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Overview and Preliminary results of a magnetotelluric experiment across the southern Barberton greenstone belt

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ABSTRACT

The Kaapvaal Craton of South Africa is the oldest well-preserved continental fragment on the planet and thus is a key area for studies of geodynamic processes of the early Earth. One major controversy concerns the importance of plate tectonic processes in Archean times and the time when this may have been first initiated. Several potential ancient suture zones have been identified at surface within the Barberton greenstone Belt, and these provide an ideal natural laboratory to test for possible subsurface remnants of mid-Archean plate tectonic processes on lithospheric scale.
Within the framework of the German-South African geo-scientific research initiative Inkaba yeAfrica a high resolution magnetotelluric (MT) field experiment, ELIBABA, was carried out in April/May 2009 in the Barberton/Badplaas area, eastern Mpumalanga, RSA. An 110 km long profile and two complementary shorter 70 km long profiles with almost 100 MT sites provide a good areal coverage of the Barberton suture and its complex geology. Preliminary two-dimensional inversion models show images of the crustal electrical conductivity distribution which will be compared to existing shallow geophysical results.

Key words: Magnetotellurics, Barberton Greenstone Belt, Kaapvaal Craton, Crustal structure, Lithospheric structure, Archean tectonics

INTRODUCTION

The existence and especially the onset of early Archean (>3.0 Ga) present day style plate tectonics remains controversial, despite many studies addressing this topic from the 1990s on (e.g. de Wit, 1998; Kato & Nakamura, 2003, Hamilton 1998; Zegers & van Keken, 2001). Ongoing research has provided some evidence for plate tectonics as early as 3.1 Ga (Smithies et al., 2007, Strik et al, 2003) and possibly as early as 3.8 Ga (Smithies at al., 2006), but this remains controversial to some extend due to the lack of deep geophysical data.

Within the German-South African geo-scientific research initiative Inkaba yeAfrica (de Wit and Horsfield, 2005), several high resolution magnetotelluric (MT) experiments across younger (Proterozoic to Permo-Triassic age) suture zones in southern Africa imaged sub-vertical, high electrical conductivity zones, likely caused by crustal shear zones within suture zones. Possible explanations for the high electrical conductivity, often expressed in form of electrical anisotropy, are graphite or sulfide enrichments on shear planes (Weckmann et al., 2007a, 2007b, Ritter et al., 2003, Weckmann et al., 2003).
Rocks of the Barberton Mountainland in eastern Mpumalanga, RSA, represent a fragment of arguably the world's best preserved remnant of Archean oceanic and continental crust, known as the Barberton Greenstone Belt, that may have been subducted (Schoene et al., 2008, 2009). Imaging the deep roots of the Barberton greenstone belt may reveal an Archean suture zone. Comparison with results of younger sutures is important to better define and understand plate tectonics of the early Earth, and to test accretionary models of continental growth during the Archean.

METHOD AND RESULTS

New high resolution magnetotelluric (MT) data were collected in April/May 2009 in an area between the Swaziland/South African border and Dullstroom on the Great Escarpment. A 110 km long profile comprising 56 sites, with an average site spacing of 2 km, crosses the southwestern boundary of the Barberton greenstone belt where a potential 3.2 Ga suture zone has been

identified through mapping and petrology (Moyen et al., 2006; Schoene et al., 2009). An additional set of 41 sites are located along two shorter profiles to the southwest and northeast of the main line providing greater areal coverage. We acquired 5-component MT data in a period range from 0.001 s to 1000 s using GPS synchronized S.P.A.M. MkIII (Ritter et al., 1998) and CASTLE broadband instruments. Metronix MFS05/06 induction coil magnetometers and non-polarizable Ag/AgCl telluric electrodes were used to record natural electric and magnetic field variations. The data were processed according to Ritter et al. (1998) and Weckmann et al. (2005).
Because of nearby mining activities and the DC railway line connecting Johannesburg with Maputo, the natural electromagnetic field variations are overprinted by these strong cultural electromagnetic signals. These signal mainly effect MT data in a period range longer than 1s which correspond to sounding depth > 10 km. As long period data require more advanced processing approaches, we concentrate on short period data within this study.

In order to evaluate if the MT data are compatible with a two-dimensional (2D) interpretation, the dimensionality of the electromagnetic fields and the geo-electric strike direction must be determined. We use the ellipticity analysis of Becken and Burkhardt (2004) to confirm that a two-dimensional interpretation is adequate to explain the most relevant features in the data.
For two-dimensional joint inversion of the MT data and the vertical magnetic field we use the inversion algorithm after Rodi and Mackie (2001), starting from a homogeneous half space. For these preliminary results we restrict the model space to the upper 10 km showing electrical conductivity structures of the upper earth's crust.
The MT data and the 2D inversion models are compared with geo-electric and gravity results in the Barberton area by de Beer et al. (1988), from which they concluded that the maximum depth extent of the greenstone belt does not exceed 7-8 km. They also associated the granitoids and plutonic rocks in the greenstone belt with extremely high electrical conductivities.

CONCLUSIONS

Our new magnetotelluric results confirm extremely high electrical resistivities in the Barberton Greenstone Belt, which were found by de Beer et al. (1988). Other results will be discussed in the framework of the existing geologic and geophysical data.

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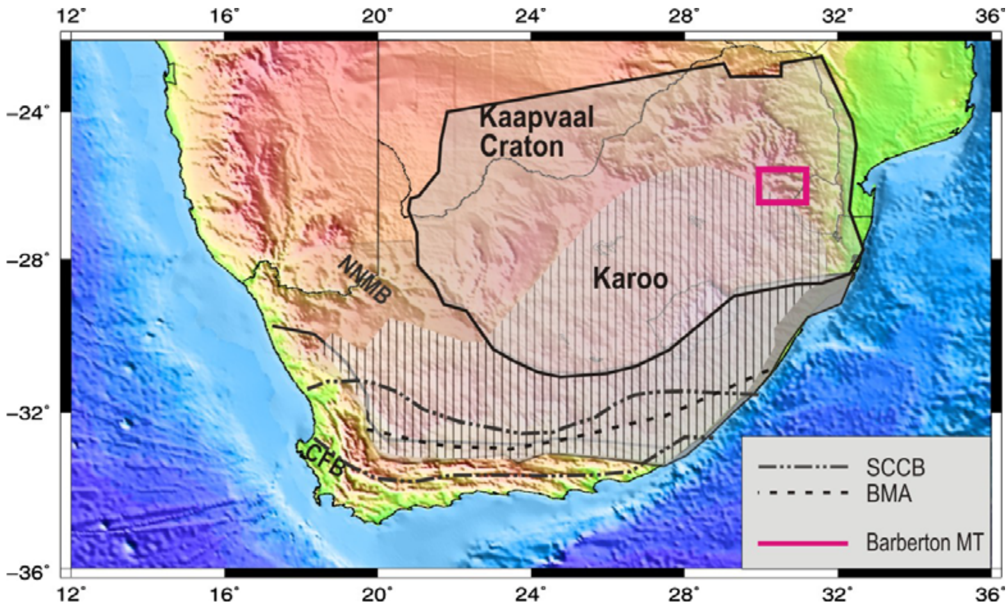

Figure 1: Simplified terrane map of southern Africa showing the Archean Kaapvaal Craton, the Mesoproterozoic Namaqua Natal Mobile Belt (NNMB) and the upper Paleozoic Cape Fold Belt (CFB). A large region is covered by Paleozoic-Mesozoic sediments and igneous rocks of the Karoo Basin (shaded). The axis of the Beattie Magnetic Anomaly (BMA) and the boundaries of the Southern Cape Conductive Belt (SCCB; Fig. 12 in de Beer et al. (1982)) are marked by a dashed line and a dot-dashed line, respectively. The location of the ELIBABA MT experiment is shown by magenta rectangle

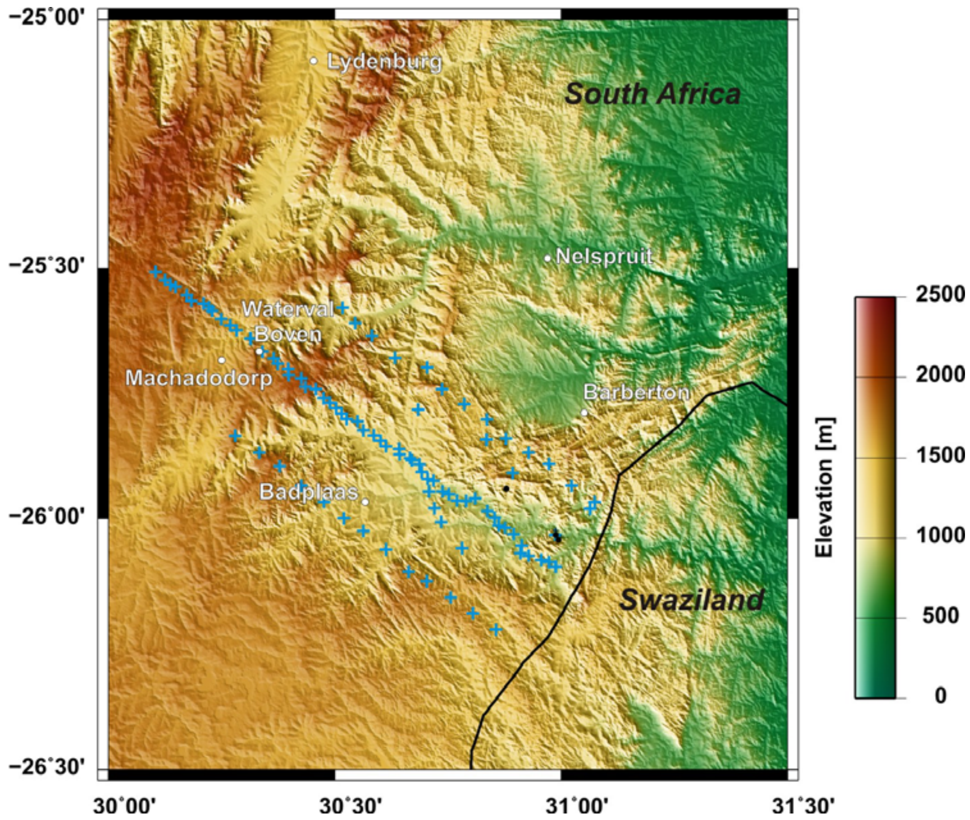

Figure 2: Location of 92 MT sites deployed along a 120 km long profile from the border to Swaziland to Dullstroom on the Great Escarpment and along 2 shorter profiles. The black dots indicate the position of 3 shallow boreholes into one of the Barberton sutures which were completed in August 2008 by de Wit et al. (pers. comm. 2008).