New Crustal Structure of the Eastern Mediterranean Basin: Detailed Integration and Modeling of Gravity, Magnetic, Seismic Refraction, and Seismic Reflection Data

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Summary
A significant body of literature has been published on the post-Paleozoic evolution of the Eastern Mediterranean Basin (EMB) however, many contrasting opinions are presented, and much is poorly understood about this particularly complex piece of the Tethyan system. With detailed integration of gravity, magnetic, seismic refraction and seismic reflection data, we document results that address the fundamental questions concerning (1) the crustal structure underlying the EMB, and (2) the tectonic evolution associated with the early basin history. A synthesis of these results has been used to test existing plate tectonic models for the early Mesozoic evolution of the region and a preferred opening geometry is presented.

Introduction
Consistent with the varied opinions concerning the plate-tectonic history of the EMB, the crustal structure of this portion of the Tethyan system is the subject of much debate. The lack of obvious seafloor magnetic anomalies has made it difficult to effectively map the distribution of oceanic crust. In order to test a variety of conceptual models and to better define the distribution of ocean crust within the study area, BP acquired proprietary gravity, magnetic, deep seismic reflection and ocean bottom seismograph (OBS) crustal refraction seismic within the offshore western Nile. The integration and detailed modeling of these data provide the basis of this presentation.

Regional Profiles
Two crustal scale cross-sections were constructed across the EMB using a combination of proprietary and public domain information. The locations of these profiles are shown on Figure 1. These profiles were iteratively modified on the basis of modeling the new gravity, magnetic and seismic data. Recent regional teleseismic studies have estimated the depth to the Moho within the area of the larger Mediterranean region (Marone et al., 2003). Al-Demagh et al., (2005) have published similar data for the larger Arabian plate, thereby constraining Moho depth and crustal thickness at the eastern terminations of our profiles. The western terminations of both profiles are constrained by projecting the profile data from Bohnhoff et al., 2001, while the depth and thickness of the oceanic plate beneath the Mediterranean Ridge and deep Herodotus Basin are constrained by the data of Makris and Yegorova (2006). The ‘Top Crystalline Basement’ map for the Levant region (Rybakov and Segev, 2004) provided depth-to-basement estimates for the eastern ends of both profiles.

Profile A
This profile crosses the offshore extension of the continental margin beneath the eastern Nile Delta and Levant. It begins SW of the island of Crete in the eastern Herodotus Basin and follows the trace of the available industry seismic data into the area of the offshore Nile. In the eastern delta, the profile
integrates key industry wells. Onshore in the northern Sinai Peninsula, it passes close to well-constrained inversion structures and then crosses the Dead Sea Fault system and terminates in Southern Jordan. The final crustal section along profile B is shown in Figure 2.

**Figure 1.** Location of regional crustal profiles / models overlain on a residual gravity map (200km high pass) of the Eastern Mediterranean Basin.

**Figure 2.** Final gravity, magnetic and seismic model for profile A across the EMB from Offshore Crete to Southern Jordan.

In this case, the following modifications were needed in order to complete the modeling:

- The oceanic slab in the NW portion of the line is required to be about 6-7 km thick.
- Increased crustal thinning was required under the central and eastern Nile Delta, suggests that the offshore parts of the delta underlain by extended continental crust about 8-9 km thick.
- A significant basement high is required beneath the core of the delta, and this is consistent with the deep reflection seismic data over the same area.
**Profile B**
 Beginning in the southern Aegean Sea to the NW of the Island of Crete, the line runs from WNW to ESE, crossing the collisional zone of the Mediterranean Ridge as it enters the Herodotus Basin. In the vicinity of the Nile delta and onshore within northern Egypt, industry wells provide constraint, particularly with regard to the position of the Cretaceous hinge-line and the level of the Messinian unconformity. The profile then crosses the northern Gulf of Suez, the southern Sinai Peninsula and the Gulf of Aqaba ending in basement outcrops of the western Saudi Arabia. The final crustal section along profile A is shown in Figure 3.

![Figure 3](image-url)

**Figure 3.** Final gravity, magnetic and seismic model for profile B across the EMB from Crete to Saudi Arabia.

The constraining data supported the model that the profile crosses a thinning continental margin and suggested that thinning continues beyond the western edge of the Nile Delta into the Herodotus basin where a transition to oceanic crust must occur. Comparing the final model with to the initial input profile (based largely on published data), we noted the following major changes.

- The oceanic slab in the NW portion of the line is required to be about 6-7 km thick.
- The depth to the top of this oceanic basement in the western Nile delta is greater than initially modelled as is the thickness of overlying sedimentary column.
- The crustal thinning (and associated extension) across the continental margin beneath the onshore and near-shore portions of the Nile Delta is higher than initially constructed.
- It is also apparent that where the profile approaches the coast, it is closely associated with an abrupt change in the geometry of the Moho and increase in crustal thickness.

**Conclusions: a Preferred Model for Eastern Mediterranean Basin Opening**

Based on detailed integration and modeling of the gravity, magnetic, seismic refraction, and seismic reflection data, as well as onshore fault trends, and regional arguments for plate tectonic reconstructions, we concur with Meshref (1990) and Garfunkel (1998; 2004) in proposing an opening direction that was strongly oblique to the present-day continental margin of northern Egypt (Figure 4). This is consistent with structural observations along the Levant Margin and offshore North Sinai (Garfunkel, 2004; Farris et al, 2004); but is in contrast to a number of other authors that suggest rifting occurred crudely N-S, at a high-angle to the present-day coastline (Stampfli et al., 2002; Robertson, 1998), implying a right-lateral transform boundary developed synchronously along the continental margin of the Levant (Israel-Lebanon-Syria).

Evidence presented by Walley (1998) agrees with a proposed ENE-WSW opening direction and suggest that the present-day coast of the Levant is underlain by a NNE-SSW-trending extensional margin of Late Triassic-Early Jurassic age. In our preferred scenario for initial development and rifting of the EMB, the southern margin of the basin develops as a left-lateral ocean-continent transform boundary separating oceanic crust of the southern Tethys from mildly-extended continental crust f the northern Egypt. Potential analogs for such a transform margin have been documented along the
Equatorial Guinean continental margin, where oceanic fracture zones intersect the coastline at an oblique angle (Wilson et al., 2003).

![Image of continental margin]

**Figure 4.** Interpreted distribution of crustal type and key basement fabric within the EMB.

**References**


