Structural evolution of the Neogene saltbasins in the Eastern Mediterranean

by

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Messinian evaporites in the Eastern Mediterranean form an integral part of the Neogene basin fill. In the deeper portions of the individual basins they were deposited in apparent depositional continuity with the underlying marine Miocene and the overlying Plio-Quaternary beds.

Stratigraphy (Fig. 1)

Evaporite deposition began during uppermost Miocene (Messinian) and persisted locally into the lowermost Pliocene.

In the deeper portions of the basin the evaporite layer reaches a thickness of around 1 km. Where the overlying Plio-Quaternary sequence is thin the evaporites are generally undisturbed.

Where loaded with thick sediments salt domes and salt ridges were formed.

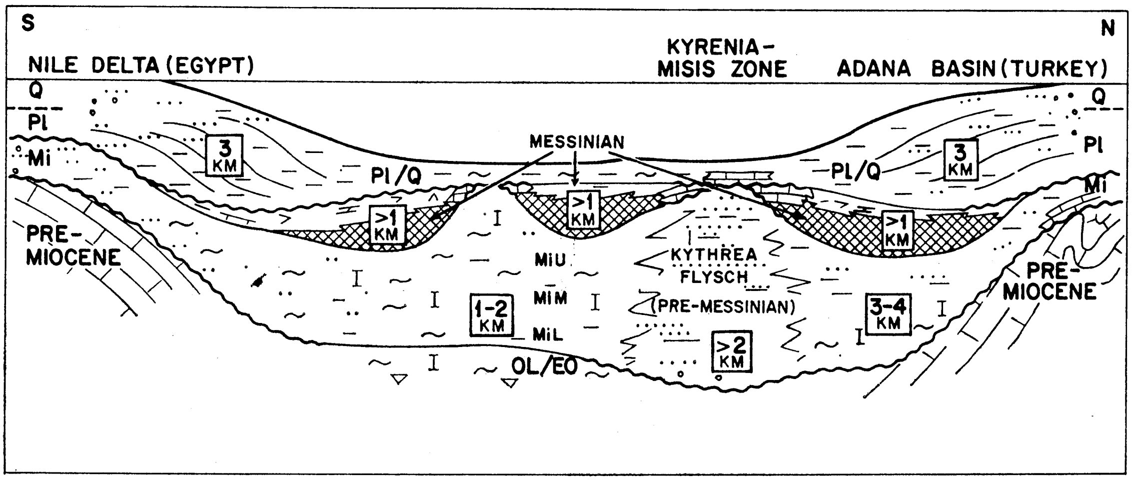

FIG. 1. — *Generalized stratigraphic scheme of Neogene facies distribution in the Eastern Mediterranean. The pre-Messinian Miocene shows largely an open marine facies development with indications of shallowing upwards and towards the basin margins. Late Miocene and early Pliocene tectonic movements led to evaporite deposition in a number of partially isolated restricted basins and to erosion on the basin margins. Subsequent Plio-Quaternary subsidence was accompanied by local thick deltaic accumulations.*

In the central areas of the basins the evaporites are overlain and underlain by and locally interbedded with pelagic sediments (Sicily) whose paleobathymetry is difficult to establish. Pelagic faunas and

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the undisturbed nature of the beds, however, indicate a considerable waterdepth. A basal unconformity or a stratigraphic gap generally separates the Neogene from underlying older Tertiary or Mesozoic sediments and the total thickness of the Neogene often reaches 3-5 km.

In the Eastern Mediterranean the pre-Messinian Miocene is commonly developped in a pelagic facies of marls and marly limestones. Thick flysch deposits were deposited along the alpine front, in the basins which flank the Kyrenia range. Outcropping carbonates in Southern Cyprus indicate an upward gradation from open pelagic conditions to shallow shelf and restricted shelf toward the end of the Miocene.

Near the basin margins evaporites are intercalated between shallow marine or locally non-marine beds. These sequences indicate continuous steady subsidence throughout the Neogene. Within the Neogene basins the evaporite level is not marked by any erosional features, channels or cut and fill phenomena, and does not represent a unique stratigraphic event. On the basin rim, however, the Pliocene is often transgressive and overlaps the evaporite interval and older beds. Locally thick deltaic sediments are deposited during the Pliocene-Quaternary (Adana basin, Nile Delta).

Tectonic setting (Fig. 2, 3, 4, 5 and 6)

Late Miocene and Pliocene tectonic movements are largely responsible for the present configuration of the Neogene basins in the Mediterranean.

The earlier Miocene basins were much larger and of a different shape than the late Miocene evaporite basins. Portions of the pre-salt basins were folded and inverted during the late- and post Miocene tectonic movements. As a consequence thick Miocene deeper water sediments are locally incorporated in folded mountain ranges, bordering the late Miocene evaporite basins.

The frontal parts of the Alpine orogenic arcs (Fig. 2) were intensely deformed during the early Pliocene. Mesozoic and Tertiary sediments of the Alpine foredeep here became involved in folding, imbrication and overthrusting. Plate tectonic models explain this deformation by a phase of underthrusting of the African craton below the alpine front in the Hellenic and Calabrian arcs [PAPAZACHOS & COMNINAKIS, 1971; RITSEMA, 1972].

Uplifting of inner portions of the alpine arcs created the slopes for large scale gravity slides (olistostromes) which were facilitated by the presence of salt in the olistostrome mass [MULDER, 1973]. In the central Mediterranean such Cenozoic slump deposits are known from Sicily and the Fossa Bradanica in southern Italy [CARISSIMO, *et al.*, 1963]. In the offshore areas, the sub-marine Messina cone [recently referred to as Calabrian ridge, BELDERSON, *et al.*, 1974] and the East Mediterranean ridge are covered by thick olistostrome deposits. Seismic profiles across the Messina cone in front of the Calabrian arc indicate that it consists of a pile of submarine slumps, and deep reflections can be traced from the abyssal plain area underneath the thrust front of these olistostrome masses for a distance of around 30-50 kms. (Fig. 3 and 4). In a similar way the arcuate East Mediterranean ridge is located in front of the Hellenic arc and is also covered with thick allochthonous masses. The present shape of the ridge, particularly its north flank is due to faulting and back-tilting during Plio-Quaternary and to the subsidence of the Hellenic trench system (Fig. 5 and 6).

In the easternmost Mediterranean the allochthonous masses of the East Mediterranean ridge diminish in size and pass laterally into little disturbed salt basins (Fig. 2). In this region several elongated salt basins are separated by narrow thrustbelts that were folded and uplifted in late Miocene — early Pliocene. The Kyrenia-Misis (N. Cyprus-Turkey) tectonic zone is an example of such a thrustbelt.

In the Adana and Iskenderun basins which are separated by the Kyrenia-Misis tectonic belt, the Upper Cenozoic basin fill reaches a thickness of 5-6 km. In the offshore Adana basin, the pre-salt sequence consists mainly of Globigerina marls and has a thickness of several kilometres. The Upper Miocene evaporites, mainly rock salt, are up to 1.5 km thick and develop salt pillows and salt domes. The top of the evaporites is observed at a depth of 2-3 km below sea level in the basin centre. The evaporites are overlain by deltaic shallow marine to continental Plio-Quaternary sediments which show shelf accretion foreset beds in their lower part. These shallow marine and continental beds prove a subsidence during Pliocene-Quaternary time of at least 3 km.

The distribution of the Messinian evaporites of the Eastern Mediterranean thus can be related to late Miocene - early Pliocene tectonic events that restricted the access of these basins to the open ocean. Similar conditions existed in the basins of the Western Mediterranean. This Neogene deformation not only affected the Alpine orogenic belt, but also the foreland and the margin of the African craton. In

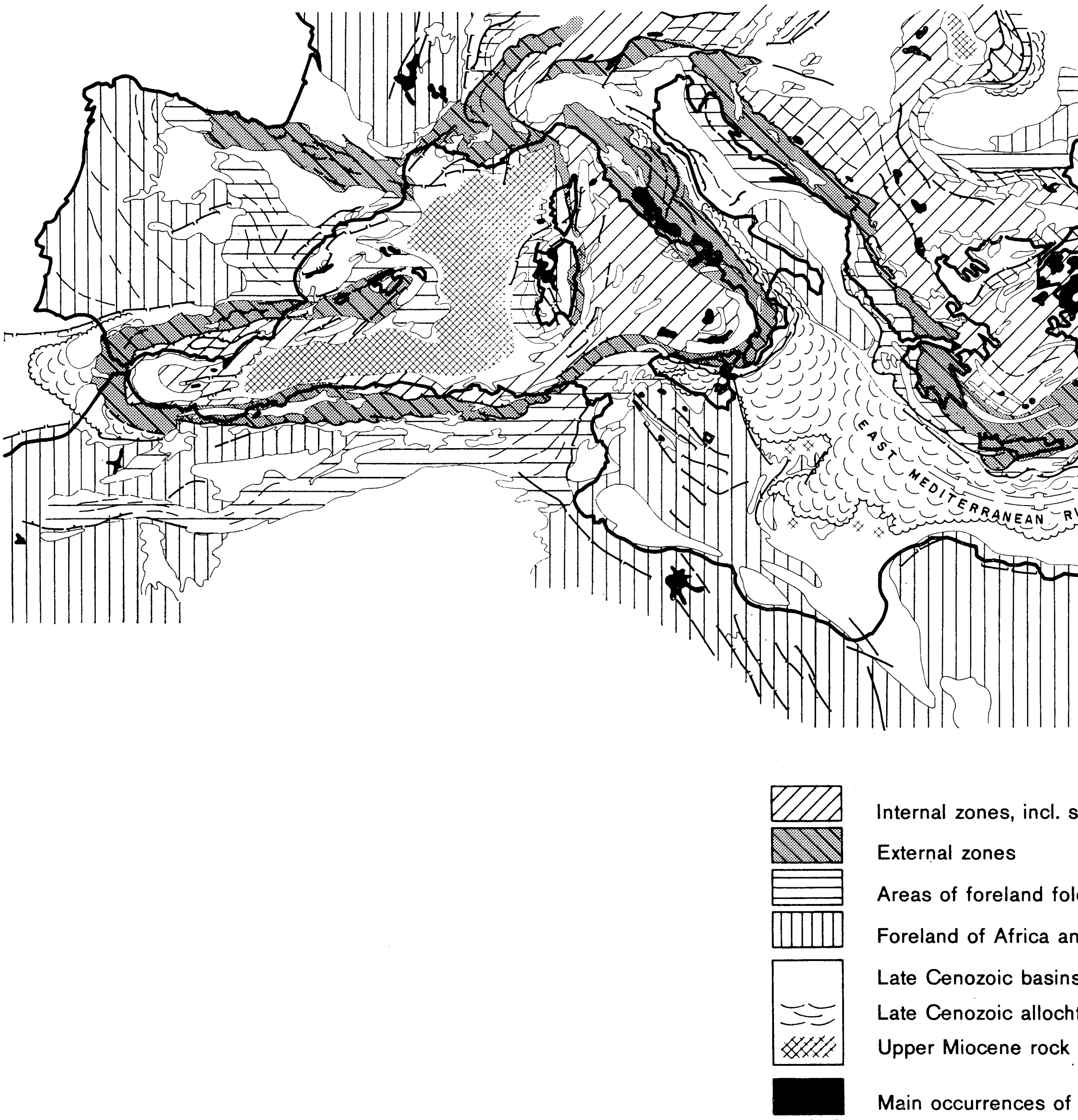

FIG. 2. — *Generalized tectonic map of the mediterranean region. The Upper Miocene salt Alpine tectonics. Typical collapse basins are present inside the major arcs, such as the Alboran basin the Tyrrhenian inside the Calabria-Sicily arc. Allochthonous blankets cover large areas of the foredee The East Mediterranean ridge is interpreted as an outer, non-volcanic ridge covered with intensely distu zoic sediments.*

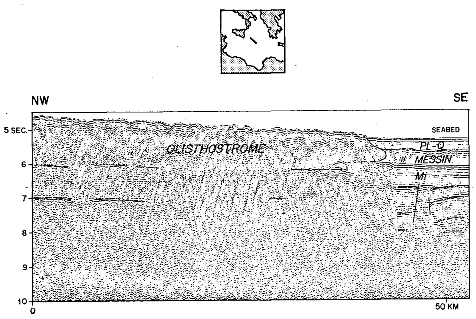

FIG. 3. — *Seismic reflection profile showing the SE front of the Messina cone in the Ionian Sea. The Messina cone is interpretated to consist of late Tertiary to Recent allochthonous sediments, passing laterally undisturbed beds of the abyssal plain. Although the disturbed sediments absorb most seismic energy, deeper reflections can be seen locally below the allochthonous sediments.*

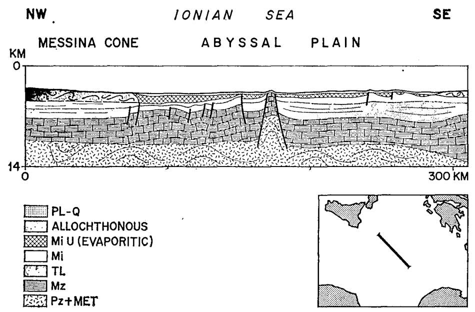

FIG. 4. — *Tentative geological interpretation of a seismic profile in the Messina cone and abyssal plain in the Ionian Sea. Interpretation in greater depth is highly speculative.*

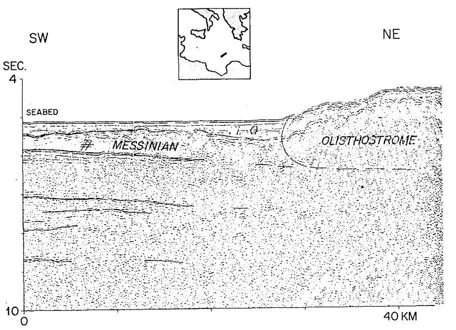

FIG. 5. — *Seismic reflection profile showing the SW margin of the East Mediterranean ridge in the Ionian Sea. The supposedly allochthonous sediments of the Mediterranean ridge pass laterally into the undisturbed sediments of the abyssal plain.*

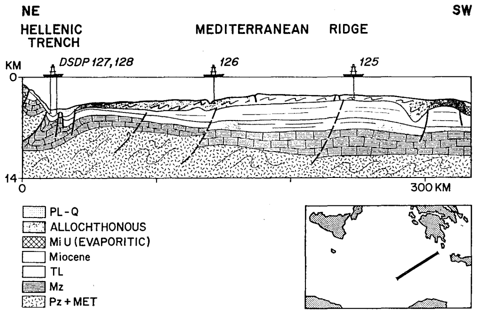

FIG. 6. — *Tentative geological interpretation in the western part of the East Mediterranean ridge, adjoining Hellenic trench and Ionian abyssal plain. Interpretation in greater depth is highly speculative.*

these latter areas it is reflected by taphrogenic deformation with dominant NW to NNW trends. Some rift systems originated late in the Cenozoic and may still be active, as for instance the central grabens on the Malta-Lampedusa platform, the Hongraben in western Libya and the axial trough of the Red Sea. The origin of others coincides in time with the main Alpine orogenic phases, like the Sirte graben, which developed mainly in Upper Cretaceous — Lower Tertiary time and the Gulf of Suez — Red Sea graben system, which began to form in late Oligocene and Miocene time.

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Discussion

Nesteroff. W : L'assimilation de la dorsale méditerranéenne profonde (Ridge) à un olistostrome *dans son ensemble* est en opposition avec les données des forages JOIDES-DSDP (sites 125 et 126) qui ont traversé sous le Plio-quaternaire les séries évaporitiques messiniennes et atteint le Serravalien. Vos schémas ne présentent pas ces formations.

Cita M.B. : My intervention refers especially to the interpretation of the Mediterranean Ridge as an allochthonous feature, a kind of super olisthostrome. You proposed the same interpretation in Utrecht one and a half years ago, during the Symposium on Messinian events in the Mediterranean, which interpretation was not accepted without strong criticism. Unfortunately, our collegues of the Utrecht State University did not publish the discussions following each presentation. So, I repeat here what I also told in Utrecht : that speculations like this can be accepted as long as we have no direct stratigraphic control, which is not the case for the Mediterranean Ridge. Site 125 of the Deep Sea Drilling Project, located on the crest of the Ridge SW of Crete, was cored continuously twice (site 125 and 125a), penetrating the Pleistocene and Pliocene successions, and reaching the underlying Messinian evaporites into which both holes were terminated.

All the foraminiferal zones and all the nannofossil zones known from the stratigraphic interval involved were recorded in their normal succession. No disturbances to be accounted to sliding or slumping were recorded in the sediments, including the sapropel layers recorded at various levels from the upper Pliocene upwards. As a consequence, your interpretation has to be refuted, since it is incompatible with the observational data available.

Réponse : I do not see it is in contradiction. Miocene may have been disturbed and originally deposited. In one Joïdes we found some indications of disturbance (mélange).

Burollet : En réponse aux observations présentées par M^me^ Cita et M. Nesteroff, je voudrais dire que, aussi intéressants que soient les forages JOIDES, ce ne sont que quelques core drills dispersés sur une immense surface. La « Mediterranean Ridge » est bien plus étendue que l'Italie. Imaginez que ce serait l'information stratigraphique avec quatre core drills sur une Italie entièrement immergée sous les eaux?

Biju-Duval : Nous sommes, dans les grandes lignes, complètement d'accord avec la très intéressante présentation qui vient d'être faite. Les participants auront reconnu que la présentation du Professeur Mulder est proche de celle que nous avons présentée ici-même. La présence de sédiments marins de mer ouverte d'âge serravallien ou langhien (cités par M^me^ Cita et W. Nesteroff d'après les résultats du JOIDES leg XIII) n'est en rien contradictoire avec l'hypothèse d'une très large allochtonie de cet âge. En effet, à titre de comparaison, je rappellerai qu'en Turquie, les nappes lyciennes, dont on a vu la mise en place par glissement après le Langhien, supportent des séries marines burdigaliennes; dans une autre région nous avons montré dans notre exposé précédent comment au Maroc les nappes de glissement de Rharb et de l'Atlantique ont continué à glisser au Miocène supérieur et au Pliocène avec, en arrière et superposés, des bassins subsidents d'âge tortonien à actuel. D'autres exemples similaires pourraient encore être développés.

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" The question put forward by Mrs Cita and Mr Nesteroff, concerning the apparent incongruity between the results of the JOIDES coreholes 125 and 126 and the concept of the Mediterranean ridge as a huge olistostrome, has been partly answered by the comments by Mr Biju-Duval and Burollet.

My own comment is that I do not envisage the Mediterranean ridge as one huge coherent olistostrome, but rather think of many superimposed sub-marine slides in different places at different times, where and when the gradient of the subsiding late Cenozoic foredeep became to great for the unconsolidated sediments to remain in place. Each slide could consist of a more or less coherent packet of sediments of variable thickness and movement could have been for a large part parallel to the bedding. The amount of horizontal movement for each individual slide was probably rather limited. The result is that in many places on the Mediterranean ridge the general stratigraphical succession is more or less preserved, although indications of slumping and internal deformation of the sediments will be frequent. "