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Lapse time dependence of coda wave attenuation in Central West Turkey

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ABSTRACT

The attenuation of coda waves has been inferred for Central West Turkey, which is characterized by a very complex tectonic evolution. The selected dataset is composed of 440 waveforms from 228 local earthquakes with a magnitude range of 2.9–4.9. The coda quality factor (Q_c) was estimated for five central frequencies ($f_c = 1.5$, 3, 5, 7, 10 Hz) and eight lapse times (t_L, ranging from 25 to 60 s), based on the assumption of single isotropic scattering model. Estimated Q_c values were strongly dependent on frequency and lapse time. The frequency dependence of Q_c values for each lapse time was inferred from $Q_c(f) = Q_0 f^n$ relationships. Q_0 values change between 32.7 and 82.1, while n values changes between 0.91 and 0.79 for the lapse times of 25 and 60 s, respectively. The obtained low Q_0 values show that the Central West Turkey region is characterized by a high seismic attenuation, in general. The whole region was divided into four subregions to examine spatial differences of attenuation characteristics. Obtained $1/Q_0$ and n values versus the lapse time for each subregion implies the tectonic complexity of the region. Lapse time dependencies of attenuation and n values were also examined for subdatasets from two different ranges of event depth ($h < 10$ km and $h \geq 10$ km) and distance ($r < 40$ km and $r \geq 40$ km). High attenuation and its high frequency dependence for long distances manifest the elevation of isotherms and increasing heterogeneity with depth. This could be associated with the extensional intra-continental plate setting, forming regional tectonics in the back-arc area.

1. Introduction

The regional extension in Central West Turkey since Late Oligocene times (e.g. Gessner et al., 2001; Seyitoğlu and Işık, 2009) has been associated with different deformation processes such as Arabia-Eurasia convergence resulting in westward extrusion of the Anatolian Plate (Tectonic escape model, e.g. Armijo et al., 1999; Dewey and Şengör, 1979); large- and small-scale upper mantle convection, resulting from Africa-Eurasia convergence, forming regional tectonics in the back-arc extensional area, and causing counterclockwise rotation of western Anatolia (back-arc spreading model, e.g. Le Pichon and Angelier, 1979; McKenzie, 1978); spreading and thinning of over-thickened crust following the latest Paleocene collision across the Neotethys (Orogenic collapse model, e.g. Seyitoğlu and Scott, 1991, 1992). The tectonic complexity of the region has been characterized by mineralization (e.g. Sayın, 2007; Yılmaz, 2007) resulting from extensive volcanism (e.g. Aldanmaz, 2006; de Boorder et al., 1998); high heat flow values (e.g. Göktürkler et al., 2003; İlkışık, 1995) resulting in several geothermal systems (e.g. Mutlu, 2007; Tarcan et al., 2000); low P_n- (e.g. Al-Lazki et al., 2004; Mutlu and Karabulut, 2011) and teleseismic P-wave velocities (e.g. Biryol et al., 2011; Salaün et al., 2012) implying high mantle and asthenosphere temperatures, respectively. A number of large-scale studies in the eastern Mediterranean (see Fichtner et al., 2013; Jolivet et al., 2013; Karabulut et al., 2013; Salaün et al., 2012 and references therein) provide insight to the complexity of the region (Fig. 1; Oner and Dilek, 2011).

Post-collisional volcanism in western Turkey displays compositionally distinct magmatic episodes controlled by the geodynamic evolution of the eastern Mediterranean region throughout the Cenozoic (e.g. Aldanmaz, 2002; Pe-Piper and Piper, 2001). It is known that post-collisional extension in the Aegean Extensional Province caused several Alpine metamorphic massifs (Fig. 1; Oner and Dilek, 2011) to be exhumed (Jolivet et al., 2013). Central West Turkey has one of them, a well developed metamorphic core complex, the Menderes Massif (e.g. Gessner et al., 2001; Seyitoğlu and Işık, 2009), which has been considered as the eastern continuation of the Cycladic Massif in the Aegean (Bozkurt and Oberhänsli, 2001). It is crosscut by the high-angle normal faults of the WE-trending Gediz and Büyük Menderes Grabens (Fig. 1; Oner and Dilek, 2011). Results of receiver function analysis implied locally flat Moho beneath the Menderes Massif (Karabulut et al., 2013; Zhu et al., 2006a), likely results from viscous flow in a hot lower crust, is unaffected by the present-day higher extensional strain rates of the Gediz and Büyük Menderes Grabens (Aktuğ et al., 2009). On the other hand, Zhu et al. (2006a) inferred that the lower crustal viscosity in the

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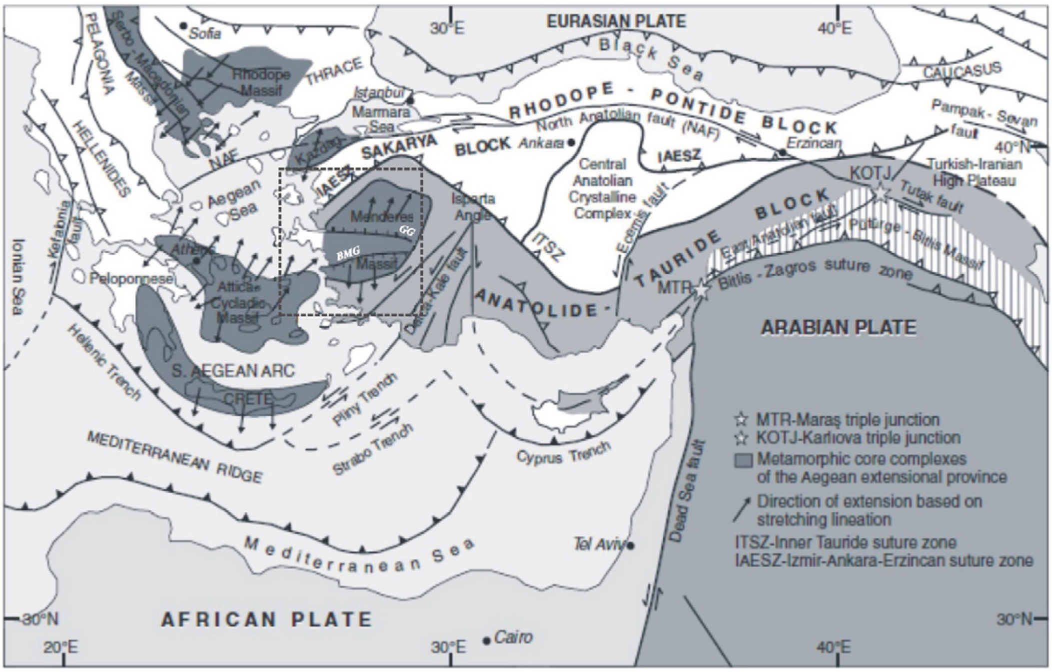

Fig. 1. Simplified tectonic map of the Aegean and eastern Mediterranean region (modified from Oner and Dilek, 2011). Thick lines with half arrows, major strike-slip faults; thick lines with filled triangles, presently active subduction zones; thick lines with open triangles, fold-and-thrust belts; stars, triple junctions. Dashed rectangle shows the region in Fig. 2. GG and BMG: Gediz and Büyük Menderes Grabens, respectively.

Aegean was at least 3 times larger than in the Basin and Range, based on the results of receiver function analysis implying differences in Moho topography amplitudes. According to them, a strong Aegean lower crust is consistent with GPS results showing that most of the Aegean moves as a group of near-rigid blocks (McClusky et al., 2000; Nyst and Thatcher, 2004).

The attenuation of seismic waves is an important parameter for studying the regional earth structure since it is directly related with the physical/chemical state of rocks such as the distribution of fractures, fluid saturation of cracks and differences of temperature and pressure in the interior Earth. Knowledge of attenuation characteristics is also necessary for earthquake hazard assessments and better understanding of source processes, tectonics and seismicity in a region. The attenuation of a medium is expressed by a dimensionless quantity called quality factor, Q, which represents the decay of wave amplitude during its propagation in the medium caused by heterogeneity or anelasticity. The coda quality factor and its spatial variation have been widely used to estimate regional attenuation parameters. The purpose of this study is to investigate lithospheric heterogeneity in Central West Turkey by examining frequency and lapse time dependencies of coda wave attenuation. Utilizing the single isotropic scattering model (Sato, 1977), Q_c values for five frequency bands and eight lapse times were estimated in the region and also for eight different subsets of the data. Many researchers have estimated coda wave attenuation for different regions in western Turkey (e.g. Akıncı et al., 1994; Horasan and Boztepe-Güney, 2004; Horasan et al., 1998; Şahin and Çınar, 2014). All of their results support the idea that tectonically active areas were characterized with strong attenuation.

2. Dataset

The data comes from WASRE (Western Anatolia Seismic Recording Experiment) network (Akyol et al., 2006; Zhu et al., 2006a, 2006b), operated about eleven months in between November 2002 and October 2003. As shown in Fig. 2, the network consists of two different array configurations (regional and linear array) equipped with STS-2 broadband and Mark L-22 short-period (2 Hz), three-component sensors. The regional array consist of five broadband (AKH, AYD, BOZ, DEU, KUL) and four short-period (MAN, NAZ, SAR, SEL) seismic stations. The linear array was located as a NS-trending profile along the Menderes Massif. During the first half of the installation stage, 20 of the short-period stations were deployed between GG (Gediz Graben) and KMG (Küçük Menderes Graben). Then, 18 of them were removed to the southern part of the area between KMG and BMG (Büyük Menderes Graben). All events were digitally recorded by Reftek 72A instruments with a sampling rate of 40 samples per second. A detailed description of the survey and technical characteristics of the recorders can be found in Zhu et al. (2006a). Geological information about site characteristics of the stations and also initial data processing stages of the data were given by Akyol et al. (2013).

Fig. 2 shows distributions of seismic stations and earthquake epicenters used in this study. The hypocentral parameters have been reported by Akyol et al. (2006). A total number of 440 records from 280 events, having signal-to-noise ratio larger than 3, were used in this study. The local magnitude of the events ranged from 2.0 to 4.9 and the focal depths were less than 27 km with a mean value of 8.9 ($\pm$4) km. The source to receiver distance of the records changed between 11 and 72 km. As shown in Fig. 2, the region was divided into four subregions. Only the events and stations within the borders were evaluated for each subregion. The subregions include data from 113, 18, 27 and 64 events, respectively. The total amount of data was dominated by DEU (23%) station, for the entire region. The data percentages of DEU (64%), AKH-LA05-MAN (42%), AYD (24%) and SAR (85%) stations dominate the data from subregions I, II, III and IV, respectively.

3. Method and results

In the single-scattering model, the coda is considered as a superposition of back-scattered wavelets from randomly distributed heterogeneities (Aki, 1969; Aki and Chouet, 1975). The single back-scattering