NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Scientific Report No. 2-80/81

SEMIANNUAL TECHNICAL SUMMARY
1 October 1980—31 March 1981

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Kjeller, June 1981

VI.8 Three-Dimensional Seismic Velocity Image of the Upper Mantle beneath Southeastern Europe

P-wave travel time residuals for a network of stations in southeastern Europe were used in an inversion experiment to map upper mantle heterogeneities in the network region (Fig. VI.8.1). ISC data from the period 1964-1976 were used. To reduce the large data base, the minimum number of stations reporting an event was set to 50 and we also required that 30% of the network stations had detected the event. We also sorted the events in azimuth/delta intervals of 10^{o}x10^{o} to get as even distribution as possible of rays through the model. The average network time residual was subtracted from the station residuals and the resulting relative residuals are assumed to be caused by lateral variations in P velocity within a confined volume immediately beneath the receivers. The velocity structure is represented by a smooth cubic interpolation between slowness values on a three-dimensional grid of knots and the slowness/velocity perturbations at the individual knots are estimated by minimizing the quantity:

$$(\underline{\delta T}-\underline{A}\underline{m})^*(\underline{\delta T}-\underline{A}\underline{m})+\theta^2\underline{m}^*\underline{m}$$

where $\underline{\delta T}$ is observed travel time residuals, A is a travel path matrix, θ^2 a stochastic inverse smoothing parameter while the $\underline{m}$ vector contains the grid elements of the unknown slowness/velocity perturbations.

The network of stations covers a region from 37.0^{o} to 47.0^{o}N and from 17.5^{o} to 31.5^{o}E, a square of side approximately 1100 km. The anomalous zone has a thickness set to 600 km which includes the upper mantle, where the levels go from 0-100 km, 100-300 km, 300-500 km and 500-600 km, but the data will not discriminate too sharply between the different levels. Level 1, shown in Fig. VI.8.2, is representative of the upper 100 km and corresponds roughly to the lithosphere. The anomalies at this level correlate very well with observed heat flow. From the theoretical correlation between seismic velocity anomalies and heat flow ($\partial v_p/\partial T = 5.0 \cdot 10^{-4}$ km/s/k (Christensen, 1979)), we get about 1.2 per cent variation in P velocity for each 10 mW/m^2 change in heat flow for a 100 km thick layer. The heat flow range of 30 to 100 mW/m^2 matches the velocity anomaly range of -5.4 to 3.4 per cent. An exception here is the velocity low of -3.6 per cent in the Ionian Sea which has a low heat flow. The velocity lows for S. Greece and SW Turkey are in agreement with high heat flow values in the same areas, and also with the extensional tectonics proposed by McKenzie for the Aegean Sea. Low velocity and high heat flow are also found in the southeastern part of the Pannonian basin, while high velocities and low heat flow are found over Bulgaria and the thermally cold Black Sea and also in southwest Yugoslavia.

The dramatic change in the anomaly picture from level 1 to level 2 agrees with the plate tectonic axiom of general decoupling between the lithosphere and the aesthenosphere. The high velocity zone north of Crete coincides with the earthquake zone which goes down to 150 km depth and clearly indicates the northern extension of a relatively cool, high velocity subducting slab (Gregersen, 1977). The high velocity extends far below southwest Greece but cannot be associated with present day subduction, although the hypothesis of a remnant slab prior to 15 m.y. ago cannot be ruled out. The low velocities beneath the northern Aegean Sea and Bulgaria are interpreted as supporting McKenzie's hypothesis of convective upwelling in the aesthenosphere as part of his extensional tectonic model for the Aegean Sea. The low velocities to the north indicate that the Pannonian basin is possibly deeply rooted in the aesthenosphere.

The levels 3 and 4 are not mapped here but the anomalies can be accounted for by variations in the depth to phase changes associated with the '400 km' discontinuity and possibly also the '650 km' discontinuity.

For further details see Hovland and Husebye (1981).

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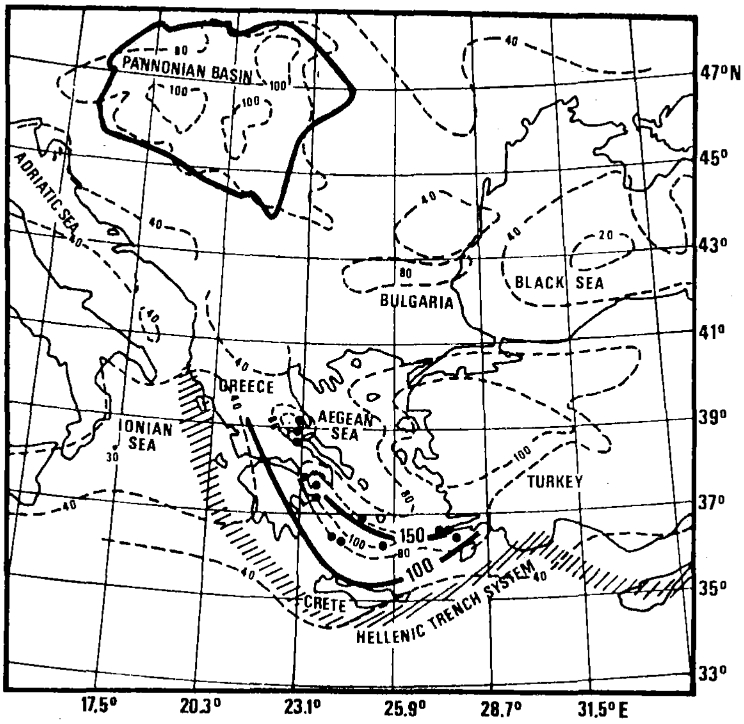

Fig. VI.8.1 Outstanding geophysical and seismological features of direct interest to this study. The heat flow data are taken from Cermak and Ryback (1979). The chain of dots north of Crete indicate volcanic activity, while the nearby two thin lines mark the 100 and 150 km iso-depth of intermediate earthquakes. To the north the intra-Carpathian basins are 'lumped' together under the notation Pannonian Basin.

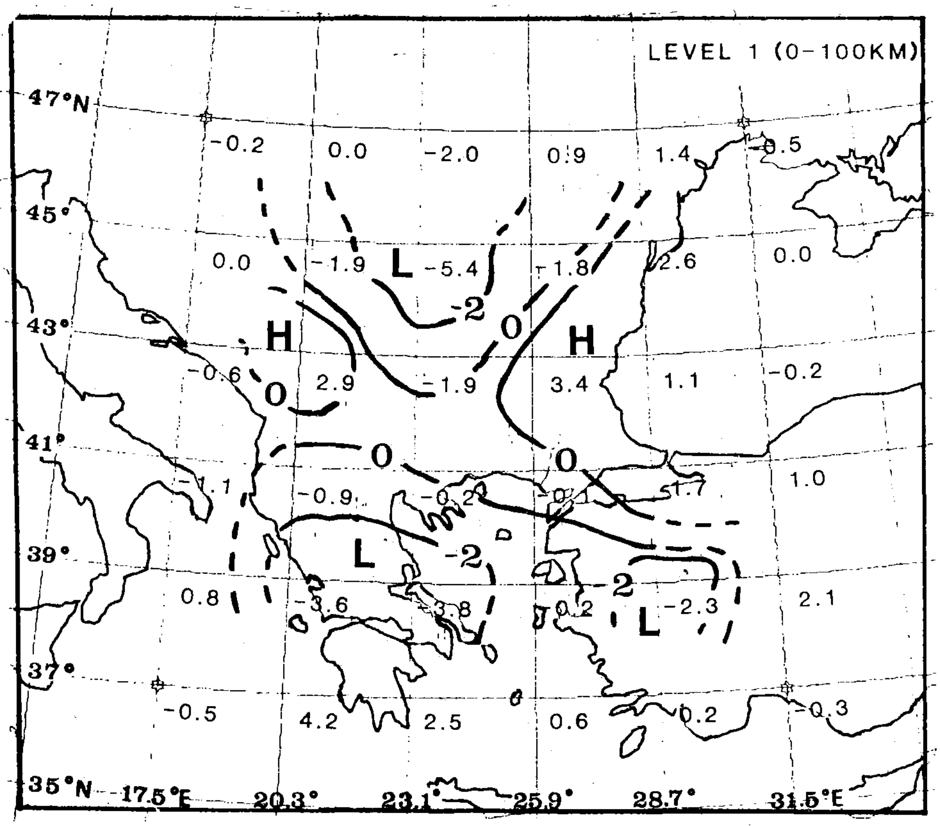

Fig. VI.8.2 Velocity perturbations (in per cent) for Level 1. Areas of high and low velocities are indicated by capital letters H and L. Resolution and standard errors for all knots are below 0.8 and 1.2, respectively.

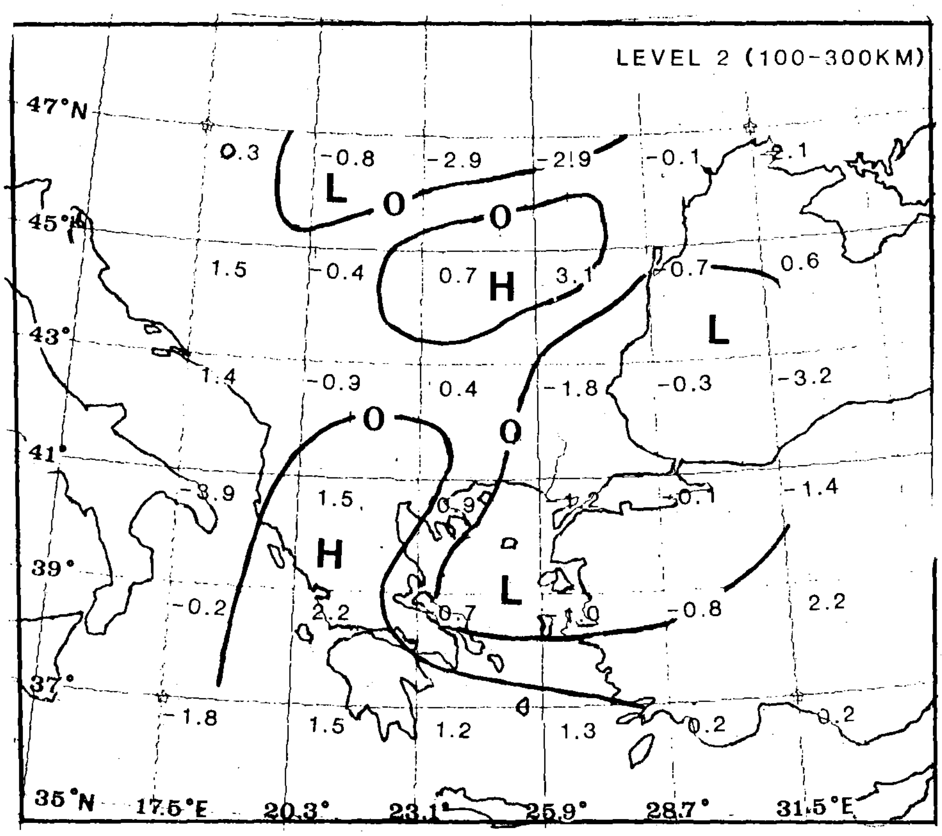

Fig. VI.8.3 Velocity perturbations (in per cent) for Level 2. Otherwise caption as for Fig. VI.8.2.