Zeitschrift für Geophysik, 1970, Band 36, Seite 387—391. Physica-Verlag, Würzburg

Briefe an den Herausgeber

Crustal and upper mantle structure of the Ethiopian Rift derived from seismic and gravity data[1])

J. MAKRIS[2]), H. MENZEL[2]), J. ZIMMERMANN[2]), K.-P. BONJER[3]), K. FUCHS[3]) and J. WOHLENBERG[4])

Eingegangen am 16. Dezember 1969

Seismic and gravity data have been combined to refine the crustal models proposed recently for the Ethiopian Plateau [BONJER, FUCHS and WOHLENBERG 1970; MAKRIS, THIELE and ZIMMERMANN 1970]. These two papers will be referred to as paper I and paper II, respectively, throughout this communication.

The crustal model derived from seismic evidence in paper I has been used to fix the depth of crustal layers at Addis Ababa. The densities have been defined from the P-wave velocities according to the empirical Nafe-Drake relationship [TALWANI, SUTTON and WORZEL 1969]. Using these constraints, the gravity data have been inverted into new twodimensional crustal models.

In Figure 1, the crustal cross-section is presented which begins in the Ethiopian Plateau, passes Addis Ababa, traverses the Northern part of the East African Rift System (Long. 39° E, Lat. 9° N) and extends into the Somali-Plateau. The Bouguer anomaly [MOHR and ROGERS 1966] is clearly related to the topography. The morphologic minimum of the rift coincides with the maximum of the Bouguer anomaly. The seismic velocities correspond to a density of 2.75 g/cm^3 which is higher than was assumed in paper II. The reduced density contrast between upper and lower crust requires additional high density material at shallower depth beneath the rift proper than was described in paper II.

---

[1]) Contribution No. 49, Geophysical Institute, University Karlsruhe.

[2]) Institut für die Physik des Erdkörpers, Universität Hamburg, 2 Hamburg 13, Binderstraße 22, Germany.

[3]) Geophysikalisches Institut, Universität Karlsruhe, 75 Karlsruhe, Hertzstr. 16, Germany.

[4]) University College Nairobi, P.O. Box 30197, Nairobi, Kenya.

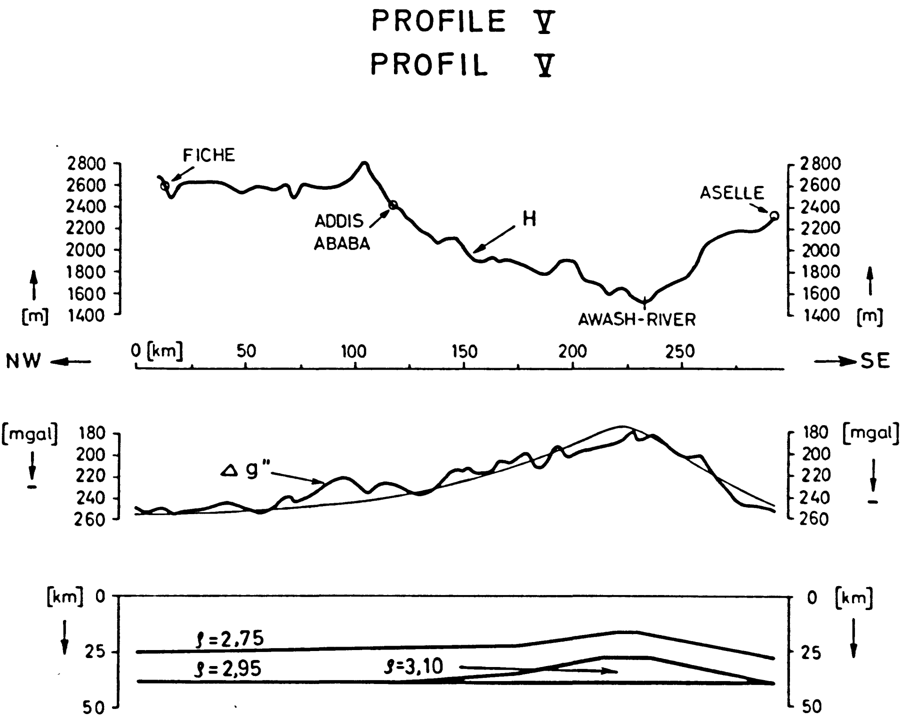

Fig. 1: Profile V crossing the northern part of the Ethiopian Rift.

H topographic elevations along the profile.

Δg″ Bouguer anomaly without terrain corrections in comparison to computed anomaly.

At the lowest part the geological body causing the anomaly.

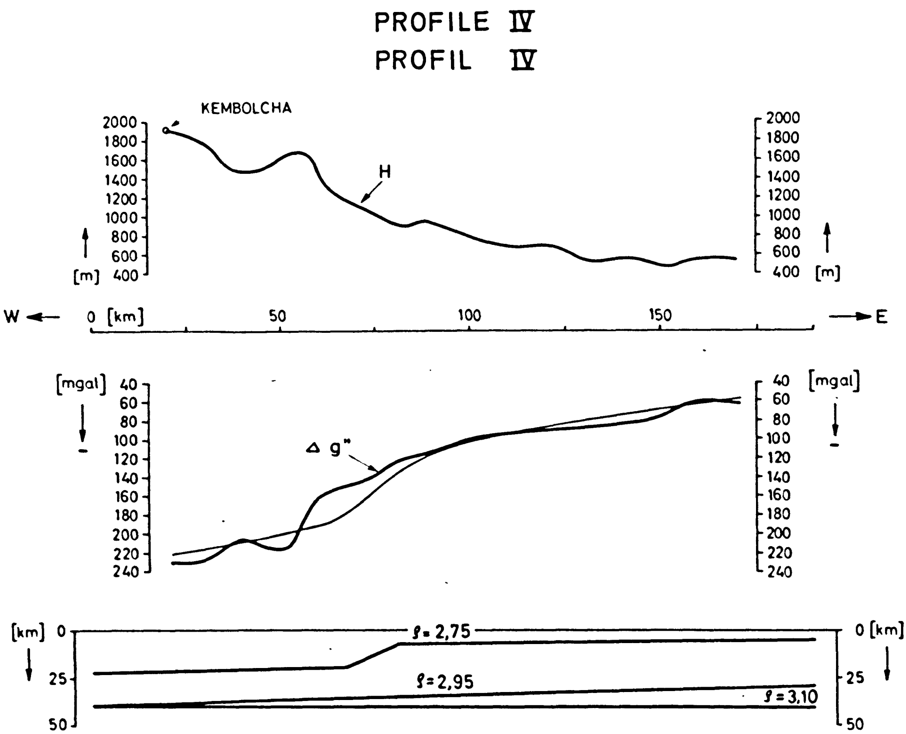

Fig. 2: Profile VI crossing the escarpment of the Ethiopian Plateau near Kembolcha towards the Depression of Afar.

For further explanations see Fig. 1.

The presently available Bouguer values for the Ethiopian Plateau range between — 200 and — 260 mgal. The Bouguer values at Addis Ababa and Dase, both located at the edge of the Plateau, are — 226 and — 230 mgal, respectively. This encouraged the authors to extrapolate the crustal model obtained in Addis Ababa to the area of Dase. In Figure 2, the crustal cross-section beginning at the edge of the Plateau and descending into the AFAR-depression is shown [GOUIN and MOHR 1964]. As a consequence of the density modification the top of the intermediate layer towards the depression of Afar had to be placed at a shallower depth.

The new crustal model differs from the corresponding model in paper II in two aspects. The base of the intermediate layer has been lowered by 5 km. Furthermore, as a consequence of the density modification within the upper part of the crust, the top of the intermediate layer towards Afar had to be placed at shallower depth. The fit of the computed and observed gravity values is better in this case than it has been in paper II. It is very likely that the densities reported in this paper are applicable to other parts of the Ethiopian Rift.

The low density of the upper mantle requires some explanation. This density, assumed in paper II, is confirmed by new seismic evidence given in paper I. The regional variation of P-travel times [HERRIN and TAGGART 1968] has been split into two parts corresponding to the crust and to the upper mantle. A delay of 1.3 sec for P-waves approaching Addis Ababa from an azimuth of N 40° E has to be attributed to the upper mantle, since the crustal model established for Addis Ababa has the same travel time as the crustal model used for the 1968 tables [HERRIN, TUCKER, TAGGART, GORDON and LOBDELL 1968].

This delay can be explained by a slab of reduced velocity in the upper mantle. Its thickness H is estimated as a function of the velocity decrement Δv assuming a standard upper mantle velocity of 8.2 km/s. We have selected a reasonable combination $H = 150$ km and $\Delta v \approx 0.45$ km/sec. This gives an estimate of the upper mantle P velocity of 7.7—7.8 km/sec. In addition, the density variation $\Delta\varrho = 0.15$ is taken from the derivative of the Birch relation [BIRCH 1961]: $\Delta v/\Delta\varrho = 3.31$. A density of 3.10 g/cm^3 has been used for the upper mantle.

If the density deficit were a local phenomenon under Addis Ababa, a strong change of the gravity level of more than 100 mgals should have been observed within the Ethiopian Plateau. Since this is not the case and the observed variations between Plateau and Afar depression must be explained by crustal inhomogeneities, we very strongly suspect that we are dealing with a regional density deficit of the upper mantle.

This research has been sponsored by the Deutsche Forschungsgemeinschaft.

References

BIRCH, F.: Composition of the Earth's Mantle. Geophys. J. 4, 295—311, 1961.

BONJER, K.-P., K. FUCHS, and J. WOHLENBERG: Crustal structure of the East African Rift System from spectral response ratios of longperiod body waves. Z. Geophys. 36, 1970.

GOUIN, P., and P. A. MOHR: Gravity traverses in Ethiopia (interim report). Haile Sellasie I University.Bulletin of the Geophysical Observatory, 7, 1964.

HERRIN, E., W. TUCKER, J. TAGGART, D. W. GORDON, and J. L. LOBDELL: Estimation of surface focus P travel times. Bull. Seism. Soc. Am. 58, 1273—1291, 1968.

HERRIN, E., and J. N. TAGGART: Regional variations in P travel times. Bull. Seism. Soc. Am. 58, 1325—1337, 1968.

MAKRIS, J., P. THIELE, and J. ZIMMERMANN: Crustal investigations from gravity measurements at the scarp of the Ethiopian Plateau. Z. Geophys. 36, 1970.

MOHR, P. A., and A. S. ROGERS: Gravity traverses in Ethiopia (Second Interim Report). Haile Sellasie I University. Bulletin of the Geoph. Observ. 9, 1966.

TALWANI, M., G. H. SUTTON, and J. L. WORZEL: A Crustal Section across the Puerto Rico Trench. J. Geophys. Res. 64, 1545—1555, 1959.