Chapter 1

Introduction

From seismological point of view, the interior of the earth can be divided into several distinct layers (crust, mantle and core), considered as a system of horizontal layers affecting the seismic energy arriving at a given station.

Only the uppermost part of the crust is available for direct sampling from boreholes. At greater depths all information about its composition is indirect. Much of our information about the earth's interior has been derived from a knowledge of the variation of seismic velocities with depth. Consequently, the recorded motion at the earth's surface depends on the elastic parameters, the thickness of these layers, as well as on the existing seismic energy and the recording instrument.

The first accurate teleseismic recording was obtained in 1889 in Potsdam, Germany, 15 minutes after an earthquake in Japan (von Rebeur-Paschwitz, 1889), while the beginning of the systematic collection of global seismic data was started in 1892 by John Milne (Milne, 1895) who developed a seismometer that was sufficiently compact to be installed in about 40 observatories around the world.

The first attempt to investigate the structure of the earth from transmission times of earthquakes was made by Oldham (1906) who discovered the earth's core. On the other hand, the efforts to determine crustal thickness dates back to 1910, when Mohorovicic first identified an abrupt increase in velocity beneath the shallow rocks under Europe. The boundary separating crustal rocks from mantle rocks is now called as the Moho. The depth of the Core-Mantle boundary was delineated accurately by Gutenberg (1913), who also investigated in 1958, the surface amplitude and polarizations of incident SV waves and the amplitudes of the SH components from the recorded S waves, assuming that the crust and the upper mantle could be represented by a simple half-space model.

In the 1950s and 1960s, the spectral analysis of long-period data was the major subject to study the crustal structure using teleseismic records besides controlled source techniques. The theoretical background of the spectral analysis method was presented by Thomson (1950) and Haskell (1953) as a matrix formulation. Phinney (1964), used Haskell's matrix method to calculate the spectral response of a layered crust to compare observed long period P-wave spectra from distant earthquakes recorded at Albuquerque and Bermuda. Most recently, Al-Amri, Necioglu and Mokhtar (1996), used the spectral analysis technique of P-wave data to investigate the crustal structure of the central Arabian Peninsula.

Teleseismic body waves have been used extensively for a long time to retrieve crustal and lithospheric structures beneath recording stations (Phinney, 1964) under the name of crustal transfer method. The method has been subsequently improved by several workers (e.g. Burdick and Langston, 1977; Vinnik and Kosarev, 1981). Owens et al. (1984) further improved the method for the application to newly available broad-band data using linearized time-domain inversion routine. It is now commonly referred to as the Receiver Function method, one of the most widely used technique to determine the crustal structure on a regional scale and below the recording station.

Receiver functions are computed first rotating the coordinate system and then deconvolving the rotated vertical component of the recorded waveforms from the corresponding rotated horizontal components. The method has been described in detail in chapter 3. The deconvolution process isolates the receiver response, so that the resulting time series contain the signatures of P-to-S converted phases and reverberations in the structure close to the recording station (Langston, 1979; Ammon, 1991). The theoretical background of the technique used to analyse the waveforms is described earlier by Vinnik (1977), Kosarev et al. (1987), Petersen and Vinnik (1991), Kosarev et al. (1993) etc. and has successfully been applied in Germany (Kind et al., 1995), southern Tibet (Yuan et al., 1997), the Middle East and north Africa (Sandvol et al., 1998b), and in north America (Ramesh et al., 2002).

The converted phases (P-to-S) have also been used to detect the 410 and 660 km discontinuities, the most significant and best observed discontinuities in the upper mantle, that mark the upper and lower boundary of the mantle transition zone. A serious drawback is that these converted phases for a single station are generally of low amplitudes which hampers their identification. To enhance the low amplitudes, delay and sum technique was used by stacking single receiver functions of a station after moveout corrections (Vinnik, 1977; Kind and Vinnik, 1988; Paulssen, 1988; Stammler et al., 1992; Petersen, 1993; Bostock, 1996 a, b, 1997; Yuan et at., 1997).

Stacking of a large amount of P-to-S converted phases to image mantle discontinuities has recently become a standard technique (Gurrola et al., 1994; Dueker and Sheehan, 1998; Gilbert et al., 2001; Gao et al., 2002).

Among the various tectonic settings in the world the Dead Sea Transform (DST) is of vital importance and studied by geologically and multidisciplinary geophysical methods. It has the significant role in the sense that it demarcates two plate boundaries, Arabian and Sinai plates. The Dead Sea Transform (DST) is a part of the boundary between the African and Arabian plates that probably started forming arround 20 M.Y. ago. The Dead Sea region has remained a stable platform almost since its formation in the late Proterozoic. This tectonic stability was only recently (20 M.Y. ago) interrupted by the formation of a transform with a left lateral motion of about 107 km as on today.

Still some of the open questions regarding the formation and nature of the DST remain. Passive source seismology is the only tool to look into the deep earth and it helps to understand the tectonic processes undergoing deep inside the earth. As the DST is the boundary between the two plate boundaries, it's nature , extent within the crust and the tectonic role playing in between these two plates are of utmost important. Also, the nature of the crust in the western side, on the DST and towards the eastern side are still elusively known.

Until recently the coverage of seismic stations in this area was rather sparse. Newly installed DESERT temporary network for one year, provide a wealth of data. These data will improve the knowledge of the crustal structure and the upper mantle transition zone. With these motivations, the well established method, the receiver function analysis to the three component passive source data has been applied and presented the unified seismic picture of this area down to the deep mantle discontinuities. The results have been discussed in the light of other geophysical results. The receiver function results show that the crustal structure in the west and east of the Araba fault is different , indicating that this fault is of deep seated nature. Also the whole structure above 410 km is seismically slower than normal.

1.1 Objectives

The goal of this study is to use the Receiver Function method in the DESERT project to determine the average crustal thickness underneath each station, as well as to deciphere the average crustal Vp/Vs ratio. Finally, the other seismic boundaries in the transition zone between the upper and lower mantle, which is bounded by the 410 and 660 km seismic discontinuities have also been investigated.

1.2 DESERT Project

In February 2000, a multinational geophysical project (**DE**ad **SE**a **R**ift **T**ransect) was started in the Middle East, where scientists from Palestine, Israel, Jordan and Germany joined to study the crust and the upper mantle of the Dead Sea Transform (DST). No large scale geoscientific investigation had been conducted across the DST until recently. Under this programme various geophysical experiments (Fig. 1.1) have been carried out, and briefly described as follows:

1. **Wide-Angle Reflection/Refraction (WRR)** profile, trending in NW-SE direction crossing the DST in the Araba valley, with a total length of about 260 km. The main objectives are to determine the P and S velocities and the crustal thickness.

2. **The Near Vertical Reflection Line (NVR)**, that stretches from near Ma'an in Jordan to Sede Boqer with a total length of about 100 km. The most important targets are to image the structure down to the Moho and crustal discontinuities and to delineate the faults along the transect in this area.

3. **Controlled Source Array (CSA)**, which centered in the middle of the NVR profile, crossing the Araba valley, 3 lines of 10 km for each line were conducted. The aim is to determine with high resolution the P and S velocities in the upper crust, to delineate the faults using reflected/converted seismic waves and to determine the seismic anisotropy in the region.

4. **Magnetotellurics (MT)**, the MT sites are located along the southern-most profile of the CSA experiment of about 10 km long, to obtain lateral resolution of conductivity variations.

5. **Passive Array (PAS)**, this experiments extends from the Mediterranean coast (Gaza city) to Ma'an area crossing the DST and along Araba valley. The main targets of the PAS are imaging the prominent seismic discontinuities from the crust down to the upper mantle transition zone.

1.3 Outline of this Thesis

Chapter 2 presents the geology across the linear profile, tectonic setting of the area in terms of deformations and displacement. Instrumental and historical seismicity are also presented in chapter 2.

Chapter 3 discusses the receiver function method and describes the different steps of data processing.

Chapter 4 introduces the dataset that was recorded by DESERT seismic stations. Discussion on the characteristics of the dataset with diagrams are presented.

Chapter 5 presents the results of this study in terms of maps of Moho delay times, crustal thickness across the DST, the Lower Crustal Discontinuity on the eastern part of the DST, Vp/Vs values, and the upper mantle 410 km and 660 km discontinuities. Data examples are presented also in chapter 5.
The concluding remarks are presented in Chapter 6. Additional information on the events and instrumentation used are in Appendices A and B.

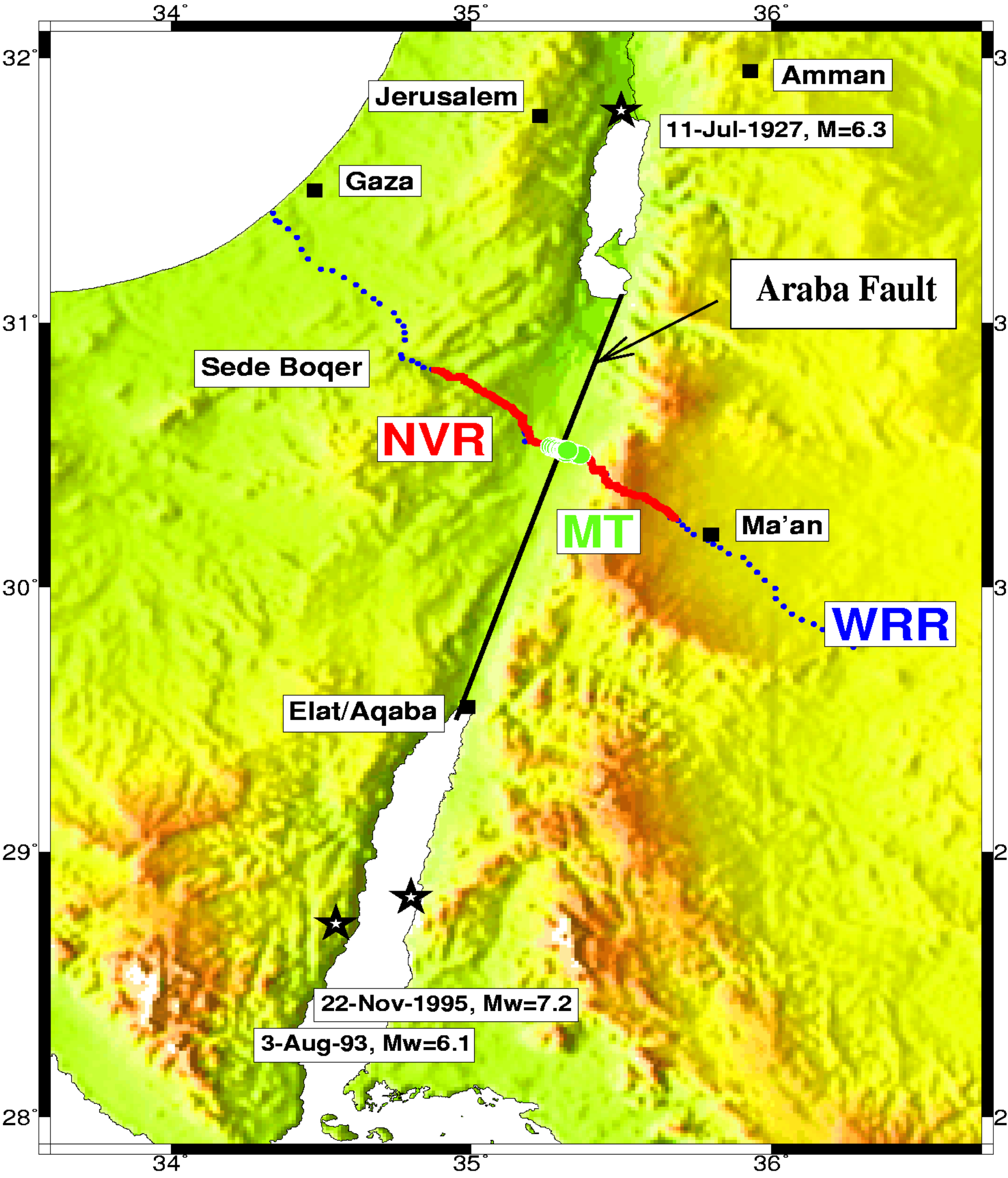

Figure 1.1: The geophysical experiments in the study area. The blue and red dots represent the wide-angle reflection/refraction profile (WRR) and the near vertical seismic reflection profile (NVR), respectively. The green dots represent the magnetotelluric studies (MT). Black stars mark large earthquakes in the area.