11th SAGA Biennial Technical Meeting and Exhibition
Swaziland, 16 - 18 September 2009, pages 380 - 384

Dispersion of surface waves in Southern Africa from inter-station measurements

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ABSTRACT

We measured Rayleigh and Love wave dispersion across southern Africa using a combination of cross-correlation and waveform inversion approaches. Phase-velocity averages between pairs of stations of the SASE array were obtained in period ranges of at least 5-200 s for Rayleigh and 5-50 s for Love waves. The new data confirm the thinning of the crust from the Limpopo Belt and northern Kaapvaal Craton towards the southern part of the craton, as observed perviously. A reduction in S-wave velocity at the bottom of the lithosphere at 150-200 km is required by the data both beneath the Kaapvaal Craton and the Limpopo Belt, although this reduction is less pronounced beneath the latter. The new data should also enable direct measurements of the depth of the lithosphere-asthenosphere boundary.

Key words: Dispersion curves, South Africa, inter-station measurements

INTRODUCTION

Southern Africa contains two of the oldest lithospheric blocks on Earth: the Kaapvaal and Zimbabwe Cratons. Understanding the physical properties of southern African lithosphere can help us learn more of the formation and evolution of continents. The Kaapvaal Craton and the neighbouring Limpopo Belt (Figure 1) have been the focus of numerous geophysical and geological studies (e.g., Freybourger et al., 2001, James et al., 2001, Nguuri et al., 2001, Weeraratne et al., 2003, Fouch et al., 2004, Li and Burke, 2006, Yang et al., 2008). Questions remain, however, regarding lateral variations in the stucture and thickness of the lithosphere. In this study, we aim to constrain accurate S-wave velocity profiles in different parts of the region. In order to do that, we measured phase velocities of surface waves in broad period ranges using a combination of cross-correlation (Meier et al., 2004) and multimode waveform inversion (Lebedev et al., 2005) approaches. With both methods, we computed dispersion curves of surface waves between pairs of stations. We then computed robust average dispersion curves for different parts of the study region.

METHOD

We used two methods to obtain surface wave dispersion curves in a broad range of frequencies. The first method (Meier et al., 2004) uses cross-correlation of the displacement field from the same source recorded at two stations. This method enables us to obtain dispersion curves in short (10-20 seconds) as well as longer periods. The second method is the Automated Multimode Inversion (AMI) (Lebedev et al., 2005) that provides average phase velocities between sources and stations. The dispersion curve between a pair of stations is then computed using the source-station measurements. This method is complementary to the first one because it provides more measurements at longer periods, especially for Love waves.

We measured dispersion curves for both Love and Rayleigh waves, using transverse and vertical components, respectively.

RESULTS AND DISCUSSION

We compared dispersion curves and S-velocity profiles in different parts of the Kaapvaal Craton and the Limpopo Belt (Figure 1). The Kaapvaal Craton is subdivided in three parts, each with a different crustal thickness (Yang et al., 2008).

The total number of measurements is 1113 for Love waves and 1019 for Rayleigh waves. Figure 2 shows the averaged dispersion curves and their standard deviations for each of the sub-regions. In Figure 3 (left) the dispersion curves are compared and plotted together.

The dispersion curves represent the average phase velocity structure of the regions of different ages and with different crustal thicknesses. Phase velocities from the Limpopo belt and the northern part of the Kaapvaal Craton are lower than those in the two other sub-regions between the periods 20 and 50 s. This is consistent with the crustal thickness map computed by Yang et al. (2008) that shows thicker crust in these regions. At longer periods, the differences between the curves are small.

Rayleigh wave data from each sub-region require a reduction in S-velocity near the bottom of the lithosphere at 150-200 km. Asthenospheric velocities are not low, however, compared to global average values. Exploring the range of the reduction in S-velocity near the bottom of the lithosphere, we found that the data of the Limpopo belt region fits best with a 0.13 km/s reduction at around 150 km. At a similar depth beneath the south-west and northern Kaapvaal Craton, reductions of 0.21 km/s and 0.41 km/s respectively are likely. In the central Kaapvaal Craton the likely reduction is between 0.19 km/s and 0.29 km/sec. In the future, our new data should also enable direct measurements of the depth of the lithosphere-asthenosphere boundary (LAB).

CONCLUSIONS

Two measurement methods were applied to a large number of seismograms and provided robust, accurate dispersion curves constraining the lithospheric structure across the Kaapvaal Craton and the Limpopo Belt. The results confirm the thinning of the crust from the Limpopo Belt and northern Kaapvaal Craton towards the southern part of the craton, observed perviously (e.g., Yang et al., 2008). A reduction in S-wave velocity near the bottom of the lithosphere at 150-200 km is required by the data both from the Kaapvaal Craton and the Limpopo Belt. This reduction is less pronounced, however, in the Limpopo region.

ACKNOWLEDGMENTS

We thank the Kaapvaal Project seismic team for collecting the data. The facilities of the IRIS Data Management System, and specifically the IRIS Data Management Center, were used for access to waveform and metadata required in this study. The IRIS DMS is funded through the National Science Foundation and specifically the GEO Directorate through the Instrumentation and Facilities Program of the National Science Foundation under Cooperative Agreement EAR-0004370.

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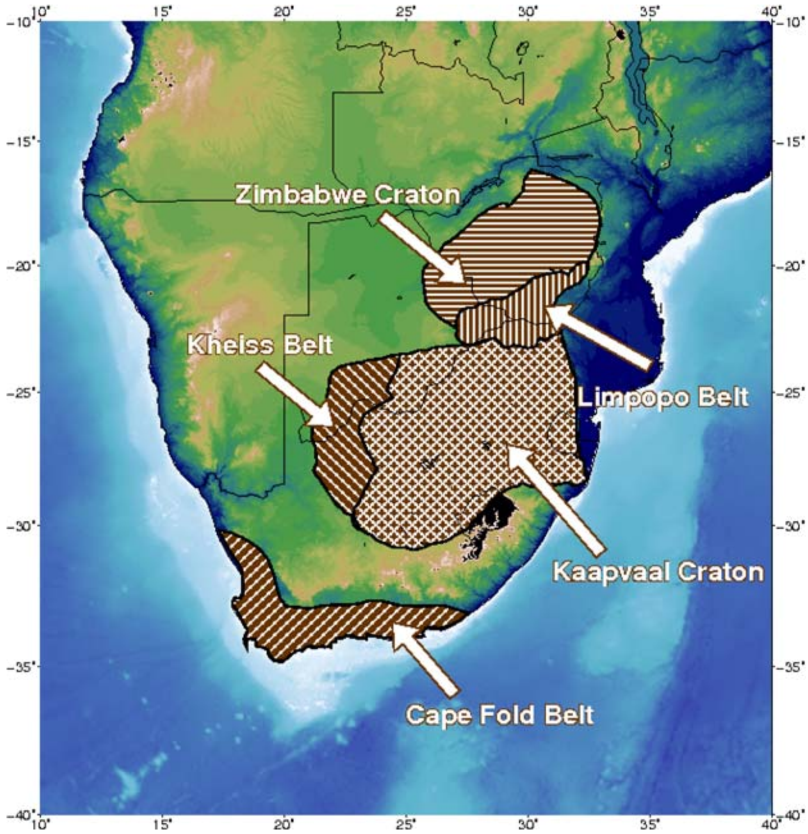

Figure 1. Sketch map of southern Africa and its geologic structure

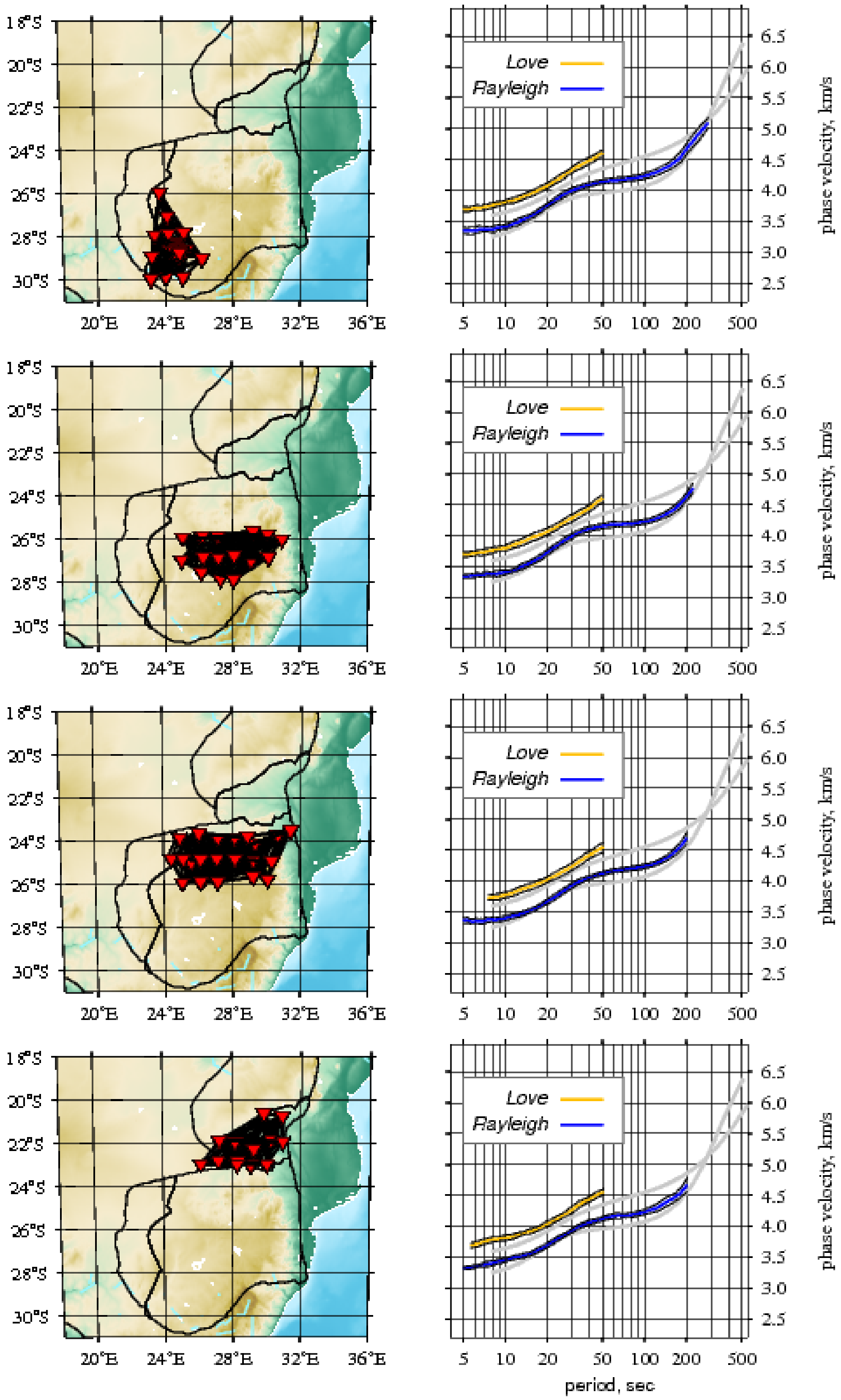

Figure 2. Average dispersion curves in four sub-regions. First column: stations and interstation paths for each region. Second column: Measured phase velocities of Love and Rayleigh waves. The gray line is the reference model AK13

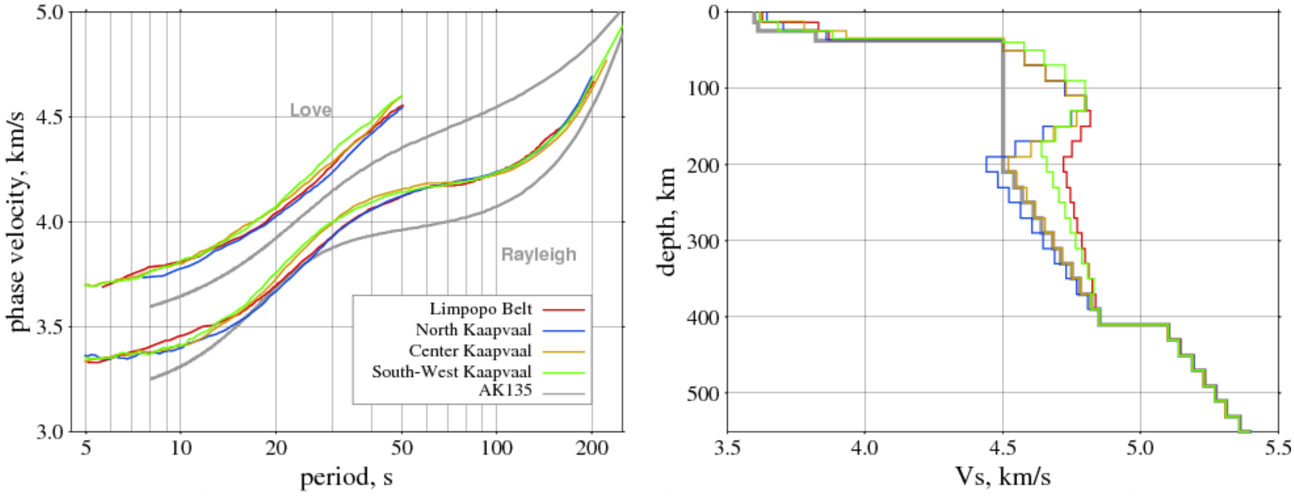

Figure 3. Left : Dispersion curves averaging over different sub-regions. The gray line is the reference model AK135. Right : S wave velocity models obtained by non-linear, gradient-search inversion of the phase-velocity curves.