Geophysical Research Abstracts, Vol. 7, 07123, 2005
SRef-ID: 1607-7962/gra/EGU05-A-07123

Structural properties of the Hellenic subduction zone derived from receiver functions and surface wave dispersion

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The Hellenic subduction zone is part of the active convergent margin between the African and Eurasian plates in the Mediterranean region. It is dominated by the north-northeasterly subduction of the oceanic African plate beneath the continental Aegean plate. It has been suggested that the subduction is close to collision with the northern boundary of continental Africa, at least in the western part of the arc. Information on structural parameters can help to constrain the spatial and temporal evolution and the dynamics of subduction in the Hellenic arc.

Beneath the Hellenic volcanic arc to the north of the forearc island Crete, the position of the downgoing plate is only poorly defined by seismicity. Crustal thickness estimates are based on few and isolated data points, sometimes leading to contradictory results. Furthermore, in volcanic arcs upflow of hot material above the subducting slab is expected to exert a strong influence on lithospheric structure. We use data of the CYC-NET (Bohnhoff et al., 2004), a temporary seismological network of 22 stations on the Cyclades in the central volcanic arc, to investigate lithospheric structure there more closely. These data offer an unique opportunity to broaden the scarce digital waveform database available for this region.

We use teleseismic receiver functions (Knapmeyer & Harjes, 2000) and Rayleigh fundamental mode dispersion (Meier et al., 2004) to jointly investigate structural variations from the surface to the depth of the subducted African Moho. Both methods are primarily sensitive to the S-velocity distribution, but also complement each other:

Receiver functions can outline sharp velocity discontinuities, but contain no absolut velocity information, whereas the shape of Rayleigh phase velocity curves depends mainly on the average S-velocity. This also makes joint inversion possible and desirable if no significant structural heterogeneity influences the data sets.

Receiver function data from several temporary short-period networks on Crete indicate considerable structural variations beneath the island (Endrun et al., 2004), including sites with strong negative phases around the expected Moho arrival time. Receiver functions from additional broad-band stations indicate that these structural heterogeneities are a general property of the forearc. 2D waveform modelling with a pseudospectral method (Ceranna, 2002) shows that these observations can at least partly be explained by Moho topography.

While the Moho depth in the forearc is larger than 30 km with a maximum of 40 km beneath the Peloponnessus, data from the central volcanic arc indicate a nearly flat Moho at a depth of on average 23 km. Receiver functions and dispersion information show close agreement in the determined Moho depths. The Moho in the volcanic arc is thus significantly deeper than the 15 km Moho depth obtained from seismic surveys (Bohnhoff et al., 2001) in the Sea of Crete. There is a good correlation between bathymetry/topography and crustal thickness in the whole region of the southern Aegean. At the southern margin of the Cyclades, roughly 8 km of Moho depth variation between the Sea of Crete and the volcanic arc causes numerous dipping phases disturbing the receiver functions from stations around Santorini, as confirmed by modelling.

In addition to the Moho, the subducting slab is well imaged down to 180 km depth by converted phases in the receiver functions and correlates well with the distribution of local seismicity. The slab has a significantly larger dip (around 35 deg) beneath the volcanic arc than observed beneath the forearc (around 15 deg).

Inversion of dispersion measurements for the volcanic arc reveals reduced crustal velocities. Reduced S-wave velocities are also found below the Moho and point to a thin lithosphere and an asthenospheric mantle wedge below 50 km depth. Around 100 km depth, slightly raised velocities correspond to the cold subducting slab. Comparison with earthquake hypocenters shows that seismicity is located within the crust and in the region of the slab, but not within the Aegean mantle inbetween. This supports the interpretation of ductile deformation in the mantle lithosphere and an asthenospheric mantle wedge.

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