Development of a Lithospheric Model and Geophysical Data Base for North Africa

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ABSTRACT:

We have begun to develop a model of the North African lithosphere via an integrated analysis of seismic, potential field, and geologic data. These data will be used to construct detailed 2-D models of the region and a geological and geophysical data base which will be made available to the scientific community. The detailed 2-D lithospheric models will be verified through modeling of regional seismic phases. Recent results of ongoing gravity, heat flow, and earthquake source parameter studies of Libya, and surface wave dispersion studies of North Africa using WWSSN stations are presented as examples of the types of data that will be used to develop regional lithospheric models.

key words: geophysical data base, North African lithosphere

OBJECTIVE:

We will develop a model of North African lithosphere via an integrated analysis of seismic, potential field, and geologic data. In particular, we will construct detailed 2-D models from known earthquake source regions to key seismic monitoring stations in the region. An outgrowth of this effort will be a data base of geological and geophysical information which will be made available to the community through electronic access.

PRELIMINARY RESULTS:

A first step in this process is the collection of pertinent geological and geophysical data for North Africa. The coverage of any one type of data is insufficient to formulate a lithospheric model. Thus, we are using an integrated approach to the problem in which all possible data are used to derive a model. As an example of this process, we use the results of recent geophysical studies of Libya, a region whose present day structure is primarily a result of Late Cretaceous and Early Tertiary age rifting.

Gravity data can be useful in extrapolating below and between regions in which seismic data provide good constraints on structure. Figure 1 shows that we have been able to compile a good database of gravity readings in Libya (Suleiman, 1993). The large anomalies present (Figure 2) attest to the complex subsurface structure of this rifted region. Modeling of gravity data suggest a total sedimentary section of more than 5 km in the Sirt basin deep (Figure 3). The crust in the region is relatively thin (< 40 km thick) with the thinnest crust found underneath the Cyrenaica shelf.

Borehole data are also useful, as demonstrated by bottom hole temperature, stratigraphic, and well log information we have gathered for Libya. These data were used in conjunction with thermal conductivity and radioactive heat production measurements of formations to estimate heat flow values (Figure 4, Nyblade et al., 1995). Heat flow in the Sirt Basin is elevated by about 10 mW/m^2 from the global mean for unrifted Proterozoic terrains. This small heat flow anomaly could be due to either enhanced crustal heat production or residual heat from Cretaceous rifting (Nyblade et al., 1995).

Waveform modeling studies of the 1935 Hun graben earthquake sequence, including the largest magnitude (moment-magnitude 6.9) earthquake in Libyan history, suggest the crust supports brittle failure to depths of at least 20 km (Suleiman and Doser, 1995). Normal faults formed during Cretaceous rifting appear to have been reactivated as strike-slip faults in the present day stress regime (Figure 5).

Surface wave dispersion studies between WWSSN stations MAL and HLW and MAL and JER (Figure 6) (Yousef, 1986) sample the average crust and mantle structure across much of extreme northern Africa. These results suggest a mantle lid at about 60 km depth and a possible crustal low velocity zone at a depth of 10 to 15 km. As part of present study we will be reanalyzing these data using updated processing techniques (Dean and Keller, 1991) and extend the analysis using new digital stations in the region.

Integration of these geophysical studies of Libya would suggest that the crust is best modeled as being no more than 40 km thick, thinning slightly from west to east. The brittle-ductile transition in the crust appears to occur at 20 km depth, with an expected velocity change corresponding to this transition. Heat flow results suggest only small decreases in crustal velocity relative to velocities associated with unrifted Proterozoic terrains, while surface wave dispersion studies suggest an asthenospheric thickness of about 60 km. This preliminary crustal/upper mantle model will need to be validated through waveform modeling studies of regional seismic phases of Libyan earthquakes.

FUTURE PLANS:

We have begun to collect geophysical and geological data sets for other regions of North Africa that will be used to determine preliminary lithospheric models in a manner similar to that demonstrated for Libya. Regional seismic waveforms are also being collected and will be modeled in order to validate and update these preliminary lithospheric models. Our final results will be a geophysical and geological data base for North Africa that will be easily accessible to the scientific community and a series of "best" lithospheric models for regions of North Africa that have been validated through waveform modeling of regional seismic phases.

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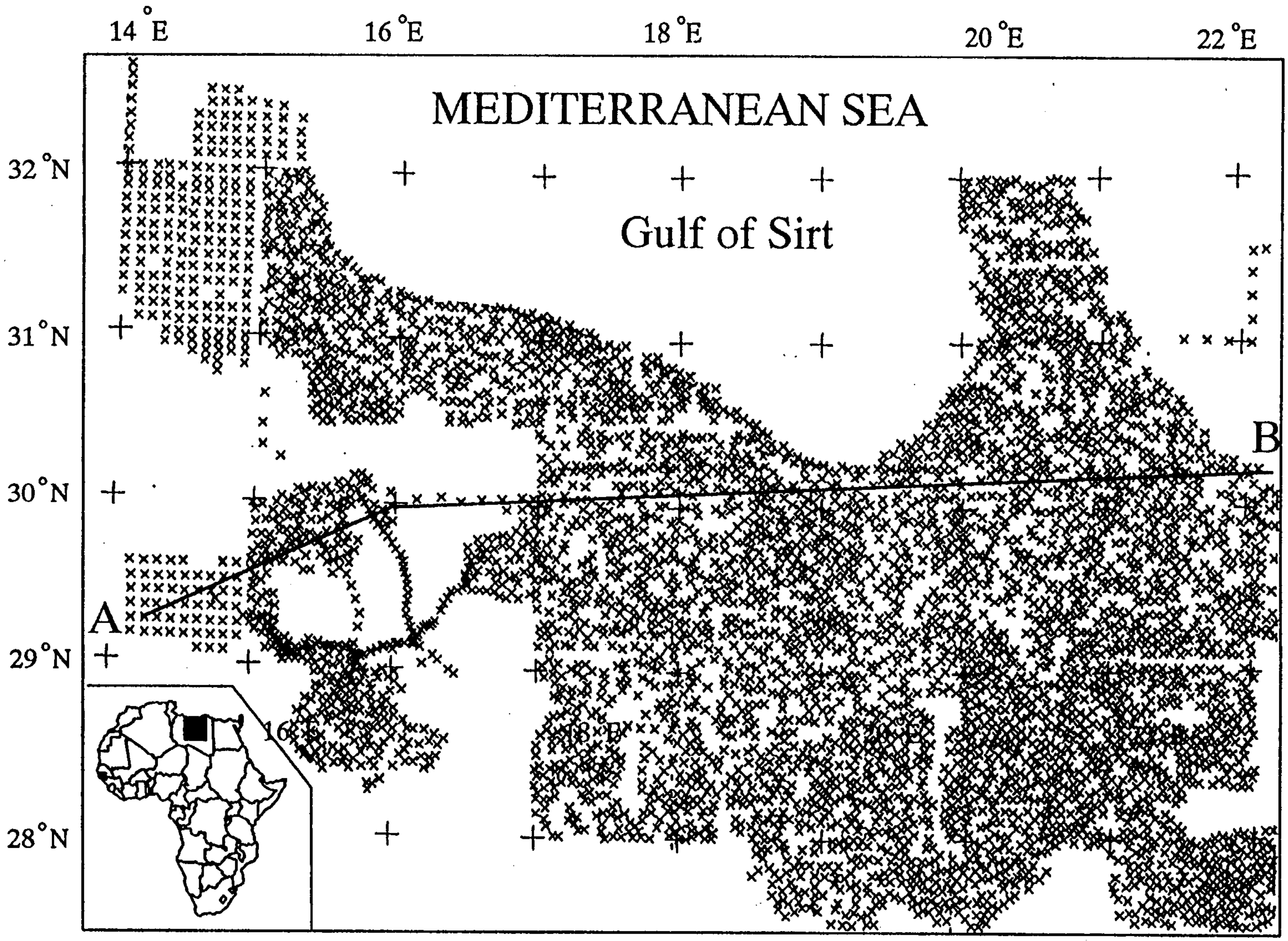

Figure 1. Map showing the gravity station distribution in the Sirt basin area. Interpretation of gravity data along profile A-B is shown in Figure 3.

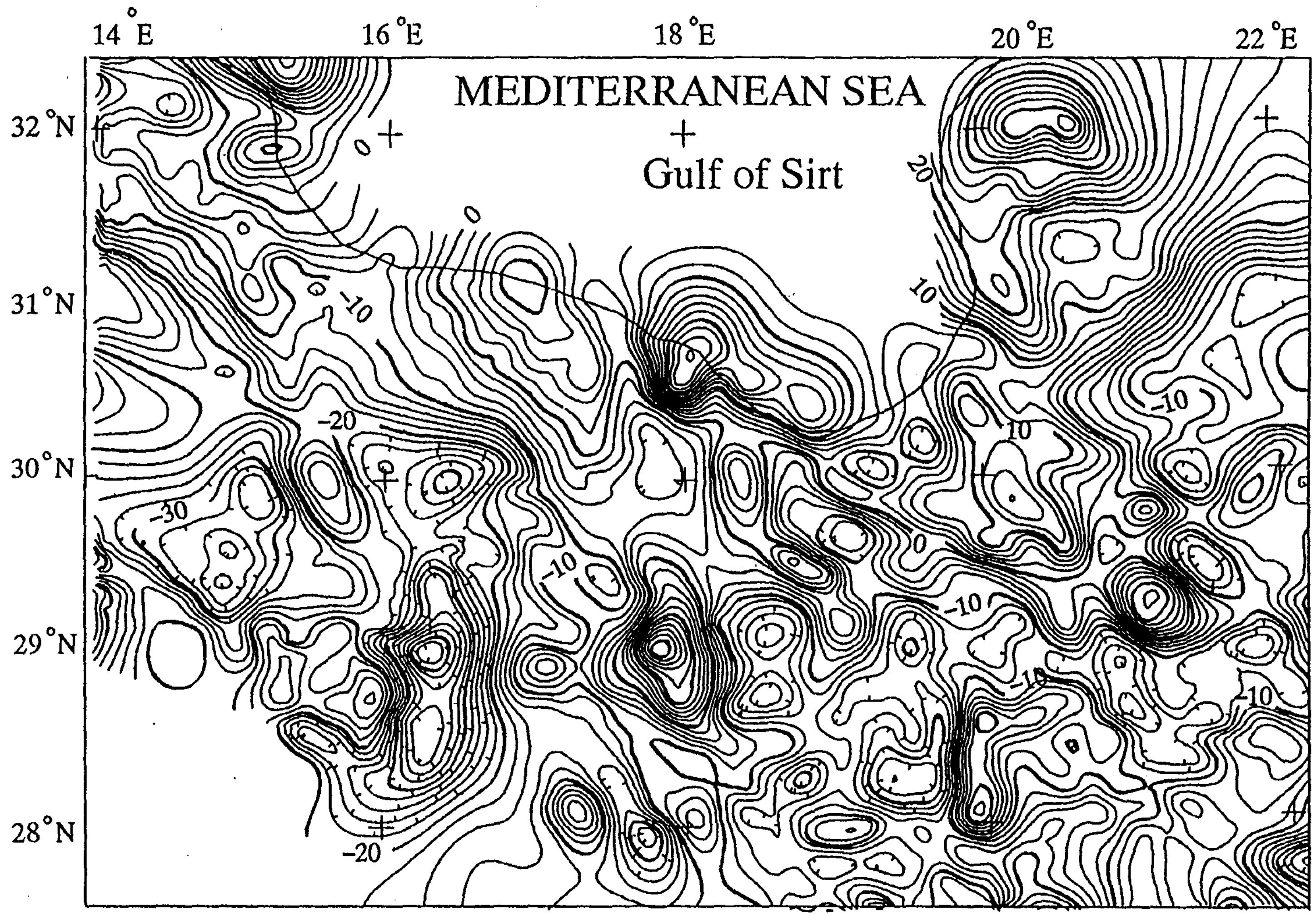

Figure 2. Bouguer anomaly map of the Sirt basin rift system from Suleiman (1993). Contour interval is 2 mgals.

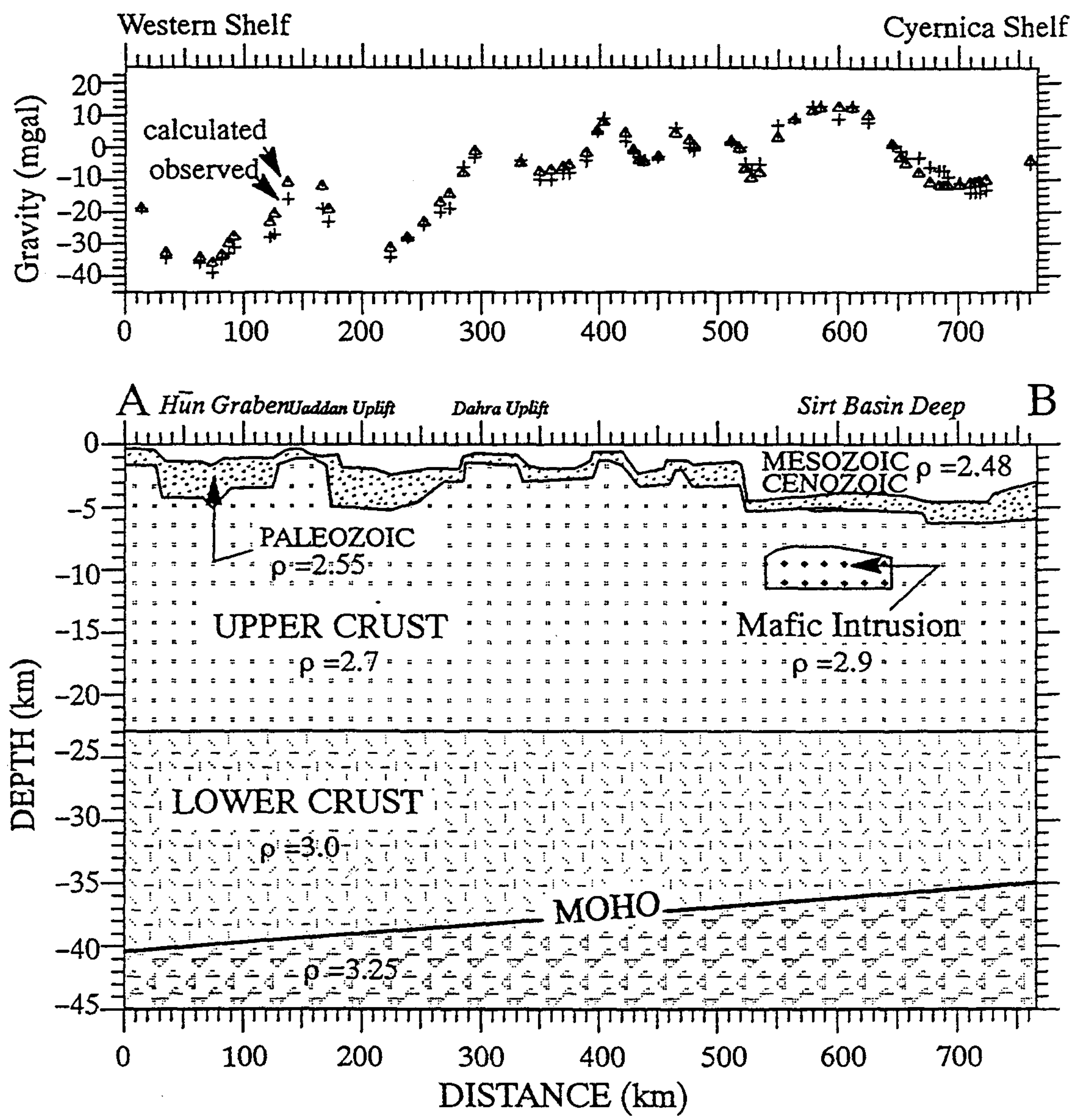

Figure 3. Interpretation of gravity profile across the Sirt basin rift system along profile A-B (see Figure 1) and corresponding computer model of crustal structure (Suleiman, 1993). Densities shown in model are in g/cm^3.

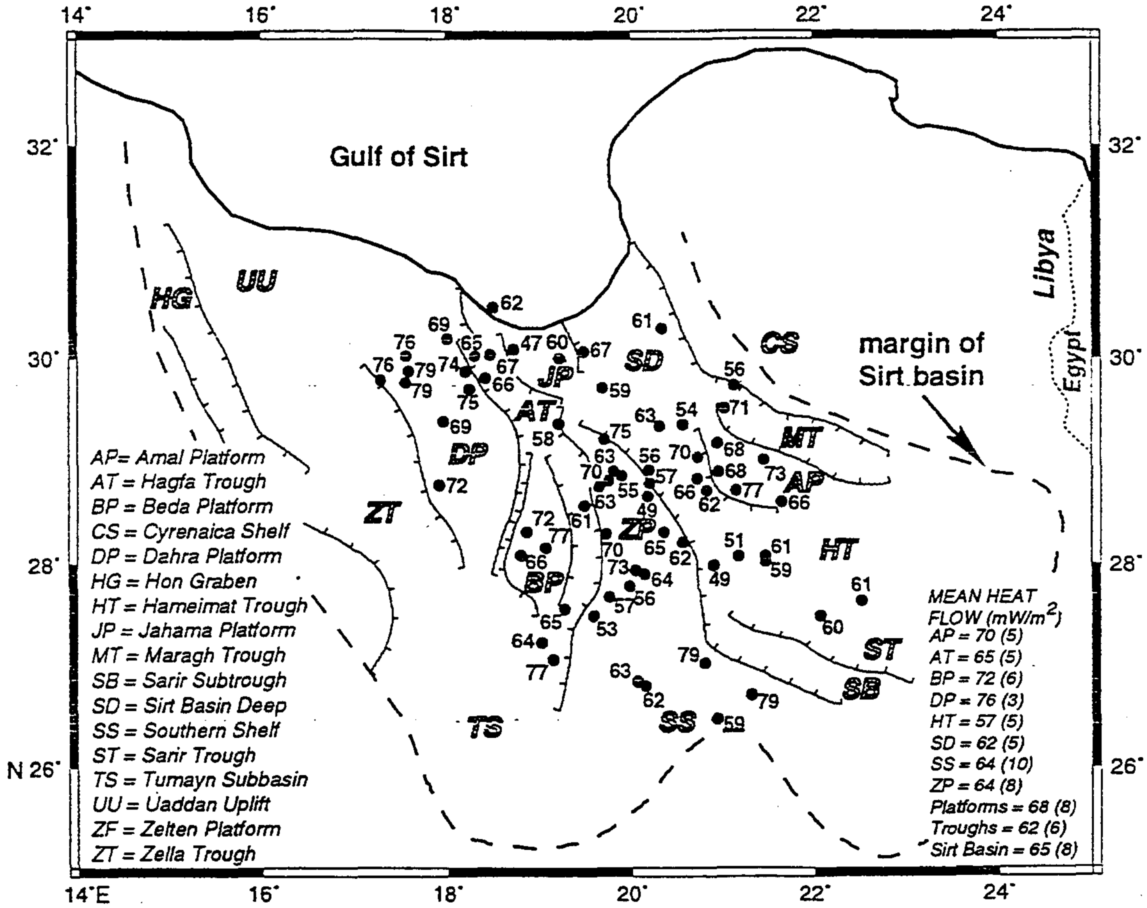

Figure 4. Map of Sirt basin showing heat flow (in mW/m^2) at wells (solid circles), major rift faults, and prominent structural features (from Nyblade et al., 1995). Mean heat flow values are given in the lower right corner, with standard deviations of the mean given in parentheses.

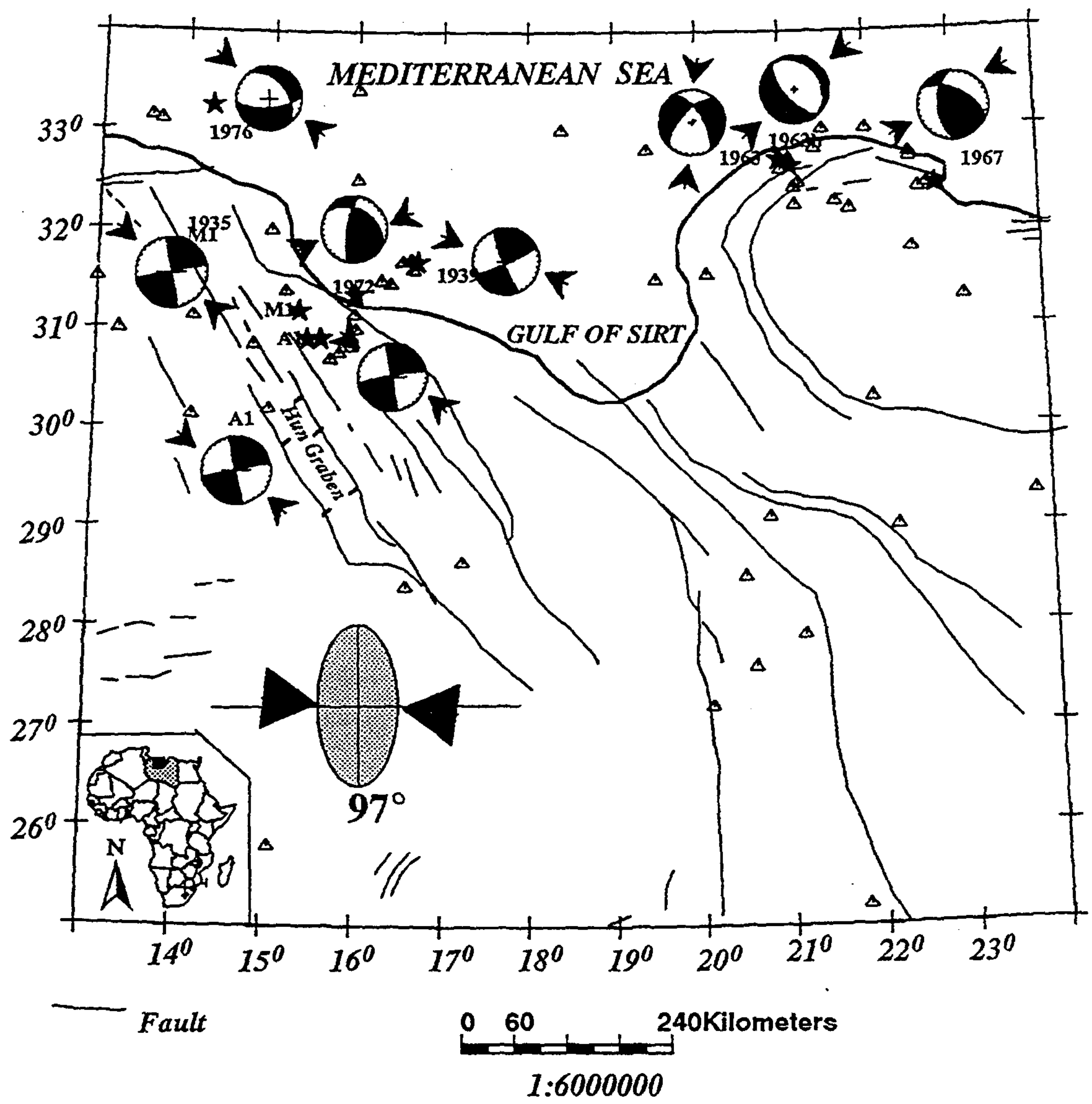

Figure 5. Northern Libya earthquakes (triangles and stars) and focal mechanisms (from Suleiman and Doser, 1995). Arrows denote strike of P-axes. Large arrows in left corner denote strike of maximum compressive stress direction determined from the inversion of northwestern Libya focal mechanisms.

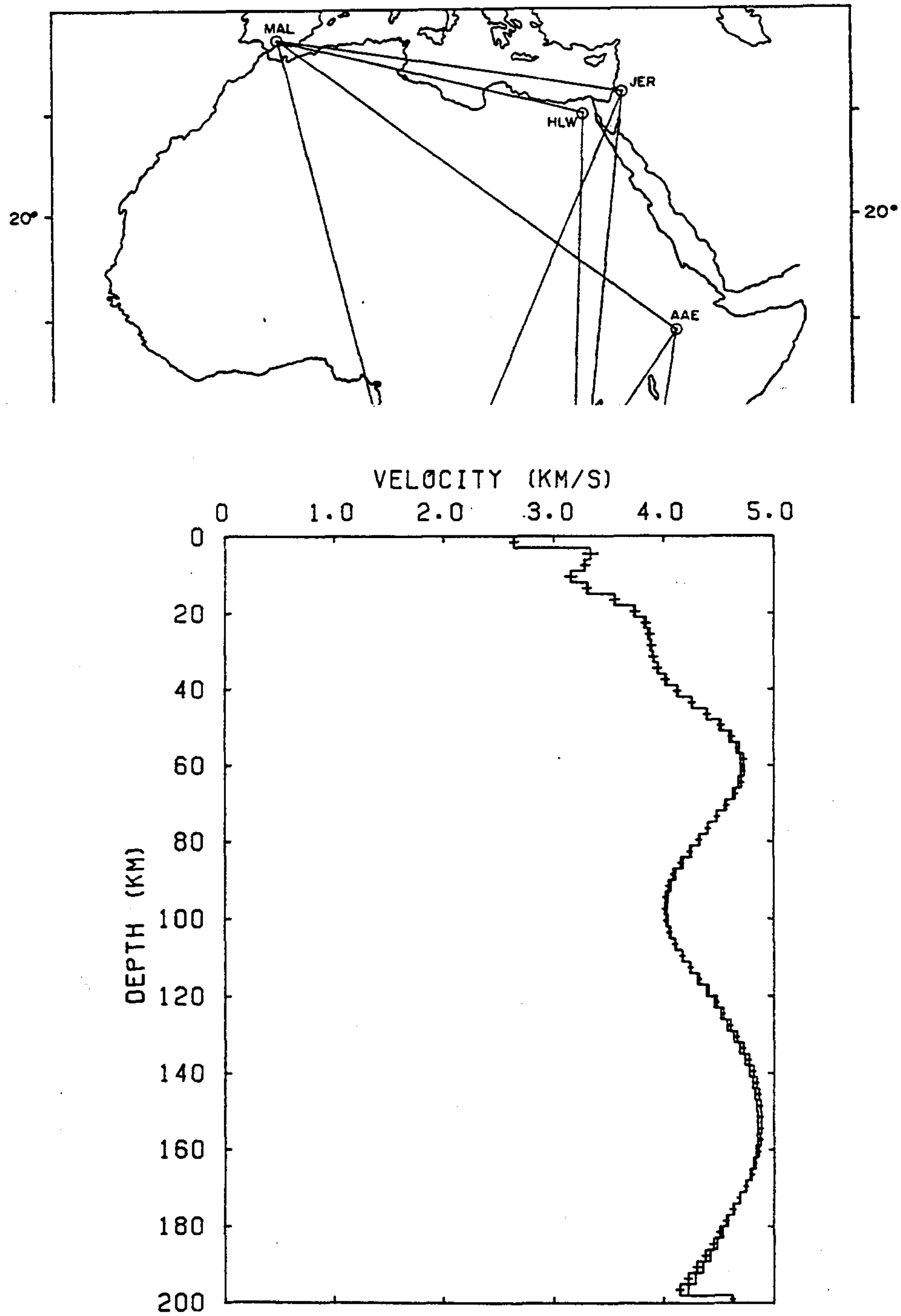

Figure 6. Location of North African travel paths and WWSSN stations used in surface wave dispersion analysis (top). Velocity model determined from inversion of dispersion data for the paths HLW-MAL and JER-MAL (from Yousef, 1986) are shown at bottom.