NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Scientific Report No. 1-81/82

SEMIANNUAL TECHNICAL SUMMARY

1 April 1981—30 September 1981

By
Jørgen Torstveit (ed.)

Kjeller, December 1981

VI.4 Mantle heterogeneities beneath Fennoscandia

As part of NORSAR's comprehensive program for seismological mapping of upper mantle heterogeneities, travel time observations from the Fennoscandian network (Fig. VI.4.1) have been subjected to a 3-D inversion analysis similar to that described in Section VI.3. The region in question is interesting in the sense that the Baltic Shield constitutes its dominant tectonic feature as shown in Fig. VI.4.2. We note in passing that NORSAR scientists and colleagues in the past have undertaken detailed studies of parts of this region, e.g., see King and Calcagnile (1975), Aki et al (1977), England et al (1978), Haddon and Husebye (1978), Christoffersson and Husebye (1979), Calcagnile and Panza (1978), Sacks et al (1978), Troitskiy et al (1981) and Thomson and Gubbins (1982).

Data analysis and results

The observations in terms of P-wave travel time residuals were taken from the ISC bulletin tapes for the period 1964-77 and thus permitted us to include stations no longer operational like KRK, GOT & KLS (Fig. VI.4.1). The motivation for this was that the minimum size of structural heterogeneities to be resolved is a function of the station interspacing within the network. In this respect the Fennoscandian network is much coarser than that of Iceland (Section VI.3) and not at all comparable to that of NORSAR itself (Troitskiy et al, 1981). At a later stage, however, we will use data from the new, southern Scandinavian network, which comprises some 25 new stations with an interspacing of around 50-75 km.

The Fennoscandian inversion results in terms of percentage seismic velocity anomalies are displayed in Fig. VI.4.2. The standard earth reference model used was that of Dziewonski et al (1975) for continental areas. The estimated standard errors were of the order of 1 per cent except for poorly resolved (resolution less than 0.5) peripheral nodes which are specially marked in Fig. VI.4.2. In the following we will comment on the velocity anomaly patterns at the respective levels.

Level 1 (0-100 km). The anomaly pattern here is dominated by a velocity high over the central parts of Fennoscandia, the Bothnian Bay. Otherwise, there is indication of a negative anomaly straddling the Barents Sea to the northwest. This is an intracontinental sedimentary basin whose crustal structure is found to be considerably different from that of the Baltic Shield (e.g., see Levshin and Berteussen, 1978; and Bungum et al, 1981). Unfortunately, the resolution was very poor in the southern part of the network area, so it was not feasible to test whether the various tectonic provinces adjacent to the Baltic Shield (Fig. VI.4.x) also have a seismic manifestation.

Level 2 (100-300 km). The anomaly pattern here is rather similar to that of level 1 with velocity lows in the Caledonides of western and northern Norway. The dominant velocity high coincides roughly with the areal extent of the Baltic Shield and thus confirms long-standing hypotheses that such tectonic provinces constitute deep-seated, relatively homogeneous parts of the upper mantle in analogy with the tectonosphere concept.

Level 3 (300-500 km). The characteristic features here are weak anomalies and no similarity to those at level 2. In a plate tectonic context we may take levels 1 and 2 to constitute the lithosphere which in turn is decoupled from the underlying asthenosphere of level 3. Sacks et al (1978) reported indications of a discontinuity beneath the Bothnian Bay at a depth of 230 km which tentatively has been interpreted as the lithosphere/asthenosphere boundary. Likewise, Calcagnile (1982) on the basis of Rayleigh wave dispersion analysis finds that the central parts of the Baltic Shield exhibit a considerably thicker lithosphere than the adjacent areas to the west.

Level 4 (500-600 km). Also this layer appears remarkably homogeneous, although less so than layer 3. The very existence of heterogeneities in this part of the upper mantle is probably related to geochemical/geothermal anomalies associated with the 650 km discontinuity. We remark that heterogeneities at depths greater than 600 km may be 'projected' into layer 4.

Discussion

The essential result obtained is that the surface expression of the Baltic Shield has a relatively high seismic velocity counterpart some 300 km down in the upper mantle. Quantitatively, this explains some characteristic features of Fennoscandian seismograph recordings, namely, relatively large amplitude P-wave recordings and 'early' arrival times for events in western Russia and central Asia. In a future study we will attempt to quantify wave propagation through 3-D media of the above kind also in terms of an associated Q-structure.

E.S. Husebye
J. Hovland

References

Aki, K., A. Christoffersson & E.S. Husebye, 1977: Determination of the three-dimensional seismic structure of the lithosphere, J. Geophys. Res., 82, 277-296.

Bungum, H., S.E. Pirhonen & E.S. Husebye, 1980: Crustal thicknesses in Fennoscandia. Geophys. J.R. astr. Soc., 63, 759-774.

Calcagnile, G., 1982: The lithosphere-asthenosphere system in northwestern Europe inferred from the dispersion of surface waves. Tectonophysics, in press.

Calcagnile, G. & G. F. Panza, 1978: Crust and upper mantle structure under the Baltic Shield and Barents Sea from the dispersion of Rayleigh waves. Tectonophysics, 47, 59-71.

Christoffersson, A. & E.S. Husebye, 1979: On 3-dimensional inversion of P-wave time residuals. Option for geological modeling. J. Geophys. Res., 84, 6168-6176.

Dziewonski, A.M., H.L. Hales & E.R. Lapwood, 1975: Parametrically simple earth models consistent with geophysical data. Phys. Earth Planet. Int., 10, 12-48.

England, P.C., B.L.N. Kennett & M.H. Worthington, 1978: A comparison of the upper mantle structure beneath Eurasia and the North Atlantic and Arctic Oceans, Geophys. J.R. astr. Soc., 54, 575-585.

Haddon, R.A.W. & E.S. Husebye, 1978: Joint interpretation of P-wave time and amplitude anomalies in terms of lithospheric heterogeneities. Geophys. J.R. astr. Soc., 55, 19-44.

Hovland, J. & E.S. Husebye, 1981: Three-dimensional seismic veloccity image of the upper mantle beneath southeastern Europe. In E.S. Husebye & S. Mykkeltveit (eds.), Identification of Seismic Sources - Earthquake or Underground Explosion, 589-605, D. Reidel Publ. Co.

Hovland, J., D. Gubbins & E.S. Husebye, 1981: Upper mantle heterogeneities beneath central Europe. Geophys. J.R. astr. Soc., 66, 261-284.

King, D.W. & G. Calcagnile, 1976: P-wave velocities in the upper mantle beneath Fennoscandia and western Russia, Geophys. J.R. astr. Soc., 46, 407.

Levshin, A. & K.-A. Berteussen, 1979: Anomalous propagation of surface waves in the Barents Sea as inferred from NORSAR recordings. Geophys. J.R. astr. Soc., 56, 97-118.

Sacks, I.S., J.A. Snoke & E.S. Husebye, 1979: Lithosphere thickness beneath the Baltic Shield. Tectonophysics, 56, 101-110.

Thomson, C. & D. Gubbins, 1982: Three-dimensional lithospheric modelling at NORSAR: Linearity of the method and amplitude variations from the anomalies. Geophys. J.R. astr. Soc., in press.

Troitskiy, P., E.S. Husebye & A. Nikolaev, 1981: Lithospheric studies based on holographic principles. Nature, 294, 618-623.

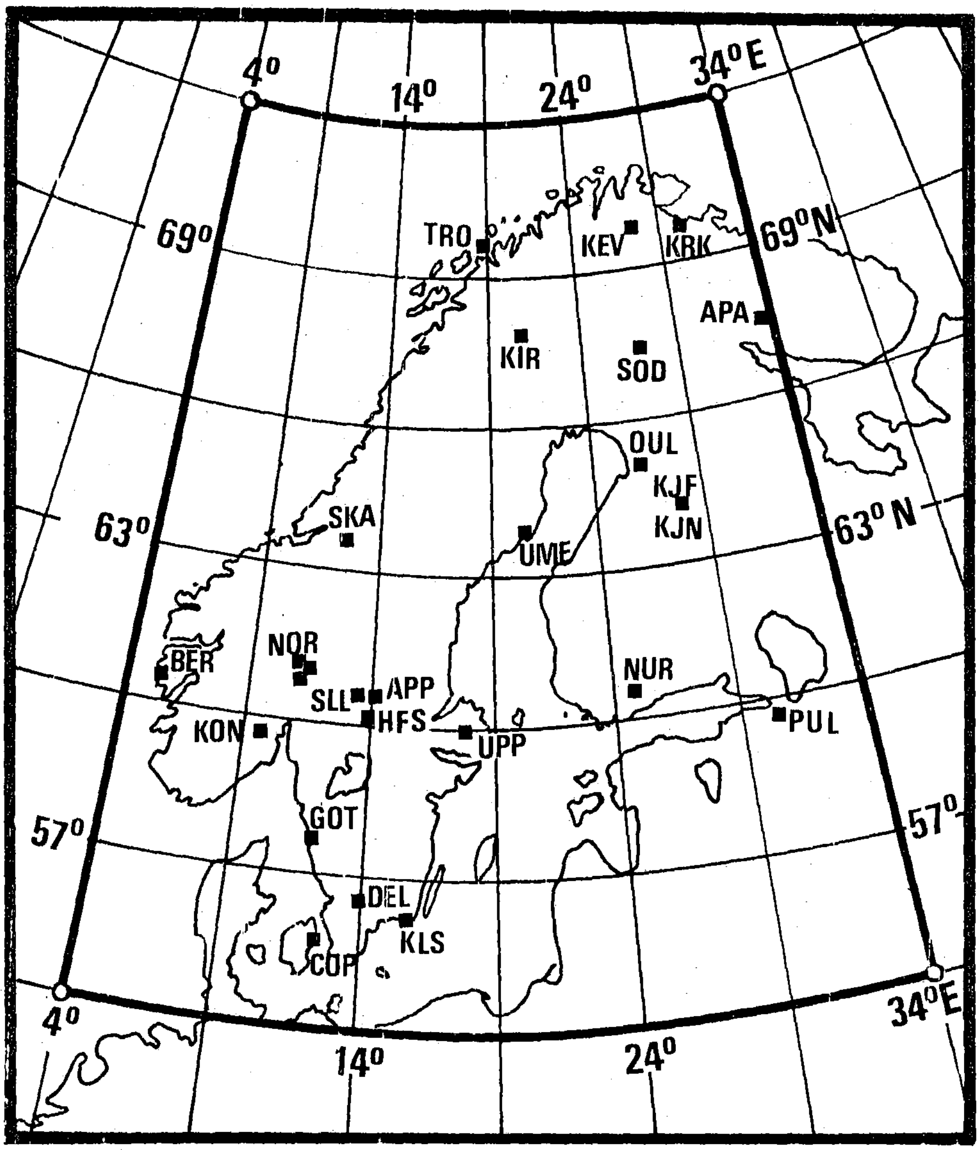

Fig. VI.4.1 Fennoscandian seismograph network whose P-wave travel time residual reportings to ISC were used in analysis.

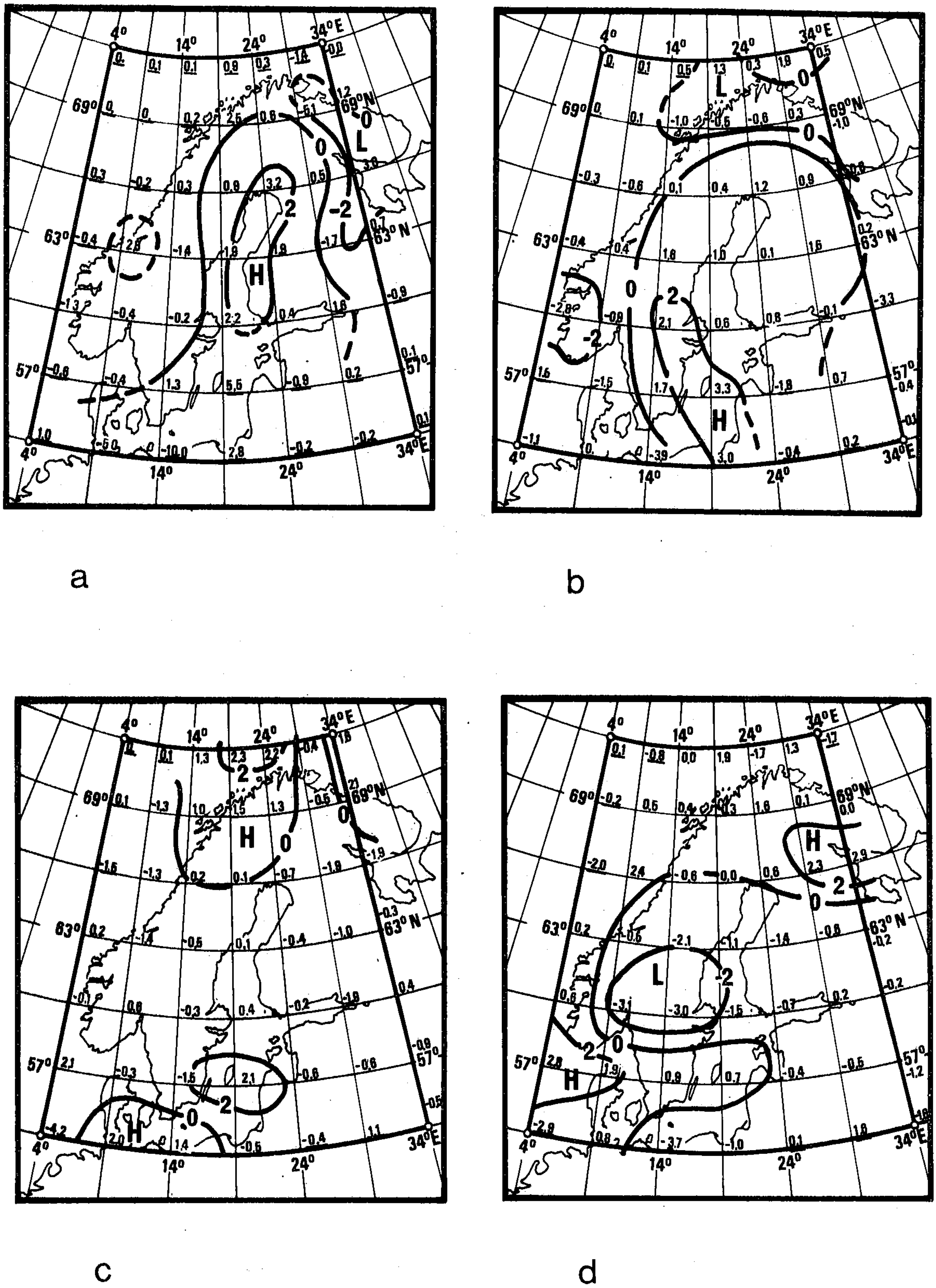

Fig. VI.4.2 (a) Velocity perturbations in per cent for Level 1 (0-100 km). Areas of high and low velocities are indicated by captial letters H and L. (b) Velocity perturbations in per cent for Level 2 (100-300 km). (c) Velocity perturbations in per cent for Level 3 (300-500 km). (d) Velocity perturbations in per cent for Level 4 (500-600 km).