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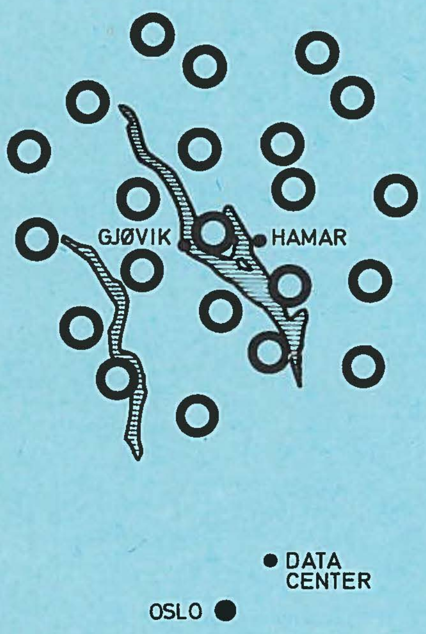
Royal Norwegian Council for Scientific and Industrial Research

VERTICAL AND LATERAL INHOMOGENEITIES IN THE EARTH'S DEEP MANTLE

by

E.S. Husebye[1], R. Kanestrøm[2] and R. Rud[1]



NORWEGIAN SEISMIC ARRAY

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1. Introduction

The gross structure of the Earth's interior is fairly well known, but we are still lacking information on the finer details, i.e., structural heterogenities causing higher order discontinuities in seismic wave velocities. The most fascinating aspect of this problem is the possibility of having lateral velocity variations in the deep mantle.

Support of the above hypothesis comes from recent analysis of measured dT/dΔ values (Chinnery and Toksöz 1967, Hales et al 1968, Johnson 1969) which indicates azimuth dependence in the observations themselves and the individual studies present significantly different results in certain distance intervals. A joint analysis of several types of geophysical data (Toksöz et al 1969) and P-wave diffraction studies (Phinney and Alexander 1969) also favor the existence of lateral inhomogenities in the lower mantle. We have investigated the above problems, using dT/dΔ data which represents an efficient tool for such analysis.

2. Methods and data used

Direct dT/dΔ measurements provide data which is very sensitive to small velocity deviations from a standard earth. In our case we have used the seismic network in Fennoscandinavia as a continental array (Fig. 1), and the dT/dΔ parameter for each event are measured directly (Husebye 1969). The observational data is P-wave arrival times published in seismic bulletins and covering the years 1964-66. Altogether we have analyzed 648 events in the teleseismic distance range 25-105 deg (Husebye et al 1971).

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The bulk of our observational data comes from the Circum-Pacific belt (Peru to New Guinea) and the Alpide belt (Iran to Indonesia) which means that epicenter distances change relatively slowly with azimuth. Before presenting the results obtained, we have to dwell briefly on possible biased errors in the dT/dΔ measurements which may be caused by anomalous structures in the site and/or source areas. In case of Fennoscandinavia, the crustal structures are fairly homogeneous and observed station correction values center around -0.6 to -0.8 sec (Hales et al 1966). A check on possible biased errors which proved negative, was performed by perturbing the array configuration during the dT/dΔ calculations. An examination of the data from the Japan region did not favor observational dependence on local source structures. Our conclusion here is simply that the observed dT/dΔ values reflect the velocity distribution in the deeper mantle.

3. Results

An anomalous velocity variation is synonymous with an anomalous dT/dΔ variation. The relationship between these parameters i given by the Herglotz-Wiechert formulas. The term anomalous implicitly refers to a standard earth which in this paper is that corresponding to the Jeffreys-Bullen tables. The final results of our investigation, i.e., a new velocity structure for the deeper mantle, is presented in Fig. 2. The most striking feature here is the lateral velocity distribution in terms of the two models NOR1 and NOR2 at depths between 1750 and 2300 km. In the latter case, the data is based on earthquakes in the Japan-Indonesia and Central-South America regions having epicentral distances between 60-80 deg. In other distance intervals, the observations seem to be independent of azimuth. Before starting a brief discussion of our results, it should be noted that with discontinuities or inhomogeneities we mean structures associated with decreasing velocity gradients.

The data gives observational evidence for the presence of significant inhomogeneities in the earth's mantle (Husebye et al 1971). These are located at depths of around 850, 1150, 1250, 1650 and 2700 km - and they produce measurable effects on the dT/dΔ curve at distances of around 35, 47, 53, 62 and 87 deg. The above anomalous regions are explainable in terms of vertical inhomogeneities although it is not clear whether the dv/dr curve changes continuously or discontinuously.

Considering the great depths and corresponding high pressures of the proposed anomalous regions, it is questionable if low velocity regions or decreasing P-wave velocity would exist in the deeper mantle. The vertical discontinuities in Fig. 2 agree reasonably with those presented by Chinnery and Toksöz (1967), Johnson (1969), Chinnery (1969) and Corbishley (1970).

On the other hand, for distances between 63-80 deg our dT/dΔ measurements deviate significantly from those of Chinnery and Toksöz (1966) and Johnson (1969), beside azimuth dependence as mentioned previously. A point here is that differences between dT/dΔ observations are much less pronounced at shorter distances. We have interpreted this phenomenon as due to lateral velocity variations, and this hypothesis is in agreement with observed travel time anomalies and those predicted from the NOR models. Further support comes from Phinney and Alexander (1969) who explain anomalous decay of diffracted body waves in terms of lateral inhomogeneities in the lower mantle.

Finally, we should like to remark that in principle, lateral heterogeneities may exist down to the mantle core boundary. This is the conclusion by Toksöz et al (1969) in a spherical harmonic analysis of geophysical data. They found that about half of the surface load differences due to topography and crustal structure are compensated istostatically at a depth of around 400 km, while the compensation process is completed in the lower mantle, or possibly at the mantle-core boundary. As demonstrated above, using seismic arrays for direct measurement of the dT/dΔ parameter seems to be an efficient tool in investigating this type of problem.

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Figure Captions

Fig. 1. The Fennoscandinavian seismograph network.

Fig. 2. Observed vertical and lateral P-velocity inhomogenities in the deeper mantle. The standard Earth is that corresponding to Jeffreys-Bullen (J.-B.) tables.

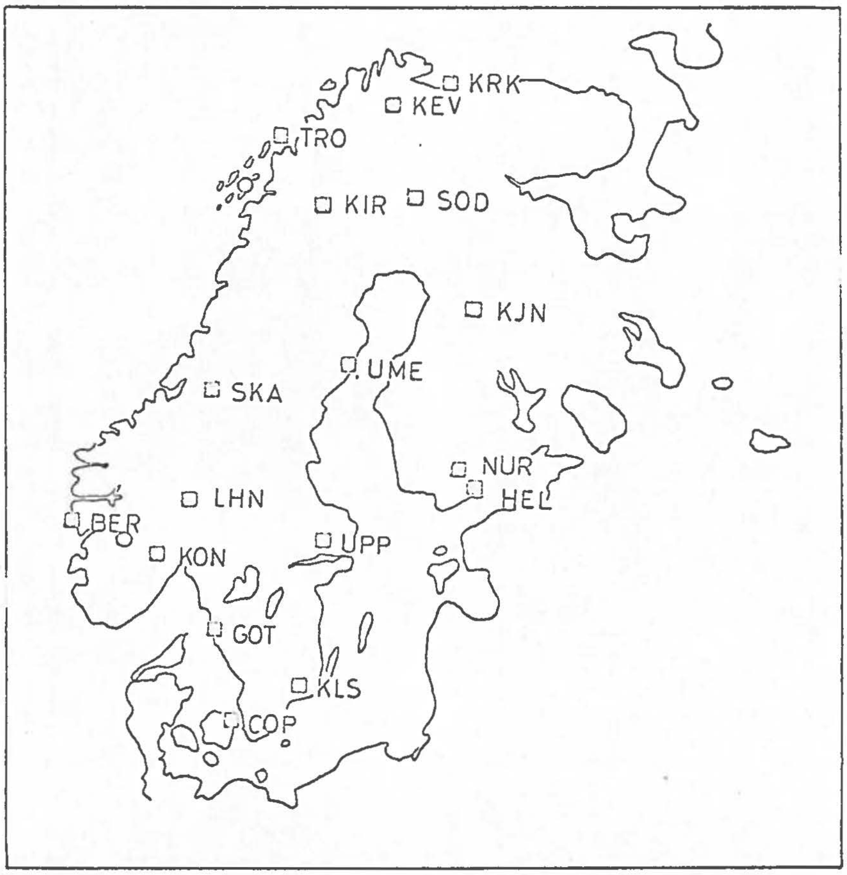
KRK
KEV
TRO
KIR
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Fig. 1

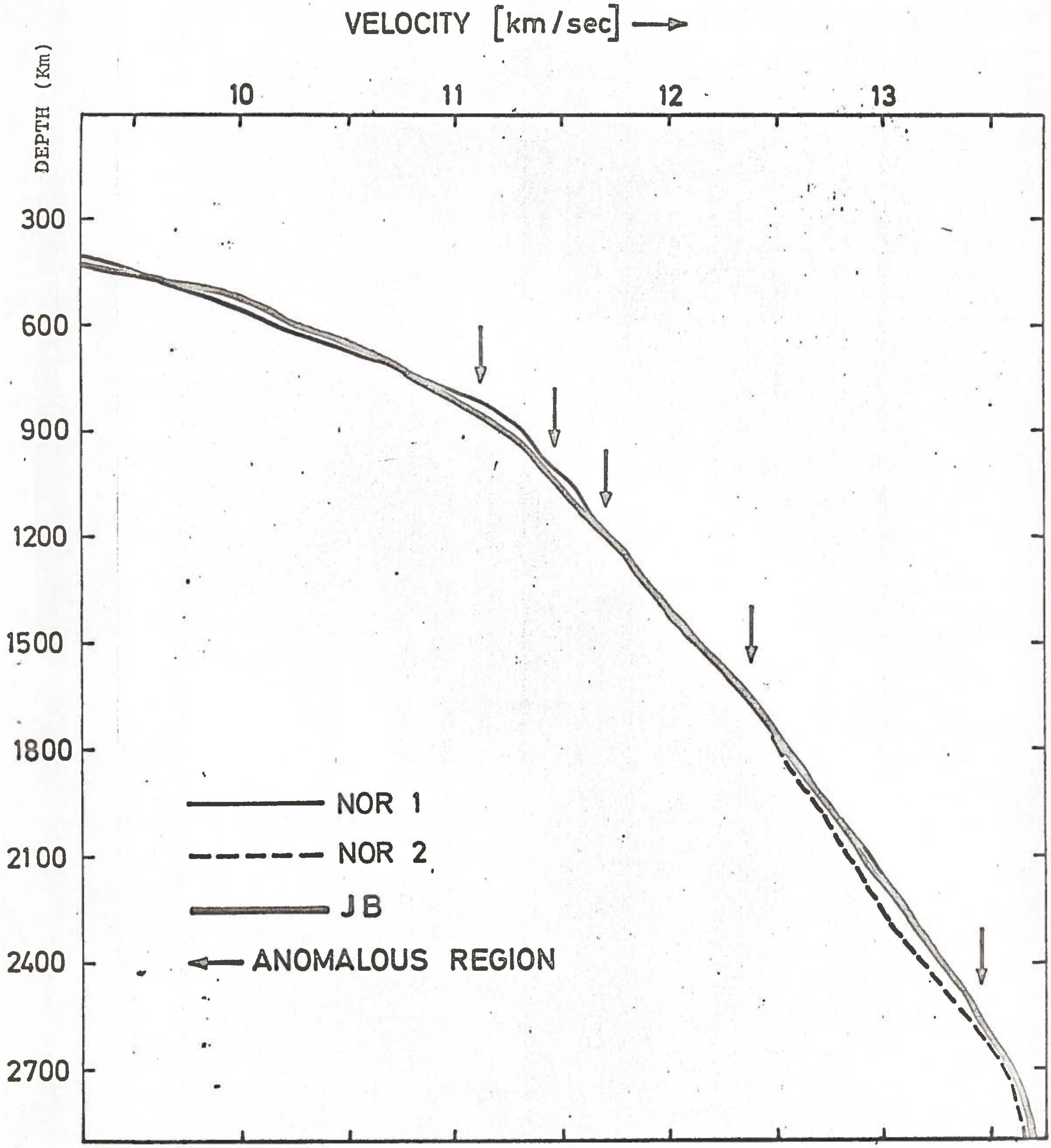
VELOCITY [km/sec]
DEPTH (Km)
10
11
12
13
300
600
900
1200
1500
1800
2100
2400
2700
NOR 1
NOR 2
JB
ANOMALOUS REGION

Fig. 2