Seismic Refraction Studies and Crustal Structure in Anatolia

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A number of refraction experiments have been carried out in Turkey in the past three years to determine the crustal structure in Anatolia. Two refraction experiments were conducted in the eastern Marmara region and in central Turkey. The objective of these refraction experiments was to determine velocity structure and calibrate regional travel times and propagation characteristics of seismic waves in these areas.

Crustal Structure East of the Marmara Region

The Marmara region is an active seismic zone. The North Anatolian fault (NAF) is the main source of the active tectonics in the region. The accuracy of the earthquake location in this region depends on the velocity structure used in the inversion of the travel times. This study was aimed to determine a suitable velocity structure for the region in order to reduce earthquake location errors to a minimum. A refraction experiment was conducted on November 4 and 5, 2000 east of the Marmara Sea. A 180 km long profile was oriented in the N-S direction to cross the North Anatolian fault zone (Figure 1). Three shots were placed along the profile, two at the ends and one in the middle. Charge sizes were 350 kg at the ends and 325 kg in the middle shot point. Explosives were put into 50 m deep holes and blasting took place between midnight and 5:00 AM.

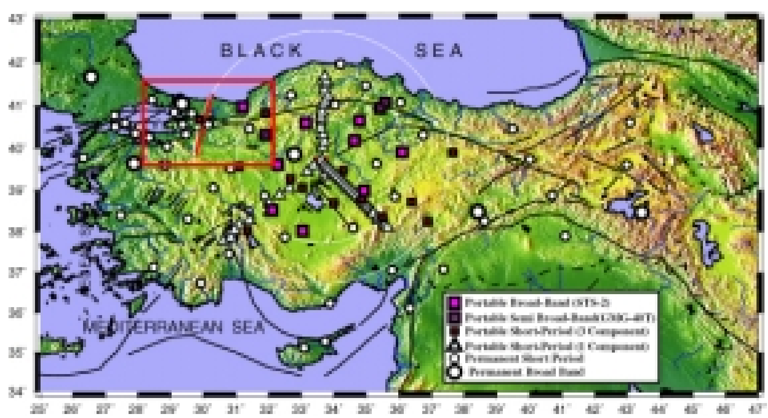

Figure 1. Station distribution and working area.

The P wave velocity structure was first obtained by forward modeling to achieve the best fit between the observed and calculated travel times by 2-D ray tracing using the SEIS83 package program (Cerveny and Psencik, 1984). In the inversion analysis the optimum model was generated using the RAYINVR program of Zelt and Smith (1992) by comparing iteratively observed and calculated travel times. The velocity structure is shown in Figure 2. The P wave velocities at the top layer vary from 3.8 km/s to 4.8 km/s along the profile. This part of the crust was characterized by high velocity gradients. Below this layer seismic velocities vary between 6.0 km/s and 6.8 km/s with variable velocity gradient at a depth range of 7 to 17 km. Depth to Moho discontinuity could not be determined from these data. The velocity profiles shown (Figure 2) indicate thickness changes of crustal layers under the two branches of the NAF. The velocity models do not have the spatial resolution to determine details of the fault zone structure. Previous studies in the region obtained a crustal thickness of 32 km and P_n velocities varying between 7.7 and 7.9 km/s (Gurbüz et al., 1992).

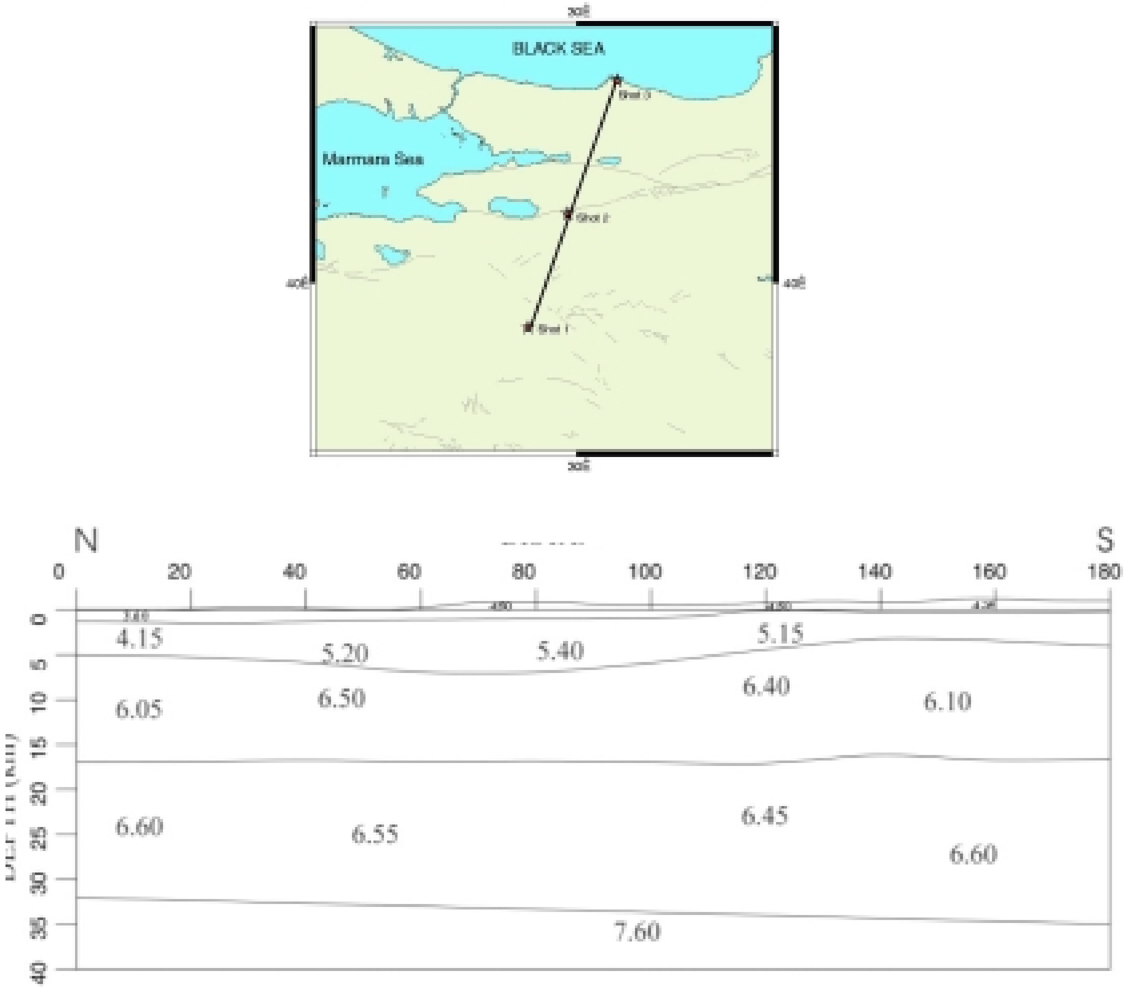

Figure 2. Crustal structure below the Marmara profile.

Crustal Structure in Central Anatolia

To determine the crustal structure in Central Anatolia, a large shot was fired in Keskin (central Turkey) in November 2002 (Toksöz et al., 2003). The explosives were loaded into 14 holes, each drilled to a depth of 80 m. Shots were located in two concentric circles with radii of 4 m and 9 m, respectively. Two tons of dynamite, 145 kg per hole, were loaded into the holes. The shot was fired around midnight in order to minimize seismic noise.

Three refraction profiles (shown in Figure 1) were laid out in the directions of north, southeast, and with respect to the shot point. Eighty temporary seismic stations were installed to monitor the shot (Figure 1).

This experiment provided the first opportunity to obtain a well-constrained crustal structure in central Turkey. The crustal structure and P_n velocities of the Anatolian plateau have been studied by various methods (Canitez and Toksöz, 1980; Gurbüz and Evans, 1991; Hearn and Ni, 1994; Turkelli et al., 1996). None of these studies included long refraction lines.

The travel time data (three profiles) and velocity models derived from them are shown in Figure 3. For each profile, velocity models are obtained by fitting the travel times with a two-dimensional, laterally varying velocity model. A 2-D ray-tracing program SEIS83 (Cerveny and Psencik,1984) is used to calculate travel times.

- *Northern profile.* The average velocity in the top layer is about 5 km/sec and the lower layer about 6.4 km/sec. The uppermost mantle velocity is 7.8 km/sec to 7.9 km/sec. The crustal thickness is 36 km under the shot. There is a prominent change in crustal thickness 120 km north of the shot. There is also an anomaly in the top crustal layer. This corresponds to the trace North Anatolian fault.
- *Southeastern profile*. The crustal model shows some prominent features. The thickening of the uppermost layer at 100 km distance is quite well-constrained. It seems to correspond to a little known Gumuskent fault. The noisy station at 100 km may have been situated in the fault zone. The anomaly at about 170 km that affects both the upper layer and the crustal thickness corresponds to the Ecemis fault. It is not as prominent as the North Anatolian fault that crosses the northern profile. The crustal thickness along this profile is 36 km, possibly thinning slightly toward the southwest.
- *Southwestern profile.* This profile has the fewest stations. The quality of the data is excellent. Because of the sparse coverage, the crustal model shown should be considered “tentative.” We will try to test this model by calculating fully elastic synthetic seismograms to match the observed records.

Keskin and eastern Marmara refraction experiments produced valuable data for obtaining crustal structure and velocities for Central Anatolia and east of the Marmara regions. There are lateral variations in crustal structure and velocities. The models show that the crust is 36 km thick under Keskin and it decreases to 30 km to the north of the NAF. The average P_n velocity is 7.8 km/sec.

In the eastern Marmara region, the Moho depth is 32 km in the north and it increases toward the south. Velocities at the upper and lower crust vary between 3.8 km/sec and 4.8 km/sec and 6.2 km/sec and 6.8 km/sec, respectively. The P_n velocity has values of 7.75 km/sec in the south and 7.95 km/sec in the north.

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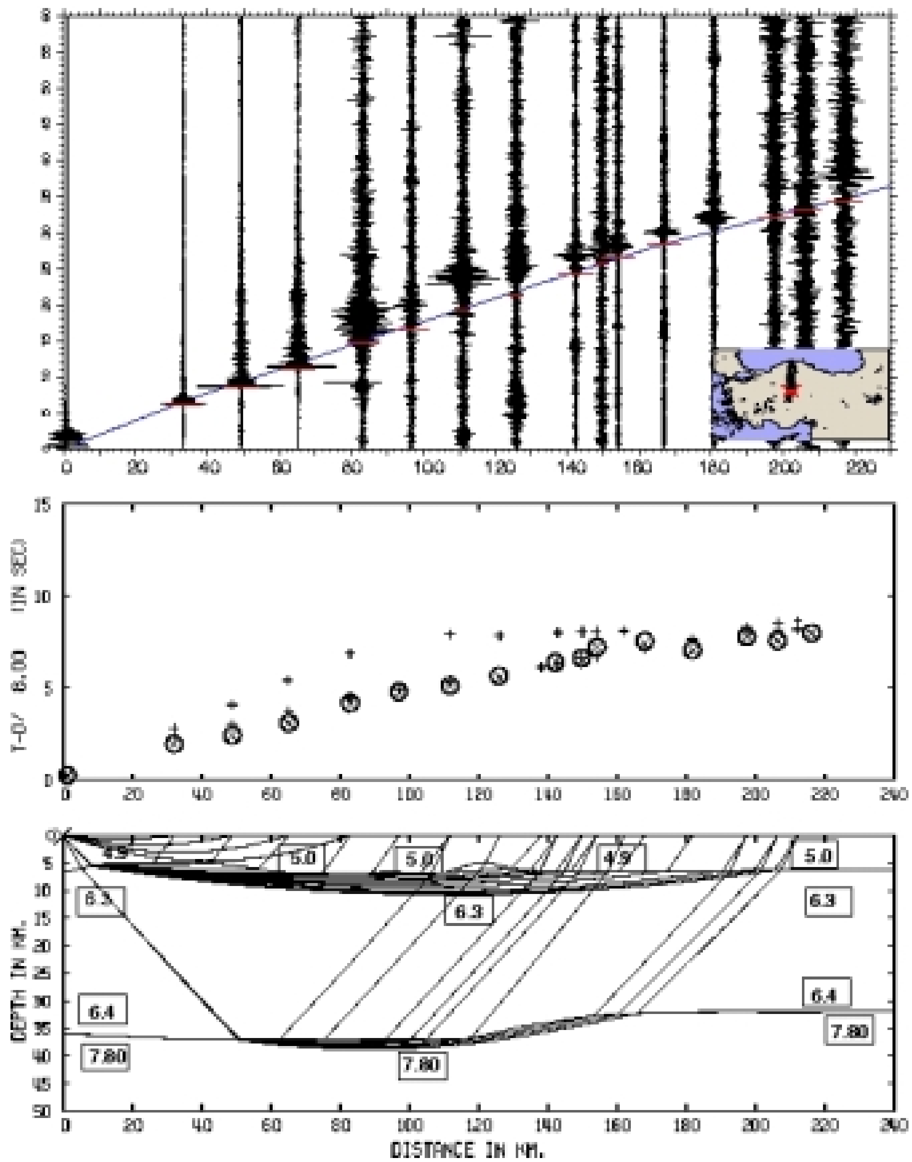

Figure 3: Seismograms and crustal model for the north profile shown in the inset. Top: Record section. Middle: Observed (circles) and calculated (crosses) travel-times. Bottom: Crustal structure and P-wave velocities. Ray paths are also shown. North Anatolian fault crosses profile at 170 km distance. Note crustal thinning across the fault.