3-D EVOLUTION OF SEDIMENT LOBES ABOVE PRE-EXISTING DORMANT OR ACTIVE RELIEF. IMPLICATIONS FOR THE NILE DEEP-SEA FAN, EASTERN MEDITERRANEAN

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Abstract

We conducted a series of physical experiments to better understand the complex structural pattern in the Nile deep-sea fan, where thin-skinned tectonics due to sediment loading of Messinian evaporites and deep-seated tectonics interact. Experiments tested the influence of active or dormant subsalt relief during progradation of sediment lobes. Results from models where the subsalt graben was dormant show the best fit with the structural pattern observed in the Nile-deep-sea fan.

Key-words: experimental modelling, Nile deep-sea fan, thin-skinned tectonics, thick-skinned tectonics, salt tectonics.

Deformation in the Mediterranean area involves both thick-skinned, crustal-scale tectonics and thin-skinned, gravity-driven deformation of the Messinian evaporites and their sediment overburden (5). This is particularly true in the Nile deep-sea fan (Figure 1), recently surveyed during the Prismed II and Fanil surveys (1998, 2000) using multibeam swath bathymetry and acoustic imagery, seismic reflection data and HR seismics. These surveys have evidenced different structural features that have formed in response to either gravity-driven salt tectonics due to loading of the Messinian evaporites by the Nile's sediments (3) or to transtensional, deep-seated tectonics (1,2,4). In this area, it is particularly difficult to distinguish structures that are truly related to large-scale tectonics from those that are solely the result of salt tectonics and, therefore, cannot be used as regional tectonic indicators (Figure 2). We consequently used experimental modelling to test the structural patterns produced by gravity spreading above salt where residual or active deep-seated relief is present.

3D spreading above active subsalt relief

In this experiment, we simulated radial spreading of a sediment lobe above an active graben beneath the evaporites. Model results show that an active subsalt graben influences spreading of the lobe only after significant graben subsidence has taken place, and that only a few structures formed with a trend parallel to the graben orientation. In this experiment, flow pattern in distal area of the greatly differed from what is observed in the Nile deep-sea fan.

To assess the contribution of a spreading lobe on the final deformation pattern, we also run an experiment where syntectonic sediments aggraded only, rather than prograded. In this model, some overburden structures formed parallel to the graben direction, but did not link with the basement faults. Furthermore, the absence of polygonal depocentres or buckle folds makes this model unable to explain the deformation pattern of the Nile deep-sea fan.

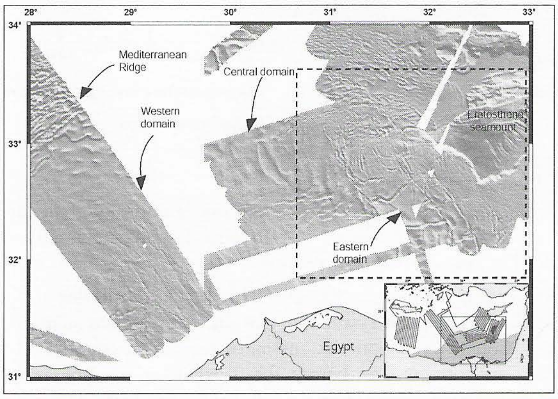

Figure1: Shaded bathymetry of the Nile deep-sea fan, acquired during the Prismed II cruise. This fan has been divided in 3 main morphostructural provinces: a Western, a Central and an Eastern province. The dotted frame indicate the area that has been compared with physical models.

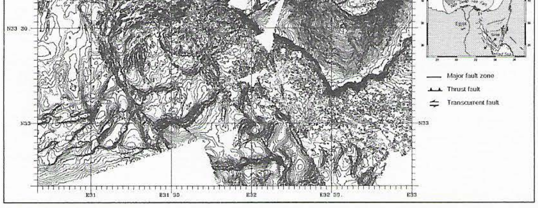

Figure 2: Eastern domain of the Nile deep-sea fan showing a complex structural pattern corresponding to both thin-skinned tectonics due to sediment loading of Messinian evaporites and deep-seated tectonics. This morphostructural domain was compared to experiments that tested the influence of active or dormant subsalt relief during progradation of sediment lobes.

3D spreading above residual subsalt relief

We also studied the influence of a dormant subsalt graben, no longer active, during progradation, and tested that set-up using lobes having various shapes.

Even during the early stages of deformation, a dormant subsalt graben influenced the spreading of the lobe by acting as an underlying corridor that channelled the movements of salt and overburden. The overburden located above the dormant graben extended and subsided faster, which caused depocentres there to be thicker. In addition, salt flow in the distal part of the models caused trains of arcuate folds, a pattern exactly identical to that observed in the Nile deep-sea fan. Experiments also indicate that formation of well-defined graben-parallel faults or salt-ridges depends essentially on the planform geometry of the sedimentary lobe: spreading of a circular lobe forms polygonal basins, having no specific preferred fault orientation, rather than graben-parallel structures. By contrast, when the lobe was elongate, numerous graben-parallel faults and ridges formed throughout the model history. Wrench structures, grabens and salt-ridges successively accommodated the overburden's movements. These lineaments can be reactivated in compression by spreading of other nearby lobes.

The following conclusions emerge from these experiments:

1. The main difference between radial spreading above dormant or active subsalt relief occurs during the early stages of overburden. Spreading is highly channelled when the underlying subsalt graben is dormant, but is not when the graben is active.
2. During the early stages of deformation, the evaporitic layer commonly decoupled the overburden from the subsalt basement. Basement faults did not propagate through the salt layer. The connection between subsalt and suprasal structures took place only during the later stages of lobe spreading, during which ponded basins became anchored onto the basement.
3. As long as the lobe had not subsided significantly, the basement's influence remained limited to causing variations in the rate of salt flow and overburden movement, both of which essentially depend on the salt layer's thickness. Lateral variations in spreading rate induced apparent strike-slip movements within the spreading overburden.
4. Spreading of an initially circular sediment lobe did not create a set of elongate, graben-parallel features but mostly radially-oriented structures.
5. By contrast, spreading of an elongate lobe parallel to the subsalt graben induced formation of different graben-parallel structures including wrench zones, grabens or salt-ridges. These faulted structures widened during the late stages of spreading, forming structural drains and pathways that can guide and funnel the sediment transport. A nearby second spreading lobe can reactivate some of these structures in compression.

Clearly, the structural pattern that developed in our experiments of progradation above dormant subsalt relief fits best the Nile deep-sea fan natural example:For example, thin-skinned contraction, expressed by arcuate buckle folds in the models, is extremely-well identified in the distal parts of the Nile deep-sea fan. Furthermore, a huge NW-SE deformed belt in the Eastern Nile deep-sea fan is associated, with transverse salt ridges, crestal grabens and polygonal depocentres. A similar association of tectonic trends and structural styles is also observed in models of lobes spreading above dormant basement relief.

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