D-2 NEW INSIGHTS ON THE MECHANISMS OF DEFORMATION OF THE EASTERN MEDITERRANEAN RIDGE

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Introduction and objectives

Shortening along the Mediterranean Ridge is the result of convergence between Africa and Eurasia plates and the motion of the Aegean microplate. The irregular shape of the plate boundary has resulted in a diachronous collision between the two margins, strain partitioning, and lateral escapes of both the Ionian and Levantine inner zones of the Mediterranean Ridge (LePichon et al., 1995). A double-vergent accretionary complex has developed with a plate boundary at the front of the wedge located at the base of the Messinian evaporites, while it cuts down from the base of the evaporites to the top of the Mesozoic carbonates in the inner portions of the wedge (Chaumillon and Mascle, 1995; 1997).

To the East, in the Herodotus basin, the nature and internal structure of the Mediterranean Ridge is less constrained. Seismic reflection studies (Chaumillon and Mascle, 1995; 1997, and Polonia et al., in press) reveal that sediment deformation styles vary considerably along the accretionary complex depending on several factors like thickness of the incoming sediment sequence, lithology, angle of convergence, and syncontractional deposition. Structural development or deformation style is represented, in a general situation, by gentle asymmetrical folding in the Messinian evaporitic sequence and in the Plio-Quaternary terrigenous sediments which affects the seafloor morphology with formation of wide sea-hills in a broad area of gentle deformation.

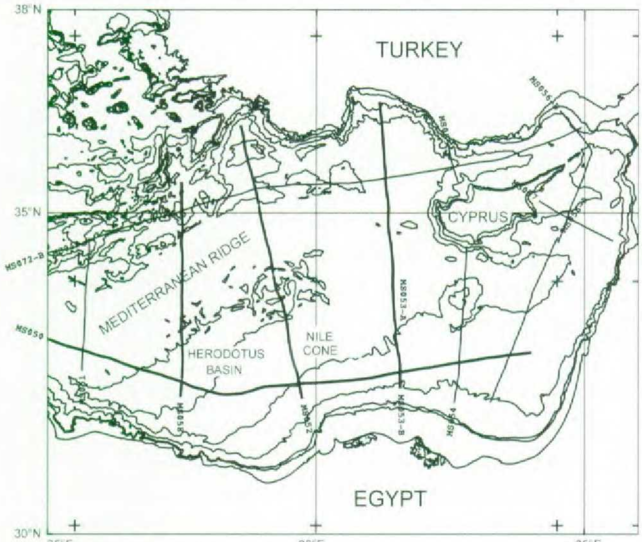
Despite the recent advances in the knowledge of the geological structure of the Eastern Mediterranean, many problems remain still open: (1) is the Eastern Ridge everywhere detaching on the Messinian evaporites? and (2) are the latter constituted by salt in a significant proportion? If so, (3) does the presence of a salt décollement influence the kinematics and thrusting sequence of wedging? (4) which is the role of the prograding Nile delta on structural development in the foredeep? Our study addresses these questions through seismic reflection data re-processing and interpretation in order to provide the basis for an optimum design of scaled physical models in the laboratory. In turn, the results from modelling give new insights accounting for controversial interpretations of geophysical data.

Methods

We have re-processed and analysed at OGS and IGM three seismic profiles, collected by OGS from 1971 to 1979 across the eastern Mediterranean ridge accretionary complex (Fig. 1) and extending to the Herodotus foredeep and African foreland (Nile river deep sea fan). These data were obtained with a 2400 m long 24-trace streamer, 12-fold coverage and a flexotir source. The re-processing involves re-generation of stack sections from the original tapes, migration, depth conversion, pre-stack partial migration and post-stack depth migration on the entire length of the profiles. Pre-stack depth migration has been performed on selected parts of the profiles. We have focused our attention to the velocity distribution with depth using available data of Expanded Seismic Profiles (deVoogdt et al., 1992), closely spaced semblance analyses performed ad-hoc, and various techniques, including tomography and ray-tracing, applied with Geodepth© software.

Scaled analogue models (maximum length 80 cm, maximum width 130 cm and thickness up to 4 cm) have been realised at the University of Parma by using a mobile wall deforming a multi-layer composed of dry quartz sand, silicone putty, and glass micro beads that simulate the progression of deformation of the wedge above detachment horizons. Each model has been time lapse photographed to obtain a video of progressive deformation. Real prototypes were obtained from the depth converted and migrated seismic profiles in which the distribution of salt has been reconstructed from the seismic velocity information. We have tried to create analogue models that are as similar as possible to the prototypes in terms of geometry, dynamics and kinematics.

Fig. 1 Location of OGS multichannel seismic profiles in the Eastern Mediterranea collected from 1971 to 1979.



Profiles considered in this study are outlined with bold lines.

Extent of salt and influence on kinematics

Specific velocity analyses have been performed on those parts of the profiles where top and bottom reflectors of the Messinian units, including evaporites and halite, are present. These analyses indicate that interval velocity in the range of 4200 - 4700 ms^{-1}, typical of salt, is present in the entire Messinian unit, that can reach and exceed 3 km in thickness. High velocities persist also where infra-Messinian acoustic lamination exists. In addition, the only reflector displaying a phase reversal is the bottom of the Messinian Unit. We conclude that the main composition of the Messinian sediments is salt, likely interbedded with other sediments that produce internal reflectivity, in layers not thick enough to provide a lower interval velocity on the data considered. Because of the low vertical resolution of the MCS data, we infer that these layers may reach a thickness of a few tens of meters.

In this respect modelling results suggest that only part of the Messinian unit must behave viscously (i.e. salt represents only part of the whole Messinian succession); folds deforming a bi-layer having the viscous décollement (single salt layer) as thick as the brittle overburden (Plio-Quaternary terrigenous fill) show a cuspidate-lobate geometry cored by the viscous layer that pierces the cover and emerges. We do not observe this geometry in the seismic profiles at least in the outer deformation zone where shortening is limited. This observation reinforces our findings of infra-Messinian reflectors, more concentrated in the lower part of the Unit, that most likely prevent viscous behaviour of the entire Messinian unit.

Another general contribution of the modelling in the laboratory is that the small taper of the wedge in the Central Mediterranean Ridge demonstrates that a viscous exsistes, and therefore detachment occurs along a salt layer also in this part of the wedge, characterised by incipient continental collision

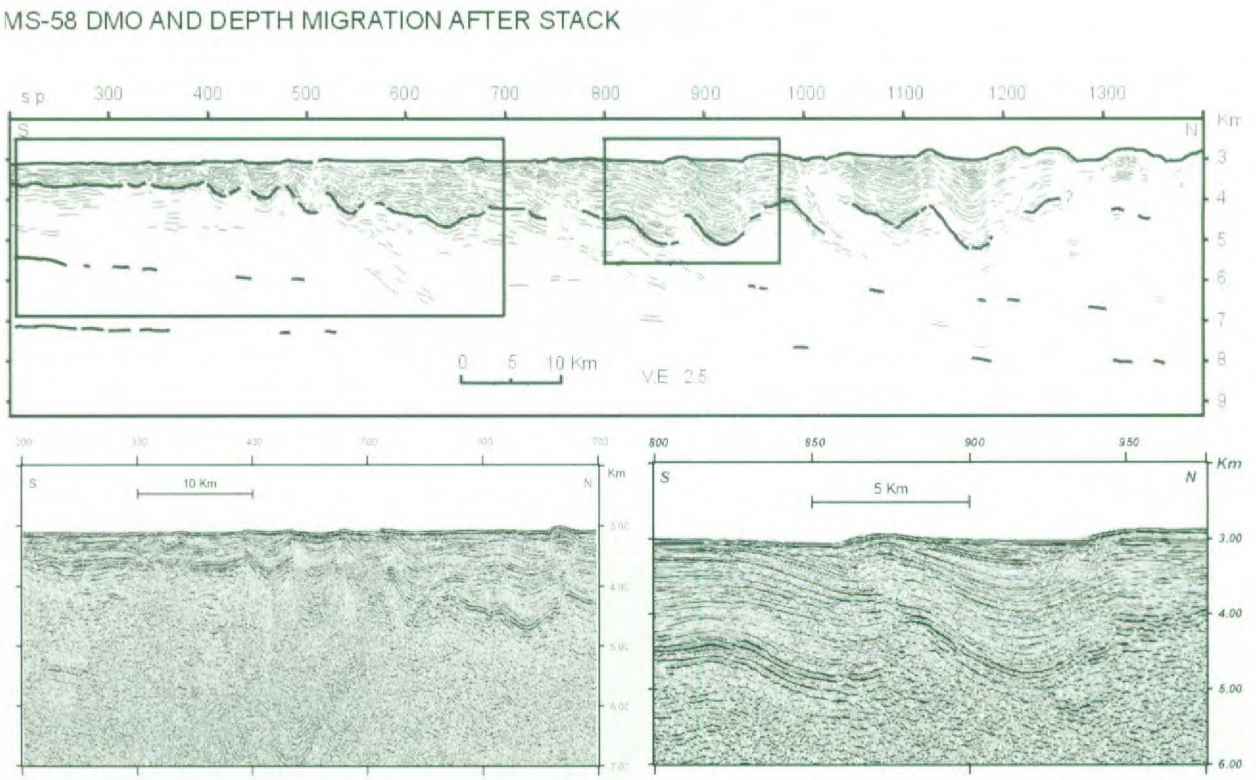


Fig. 2 TOP: Line drawing of depth migrated line MS-58. BOTTOM: close ups of representative folds that include the Messinian evaporitic layer.

Geometry of deformed units

The analysis of the geometry of sediment deformation is performed on a basin-wide scale. Fig. 2 displays migrated seismic profiles MS-58. Re-processing involves DMO and post-stack depth migration. The amplitude and wavelength of folds increase toward the north (Fig. 2a and 2b) as a progressively thicker sedimentary packet is involved in the deformation. Many asymmetrical folds have revealed to be related to thrusts splaying from the sole thrust located at the base of the Messinian evaporites. Wavelength of folding is larger in line MS-52 (Fig. 3), which intersects the outer part of the Nile cone where the average thickness of the Plio-Quaternary unit is more than 1.5 km thik reaching 2.5 km in the sedimentary basins between adjacent anticlines. Folds are not regularly spaced, and wavelength varies from 7 to 15 km (twice or three times those encountered in MS-58). Fold amplitude does not show a trend like in line MS-58 and is always rather large.

When detected, the base of the evaporitic unit is discordant with the top of the sequence in the core of the anticlines, thus suggesting the occurrence of a décollement along the base-of-salt reflector and salt flowage towards incipient diapiric structures. In some places the décollement displays pull-up effects caused by the variations in thickness of the salt layer. Thinning and wedging-out patterns present in the salt overburden may have developed as a result of uplift/subsidence effects related to syn-depositional movement of the salt.

The difference in structural style and in folding wavelength and amplitude are due to the different position of the two sections within the Mediterranean Ridge. The higher vertical shear component of stress in the areas closer to the continent favours the formation of asymmetric thrust-related-folds. The different geometries of deformation are shown in the cross sections cutting at various points the physical model of the Eastern Mediterranean Ridge (Fig. 4).

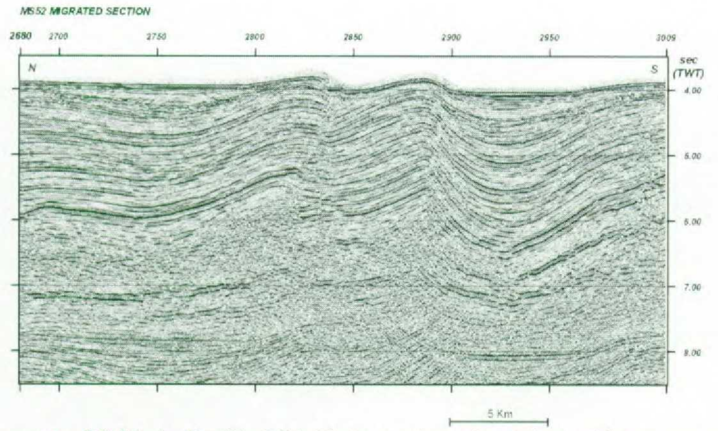


Fig. 3 Time-migrated close up of folds in Profile MS-52 (opposite orientation with respect to profiles in Fig. 2).

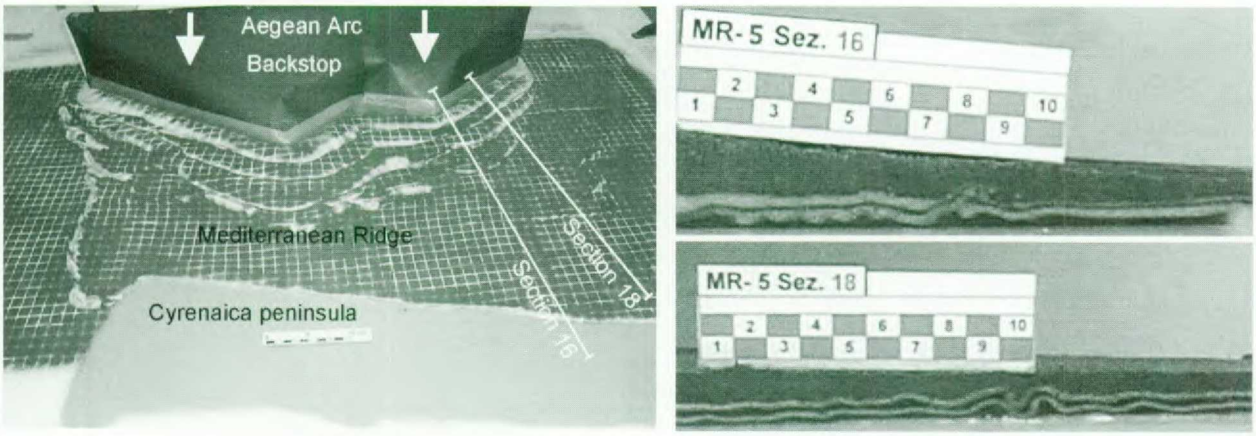


Fig. 4 LEFT: Oblique view of the model reproducing the MR; RIGHT: sections 16 and 18 cut in the same positions as the seismic line MS-58 and MS-52, respectively.

Acknowledgements

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