**ABSTRACT**

The Middle East region incorporates all known types of major plate boundaries in its territory as well as significant active intraplate deformation. Until recently, understanding the tectonics in this complex region has been hindered by a relative lack of data and the complexity of the geologic and tectonic problems. Even with the increase in the amount of data in the past decade or so, the complexities of the region require a multidisciplinary approach to understand the geology and tectonics. In order to handle large, multidisciplinary data sets with varying quality and resolution, we have adopted a Geographic Information System (GIS) approach for construction of a multipurpose database to look at these problems in a comprehensive and unconventional way. Here, we present new compilation maps of surficial tectonic features and depth to the Moho for the Middle East, and describe a cross-section tool to work with data in a GIS format. These maps are available at our web site at http://atlas.geo.cornell.edu.

**INTRODUCTION**

At present, the earth sciences are undergoing a revolution. Evidence comes from collection to analysis of data, interpretation, and publication. Classical approaches are being increasingly supplemented by digital techniques, i.e., analog maps by digital counterparts, air photos by high-resolution satellite imagery, hand-collection of field data by GPS receivers and laptop computers, simple modeling by computer using sophisticated software, and electronic publication of results. This development is an inevitable outcome of modern technology. However, this technological revolution is not without problems. Already, somewhat chaotically organized databases are appearing in the digital world owing to problems like data accessibility and formats. Geographic Information Systems (GIS) provide a means to eliminate these problems and to keep data in an organized and centralized system (see also Walker et al., 1996). Structured properly, well-engineered databases are easy to use, update, modify, manage, distribute, and exchange.

One of the common misconceptions about GIS database development is that it

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**Figure 1.** New map of the Middle East region showing locations of oceanic trenches, rift zones and major faults (thick yellow lines; see names in Figure 2), secondary faults, ophiolites, regions of basement outcrop, and principal areas of volcanism. This map is compiled from GIS data set that includes tectonic and geologic maps of various scales from the different countries in the region. See Figure 2 for tectonic interpretation. The gray background image is the shaded topographic relief map, illuminated from the north (shown in more detail in Figure 3). A clear correlation between topographic features and faults suggests that most of the faults shown on the map are still active.
DATABASE FOR THE MIDDLE EAST

To develop a comprehensive database on the Middle East, we are working on a project named DATABASE FOR THE MIDDLE EAST. This project aims to compile and manage a comprehensive database at a resolution of 1:1,000,000 scale which can be used as both a scientific and educational tool. The database will be used in classrooms and by scientists worldwide, regardless of their race, citizenship, gender, religion, or political viewpoint. The database is intended to further science and education upon payment of the appropriate fee ($0.25 per page) directly to the Copyright Clearance Center, 27 Congress Street, Salem, Massachusetts 01970, phone (508) 744-3350 (when paying, reference GSA Today, ISSN 1052-5173). Written permission is required from GSA for all other forms of capture, reproduction, and/or distribution of any item in this publication by any means. GSA provides this and other forums for the presentation of diverse opinions and positions by scientists worldwide, regardless of their race, citizenship, gender, religion, or political viewpoint. Opinions presented in this publication do not reflect official positions of the Society.

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is primarily a mapping tool. Although the output is commonly in map form, the main use of GIS is to analyze, search, manipulate, and select databases for a specific purpose. The use of GIS systems opens new avenues for comprehensive studies and solving complex problems related to integrated and dynamic earth systems. Earth sciences, by their very nature, are among the most suitable disciplines for GIS applications.

BUILDING A COMPREHENSIVE DATABASE FOR THE MIDDLE EAST

In this paper, we apply GIS technology to regional-scale tectonic problems of the Middle East. To do this, we are developing a comprehensive database at a resolution of 1:1,000,000 scale which can be used as both a scientific and educational tool. Developing such a database system for multiple users is most advantageous, if easy-to-use tools for accessing and manipulating data sets are built into the system so that scientists can use...
the database in innovative ways to make research advances. The principal reasons for constructing this database in the Middle East are to help in the monitoring and verification of the recently signed global Comprehensive Test Ban Treaty (CTBT) (see Barazangi et al., 1996) and to study the complex tectonic and geologic problems of the region. This database will also have an impact in natural hazard evaluation, particularly in understanding the earthquake occurrences in the region and seismic risk assessment. The data set can also be used in classrooms as an educational tool.

**GIS Data and an Improved Middle East Tectonic Map**

A tectonic map made from our GIS data set showing the major plate boundaries and surface features of the Middle East is shown in Figure 1. The background for the map is a high-resolution (~90 m) digital topographic map of the Middle East obtained from the Defense Mapping Agency (DMA). Information on the map includes locations of trenches, rifts, secondary faults, volcanic rock and ophiolite distributions, basement outcrops, and basins. The features have been compiled from regional tectonic and geologic maps among which the most important are the Geological Survey of Iran Seismotectonic Map of the Middle East, the Syrian Arab Republic Ministry of Petroleum and Mineral Resources Geologic Map of Syria, and the General Directorate of Mineral Research and Exploration of Turkey Active Fault Map of Turkey. In the GIS database, geologic features on the maps have all been assigned attributes defining their properties.

Using the Middle East GIS data system, one can display any set of data needed for a particular study. For example, faults longer or shorter than any given length can be selected, or active faults and volcanoes can be displayed. High-resolution satellite imagery and field geology data can be incorporated in the database system for special studies such as the effects of erosion on topography. Among important problems for study in the Middle East are reasons for volcanic activity in both tectonically active and platformlike environments, for the complex patterns of seismicity, and for variations in crustal structure.

The map shown in Figure 2 has been modified from previous versions through the use of our GIS database. Particularly important in this modification was the use of the high-resolution (~90 m) digital topographic map shown in the background of Figure 1 and in Figure 3. Digital Elevation Models (DEMs) like this provide highly accurate elevation information that can be used as a guide in defining boundaries of tectonic units, especially those related to young (i.e., Quaternary) deformation. Using the DEM with our database, we have found first-order correlations between topography, faults, and seismicity that indicate that most of the major faults in Figure 1 are still active and that the topography is in large part shaped by active tectonic processes. Taking advantage of this correlation, we have refined the positions of the North and East Anatolian faults and defined a new boundary for the Turkish-Iranian plateau.

Figures 1 and 2 can be used as a guide for a tutorial on the major tectonic features of the Middle East. As shown, the region incorporates all known types of major plate boundaries around the borders of the Arabian plate (e.g., Dewey and Şengör, 1979). To the south along the Red Sea and the Gulf of Aden, new oceans are opening (see Cochran, 1983; Le Pichon and Francheteau, 1978). To the north and east, continental collision is occurring along the Bitlis suture zone in southern Turkey (Şengör and Kidd, 1979; Şengör et al., 1985) and the Zagros suture zone in western Iran (Snyder and Barazangi, 1986; Ni and Barazangi, 1986). The current counterclockwise rotation and northward motion of the Arabian plate relative to Eurasia are accommodated along these collision zones. Well-developed arc volcanoes and a foreland basin along the entire Zagros mountain system indicate Neogene subduction in this region. Although a similar volcanic arc and foreland basin are not easily identified along the Bitlis suture, a Neogene subduction zone is also inferred in this region, especially in southeast Turkey. To the northwest, the Dead Sea fault system manifests itself as a left-lateral strike-slip plate boundary that extends approximately 900 km along the boundary between the Arabian and African-Levant plate. (Garfunkel, 1981; Girdler, 1990; Chaimov et al., 1990). Other major strike-slip zones are the right-lateral North Anatolian fault in northern Turkey and the left-lateral East Anatolian fault in eastern Turkey, which form respectively the northern and eastern boundaries of the

**GIS continued on p. 4**
Anatolian block. These faults developed to accommodate escape of the Anatolian block toward the west in response to the collision of Arabia and Asia (Şengör et al., 1985).

A consequence of the collision between the Arabian and Eurasian plates was the development of the high Turkish and Iranian plateau in eastern Turkey and northwestern Iran. This plateau covers a wide region behind the main Zagros and Bitlis suture zones. By following the 1500 m elevation contour on the high-resolution topographic image, we have been able to map the boundary of this plateau. This contour represents the maximum elevation or base level of the plateau that defines a continuous elevated surface over the entire region. Although the mechanism that holds up this high plateau is not well understood, extensive volcanism and strong seismic shear wave attenuation in the mantle lithosphere beneath the plateau (e.g., Kadinsky-Cade et al., 1981) suggest that a thermal component is required. Further work is needed to fully understand the crustal and upper mantle structures of this region.

The western part of the Arabian platform, east of the Red Sea, has a large region called the Arabian shield where Precambrian crystalline rocks are exposed (Fig. 2). Unlike other shields, which by definition are regions of long-term tectonic stability, the Arabian shield has been subjected to recent tectonic activity. In particular, the continuing rifting process that formed the Red Sea has affected the region. The presence of Cenozoic volcanic activity within the Arabian shield area shows a real departure from a typical shield environment (e.g., Camp and Roobol, 1992). The very low seismic crustal Q values of the Arabian shield (Seber and Mitchell, 1992), which are atypical of shield regions, reflect this tectonic and magmatic activity.

**New Moho Map and Crustal Cross Section of the Middle East**

One of the least known geological features in the Middle East region is the thickness of the continental crust—that is, the depth to the crust-mantle boundary or Moho. To constrain Moho depth in this region, we have digitized more than 50 interpreted crustal-scale refraction and gravity profiles (Fig. 4) from the published literature. All boundaries have been assigned specific attribute names like “basement” and “Moho.” To this database, we have added Moho depth estimates obtained using a single-station technique (Sandvol et al., 1996). Moho depth values from surface-wave tomographic studies (Ghalib, 1992) and interpretations of Bouguer gravity data in Iran (Dehghanian, 1981) were also incorporated. The Moho map in Figure 4 was made by selecting and gridding all of the Moho depth values in the database. In regions where data were limited, Moho depth was determined by interpolating from the nearest data points.

Examination of the map in Figure 4 points to several first-order crustal characteristics in the Arabian plate region. First, the thickest crust occurs beneath the Zagros Mountains in Iran where continental collision is taking place. Second, the thinnest crust occurs beneath the southern Red Sea where new oceanic crust is forming. Third, the crustal thickness beneath the Arabian shield appears to be mostly around 40–45 km. This result is constrained by a single profile, and should be taken cautiously. However, seismological data recently collected by Scripps Institution of Oceanography and Saudi scientists will soon allow us to provide additional constraints in Moho depth in this region. Fourth, the crust is very thin (~8 km) beneath the Afar triangle of Africa, just west of the southern Red Sea. This region is thought to be underlain by either an oceanic crust or stretched continental crust heavily injected by migmatic rocks (e.g., Mohr, 1989).

A tool called Profile Maker that we have developed for use with gridded databases is useful in detailed studies of crustal variations. This tool extracts and draws two-dimensional crustal scale cross sections between any two points within the area of data coverage. Any combination of topographic, basement depth, crustal thickness, seismic velocity, gravity, and any other available data can be incorporated. These profiles can be used for multiple research purposes such as seismic waveform or gravity modeling, or for teaching.

A cross section made with this tool which incorporates topography, depth to crystalline basement, and total crustal thickness (Fig. 5) illustrates the thin crust in the Red Sea and the thick crust beneath the Zagros Mountains in comparison with the rest of the Arabian platform. The Mesopotamian foredeep is identifiable by the thickening of sedimentary rock toward the Zagros collision zone.