SKS Splitting Observed at MedNet Vitosha Station, Bulgaria
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SUMMARY

None

Introduction

Shear-wave splitting analysis was first used by Vinnik et. al (1989) to determine Upper Mantle anisotropy by calculating splitting parameters from SKS and SKKS waves. The method is based on the theory that SK(K)S (S waves passing through Earth's External Core) will be polarized and split while travelling through the Upper Mantle underneath the recording station. This phenomenon is assumed to be caused by preferred orientation of olivine crystals comprised in Mantle material. The orientation of these crystals can be generated by three mechanisms: mantle flow, vertical coherent deformation and frozen (fossil) anisotropy. Another possible cause of shear-wave splitting is the preferred orientation of cracks and faults in Earth's Crust nearby the recording station.

This study is meant to continue previous analysis made at several seismological stations in the area (Romania, Poland and Ukraine). Shear-wave splitting analysis was observed at MedNet Vitosha Station (VTS), situated in Bulgaria (recordings were made by a STS-1 broad-band seismometer). Mean values for splitting parameters calculated at this station are $129.735^\circ \pm 5^\circ$ for the fast axis direction (ϕ) and $1.101s \pm 0.07s$ for the delay time (δt) and are close to several previous result (Dricker et al., 1999; Ivan et al., 2000/2008; Wiejacz, 2001).

Method, Data Analysis and Results

Digital broad-band data was available online at IRIS DMC. 71 events between 12.12.1996 and 31.12.2006 were selected, all having magnitude greater than 6, focal depths greater than 100 km and teleseismic distances between 85° and 116° . A further examination of the available recordings determined me to pick only 53 events for the final analysis, due to low signal-to-noise ratio. Arrivals of SKS phases were also checked with respect to travel times computed with IASP91 TTIM software (Buland and Chapman, 1983; Kennet and Engdhal, 1991). The software used for data processing was PITSA (Scherbaum and Johnson, 1992). A few tools provided by this software were used in a sequence of steps: first, a zero-phase Butterworth band-pass filter (3s–30s) was applied to the recording (Figure 1); next, the SKS phase was isolated with medium precision and the Particle-motion tool was used to examine the theoretical predicted quasi-elliptical polarization along the source-to-receiver path (Figure 2a); this tool was also used to determine with high confidence the start and end of time-windows that had to be used in splitting analysis (Figure 2b).

Figure 1: a) – raw data for event 03.19.2002 (Banda Sea)
b) – filtered data for event 03.19.2002 (Banda Sea); zero – phase Butterworth band-pass filter (3-30s)

Figure 2: a) – elliptical particle motion corresponding to the SKS wave arrival shown on Figure 1b
b) – time windows on horizontal channels (BHE and BHN) determined for the event shown on Figure 1 by using the Particle-motion Monitor; these two windows represent the input for the splitting analysis software

This analysis was performed using two different approaches on the same time windows. The first one used the “ah_splitest2” software created by Levin et. al (1999), while the second one used the “SKS” software, developed by Marian Ivan (2000); the theoretical background of the shear-wave splitting algorithm is summarized in Appendix A of “SKS splitting observed at Romanian broad-band seismic network” (Ivan et al., 2008). There was good agreement between the two parameter sets, this being considered a validation of the computational method (the differences between the two sets were 6° for the fast axis direction ϕ and 0.15s for the delay time δt). The average splitting parameters determined for VTS Station are $\phi = 129.735^\circ \pm 5^\circ$ and $\delta t = 1.101s \pm 0.07s$. These results were correlated with those obtained by Marian Ivan at Romanian, Ukrainian and Polish stations, in order to make some large-scale connections. These results are presented in Figure 3.

Figure 3: Results obtained at VTS and at Romanian, Ukrainian and Polish stations; directions of the segments represent fast axis azimuths (ϕ); lengths of segments represent delay times (δt).

It can be easily observed that the fast axis direction calculated in VTS Station is approximately parallel to those calculated at nearby stations. Exceptions are found at Romanian stations VOIR, MLR and VRI, situated in Vrancea seismogenic area, where the fast axis azimuth has a mean value of 50° , with no apparent variation of splitting parameters with back-azimuth. This area presents a very complicated structure, origin of earthquakes occurring here being still unknown. A more detailed analysis of shear-wave splitting in this area can be found in the paper “SKS splitting observed at Romanian broad-band seismic network”, published by M. Ivan et al. (2008). Figure 4 presents two plots showing variation of the fast axis direction ϕ with the back-azimuth angle. The regression calculated on available data suggests that a slight variation of ϕ with back-azimuth might be possible. However, the data used to calculate the variation function include parameters obtained from low-quality recordings; also, the number of points is not large enough to statistically sustain this theory.

Figure 4: a) – ϕ plotted against back-azimuth angle (bAz)
b) – ϕ plotted against normalized back-azimuth angle (bAz-180°)

Figure 5: Tectonic map of Vitosha zone

As observed in Figure 5, the fast axis direction coincides with the main orientation of major cracks and faults in the area. This fact would lead us to the idea that SKS splitting observed at VTS Station can also be linked to the structure of the Earth's crust; however, this hypothesis will not be considered, due to the wavelengths of the phases involved in the analysis, wavelengths that are too high to respond to such a splitting mechanism.

An alternative explanation for the splitting values calculated at the stations presented in Figure 3 could be represented by a parallel large scale mantle flow ($\phi \sim 135^\circ$), similar to the assumption of Dricker et al. (1999). However, the absolute plate motion in the area is around 248° from North, relative to hotspots frame (Gripp and Gordon, 2002).

Conclusions

VTS Station in Bulgaria shows a fast polarization azimuth around 130° , this value being similar to values calculated at nearby stations (with a notable exception in Vrancea area). The consistency of these values over a large area suggests that the Upper Mantle in that zone shows an extended anomalous anisotropic layer presenting the same orientation of the olivine crystals. The spatial distribution of the stations and the small number of available data for most stations does not allow one to clearly identify the source of SKS splitting as a fossil lithospheric anisotropy or an astenospheric

mantle flow. Still, the first hypothesis is compatible to a continental collision in the area, as suggested by Cloetingh et al. (2004).

The delay time δt is directly generated by the propagation of the wave through the anisotropic layer, this parameter being a measure of the thickness of this layer. It was established that, for anisotropic Mantle material, the value of δt increases with 0.1 s per 10 km of anisotropic layer (Vinnik et al., 1992; Ivan et al., 2008). This leads to the conclusion that, underneath VTS Station, this layer has a thickness of about 100 – 110 km. No rule could be established yet for the variation of the thickness of this part of the mantle over the studied perimeter; the values of δt at different stations are represented in Figure 3.

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