Geophysical and geochemical signatures of Archaean and Proterozoic lithosphere in Siberia and Fennoscandia

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Mantle-derived xenoliths and xenocrysts can be used to obtain information on the thermal state and composition of the lithosphere using techniques developed by O'Reilly & Griffin (1996) and Ryan et al. (1996). These techniques provide an estimate of the paleogeotherm, which serves as a reference for determining the depth of origin of individual mineral grains (garnet, chromite) for which temperatures are determined by trace-element thermometers (Ryan et al. 1996). The depth to the base of the chemically defined lithosphere is determined by the change from depleted (lithospheric) to undepleted (asthenospheric) trace-element signatures in garnet (Griffin & Ryan 1995).

For the geophysical analysis, we use a method based on the wavelength relationship between gravity and topography data (Forsyth 1985, Poudjom Djomani et al. 1995, 1999) to estimate the flexural rigidity (D) of the lithosphere, or its effective elastic thickness (*Te*). This technique is used to map major lithospheric domains with different geophysical properties. We then use a combined interpretation of the mantle petrology and geophysical data to define fundamental lithospheric terranes with different stabilisation ages on the Siberian platform and in Fennoscandia.

Geological setting

The Siberian platform represents a relatively stable area, surrounded by major Phanerozoic suture zones formed during the assembly of the Pangean supercontinent during the Paleozoic and Mesozoic. Provinces and terranes within the craton have been mapped on the basis of known crustal shear zones, boreholes to basement, crustal xenolith suites in kimberlites and especially by regional-scale magnetic anomaly patterns. A 1000-km long kimberlite field with ages ranging from Paleozoic to Mesozoic runs NNE from the centre of the craton to its northern margin. Mantle material from these kimberlite fields has been analysed to construct mantle sections on the Siberian platform (Griffin et al. 1998, O'Reilly et al. 2001).

Fennoscandia represents a part of the East European platform and is made up of the Baltic shield and the Caledonides of Norway and northern Sweden. This part of the platform has been formed by a series of major orogenic events over the period from Archaean (ca. 3 Ga) to Paleozoic (< 0.5 Ga). A series of crustal provinces can be recognised, based on the age and structure of the underlying crust (Gaal & Gorbatschev 1987). Mantle material from several xenolith localities throughout the area has been analysed to provide information on the thickness, composition and thermal state of the lithosphere in Fennoscandia (Griffin & Kresten 1987, Kukkonen & Peltonen 1999).

Results and conclusions

On the Eastern Siberian platform, mantle sections constructed from the analysis of garnet and chromite concentrates reveal that the Archaean terranes are underlain by typical depleted Archaean lithosphere > 200 km thick, while the Proterozoic terranes are underlain by thinner and less depleted lithosphere (Griffin et al. 1998). The estimation of the *Te* of the lithosphere refines these lithospheric boundaries, and reveals a major zone, ~ 150 km wide, of very weak lithosphere (*Te* < 10 km) running N-S across the western part of the craton (Poudjom Djomani et al., submitted to Exploration Geophysics; Fig. 1). This zone coincides with thicker lithosphere, lower surface heat flow and thicker lower crust, as well as abnormally high sub-Moho P-wave velocities suggesting an anisotropy in the upper mantle. The kimberlite fields in the Archaean part of the platform are localised on the western flank of this zone of weak lithosphere. We suggest that the low *Te* reflects a mantle shear zone which has been a preferred conduit for fluids (e.g. magmas) into the lower crust, and has controlled the location of kimberlite emplacement in the study area.

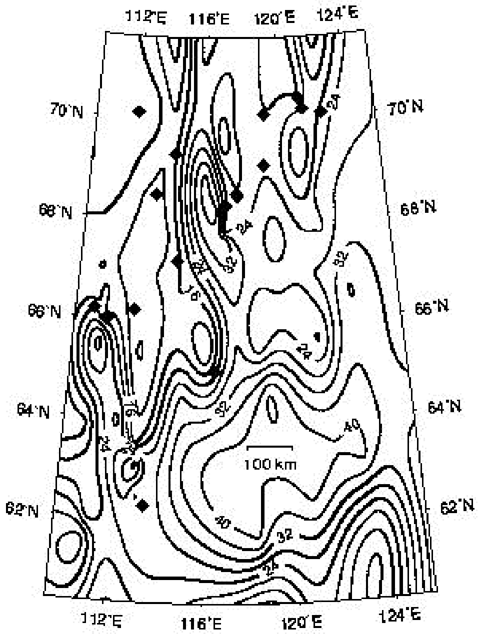

Figure1. Effective elastic thickness contour map of the Siberian platform. Contour interval 4 km. The black diamonds represent the kimberlite fields where mantle material was analysed to construct mantle sections.

In Fennoscandia, the geophysical analysis shows a regional variation in elastic plate thickness from 8 km in relatively "young" areas, to 70 km in "older" areas (Poudjom Djomani et al. 1999). These results suggest that the lithosphere is strongest in the relatively stable Archaean Province, weaker in the regions characterised by Proterozoic crustal formation, and lowest in the tectonically reworked and deformed Caledonian belt. Furthermore, the results show that there is a direct correlation between lithosphere strength (*Te*), the age of the last major tectonothermal event registered in the crust and lithospheric mantle composition. These broad correlations reflect thinner and more fertile lithosphere, and higher geothermal gradients, beneath regions of progressively younger crust. These results are summarised in Table 1.

Table 1. Comparison of Te with crustal provinces and other parameters in Fennoscandia. The Paleo LAB (the Lithosphere-asthenosphere boundary) and geothermal gradients are estimated from xenocrysts in volcanic rocks at different points in the study area. The Present LAB is the lithosphere-asthenosphere boundary seismically determined.

Crustal Provinces	Tectono-thermal age	Paleo LAB (km)	Geothermal gradients	Heat flow (mW.m-2)	Present LAB (km)	Moho depth (km)	Te (km)
Karelia	3 Ga	~220	low	<30	220	44-46	68
Kola	2.3 Ga	~220	low	30-40	200	42	48-60
Svecofennia	1.9 Ga	<150	high	50-60	110-150	40-44	20-28
Sveconorwegian	1.0 Ga	<100	high	60-70	110-130	~40	20-28
Caledonides	400-500 Ma	<100	high	50-60	~110	~30	<12
Oslo Rift	250-300 Ma	<100	high	60	~120	~34	10

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