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Gakkel Ridge at 85°E/85°N: Seismicity and Structure of an Ultraslow Spreading Centre

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Ultraslow spreading ridges are divergent plate boundaries, which spread apart with less than 20 mm/yr. Their appearance is very rugged, with steep rift flanks, numerous normal faults and discontinuous volcanic activity at discrete volcanic centres - drastically different from ridges which spread faster. Due to the inaccessible area where these ridges are found, much less is know about lithospheric structure than at faster spreading ridges.

Gakkel Ridge spans between Greenland and Siberia, crossing through the Arctic Ocean. There, a perennial ice cover inhibits seismic surveys. At 85°E/85°N where the spreading rate is only about 10.2 mm/yr, a volcanic spreading centre is located. It was spectacularly active in 1999, spawning over 250 teleseismically registered earthquakes with body wave magnitudes up to 5.2 and lasting 9 months. At this site, volcanic cones and fresh lava were captured by seafloor imagery in 2007.

Making use of the ice cover, three arrays of four seismometers each were deployed in 2007 on ice floes, drifting 16 days over the area and recording more than 300 local events. Due to the drift of the ice floes, the location of the arrays changed with time, resulting in sufficient ray coverage suitable for a local earthquake tomography. We present here the results of this tomography, the first ever done at an ultraslow spreading centre.

We compiled a 1D local velocity model from confidently located hypocentres. While incorporating the varying 3D bathymetry and the water layer, we used 124 microearthquakes which had been recorded by at least two arrays for generating a local 3D earthquake tomographic model. At spreading rates below 20 mm/yr it has been proposed that conductive heat loss should increase, leading to a thinner crust. Yet, our results infer a deep Moho at about 7 km beneath seafloor and hypocentres as deep as 16 km (bsf.) which implies an exceptionally thick crust and cold lithosphere. Theoretical thermal models for the axial lithospheric depth for ultraslow spreading ridges also predict a lesser maximum depth and therefore may have to be refined.

In contrast to faster spreading ridges which show a symmetric pattern of velocity anomalies with respect to the rift axis, our P-wave velocity image revealed an area of decreased seismic velocities (up to 0.2 km/s variation) crossing the rift valley at the location of the volcanic cones, which were believed to be the site of the most recent volcanic activity. A region of increased seismic velocities (up to 0.2 km/s variation) lies directly to the southeast, also in the middle of the rift valley. Mainly, seismicity is located where the velocity gradient is highest between the positive and the negative velocity perturbation. This implies that the microearthquake activity stems from the relaxation of thermal stresses caused by recently emplaced warm material.