Northwestern Anatolia Lithospheric Resistivity Structure Revealed by 3D Inversion of Long Period Magnetotelluric Data: Comparison With Velociy Lithospheric Structure

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ABSTRACT

In this study, we revealed lithospherc resistivity structure of northwestern Anatolia by using 3D inverison of Magnetotelluric (MT) data. The survey arae is approximately 300kmx200km in size, located between N38°30’ - N41°05' latitudes and D29°30' - D32°00' longitudes in Northwestern Anatolia.We collected broadband MT data on 358 stations and long period magnetotelluric (LMT) data on the 64 stations along 4 parallel lines in the survey area. The broadband data collected between 2007-2011 under the TUBITAK project, numbered 105G145. The LMT data collected under our another TUBİTAK project, numbered 119Y197 between the years, 2020-2022. The MT lines are crossing main tectonic traverses such as North Anatolia Fault Zones, Intra-Pontid Suture zones. After the time series analysis and main data processing procedure such as phase tensor decomposition and static shift correction, we combined broadband and LMT data for each line and interpreted by using two dimensional inversion algorithm. THe 2D inversion results showed us the main techtonic units. We also inverted combined set of MT ve LMT data by using three dimensional inversion algorithm. The three dimensional resistivity model also showed us to main tectonic units as two dimensional resistivity models. Additionally, crust and lithosphere relations also revealed. We obtained upper and lower crust boundary by using magnetic data and crust depth by using gravity data. Those results are also validated our resistivity models obtained from MT data inversion. We also revealed lithosphere astonesphere boundary from the 3D resistivity model. We compared resistivity lithospheric structure obtained in this study and velocity lithospheric structure that already obtained by the other researcher studies. The both lithospheric structures are supports each other.

KEY WORDS : Northwestern Anatolia, Lithosphere, Magnetotelluric, 3D, Inverison

1- INTRODUCTION

The magnetotelluric (MT) method is widely used to investigate the structure of the lithosphere. There are many studies conducted in the last 15 years on the investigation of the upper crust-lower crust boundary and tectonic structures, suture zones and fault zones within the crust with MT (e.g. Becken et al. 2008, Bertrand et al. 2012; Zeng et al., 2015). Many international projects have been carried out in the last 20 years to investigate the relationship between the lithosphere and the crust within it using the magnetotelluric method (e.g. Wei vd. 2001; Unsworth 2010; Xie 2016).

There are many studies investigating the main tectonic zones, fault zones and crustal structure in Western Anatolia (e.g. Gürer and Bayrak 2007; Ulugergerli et al. 2007; Kaya 2010). Studies on investigating the upper crust-lower crust relationship, suture zones and fault zones in Northwest Anatolia were carried out within the scope of our previous TÜBİTAK project (Candansayar et al. 2009, 2010, 2012; Kaya 2010). So far, a resistivity lithosphere model has not been obtained with the MT method in Western Anatolia. The aim of this study is to investigate upper-lower crust relation, Moho depth and resistivity lithhosperic structure of the survey area. Within the scope of the study, broadband and long-term MT (MT and LMT) data were measured in approximately 200 by 300 km area between approximately 38^o-41^o latitudes and 29^o-31^o longitudes in Northwest Anatolia.

2- METHOD and APPLICATION

MT is natural (or passive) source geophysical electromagnetic method. IT is mainly used for investigating deep resistivity structure. In this method, in each station vertical electric fields (Ex and Ey) and vertical and horizontal magnetic fields (Hx,Hy and Hz) is measured as a function of time. This data transferred to frequency domain by using fast fourier transform and in frequency domain impedance and tipper tensor data is obtained.

In this study, we used MT and LMT data collected on 358 and 64 stations, respectively. (Figure 1). LMT data are collected new generation Phoenix MTU-5C receiver. This receiver has network card that enuble us to transfer time series data via GSM operator during measurement. Therefore, we can make quality control of MT data during measurement. There are approximatly 12 years slots between MT and LMT data measurements. However, when we compare MT and LMT data that collected approximately on the same station locations, we can see that the data obtained for the same periods are mostly fit the each other (Figure 2).

We first did phase tensor analysis (Caldwell et al. 2004) before 2D and 3D inverison. There is no constant shift effect in the phase tensor data, and in recent years, β(°), obtained from the phase tensor and known as the "phase tensor skew angle", is used instead of "skew" in dimensionality analysis (Patro et al. 2014; Xue et al. 2021; Kirkby et al. 2020; Zhao et al. 2022). As β(°) moves away from zero degrees, the medium becomes three-dimensional. As a result of phase sensor analysis, β(°) values obtained at all stations and periods in a direction were drawn as a cross section. As an example, we present β(°) section for Profile 1. When looking at beta sections, the beta angle is around zero degrees in low periods (shallow sections), while this angle value is significantly away from zero degrees in high periods (deep). It is seen that the beta angle is scattered in some regional areas. Therefore, it seems that a meaningful model cannot be found with 2D inversion of very deep structures. After MT data analysis, we did 2D and 3D inversion of MT and LMT data.

3- DISCUSSION and RESULTS

We combined MT and LMT data sets for each line. We did 2D inversion of all lines data. As an representative, we showed 2D inversion result of Line 1 (Figure 4). We also did 3D inversion of MT and LMT data collected from all stations along four lines. Xz-section obtained form 3D inversion resut showed in Figure 5. We interpreted the upper and lower crust boundary and crust and upper mantle boundary (Moho discontinuity) from 2D and 3D resistiviy model. We also obtained solid lithosphere and astenosphere boundary from 3D MT inversion reuslt. We compared our result with Gravity, Magnetic and pasive seismic tomography result.

4- CONCLUSION

Within the scope of the study, a 3D resistivity model of the region up to a depth of 200 km was obtained by 3D inversion of MT and LMT data. As a result of the interpretation of the 3D resistivity model, it was found that the upper crust and lower crust boundary varies between 8-23km in the region. Moho depth was found to vary between 28-51 km. The boundary between lithosphere and asthenosphere was found between depths of 80-120 km. All these borders deepen from south to north. The results obtained are supported by previously conducted Seismology, Gravity and Magnetic studies.

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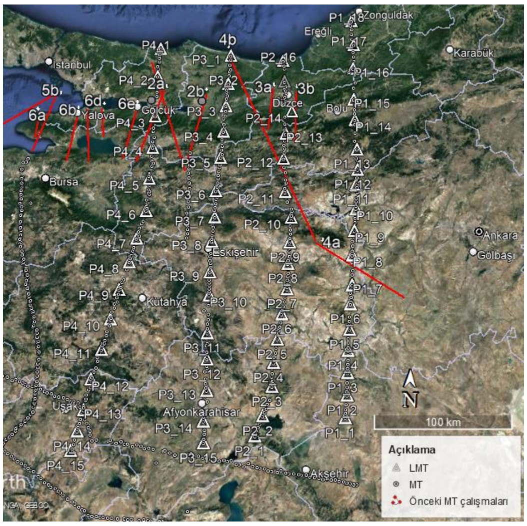

Figure 1. Google earth map of the study area. MT (circle symbols) and LMT (triangle symbols) stations location and previous studies (red lines)

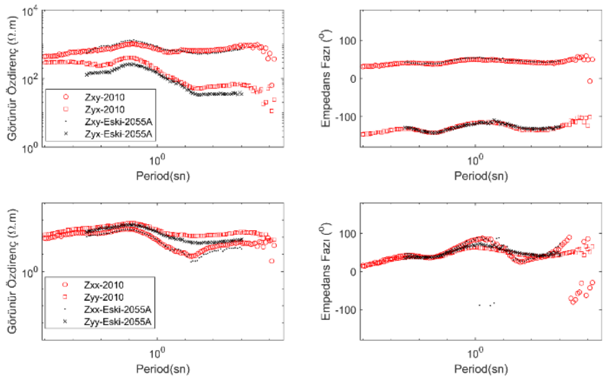

Figure 2. Comparison of the measured LMT data at station number 2010 with the MT data measured around this station 12 years ago. Apparent resistivity and Phase curves for Zxy, Zyx, Zxx vand Zyy impedance components.

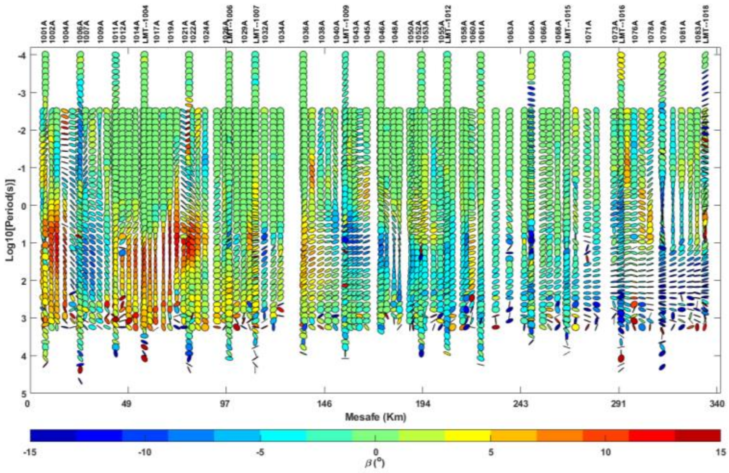

Figure 3. Line 1 $\boldsymbol{\beta}(°)$ section. Here at LMT stations, the lowest period is 0.0001 and the highest period is usually over 10,000s. At MT stations, the lowest period is 0.03 sec. and the highest period is generally around 2000 s. Therefore, not all MT stations were added to the section to avoid overlapping of stations.

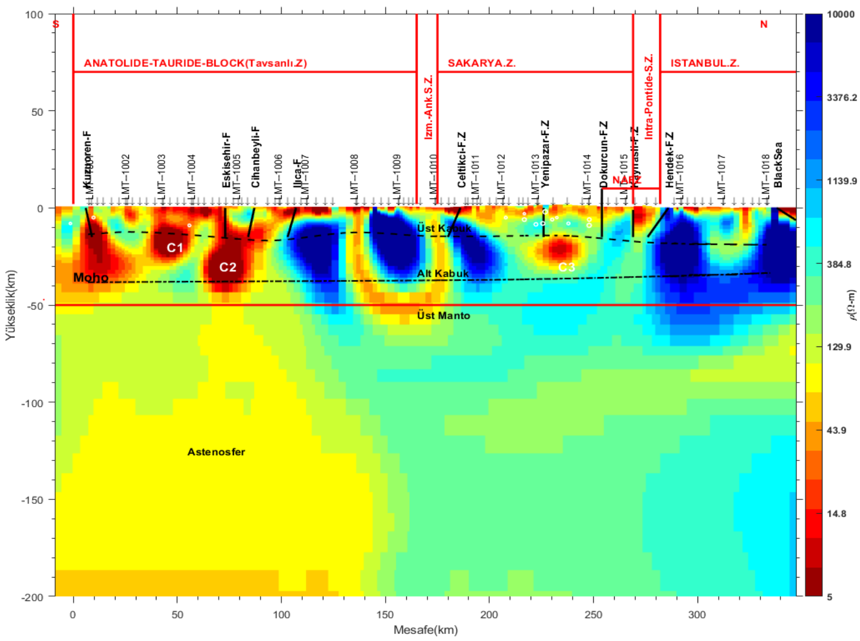

Figure 4. (a) Line-1 2D inversion result. The Curie point depth calculated from magnetic data is shown on the model with thick black lines, and the Moho depth obtained from gravity data is shown with black dotted lines. The red line shows the lower bound of the model obtained from the 2D inversion of MT data. The main tectonic zones are shown on the top of the resistivity model.

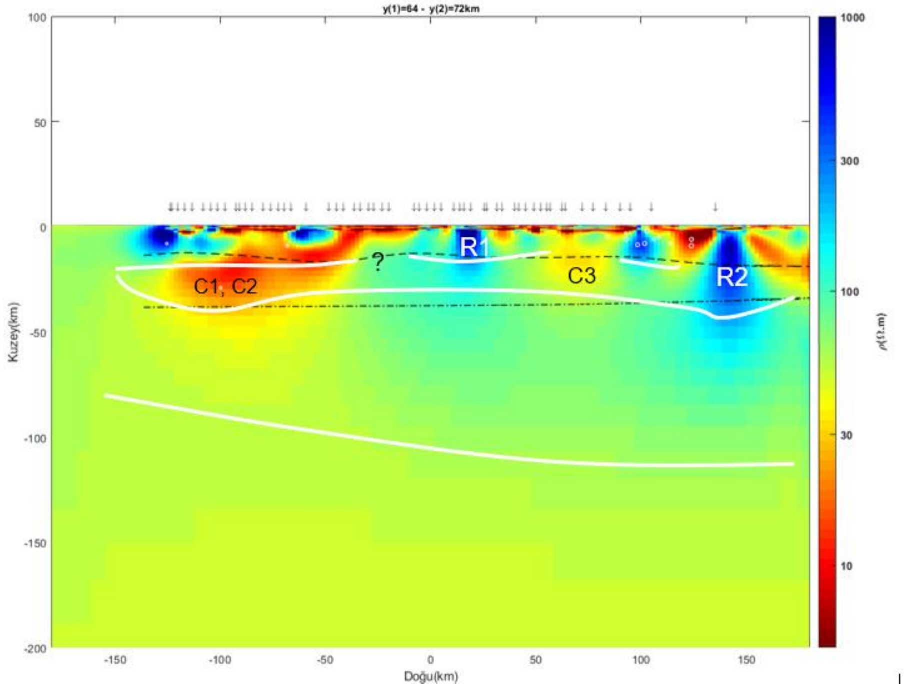

Figure 5. xz-section close to the Line-1 profile direction as a result of the 3D inversion. Solid white lines indicate the upper and lower crustal boundary, Moho depth, and lithosphere-asthenosphere boundary, respectively, from shallowest to deepest.