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Edited by

H. Gjøystdal

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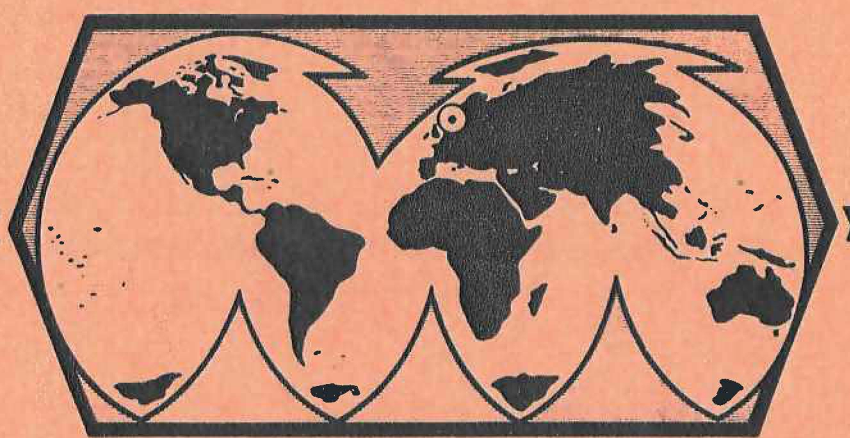

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VI.3 Short Period P-wave Amplitude Variability

In an earlier NORSAR technical summary report (Gjøystdal, 1977) we described in some detail a rather extensive experiment on a deterministic approach to the analysis of short period P-wave amplitude anomalies as observed across the NORSAR array. The essence of this work was that from observed travel time residuals various models for lithospheric velocity contrasts in the form of thin lenses were constructed. Then using a finite difference calculation scheme the expected P-wave amplitude distribution was obtained which in turn was compared to that actually observed from real events. The best fit between observed and calculated amplitude anomalies was obtained for lenses in the depth range 150-200 km, although the theoretical amplitude values could only account for about some 40% of the variance in the observational data. However, the fit between observed and theoretical results is clearly better than the quoted number indicates, that is, the respective anomaly patterns are quite similar and the indicated deteriorated fit stems partly from problems in 'exact' positioning of the two patterns. A reasonable physical explanation here appears to be that the observed wavelength of observed P-time anomalies is significantly larger than that of corresponding P-amplitude anomalies which implies that the 'time'-derived lens models are not sufficiently detailed for very precise amplitude calculation. A consequence of this hypothesis is that the reverse process should be more rewarding, that is, we would intuitively expect a better fit if we tried to predict time anomalies. This has actually be achieved using an energy flux formulation for the lens focusing/defocusing effects which ultimately led to a Poisson differential equation. The main results here were a correlation of about 0.90 between observed and predicted time anomalies.

On the basis of this study (Haddon and Husebye, 1978) it is concluded that time and amplitude anomalies originate from the same lithospheric structures which, as a good first approximation, may be represented in terms of a 2-D heterogeneous layer at depths around 150-200 km or the bottom of the lithosphere. We note in passing that the lithosphere, an integral concept of modern plate tectonics, is not well defined seismologically. However, more recent observations, also at NORSAR, of S-to-P converted waves indicated a well-defined discontinuity at a depth of around 230 km (Sacks et al, 1978; see also Sec. VI.11) which may be taken to indicate a lithospheric thickness of the same order. Furthermore, velocity perturbations required for accounting for the anomalous P-wave amplitude observations amounts to a few per cent and thus are directly compatible with similar results obtained by Aki et al (1976, 1977) and by scattering analysis of precursor and coda waves (Husebye et al, 1976; King et al, 1975; Haddon et al, 1977).

Perspectives. The above study has been completed (Haddon and Husebye, 1978) and some wider applications have been considered, that is, can the methodology used here be adapted to other arrays, networks or conventional seismograph stations. Indeed, we have undertaken some preliminary analysis of LASA data but as the spatial earthquake sampling of this array is less symmetrical than that of NORSAR we have temporarily halted this work. As pointed out above, a major problem in reproducing amplitude anomalies from time anomalies is the difference in wavelengths of these two types of anomalies. On the other hand, the time residual projection scheme used in constructing the lens models has proved very valuable in analysis of absolute travel time anomalies (say those listed in ISC-catalogues). For example, using absolute NORSAR time anomalies we have reproduced those areas of overlap of the thin lens models derived from relative travel times. This result was not too unexpected in view of the exceptionally high quality of the NORSAR data, but as demonstrated by Husebye and Ringdal (1978), the above projection scheme may also be an alternative to conventional analysis of time residuals from seismograph networks of continental dimensions. Furthermore, we are also considering a joint inversion scheme of NORSAR time and amplitude data and in this particular case based on ray tracing principles. Finally, we do consider this type of problem, that is, a better understanding of intrinsic amplitude variations in particular for near-field observations in the distance range 0^o-30^o to be of fundamental importance in a seismic discrimination context. A key word to success here is of course flexibility in modelling seismic heterogeneities in the mantle.

E.S. Husebye
R.A.W. Haddon (Univ. of Sydney)

References

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

Aki, K., A. Christoffersson and E.S. Husebye (1976): Three-dimensional seismic structure of the lithosphere under Montana LASA, Bull. Seism. Soc. Amer., 66, 501-524.

Gjøystdal, H. (1977): Final Report, 1 April - 30 September 1977, NORSAR Scientific Rep. No. 3-76/77, Kjeller, Norway.

Haddon, R.A.W., and E.S. Husebye (1978): Joint interpretation of P-wave travel time and amplitude anomalies in terms of lithospheric heterogeneities. Geophys. J. R. Astr. Soc., in press.

Haddon, R.A.W., E.S. Husebye and D.W. King (1976): Origins of precursors to P'P', Phys. Earth Planet. Inter., 14, 41-70.

Husebye, E.S., A. Christoffersson, K. Aki and C. Powell (1976): Preliminary results on the 3-dimensional seismic structure of the lithosphere under the USGS Central California Seismic Array. Geophys. J.R. Astr. Soc., 46, 319-340.

Husebye, E.S., and F. Ringdal (1978): Seismic mapping of the Fennoscandian lithosphere and asthenosphere, in I.B. Ramberg and E.R. Neumann (Eds.), Tectonics and geophysics of continental rifts, D. Reidel Publ. Co., Dordrecht, Holland, in press.

King, D.W., R.A.W. Haddon and E.S. Husebye (1975): Precursors to PP. Phys. Earth Planet. Inter., 10, 103-127.

Sacks, I.S., A. Snoke and E.S. Husebye (1978): Lithospheric thickness beneath the Baltic Shield. J. Geophys., in press.