# THE USE OF GRAVITY MODELS TO CONSTRAIN REGIONAL VELOCITY MODELS FOR THE LIBYA AREA

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## ABSTRACT

The tectonic evolution of Libya has yielded a complex crustal structure, which is composed of a series of basins and uplifts. A considerable amount of oil exploration has been undertaken in the area and numerous studies have been published on the shallow (<10-km depth) geology and geophysics of the region. In addition, over 6000 gravity measurements are available for the northern Libya region. We are using these data in conjunction with other geologic and geophysical controls to construct a three-dimensional (3-D) model of density/geology for northern Libya and surrounding regions. Northern Libya is the most seismologically active portion of the country. This 3-D model will then be used to develop a regional velocity model that can be verified/modified by analysis of regional waveform data we are collecting from earthquakes occurring within northern Libya.

## OBJECTIVE

### Introduction

Libya sits at the northern extreme of the African continent and includes classic examples of continental rifts and domal uplifts. Throughout the year to come, we will be carrying out further studies to investigate lithospheric thickness and structure of the African continent beneath Libya. However, at this stage, the study is still in its infancy. In order to set the stage for this project, we are in the process of constructing a 3-D gravity model of density/geology for northern Libya and its surrounding regions. Further analysis of waveform data will be used to construct a reliable velocity model. Previous studies have used seismic and gravity data (e.g., Dial, 1998) to investigate variations in the lithosphere throughout the northern portion of the African continent.

Although geological and geophysical studies in the Libya region of northern Africa are adding to the growing database of knowledge in the region, few data are available on the lithospheric structure of the region (Dial, 1998). Using existing geological (Figure 1) and geophysical data as a foundation, this project ultimately seeks to construct updated lithospheric models for the Libya region employing integrated gravity modeling, waveform modeling, remote sensing data, well logs and all other available geological or geophysical data.

## RESEARCH ACCOMPLISHED

### Data Collection

Waveform modeling has become one of the most powerful tools available to seismologists for refining Earth structure models and understanding the fault rupture processes. Waveform modeling will be one of the primary tools used in this study. For the body waveform modeling section of this study, we are in the process of collecting hard copies of seismograms from California Institute of Technology's (Caltech's) microfiche collection of seismograms from stations that were members of WWSSN (see Table 1 and Figure 2). The seismograms collected are those of magnitude 4.5 or greater. In addition, we will be downloading digitally recorded seismograms for the more recent events from reliable seismic data collection agencies.

Over 6000 reduced gravity data points have already been compiled and will be used in this study. These gravity points were collected from a number of databases. The majority of these points were collected from the worldwide gravity database maintained by the National Imagery and Mapping Agency (NIMA). The other points were pulled from our local database here at the University of Texas at El Paso (UTEP). Figure 3 shows a Generic Mapping Tool (GMT) plot of the location of the gravity points that will be used in the study.

Remotely sensed images collected by the Landsat 4 and Landsat 5 instruments will be incorporated to better understand structural features within the study area. Landsat 4 and 5 refer to the dataset collected by the unmanned satellites that were launched in the 1980s. The Landsat images that were ordered for this project were carefully selected in order to minimize the expense while optimizing the coverage. The satellite images have not been delivered at the time this paper was written; therefore, not much more can be said about this section of the study.

A vast number of well logs is available, owing to the fact that Libya has been extensively drilled for the purpose of oil exploration. Some of these wells will be critical in the characterization of the subsurface geology. The well logs will be consulted during and after processing to make sure that the models are geologically feasible.

### Processing

Once collected, the seismograms will be scanned and digitized using either SEISCAN (Liberty and Pelton, 1995), which is a Matlab (version 5) based program or 'mapdig', a UNIX-based program developed at the University of Texas El Paso (UTEP), which involves manually digitizing the seismograms on a digitizing board followed by processing by another UNIX based program called 'xydig'. Once processed, the inversion technique of Baker and Doser (1988) will be used to carry out the waveform modeling, which will determine fault orientation, focal depth and rupture process. In general, waveform modeling is an iterative process in which differences between the observed and adjusted Earth structure or source representation minimizes synthetic seismograms. The synthetic seismogram is a mathematical construction that uses wave propagation effects, source effects and characteristics of the seismometer to predict the character of a seismogram in a realistic model of the earth (Lay and Wallace, 1995).

The gravity data used in this study covers an area extending from 8°E, 35°N to 26°E, 19°N. The data will be gridded as a 5 by 5 grid constructed using a minimum curvature technique. These data were reduced to Bouguer anomaly values using a standard density of $2.67 g/cm^3$. Gravity station locations (over 6000 stations) are shown in Figure 3, and this figure shows the high density of coverage that exists in the northern regions as opposed to a sparse coverage existing in southern regions.

The program "SURFGRAV" will be used to construct the 3-D gravity model. SURFGRAV is a general-purpose 3-D gravity-modeling program. The computation is based on representing the Earth's surface as a gridded Digital Elevation Model (DEM) with an associated grid derived from mapped geologic units. For this computation, Figure 1 has been gridded and will be used in conjunction with the DEM shown in Figure 4. The output computed gravity (a kernel file) is presented as a matrix or spreadsheet data set with each row a gravity station, and the columns containing unit-density gravity contributions for each of the geologic units in the area of computation. Spreadsheet, Matlab or other specialized software can then combine these kernel files to give terrain-corrections, regional/local contributions, tests of forward models at different densities, or the Jacobian for use in inverse algorithms (Baker 2001). The results of the 3-D gravity modeling will be correlated with well logs to check for validity.

## CONCLUSIONS AND RECOMMENDATIONS

We believe that our integrated analysis will be the most comprehensive study of the Libyan lithosphere ever undertaken. Thus, we believe that it will provide significant insight on the tectonics and wave propagation in the area.

## REFERENCES

Baker, M. R., and D. I. Doser, 1988, Joint inversion of regional and teleseismic earthquake waveforms, *J. Geophys. Res.* **93**, 2037-2045.

Dial, P., 1998, An integrated geophysical study of North Africa and Mediterranean and lithospheric structure, *PhD. Dissertation,* p.1-38.

Hearn, P. Jr., *et al*, 2001, *Global GIS Database: Digital Atlas of Africa*, USGS. Digital Data Series (DDS-62-B).

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Wessel, P. and W. H. F. Smith, 1995, New version of the generic mapping tools released, *EOS Trans. Amer. Geophys. U.*, **76**, 329.

**Table 1 Location time of occurrence and magnitude of the earthquake events that will be used to do the waveform modeling.**

| Date | Time | Location | | |
|---|---|---|---|---|
| YYYY:MM:DD | HH:MM:SS.SS | Lat. | Long. | Magnitude |
| 1935:04:19 | 15:23:24 | 31.00 | 15.20 | 7.1 |
| 1935:04:19 | 20:31:39 | 30.80 | 15.50 | 6.0 |
| 1935:04:20 | 05:10:56 | 30.81 | 15.51 | 6.5 |
| 1963:02:21 | 17:14:31 | 32.69 | 20.97 | 5.5 |
| 1963:02:21 | 18:32:55 | 32.00 | 20.60 | 4.5 |
| 1963:02:21 | 20:26:39 | 32.66 | 21.10 | 4.5 |
| 1964:03:31 | 21:38:37.20 | 33.23 | 21.40 | 4.5 |
| 1967:01:02 | 08:19:37.00 | 32.44 | 22.62 | 4.6 |
| 1967:03:09 | 19:54:38.00 | 31.00 | 18.00 | 4.7 |
| 1968:05:24 | 17:57:22.00 | 23.90 | 11.90 | 4.6 |
| 1968:05:26 | 00:05:44.00 | 26.70 | 14.60 | 4.6 |
| 1972:03:27 | 13:33:30.29 | 32.1586 | 21.7809 | 4.6 |
| 1972:09:02 | 14:53:47.75 | 31.3939 | 16.0939 | 5.1 |
| 1974:09:04 | 06:29:13.97 | 33.0899 | 13.5020 | 5.2 |
| 1975:11:13 | 03:07:20.48 | 33.4177 | 22.8430 | 5.1 |
| 1976:12:19 | 21:21:52.66 | 33.0098 | 13.9704 | 4.5 |

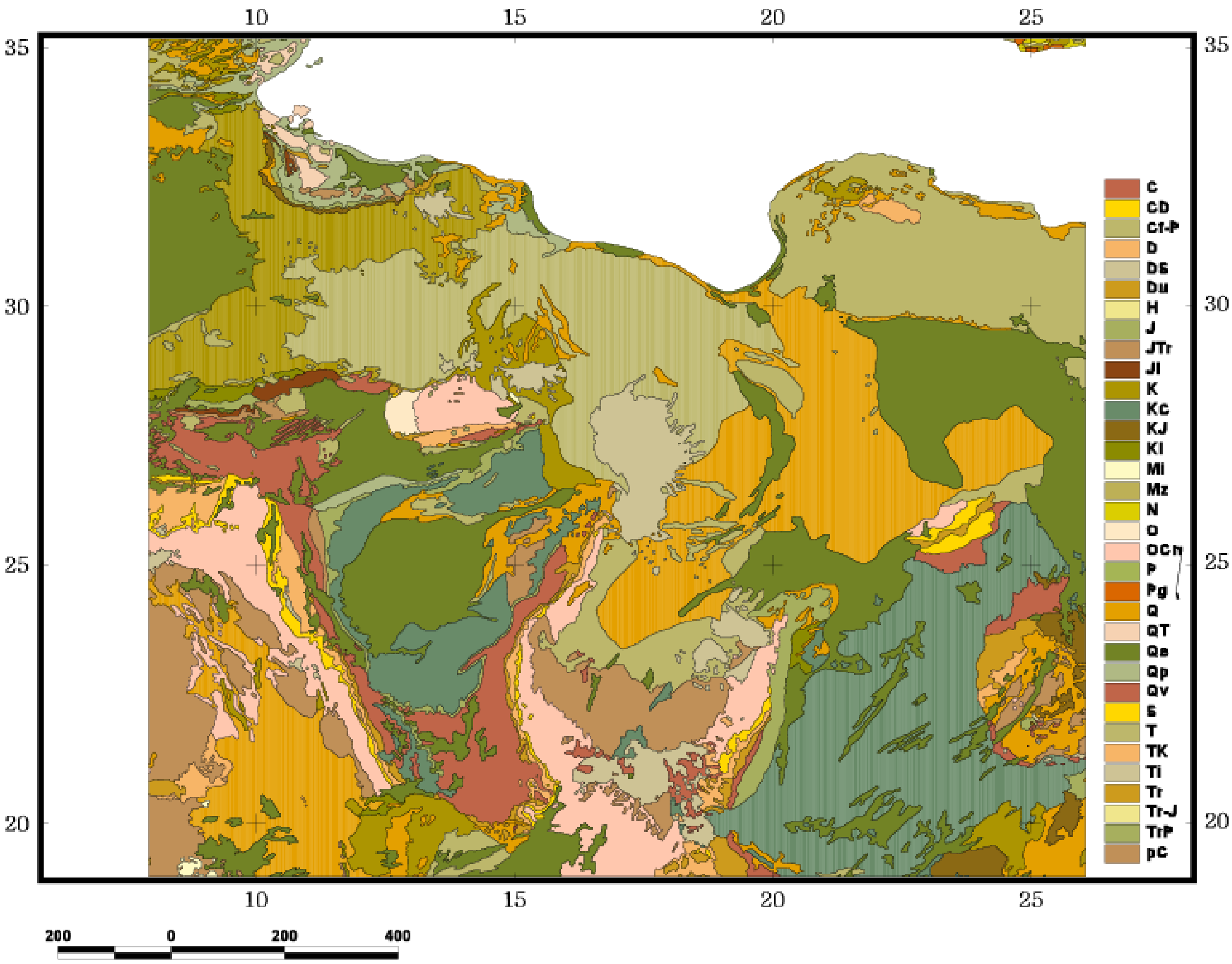


**Figure 1. Geologic map of Libya and adjacent areas (modified from Hearn, 2001)**

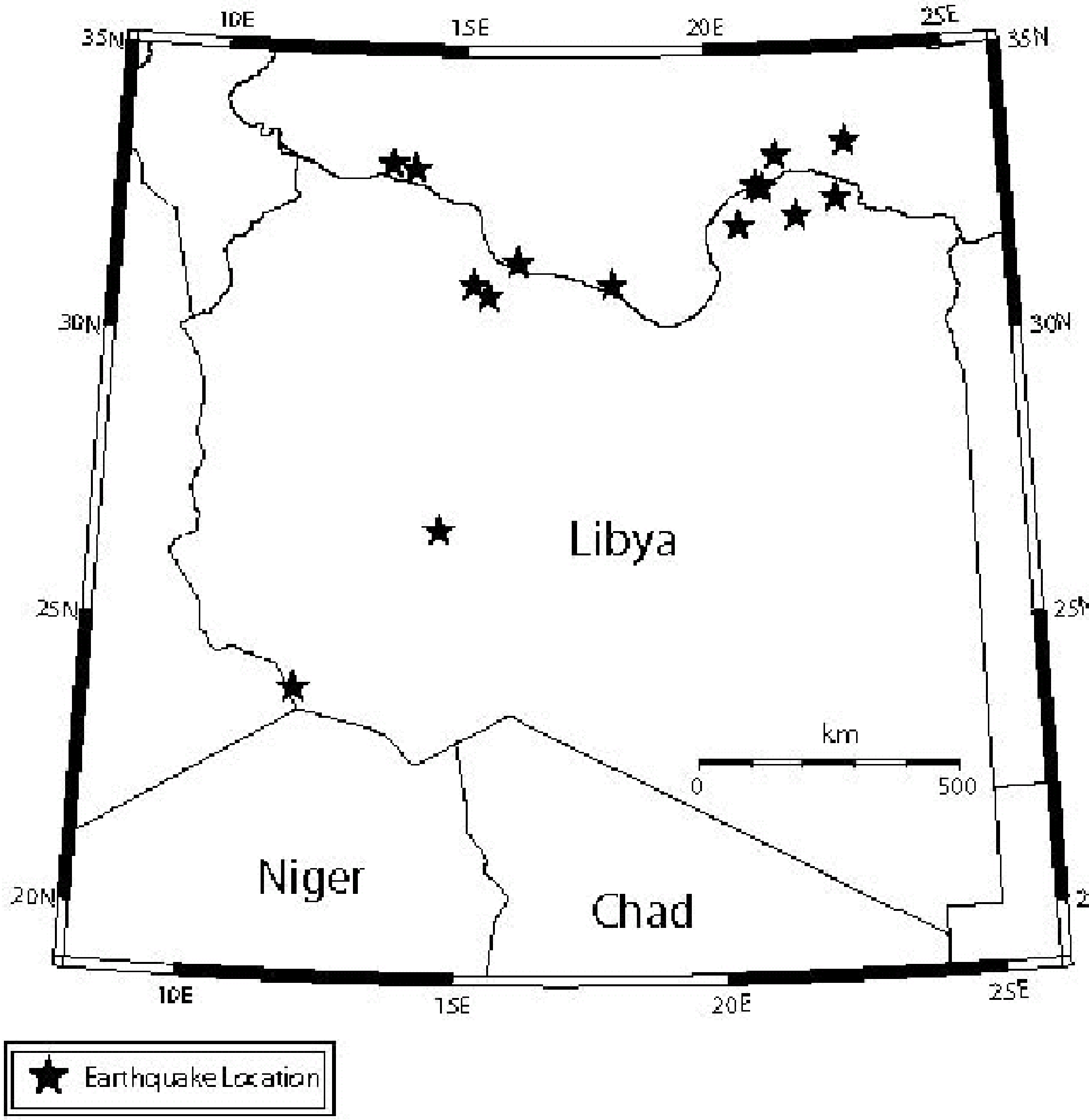


**Figure 2. This figure shows the location of the earthquakes that will be used to do the waveform modeling in the Libya region.**

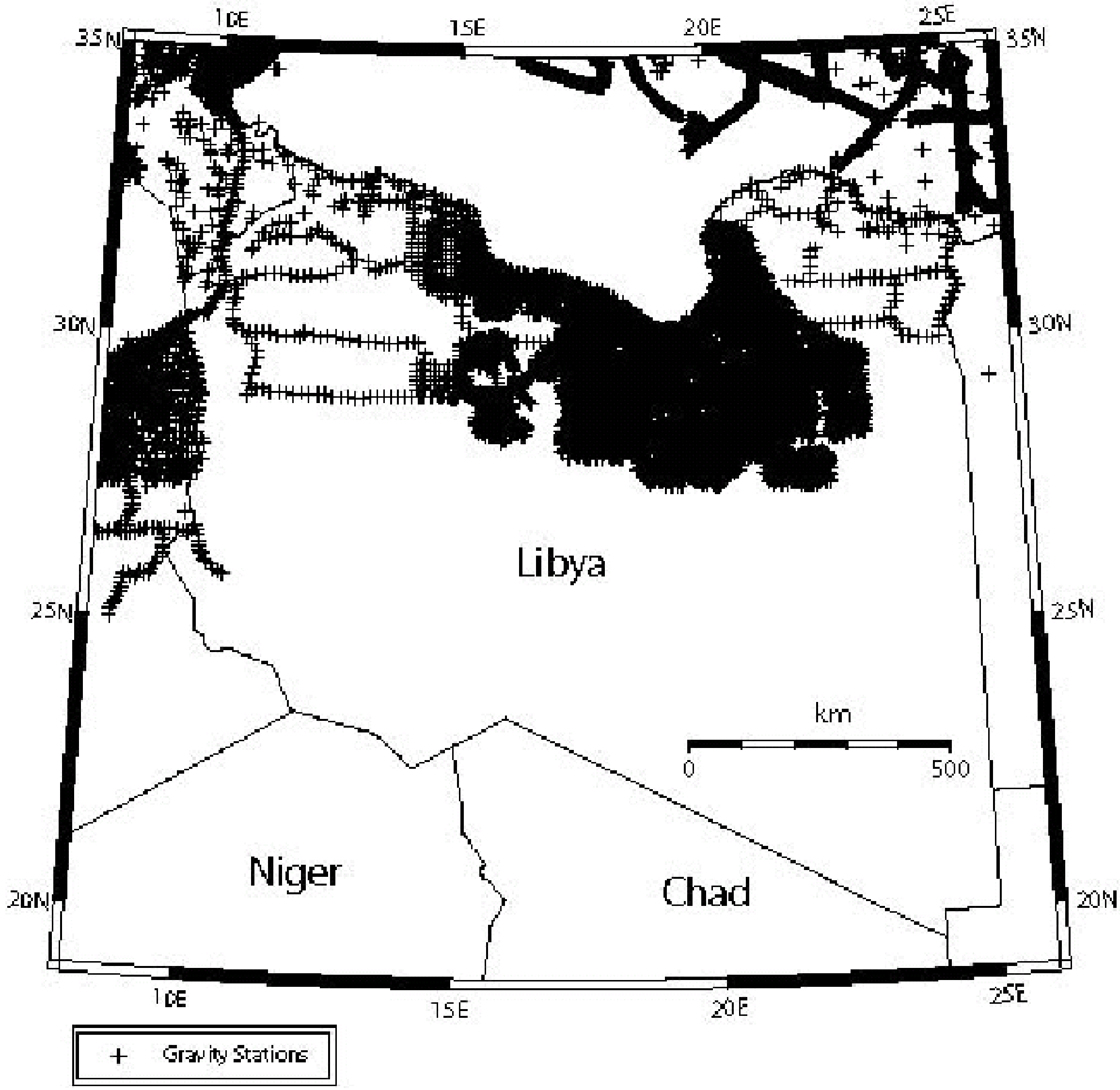


**Figure 3. Map of Libya showing the locations of the gravity stations that have been reduced and will be used in the gravity study**.

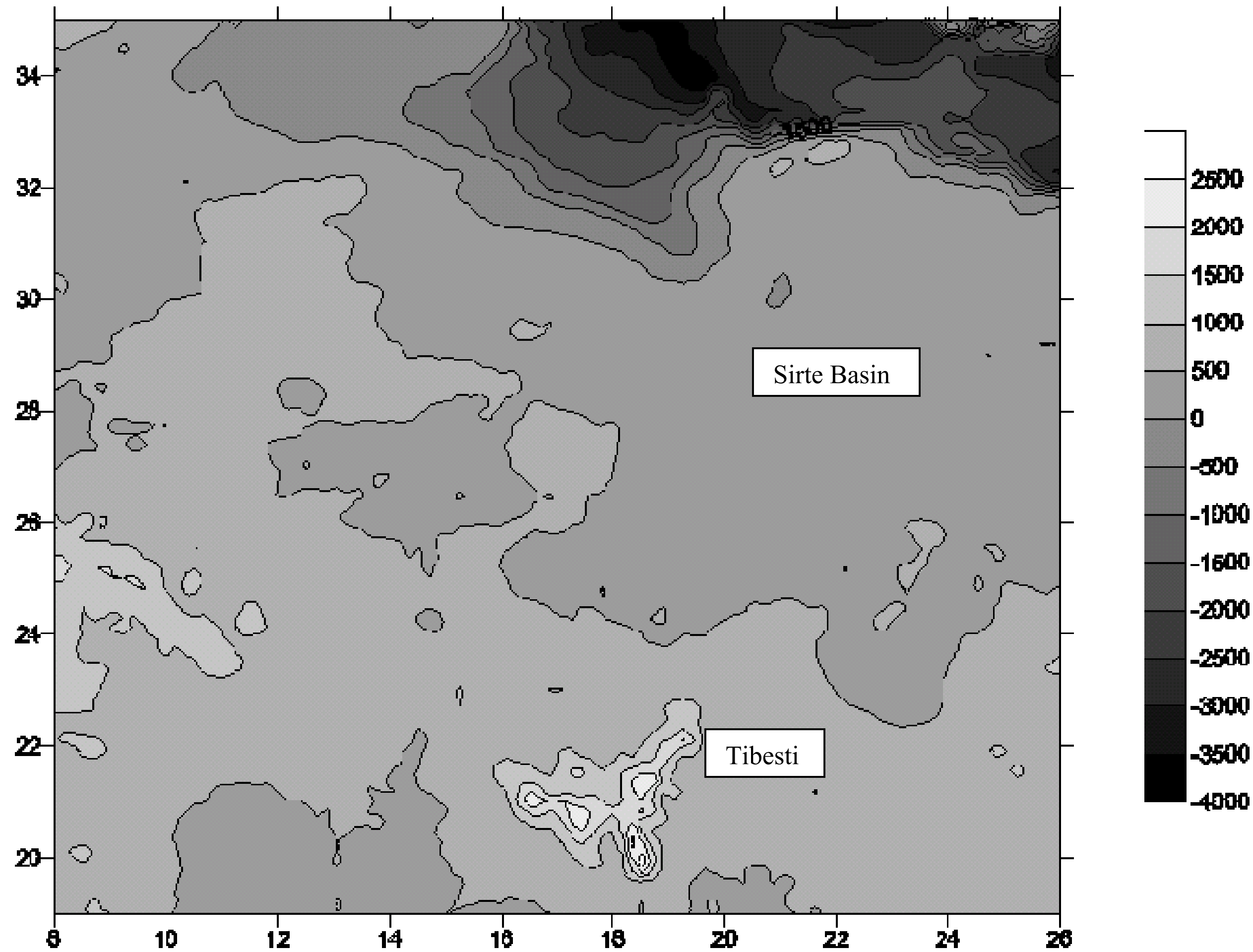


**Figure 4. Contour map of the Libya region. The data used to plot this contour map have been gridded to be used as the digital elevation model to be used in SURFGRAV.**