SEISMOLOGICAL EVIDENCE FOR A CORRELATION BETWEEN LITHOSPHERE AND MANTLE TRANSITION ZONE

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We address two major problems in geodynamics with seismic data: How deeply do the continents penetrate into the mantle, and does there exist another reflector in the mantle transition zone at 520 km depth? Differential travel times of underside reflections from these discontinuities that appear as precursors to SS, show in large parts of the globe a clear correlation with oceans and continents. They are significantly larger beneath the Asian and North American continents than underneath the neighbouring Pacific. From this observation we conclude that the Asian and North American continents penetrate well below 410 km into the mantle. Changes of the thickness of the transition zone can explain our observations, which are in agreement with the hypothesis of petrological phase changes causing the 410 and 660 km seismic discontinuities. Weak reflections from 520 km depth with an impedance contrast of about 2 % can be observed only in some areas of the Earth, while stacking results from other locations definitively show no signal from this depth. Therefore we propose, that the 520-km reflector is only a regional feature.

Questions as to the depth extent of continental roots and the nature of upper mantle seismic discontinuities have been debated for decades, and without definitive answers, it is not possible to derive complete geodynamic models [1]. Results obtained from global seismic tomography show that variations of seismic velocities are largest in the upper 300-400 km of the mantle and are closely related to plate tectonic features, while in the transition zone, i.e. the depth intervall between the 410 and 660 km discontinuities, seismic velocities vary only by about 1 % relative to reference models and only some continuity exists with the structure of the overlying mantle [2]. In this study we use underside reflections from the 410 and 660 km discontinuities that appear as precursors to SS. Differential times of these reflections contain information which is related mainly to the structure of the transition zone and is independent of the structure above 410 km. Earlier observations indicate reduced thicknesses of the transition zone in the Pacific and Indian Ocean, while for the region of the subduction zone of the northwestern Pacific, conflicting results have been published [3, 4]. Recent long-period P- and S-wave investigations also show evidence for another reflector in the transition zone at 520 km depth [3, 5], although this is disputed [6].

The data used in this study are long-period recordings from the Global Digital Seismic Network for the years 1980-1991 distributed by the US Geological Survey. We selected 3100 SS records of the transverse-horizontal component, which were the best out of 8313 possible ones in this data set. Precursors to SS are very weak phases and unambiguous identification is rarely possible in individual records. Since the signal-to-noise ratio of SS precursors is usually small, signal processing is necessary to enhance these phases. It consists of a deconvolution and a delay-and-sum procedure of all records with bounce points in a defined region. Therefore the surface of the globe was divided into 30 by 30 regions.

Residuals of the differential traveltime between 410-km and 660-km reflections range from - 10 to +4 % of the IASP91 [7] times, which are significantly larger than the anomaly obtained from S-wave tomography [2]. They are strongly negative in the region of the Pacific and Indian Oceans, and positive in the regions of the Asian and North

American continents. No reliable data are available for the continents in the southern hemisphere. It is important to note that the continents are mostly associated with differential times that are larger than in the global model, while the oceans have significantly smaller differential times. Applying tomographicvelocity corrections [8] yields that the transition zone is about 5 km thicker under continents, and 9 km thinner under oceans relative to the IASP91 reference model. Peak values are -21 km in the Indian Ocean and +10 km in Northern Siberia.

The findings are in good agreement with the hypothesis that phase transitions in the olivine component of mantle rock cause the 410 and 660 km discontinuties. The transitions from olivine-to-beta phase and from gamma spinel-to-perovskite plus magnesiowustite structure usually associated with these discontinuities have Clapeyron slopes of opposite sign such that the inferred thickness change of about 14 km implies a temperature contrast of about 100 C between the oceanic and continental transition zones [1]. Here, it is noteworthy that our results for Northern Siberia (where we observed the strongest positive anomaly) support the hypothesis of an old, undisturbed platform, because even its transition zone is colder than elsewhere.

Additionally, conclusions about the existence of a 520-km reflector can be derived from our results, because we used enhanced signal processing methods. We tested this by stacking synthetic seismograms. Although, there are some areas for which such a decision is not possible because of an increased noise level of the stacking result, we can identify reflected phases from this depth in several areas of the world (India and Central Asia, Northwest Pacific Region, Central Southern Pacific, and the Canadian Shield), while at other locations absolutely no 520-km reflection phase can be observed (Indian Ocean, Southeast Asia, Northeast Pacific and Western USA, and parts of the Polar Region and the North Atlantic Ocean). As we could exclude sidelobe artifacts as a reason for this signal, our results agree with the regional existence of a weak 520-km discontinuity with an impedance contrast of about 2 %. Other reflectors, especially at 220 and 900 km depth could not be detected. Because polymorphic phase transitions at the upper mantle discontinuities pose no hindrance to whole mantle convection [1], in contrast to compositional changes, our data support whole mantle convection. However, the coverage with bounce points is still very poor in many regions of the world. Future work using data from additional permanent and portable seismographs should complement our results.

References

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