Metin Kahraman

Thesis Supervisor: Prof. Niyazi Türkelli

Crust and Upper-Mantle Imaging by Using P and S Receiver Functions in Different Tectonic Regimes

Abstract

P and S receiver functions have a strong potential to solve crustal and upper-mantle velocity contrasts depending on dimension of seismic networks, azimuth distribution of teleseismic events and signal to noise ratio of recorded data. In early 90s, receiver functions used to reveal only to the crustal thickness with corresponding Vp/Vs. The crustal velocity calculation was still being in progress to minimize the dependency to initial model in the inversion methods. However, we can produce reliable, high resolved depth images beneath seismic stations having the advantage of newly introduced methods with large amount of digital seismic recording in these days. In this respect, we could utilize receiver function images not only to define Moho with proper Vp/Vs value but also rather to define depth extent and geometry of faults and relate them with understanding of fault dynamics and hazards. Moreover, upper and lower crustal structures could be imaged to relate them with tectonic evaluation of region. Furthermore, the limits of subduction zones in crust and upper mantle could be defined which are not resolved global or regional tomography methods. By taking into consideration of all possible explorations above, we imaged following Anatolian regions with P and S receiver functions.

Firstly, we used data from a dense broadband network (DANA) of 71 seismic stations with a nominal station spacing of 7 km in the vicinity of the 1999 Izmit earthquake. We detect previously unknown small-scale structure in the crust and upper mantle along western segment of the North Anatolian Fault Zone (NAFZ). We show that lithological and structural variations exist in the upper, mid and lower crust on length scales of less than 10 km and less than 20 km in the upper mantle. The surface expression of the NAFZ in this region comprises two major branches; both are shown to continue at depth with differences in dip, depth extent and (possibly) width. We interpret a <10 km wide northern branch that passes downward into a shear zone that traverses the entire crust and penetrates the upper mantle to a depth of at least 50 km. The dip of this structure appears to decrease west-east from ~90° to ~65° to the north over a distance of 30 to 40 km. Deformation along the southern branch may be accommodated over a wider (>10 km) zone in the crust with a similar variation of dip but there is no clear evidence that this shear zone penetrates the Moho. Layers of anomalously low velocity in the mid crust (20-25 km depth) and high velocity in the lower crust (extending from depths of 28-30 km to the Moho) are best developed between the two shear zones. A mafic lower crust, resulting possibly from ophiolitic obduction or magmatic intrusion, can best explain the coherent lower crustal structure of the block between the two fault strands. Our images provide evidence that strain is likely to have developed on both the northern and southern strands of the North Anatolian Fault and that crustal heterogeneity should also be considered in any seismic risk evaluation of the region. Our new high resolution images provide new insights into the structure and evolution of the NAFZ and show that a small and dense passive seismic network is able to image previously undetectable crustal heterogeneity changing laterally on length scales of 5-10 km.

Secondly, we used P waveforms of teleseismic earthquakes (Mw ≥ 5.5) recorded by 47 permanent broadband seismic stations within N-S extension dominated Western Anatolian region and obtained a total of 3563 high quality P wave receiver functions by applying iterative time-

domain deconvolution algorithm with a cut-off frequency of ~1 Hz. Receiver functions are sensitive to seismic discontinuities and Vp/Vs ratio rather than absolute velocities. Thus, we performed a grid search using direct and multiple phases of the crust to estimate crustal thickness and Vp/Vs ratio beneath each station. Later, we applied the common conversion point method with our Vp/Vs estimates and constructed 2-D cross-sections and depth slices displaying crustal discontinuity structure beneath the study area. According to our results, crustal thickness becomes gradually thinner from east to west but towards southeast displays a sharp change (Moho offset) that spatially correlates with the Fethiye-Burdur Fault Zone. In the region, crustal Vp/Vs ratio is low beneath the core complex, becomes higher at the edges and towards southeast suddenly increases reaching to maximum beneath city of Denizli where rich geothermal fields have been discovered. We have also identified crustal low velocity zones at different parts of the region but the most prominent one represented by the largest negative amplitudes is located at mid-crustal depths beneath the central part of the core complex near Büyük Menderes Graben.

Lastly, we used both P and S receiver functions to present high resolution crustal and upper mantle depth images down to 200 km in Isparta Angle region. Moho and upper crustal discontinuities were well resolved by P receiver functions; however S receiver functions were utilized to image lithospheric-asthenospheric boundaries having the benefit of being free of multiple conversions. The receiver functions were calculated from 916 teleseismic earthquakes (Mw ≥ 5.5) recorded by 42 permanent and temporary broadband seismic station network within the region. Totally, 4501 P and 946 S RFs with the cut-off frequencies of ~1.0 Hz and ~0.5 Hz, respectively, were obtained by applying iterative-time domain deconvolution. Crustal thickness and Vp/Vs ratios were calculated by grid search of maximum amplitude of P receiver functions (Ps, PpPs and PsPs+PpSs) in depth and Vp/Vs domain. Then, we created 2-D P and S migrated cross-sections to observe crustal and lithospheric-asthenospheric discontinuities beneath the region. P receiver functions indicates that, average crustal thickness and Vp/Vs ratio is ~36 km and 1.78 in the region with small changing values close to the region edges. Migrated P receiver function cross-sections revealed a sharp change in Moho (Moho offset) on the western boundary that spatially correlates with the FBFZ. We also found a relatively flat Moho in the center and what appear to be imaged northern tips of slab at ~45 km depth. Finally ~30km crustal thickness was calculated in southeast beneath the Cyprus. On the other hand, results of S receiver function cross-sections present the LAB boundary between ~50 to ~90 km depth range, observed almost beneath all profiles and clear positive phase arrivals right below the LAB depths.

PUBLICATIONS

Journals

1. **Metin Kahraman**, David G. Cornwell, David Thompson, Sebastian Rost, Gregory Housemann, Niyazi Turkelli, Ugur Teoman, Selda Altuncu Poyraz, Murat Utkucu and Levent Gulen, "Crustal-scale shear zones and heterogeneous structure beneath the North Anatolian Fault Zone, Turkey, revealed by a high-density seismometer array", *Earth and Planetary Science Letters, Elsevier,* Vol: 430, No: 1, pp 129-139, November, 2015, (SCI, SCI-E)
2. Selda Altuncu Poyraz , Uğur Teoman, Niyazi Türkelli, **Metin Kahraman**, Sebastian Rost, Greg Houseman, David Thompson, Murat Utkucu, David Cornwell and Levent Gülen, "New constraints on micro-seismicity and Stress state in western part of the North Anatolian Fault Zone: Observations from a dense seismic array", *Tectonophysics, Elsevier,* Vol:656, No: 1, pp 190-201, August, 2015, (SCI, SCI-E)
3. Andrew W. Frederiksen, David Thompson, Sebastian. Rost, David G. Cornwell, Levent Gülen, Greg A. Houseman, **Metin Kahraman**, Selda A. Poyraz, Uğur M. Teoman, Niyazi Türkelli and

Murat Utkucu, "Crustal thickness variations and isostatic disequilibrium across the North Anatolian Fault, western Turkey", *Geophysical Research Letters, American Geophysical Union Publications, Wiley,* Vol: 43, No: 3, pp 751-757, February, 2015, (SCI, SCI-E)

4. Şakir Şahin, Xueyang Bao, Niyazi Türkelli, Eric Sandvol,Uğur Teoman and **Metin Kahraman**, "Lg wave Attenuation in the Isparta Angle and Anatolian Plateau (Turkey)", *Pure and Applied Geophysics, Springer,*Vol: 170, No: 3, pp 337-351, March 2013, (SCI, SCI-E)

Conferences

1. **Metin Kahraman**, A. Arda Özacar and Niyazi Türkelli, "Imaging Crustal Structure from Receiver Function Analysis in Western Turkey", *8-th International Symposium on Eastern Mediterranean Geology*, October, 2014, Muğla, TURKEY
2. **Metin Kahraman**, Niyazi Türkelli, Selda Altuncu Poyraz, M. Uğur Teoman, Ahu Komeç, Didem Samut, Sebastian Rost, Greg Housemann, David Thompson, David Cornvell, Murat Utkucu and Levent Gülen, "Moho Topography beneath the Western Segment of NAFZ – Primary Result from a Dense Seismic Array", *The 5-th International Conference of young scientists and students,* November 2013, Bakü, Azerbaijan
3. **Metin Kahraman**, Niyazi Türkelli, Selda Altuncu Poyraz, M. Uğur Teoman, Ahu Komeç, Didem Samut, Sebastian Rost, Greg Housemann, David Thompson, David Cornvell, Murat Utkucu and Levent Gülen, "Kuzey Anadolu Fay Zonu' nun bati segmenti altindaki Moho degisimi – İlksel sonuçlar", *ATAG*, Ekim 2013, Antalya, TURKEY
4. **Metin Kahraman**, NiyaziTurkelli, N., Teoman, U M., Sahin S., Sandvol E A., Gok, R., "Crustal nature along the African - Anatolian collision Zone", *AGU Fall Meeting*, December 2010, San Francisco, USA
5. **Metin Kahraman**, Niyazi Türkelli, Uğur M. Teoman, Şakir Şahin, "P-Alıcı Fonksiyonu Yöntemiyle Isparta Büklümü ve Çevresinin Kabuk Yapısı Bulunması", *ATAG*, Ekim 2010, Adıyaman, TURKEY

Defense Jury Members

1.	Prof. Niyazi Türkelli	Boğaziçi University
2.	Assist. Prof. A. Arda Özacar	Middle East Technical University
3.	Assist. Prof. A. Özgün Konca	Boğaziçi University
4.	Assist. Prof. Çağrı Diner	Boğaziçi University
5.	Assist. Prof. Tuna Eken	Istanbul Technical University

Defense Date: 11.12.2015