (Parnes, 1962).

The Saharonim Formation thickens towards the north and northwest from 36 m at Abu-Hamth borehole through 174 m in Ramon 1 to 290 m at Haqanaim 3. It marks the most southern extent of any Triassic shoreline.

The regressive phase, which started already in Ladinian times during deposition of the upper part of the Saharonim Formation, intensified during the Carnian and Norian. The Mohilla Formation (Zak, 1963) was deposited during this phase. Its lower part consists of dolomicrites with abundant algal laminites and stromatolites, its higher parts of nodular and laminar anhydrite interlayered by dolomicrite layers and algal stromatolites. The evaporitic facies interfinger laterally with a dolomicritic facies with abundant algal mats. The evaporitic facies appears in distinct basins, with thicknesses of about 200 m, and the dolomitic facies appears on relative "highs" with thicknesses of 50—100 m only. These facies and thickness changes appear to indicate differential subsidence or even folding in a north-northeast direction. Similar patterns of movement were renewed during the Early Jurassic (Goldberg, 1970).

The Mohilla Formation probably represents supratidal sabkhas and very shallow lagoons, in which the evaporites accumulated in the subsiding areas and the dolomicrite on the interbasinal highs.

At the end of the Triassic a regional emergence caused exposure of the Upper Triassic terrain. Slight erosion occurred and lateritic soils and vadous pisolites were formed (Goldberg and Friedman, in preparation). The age of the Mohilla Formation is Carnian-Norian. This is based on the occurrence of *Spiriferina lipoldi* and *Myophoria inequicostata* (Parnes, 1962) as well as on several sporomorphs, indicating a Keuper age (Glickson, 1964; Horowitz, 1970; Dunay, in preparation).

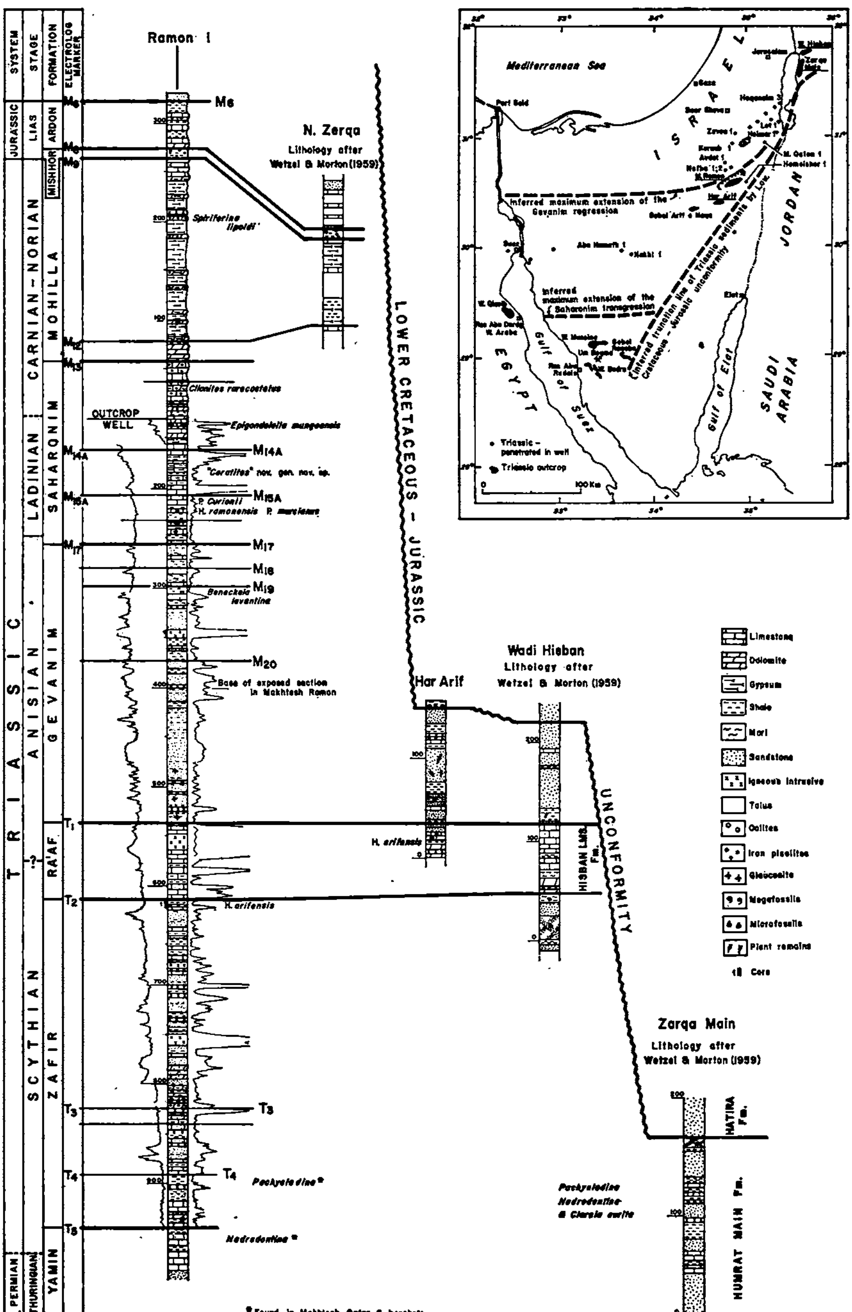

Figure 2. Nomenclature and stratigraphic relationships of the Triassic lithostratigraphic units in southern Israel and Sinai.

During the whole Triassic southwestern Sinai was dominated by continental fluvial sedimentation of the Budra Formation (Fig. 2). It consists of brown, purple and gray, coarse to fine sandstones, variegated shale and siltstones, with channel and bank deposits, abundant ripple marks, mud cracks, cross bedding and silicified tree trunks of several meters length.

Relations between the Triassic and Upper Paleozoic

In southern Israel, marine sedimentation was continuous across the Permian-Triassic boundary. The latter was established by a Scythian conodont fauna in the lower part of the Zafir Formation in Makhtesh Qatan 2 (HIRSCH, in press) accompanied by pollen of the same age (DUNAY, in preparation) and by Upper Permian pollen in the upper part of the underlying Yamin Formation (HOROWITZ, 1970). More southward, however, at Abu Hamth (central Sinai) the Upper Permian Yamin Formation (WEISSBROD, personal communication) is overlain by the continental Triassic Budra Formation. Further to the south in the Um-Bogma area, the Yamin Formation is no longer present and the Triassic Budra Formation overlies the Lower Carboniferous Ataqa Formation.

The same relations seem to exist west of the Gulf of Suez, where the supposed Triassic Qiseib Formation onlaps from north to south over gradually older formations (ABDALLAH, EL-ADINDANI and FAHMI, 1965). In the north the Qiseib Formation overlies the Upper Carboniferous-Lower Permian Aheimer Formation, at Abu Darag the Upper Carboniferous Abu Darag Formation, and southwards at Wadi Araba the Upper Carboniferous Rod el-Hamal Formation.

It seems therefore that conformable relations between the Permian and Lower Triassic sequence existed all over southern Israel, northern and central Sinai, whereas southwards overlapping Triassic deposition covered an eroded Upper Paleozoic relief (Fig. 2).

Conclusions

During most of the Triassic, shallow marine conditions prevailed over southern Israel, governed by the epicontinental Tethys sea northwest of the area. Continental, mainly fluvial conditions occurred over central and southern Sinai, which was part of the Arabo-Nubian massif.

Transition environments like tidal flats and deltaic complexes shifted north and south over central and northern Sinai and the southern Negev.

The main transgression of the Triassic occurred during the Late Anisian and Ladinian, shifting the shoreline to its most southern extent.

A significant unconformity exists between the continental Triassic and Upper Paleozoic in southwestern Sinai, whereas in southern Israel continuous shallow marine conditions prevailed throughout.

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