T11D-09 Lithospheric Structure in Fennoscandia

Yvette H.Poudjom Djomani, Department of Earth Sciences, University of Leeds, LS2 9JT, England, Y.Poudjom@earth.leeds.ac.uk
J. Derek Fairhead, GETECH, Department of Earth Sciences, University of Leeds, LS2 9JT, England.

1. OBJECTIVES

- To use existing gravity data to refine tectonic domains.
- To use gravity and topographic data to estimate the flexural rigidity or, equivalently, the Effective Elastic Thickness (Te) of the lithosphere and its isostatic response.
- To compare our Te results with other geological and geophysical data in order to find the relationship between Te and other parameters.

2. Fennoscandia: the Background

Figure 1 shows the main tectonic provinces of Fennoscandia with ages ranging from Archean in the northeast, to Late Proterozoic in the southwest, and the Svecofennian Domain in the center. The Archean domain is made of the granite-greenstone terrains of Karelia and the Kola Peninsula separated by the Belomorian Province. These greenstone belts are probably related to suture zones in the Archean crust.

The Svecofennian domain is formed of granitoid intrusions coeval with calc-alkaline volcanism. The Lapland Granulite Belt (LGB) limited to the south by a major thrust fault is a dominant feature in the Svecfennian domain. Its continuation to the southeast is not well resolved.

The Southwest Scandinavian domain, derived from the hot lithospheric regime of Lower Proterozoic times, consists essentially of rocks accreted to the craton and later reworked during the Caledonian orogeny.

The youngest structural units in Fennoscandia are the volcanic material filling the Oslo rift, bounded by large normal faults.

3. Previous Geophysical Studies

Fennoscandia has been studied as part of the European Geotraverse (EGT) mainly by the FENNOLORA and POLAR projects.

- Seismic reflection/refraction

Figure 2 shows a Moho depth contour map of Fennoscandia derived from seismic reflection profiling techniques calibrated with seismic refraction data where available (Kinck et al., 1993). The main feature on the map is a thickening of the crust towards the Eastern part of Fennoscandia. The crust beneath the Caledonides is relatively thin (30-36 km) while in the Svecofennian domain, the crust thickens from 40 to about 44 km. The Oslo rift is associated with a pronounced Moho elevation. The maximum Moho depth is found to the south of the Kola Peninsula where it exceeds 50 km.

- Tomographic Studies

A 3-D inversion of teleseismic delay time of P- and S-wave velocities shows that the Fennoscandian border zone, the Oslo rift, the basin areas offshore and the Caledonides are associated with relative low P- and S-wave velocities as compared to the rest of Fennoscandia (e.g., Bannister et al., 1991).

- Seismicity

A global seismicity map of Fennoscandia (Ringdal et al., 1982; Gregersen et al., 1992) shows that most of the earthquakes are concentrated in the offshore areas where the Moho depth is shallowest.

• Heat flow

Figure 3 shows the heat flow contour map of Fennoscandia (Cermak et al., 1993). On this map, the Archean crust to the east is associated with relatively low heat flow (≤40 $mW.m^{-2}$) while the heat flow to the southwest and Caledonian domain is between 60-70 $mW.m^{-2}$

• Thermal Lithospheric Thickness

Pasquale et al. (1991) calculated the thermal lithosphere thickness in the Baltic shield based on steady-state heat conduction modelling. They found that the lithosphere is thickest in shield areas (Kola Peninsula, Bothnian Bay) and thinnest (~100-150 km) in the rest of Fennoscandia. The results show that there is a negative correlation between the thermal lithosphere thickness and the mantle heat-flow density.

Summary: Seismic, seismicity, geological and thermal data show that the lithosphere has a different behavior in parts of Fennoscandia. In this study, we use gravity and topography data as a new input in the knowledge of the lithospheric structure in Fennoscandia.

4. THIS STUDY

A. <u>Refining the tectonic domains</u>

A 8 km gravity grid was used to delineate the tectonic domains in Fennoscandia. **Figure 4** shows a Bouguer gravity map of Fennoscandia overlaid on a gradient map. The map clearly shows:

- the long wavelength gravity low associated with the Caledonides to the west changing gradually to positive anomalies towards the east.
- The continuation of the Lapland Granulite thrust belt to the east (south of the Kola Peninsula) is also well evidenced on the map.
- The positive anomalies associated with the Riphean aulacogens filled with Upper Paleozoic sediments.

Figure 5 shows the 8 km topographic elevation grid in Fennoscandia. The map is dominated by high elevation over the Caledonides and the Archean domain, and the elevation drops gradually to negative values in the sea.

B. <u>Isostatic Response</u>

We estimate the flexural rigidity (D), or, equivalently the effective elastic thickness (Te) of the lithosphere in Fennoscandia. The method used is the coherence function analysis which exploits the wavelength dependence between gravity and topography (Forsyth, 1985).

We selected a total of 30 subgrids in Fennoscandia to solve for Te. The size of the subgrids was small enough such that Te does not vary significantly within a subregion. Then, the Te values obtained were gridded using a minimum curvature algorithm and a cell size of 80 km (approximate distance between 2 data points).

Figure 6 shows the resulting Te contour map of Fennoscandia. Te varies from 8 km in the Caledonides to more than 70 km in the east. The contour map clearly shows the sharp boundary between the Caledonides and the Svecofennian domain. The lithosphere is stronger in the Archean domain in the northeast, relatively weak in the Svecofennian domain in the center and weakest in the southwest Caledonides. This shows that there is a correlation between Te and tectonic provinces.

C. Correlations between Te and other parameters.

- Te and tectonic age: Variations in Te correlate with the tectonic age of the major crustal domains in Fennoscandia. The Archean domain is stronger than the southwest Caledonian domain which is tectonically more recent.
- Te and Moho depths: A comparison of **Figures 2** and **6** shows that areas of thick crust (eastern part of Fennoscandia) correlate with relatively high Te or strong lithosphere.
- Te and seismicity: The earthquakes are confined in the offshore areas where we obtain the lowest values of Te (8-10 km). This correlation suggests that the strength of the lithosphere controls the occurrence of seismic events.
- Te and seismic wave velocities: Our Te results show that areas of lithospheric weakness correlate with areas where P- and S-wave velocities are slow or areas associated with an abnormal upper mantle structure.
- Te and heat flow: A comparison of **Figure 3** and **6** shows that areas of relatively low Te correlate with areas where the heat flow is high suggesting that there is a negative correlation between the two parameters.

5. CONCLUSIONS

- Using gravity data, we have delineated the possible continuation of the thrust fault south of the Lapland Granulite Belt to the southeast.
- The main in come of this study is an effective elastic thickness (Te) contour map of Fennoscandia. This map shows that Te is at it minimum in the Caledonides and its maximum in the Archean domain.
- Te is proportional to crustal thickness and inversely proportional to geothermal gradients (heat flow) and seismicity.
- The lithosphere is weak in areas where P- and S-wave velocities are slow.
- The Te contour map shows sharp boundaries between the tectonic domains (e.g., the Caledonides and the Svecofennian domain).

The above variations in Te and correlations with other parameters suggest that the lithosphere in the crustal domains of Fennoscandia has a differing isostatic response. Thus, Te can be used to map out variations in lithospheric structure.

6. SELECTED REFERENCES

Cerwak, V., Balling, N., Kukkonen, I., and Zui, V.I., 1993. Heat flow in the Baltic Shield - results of the lithospheric geothermal modelling. *Precambrian Res.*, 64: 53-65.

Forsyth, D.W., 1985. Subsurface loading and estimate of flexural rigidity of continental lithosphere. *J. Geophys. Res.*, 90: 12,623-12,632.

Gaal, G., and Gorbatschev, R., 1987. An outline of the Precambrian evolution of the Baltic Shield. *Precambrian Res.*, 35: 15-52.

Gregersen, S., Korhonen, H., and Husebye, E.S., 1991. Fennoscandian dynamics present-day earthquake activity. *Tectonophysics*, 189: 333-344.

Kinck, J.J., Husebye, E.S., and Larsson, F.R., 1993. The Moho depth distribution in Fennoscandia and the regional tectonic evolution from Archean to Permian times. *Precambrian Res.*, 64: 23-51.

Pasquale, V., Verdoya, M., and Chiozzi, P., 1991. Lithospheric thermal structure in the Baltic shield. *Geophys. J. Int.*, 106: 611-620.