DEEP SEISMIC STRUCTURE AND KIMBERLITES OF THE KAAPVAAL CRATON

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The Kaapvaal craton in South Africa is remarkable by the intensive Jurassic-Cretaceous kimberlite magmatism. Some inclusions in kimberlites could be brought from depths in excess of 300 km, and it is even possible that the ultimate source regions of kimberlites lie in the mantle transition zone (Ringwood et al. 1992). No seismic data that could resolve specific features of the mantle at these depths have been published so far either for the Kaapvaal craton or any other kimberlite-intruded region. The Kaapvaal craton belongs to the high plateaus of southern and eastern Africa that together with the region of anomalous bathymetry in the southeastern Atlantic form a superswell (Nyblade and Robinson 1994). Various parts of this superswell have broadly similar uplift histories in the Mesozoic and Cenozoic. There are indications that the uplift is caused, at least partly, by hotspot heating of the subcrustal lithosphere, although within the Kaapvaal craton, heat flow data give no evidence of a thermal perturbation.

We performed the analysis of deep structure of the Kaapvaal craton by using teleseismic P-to-S converted phases. The techniques based on the observations of these phases provide unsurpassed resolution for the S velocity gradients at depths exceeding 300 km. The records were obtained at 8 digital broad-band seismograph stations. The Ps seismic phases that are converted from P to S in the mantle at the receiver side of the wavepath are recorded in the tail of the P wave pulse with an amplitude on the order of a few per cent of the P wave amplitude. To detect such weak phases, a special signal processing technique is required. The major component of this technique is stacking the records of the same station or the same group of stations with appropriate moveout time corrections. We have stacked more than 40 records and detected two mantle converted phases. One is related to 650 km discontinuity, the other - to 400 km discontinuity. The waveform of the latter is strongly different from the waveform of the parent P wave phase. The waveform inversion for the 400 km phase suggests that the S wave velocity in the depth range between 370 km and 480 km beneath the Kaapvaal craton is a few per cent lower than the standard values.

Analyses of the mantle Ps phases have been made so far for a number of continental stations, but the anomaly comparable with that found in South Africa has never been observed. Numerous velocity models derived from various kinds of seismic data for many regions usually show that in the interval between 300 and 650 km, the velocities rise with depth. Some complications may exist in the presently active subduction zones, but outside subduction zones, this phenomenon, if present, is very rare. With the indications of heating of the upper mantle in southern Africa taken into account, the low velocity layer near 400 km depth can be explained with elevated temperature that comes close to the solidus temperature. Part of the low velocity zone may correspond to the layer enriched in sodium, potassium, iron, incompatible elements and volatiles (Gasparik 1992). This layer may contain water stored in dense hydrous magnesium silicates, like K-amphibole (Thomson 1992). If temperature is elevated by a thermal plune, water is released by dehydration, temperature of the mantle solidus is lowered and melts are formed. The 370 km discontinuity may separate the root of the craton which migrates coherently with the plate, from the underlying mantle. The S velocity above the discontinuity is higher, because the root may have a different composition and a higher solidus temperature (Jordan 1988).

Ages of a group of south-African kimberlites decrease linearly from about 200 Ma in the North-East of the study region to about 100 Ma in the West, suggesting that their origin is related to the passage of the plate over a hot spot (Skinner 1989). In the Mesozoic, southern Africa moved across several hot spots. that now reside in the adjacent region of the Atlantic (Morgan 1983). Hence, there are reasons to suggest that the low-velocity layer or its rudiment were present beneath the Kaapvaal craton already in the Mesozoic, and it might serve as a "protosource" for kimberlites.