shear wave splitting & anisotropy in dronning maud land / antarctica

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a n t a r c t i c a

::: introduction

Recent investigations on shear wave splitting from recordings of temporary Antarctic seismological stations have shown a significant delay time, δt, of more than 3 seconds. These high values are amongst the highest yet measured and need to be explained in the context of geological/tectonic settings of East-Antarctica and as being caused by complicated mantle strain.

Shear wave splitting occurs when a linear polarized shear wave traverses a seismically anisotropic medium and is split into orthogonally polarized fast and slow shear wave separated by a characteristic delay time, δt. The fast polarisation direction, Φ, expressed as an azimuth, is parallel to the principal axis of extensional finite strain in the deformed, anisotropic medium. The major contribution to the delay time originates in the upper mantle [e.g. Silver & Savage, 1994].

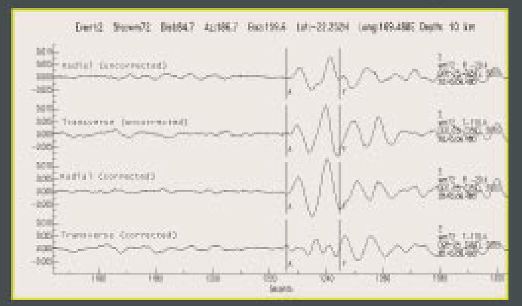
In the upper mantle, splitting is due to (1) Vertically Coherent Deformation (VCD): The crust and subcontinental mantle were deformed coherently in orogenies and anisotropy in the lithosphere remained frozen or/and (2) Simple Asthenospheric Flow (SAF): A decoubling zone exists between the motion of the continental plate and (presumed stationary) mantle below [Silver & Chan, 1988, 1991]. First hypothesis, VCD, is observed i.e. in South America, where the fast polarization axis are parallel to geological features [James & Assumpcao, 1996]. Second hypothesis, SAF, is observed in North America or South Africa [Vinnik, 1995].

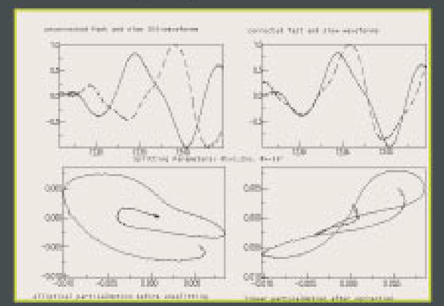
::: splitting measurement

The general idea of measuring the above mentioned splitting parameters, δt and Φ, is to un-split the generated shear wave. [Silver & Chan, 1991] developed a method that estimates the fast polarisation direction Φ and the time delay δt by minimizing the energy on the transverse T-component.

For our investigations individual splitting measurements of generated SKS phases were only taken into account when (1) there was a clear correlation between the waveforms of fast and slow component, (2) a clear elliptical partical motion of the uncorrected waveform was observed, (3) the partical motion after correction was linear, (4) the energy of the transverse component was removed after correction, (5) the SNR between the wavelets were significant high.

Fig. 1,2: These figures represent a final result of one of our temporarely deployed seismological stations on the Wohlthat-Massiv in Central Dronning Maud Land/Antactica. A significant high time delay of more than 3 seconds was several times observed from earthquakes occured in Loyalty Islands.





::: geological & tectonic settings

Several geological and tectonic scenarios during the earth history formed the present-day Antarctic continent. Within the Dronning Maud Land outcrops were formed by several orogenies: (1) The Grenville 1.1 Ga years ago by building the supercontinent Rodinia, (2) the Ross-/Panafrican 500 Ma ago by building the supercontinent Gondwana because of collision between West and East Gondwana - see Fig.3 below.

The break-up of Gondwanaland 180 Ma ago started at the Weddell-Sea (oceanic area in front of DML) and was accompanied by large volcanic activity, magmatism and major outpourings of continental flood basalts [Jacobs, 1998].

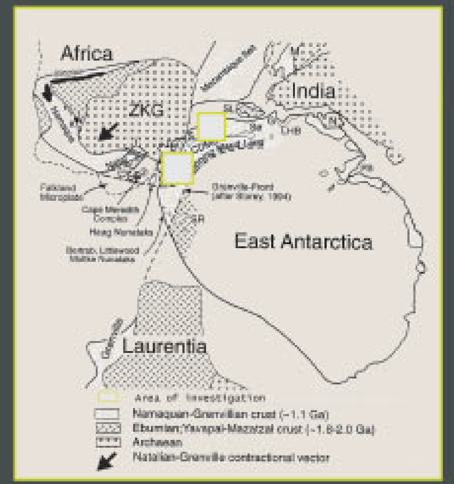
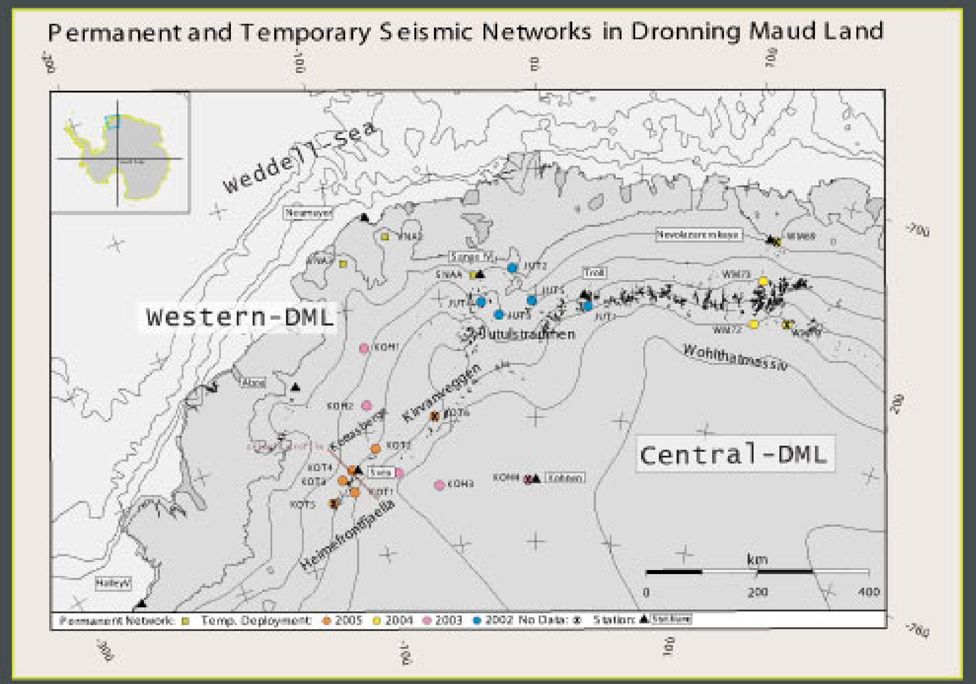


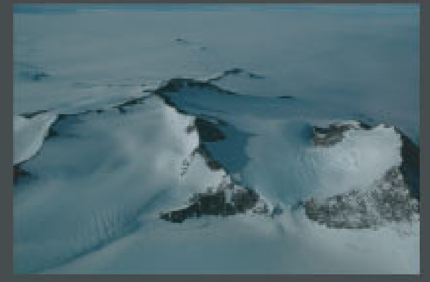
Fig. 3: These cartoon [Jacobs et al. 1998] demonstrates the collision of East and West Gondwana 500 Ma years ago.

Abbreviations are: Heimefrontfjella (H), Central Dronning Maud Land (CDML), Borgmassivet (B), Kirvanveggen (Ki), Lützow-Holm-Butka (LHB), Sverdrupfjella (S), Sri Lanka (SL), Sor Rondane (So), Shackleton Range (SR), Zimbabwe-Kaapvaal-Grunehogna Kraton (ZKG).

::: areas of investigation

Within several polar-summer expeditions seismological stations were deployed along the mountain range in Western Dronning Maud Land (WDML) and Central Dronning Maud Land (CDML) - see Fig. 4 below.





These pictures were taken during the last summer campaign 11.2004 till' 02.2005:

Seismometer were set up along the Kottas Mountains on solid rocks. Average time of registration was about 21 day. Some earthquakes with magnitudes greater 5.5 occured and the generated core shear waves give a result of the splitting parameters (see next sections).

The Panafrican overprint decreases from Central to Western DML. The Kottas Terrane consists mainly of Grenvillian crust, the other part of the shear zone of a Panafrican overprinted crust [Jacobs, 1991].

A seismic profile [Eckstaller, 1991] through this so called Heimefront shear zone shows different crustal thickness:

::: data & first results

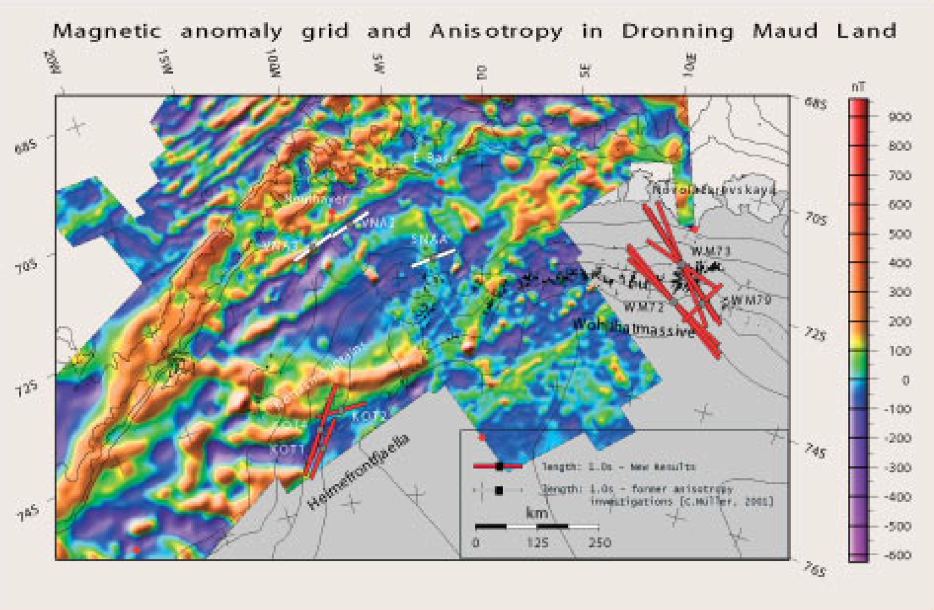
1. Central Dronning Maud Land - Wohlthat-Massiv:

   Some earthquakes occured on Loyalty Islands (BAZ: ~160°, Lat: ~22N, Long: ~169E) during time of registration and were taken into account for our splitting measurements (see Fig.1+2, Tab.1 and Fig. 5 below). Note: The high values of delay time.

2. Western Dronning Maud Land - Kottas Mountains:

   Earthquakes occured on Northern Sumatera and Andaman Islands within time of registration and were taken into account (see Fig.5 below, Tab.2 below and Fig.6). Note: The fast pol. directions follows small-scaled magnetic anomalies (see also Fig.6).

Fig. 5: Results of anisotropy measurements in combination with the actually magnetic anomaly grid. Length of the bars represent measured delay times, fast pol. directions are shown by azimuth.



Tab.1:

Station	time (YYYY-JJJ HH:MM:SS)	pol. direction Φ [°]	time delay δt [s]
wm72	2003-359 20:42:33	-58.0	3.25
	2003-361 16:00:59	-50.0	3.78
	2003-361 22:38:01	-53.0	3.63
wm73	2003-359 20:42:33	-33.0	3.51
	2003-360 21:26:04	-43.0	3.38
	2003-361 16:00:59	-45.0	3.56
	2003-361 22:38:01	-44.0	3.71
	2004-003 08:21:48	-67.0	2.10
wm79	2004-003 16:23:21	33.0	1.31

Tab.2:

Station	time (YYYY-JJJ HH:MM:SS)	pol. direction Φ [°]	time delay δt [s]
KOT1	2005-004 09:13:11	33.0	1.68
KOT2	2004-362 09:39:06	84.0	1.36
	2005-009 22:12:56	84.0	1.30
KOT4	2004-364 21:12:59	30.0	2.51
	2003-360 21:26:04	27.0	1.59

::: summarize & outlook - read this!

Splitting parameters of Kottas Mountains (WDML) are showing time delays, δt, between 1 and 2 seconds and represent therefore values that are often globally observed in similar tectonic regimes. The direction of the fast polarisation axis, Φ, tends to be parallel to the mountain range: Φ is parallel to the principal axis of extensional finite strain (see introduction).

In contrary, abnormal high time delays, δt, between SH-wave and SV-wave are found from recordings of seismological stations that were set up in the Wohlthat-Massiv in CDML. Such values are seldom and only found in the earth upper mantle with a complicated strain field and a strongly deformed upper mantle.

To explain our data in DML some global observation might help to interpet our results: Orogenies built by continent-continent collision (see Fig. 3) occasionally show such high values. Schoenecker et. al. (1997) presented delay times from Hindu Kush-Pamir region in the same order and interpreted the results in the context of subducted slabs and shear and compressional flattering around the slabs caused by the former India-Eurasia collision (continent-continent). Chen et. al, (2003) demonstrated a unequivocal case of anisotropy in the transition zone beneath Fiji-Tonga. They interpreted the anisotropy as a strong fabric assossiated with a large petrologic anomaly in the core of a remnant lithosphere which is buoyant and stagnates in the transition zone.

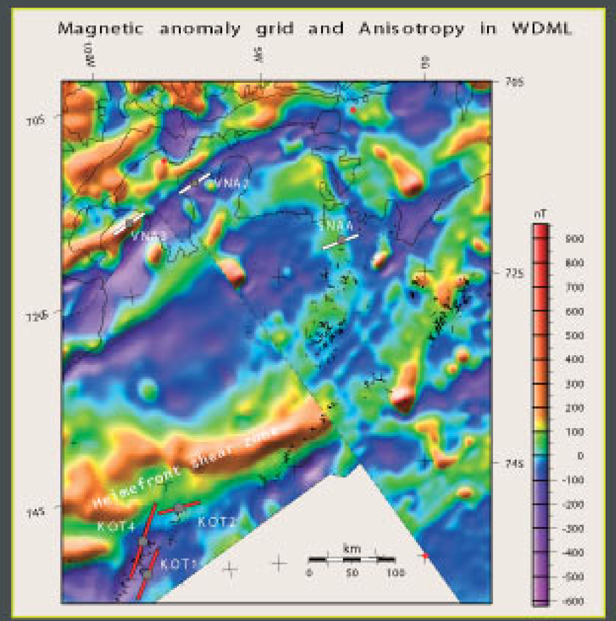


Fig. 6:

Registrations of the Kottas Mountains show that directions of the fast polarisation axis, Φ, are parallel to small-scale magnetic anomalies, and the Heimefront shear zone, which is build up of crust with different ages.

Future work in this area will include investigations on

:: local seismicity

:: the crustal thickness beneath the recording seismological stations from Receiver Functions

:: the magnetic anomaly field especially of the Central Dronning Maud Land and the Wohlthat Massiv. This data set will be integrated with the seismology results.

To extend the local information on the crustal thickness, aerogravity data will be used to provide a first order regional model on crustal thickness.

a n i s o t r o p y

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