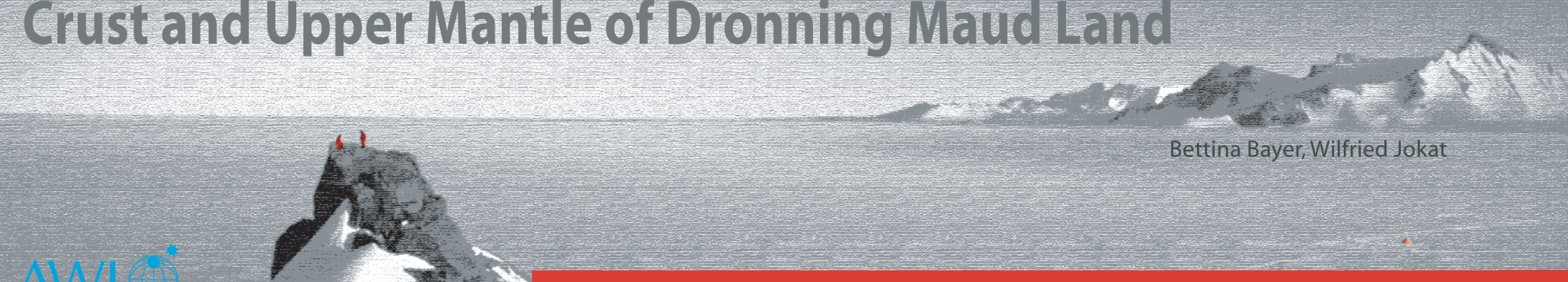
Crust and Upper Mantle of Dronning Maud Land



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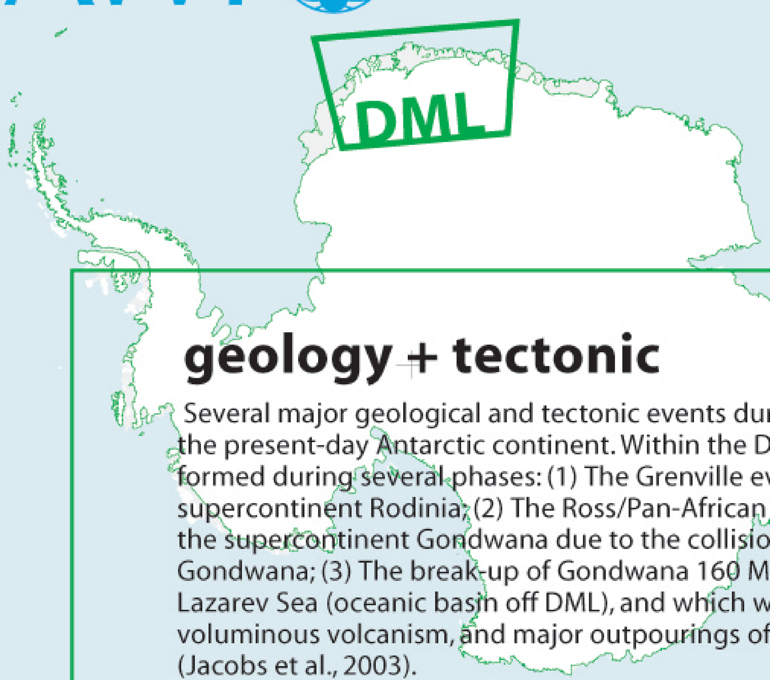

geology + tectonic

Several major geological and tectonic events during Earth's history formed the present-day Antarctic continent. Within the DML geological units were formed during several phases: (1) The Grenville event, at 1.1 Ga, forming the supercontinent Rodinia; (2) The Ross/Pan-African event at 500 Ma, forming the supercontinent Gondwana due to the collision between West and East Gondwana; (3) The break-up of Gondwana 160 Ma ago, which started in the Lazarev Sea (oceanic basin off DML), and which was accompanied by voluminous volcanism, and major outpourings of continental flood basalts (Jacobs et al., 2003).

In western DML, an Archean cratonic fragment named Grunehogna craton (GRU) is exposed (Fig. 1). GRU is most likely a piece of the Kalahari-Kaapvaal craton dispersed during fragmentation of Gondwana (Groenewald et al., 1991). The entire southern side of GRU is rimmed by the Maudheim province (MP) comprised of Proterozoic high-grade metamorphic rocks of Grenvillian age (1163-850 Ma).

experimental set-up

During several experiments, portable broadband seismometers (Lennartz with 5 and 20 s eigenfrequency) with Reftek recording systems were deployed in Dronning Maud Land (DML), Antarctica. These experiments were carried out across the Heimefront shear zone (HSZ) during the polar summer of 2003 and along the Kottas mountain range during the polar summer of 2004, both in western DML (Fig. 1).

Temporary deployed stations across HSZ (KOH1-KOH5, Fig. 1) were placed on ice. Stations in the Kottas mountain range (Weigel, KOT1, KOT4, Fig. 1) were deployed directly on exposed rocks. In addition, permanent broadband recordings from 2002 to 2005 of the South African base Sanae IV (SNAA) were investigated and yielded the greatest number of observations. We also used recordings of seismographs, operated during the polar winter 2005 at the Russian base Novolazarevskaya (NOVO) in central DML and at Weigel nunatak in the Kottas mountains.

upper mantle

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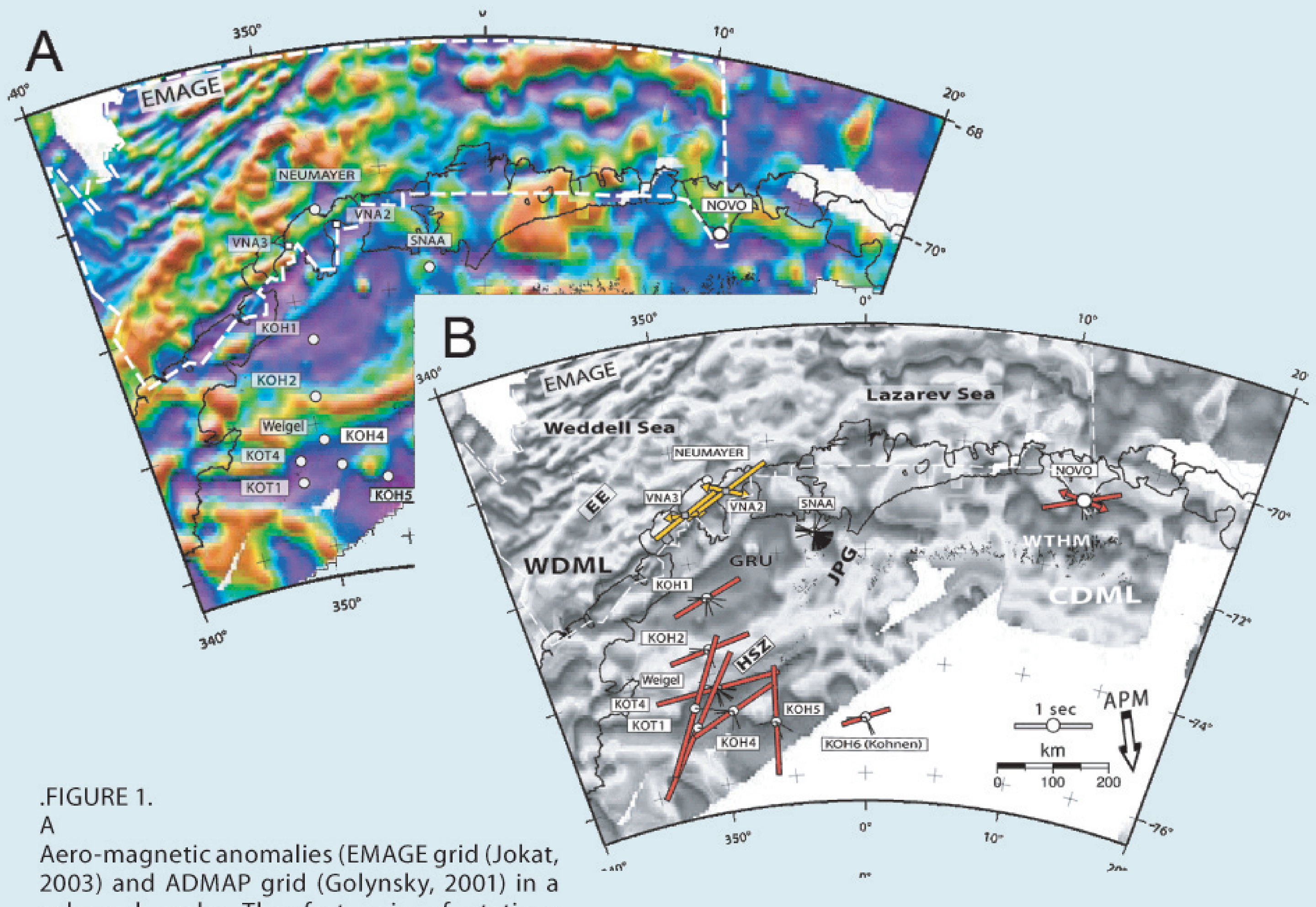
Seismic anisotropy

If a shear-wave traverses an anisotropic medium it splits into two phases. Two parameter describe such a medium: the time delay between the two phases and the polarization axis of the faster phase (so-called fast axis).



.FIGURE 1.
A
Aero-magnetic anomalies (EMAGE grid (Jokat, 2003) and ADMAP grid (Golynsky, 2001) in a coloured scale. The fast axis of stations deployed across HSZ, Novo and Neumayer are aligned in a parallel manner with small-scaled geological features.

B
Estimated splitting parameters plottet over grey scaled anomaly grids. Thick red bars indicate fast axis and length is proportional to time delay. Thin black bars on the stations dot denote backazimuths of included phases.

Abbreviations are: EE, Explora Escarpment; JPG, Jutul-Penck-Graben; GRU, Grunehogna craton; CDML, Central Dronning Maud Land; WDML, Western Dronning Maud Land; WTHM, Wohlthat massif; KOH, Kohnen Traverse Stations; KOT, Kottas Stations; HSZ, Heimefront Shear Zone; APM, Absolute Plate Motion.

conclusions

1 **Anisotropic features** are **not caused by asthenospheric flow**.

2 **Crustal anomalies correlate** with fabrics in the deeper **lithospheric mantle**, and the **crust and mantle were strongly coupled** in major orogenic episodes.

3 The abrupt spatial **variation in fast axes** within HSZ suggests that the **shear zone penetrate through the crust into the mantle**. This implies a **suture** zone.

4 At near-coastal stations there is **double-layer seismic anisotropy**. Both layers reflect fossil fabrics (**lower layer** was created during **Gondwana break-up,** the **upper layer** was created during **Mesoproterozoic orogenies.**

5 **Inconsistent results** regarding the azimuthal distribution of isotropic and anisotropic measurements were retrieved at **SNAA**. The observation of signal fractions suggest **large scale lateral heterogeneous** structures.

(Reference: Seismic anisotropy beneath Dronning Maud Land, Antarctica, revealed by shear-wave splitting, GJI, 2007, in press.)

conclusions

crustal structure

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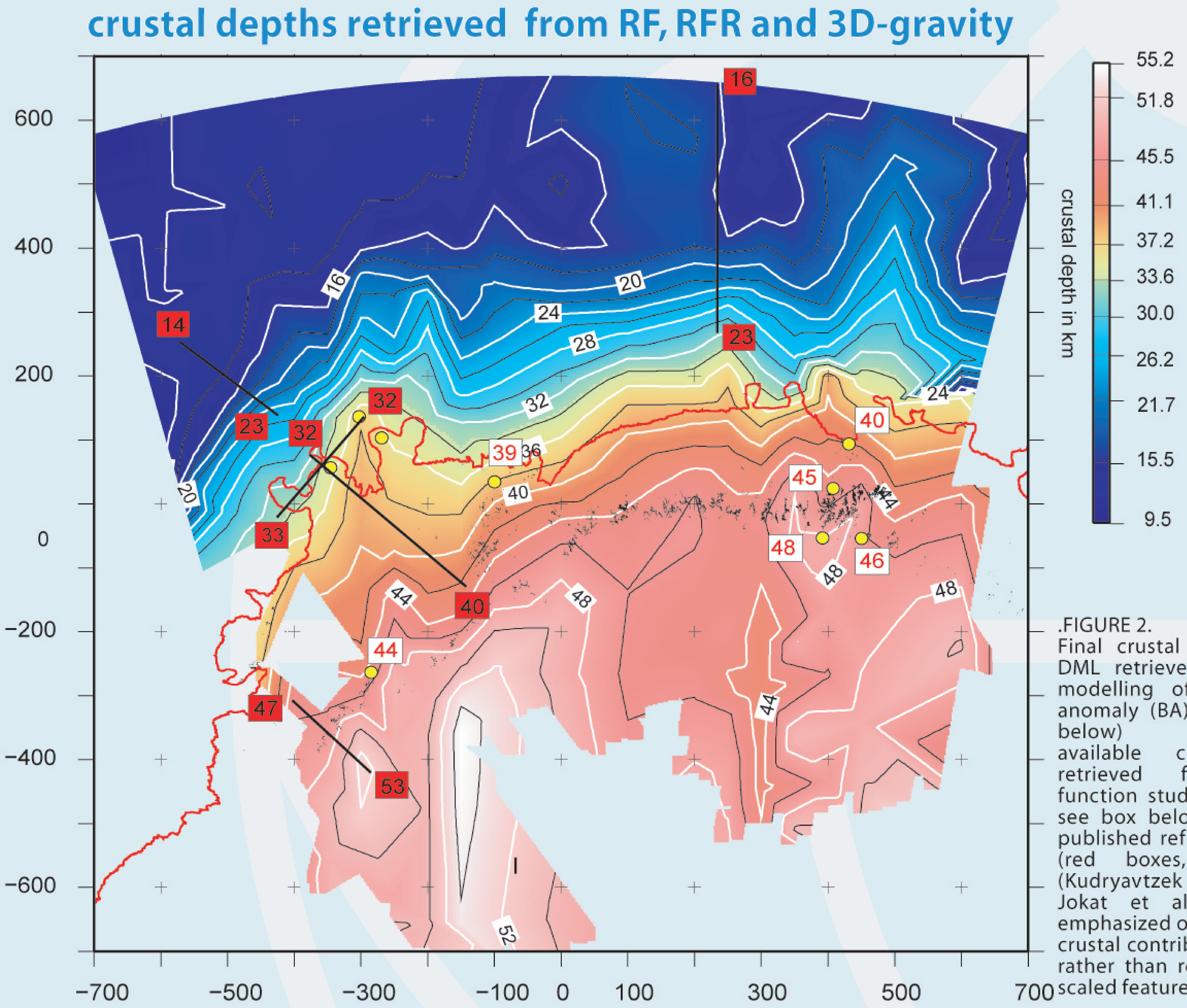
crustal depths retrieved from RF, RFR and 3D-gravity



.FIGURE 2.
Final crustal depths of the DML retrieved from a 3D-modelling of the bouguer anomaly (BA) field (see box below) including the available crustal depths retrieved from receiver function studies (red values, see box below) and several published refraction seismics (red boxes, black lines (Kudryavtzek et al., 1991, Jokat et al., 2004)). We emphasized on modelling the crustal contribution of the BA rather than resolving small-scaled features.

conclusions

1 We found with receiver functions an **increasing crustal thickness from the coast towards the southern orogens**, with a value approaching about 40 km at the coast and about 45 km towards the mountains. Thickened crust between 45 and 48 km is found underneath the Wohlthat Massif, which might indicate the **presence of an orogenic root**. For all stations, a sharp converted signal (Ps, see box 'RF' below) at the Moho is observable, standing for a **strong separation of the crust and upper mantle**.

2 **The western part of DML yield a higher Vp/Vs ratio than the central DML** . For the Kottas Mountains in western DML, the Vp/Vs ratio = 1.72. For the central DML, the Vp/Vs ratio = 1.67, indicating a predominantly **quartz-rich, felsic bulk composition of the crust**. Such low values support the idea of a Pan-African **crustal delamination**, which is proposed for the CDML considering geological aspects (Jacobs, 2003).

3 The Moho underneath the Heimefront shear zone in the Kottas Mountains shows a **7 km offset** (see box 'RFR' below). This Moho offset might indicate a **suture** between the Mesoproterozoic Maudheim Province and the arc-related Kottas Mountains Kibarian in age.

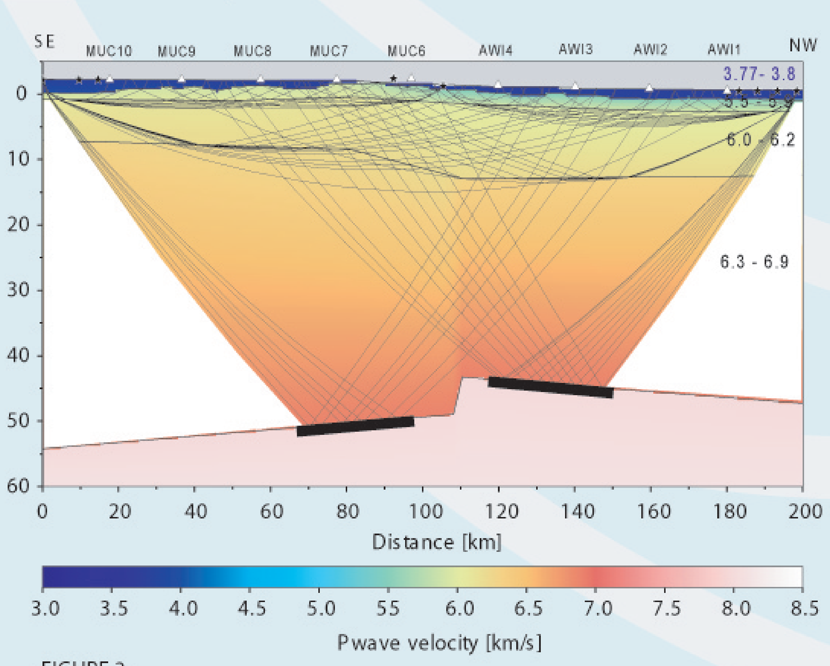
4 At SNAA, the crustal thickness approaches 39 km and the Vp/Vs ratio amounts to 1.80. The high Vp/Vs ratio corresponds to a **more mafic crust** and indicates **intrusions of basaltic material** into the crust during the Jurassic **Gondwana break-up**. Such intrusions were deduced from an aero-magnetic study (Ferraccioli, 2005).

(Reference: Seismic Imaging of the Crust beneath Dronning Maud Land, Antarctica, GJI, 2007, in review.)

conclusions

refraction seismics (RFR)

During the polar expedition ANT-VIII/5 in 1989/90, a refraction profile (named KOTTAS, Fig. 6) across the south western part of Heimefront shear zone was acquired. The maximum offset between shot points and seismic stations was 200 km.

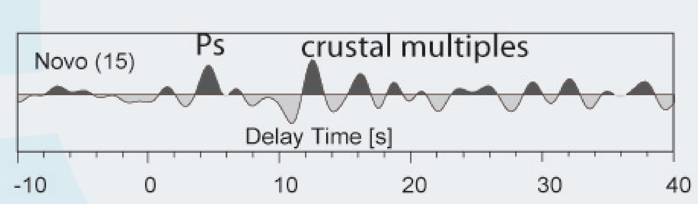


.FIGURE 3.
Crustal model of Kottas retrieved by ray tracing of P-waves. The Moho reaches values between 45 and 53 km.

receiver functions (RF)

The principle of the calculation of receiver functions (RF) is that at discontinuities (e.g. the Moho) some parts of the teleseismic compressional energy converts to shear energy.

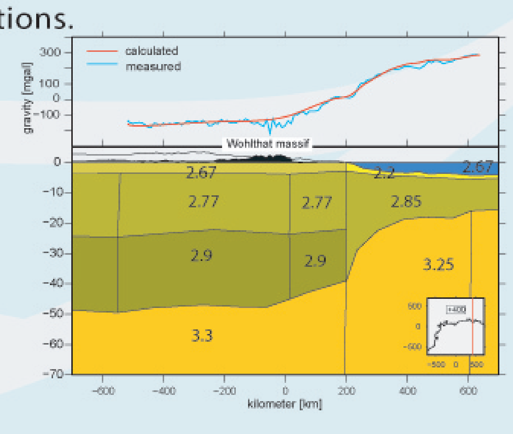
The retrieved **crustal depths** are shown in Fig. 2 (red values). They **range between ca. 39 km** for coastal stations and ca. **45 km** for stations further inland.



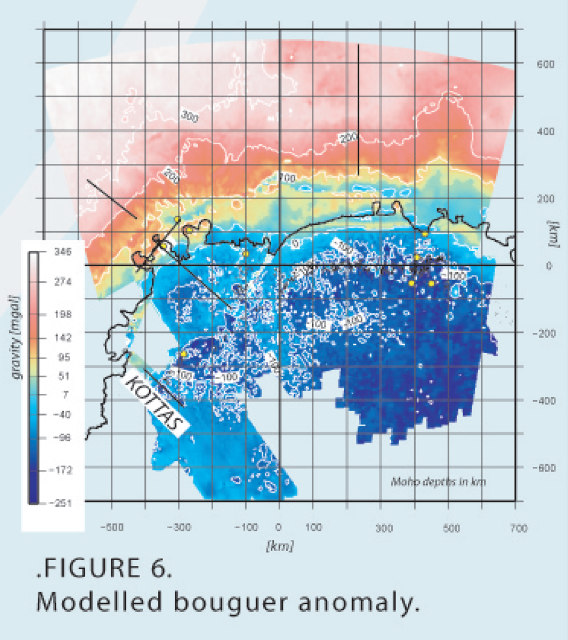
.FIGURE 4.
As an example a sum trace of 15 receiver functions for station NOVO.

3D-gravity

The bouguer anomaly was modelled using high resolution aero-gravity data (S. Riedel) for the continental area in combination with ETOPO data for the oceanic area (Fig. 6) to combine the wide nature of crustal thickness. We divided the area of investigation into 23 N-S oriented planes (Fig. 5). The crustal depths retrieved from RF study and RFR were included as boundary conditions.



.FIGURE 5.
Principle model through the crustal section at 400 km. Black values are the assumed densities. Upper two curved represent the measured and modelled gravity.



.FIGURE 6.
Modelled bouguer anomaly.