

Thickness of Pleistocene Deposits Determined by Gravimetric Methods in Numedalen, Norway

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Two gravity profiles across thick fluvial and glaciofluvial deposits in Numedalen, Norway are interpreted. The maximum depths of the sedimentary deposits are 55 and 110 m respectively, based on calculations using two dimensional models.

A seismic refraction survey has been shot along one of the profiles and the gravity model is in good agreement with the seismic results.

The study shows that the gravimetric method can be used as a more economic and supplementary method to traditional seismic and drilling methods for determining the thickness of Pleistocene deposits with a high porosity.

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The present study was performed as part of the Numedal project (Rosenqvist 1969). This specific area was chosen since detailed Quaternary geologic maps already existed, and since one of the important aims of the Numedal project was to obtain a reasonable estimate of the sediment thickness in different parts of the valley. Among various methods which may be used for this are: electric measurements, drilling down to bedrock, and seismic refraction shooting. The last two methods are reliable and give fairly accurate depth estimates, but they are time-consuming and rather expensive.

We decided to test the gravimetric method to see if it was an (economic) alternative to the traditional methods, and if gravity measurements could be used as a supplement to already existing methods. We also wanted to find out if the method was applicable at all, i.e. if the density contrast between the Quaternary deposits and the bedrock and the thickness of the overburden were large enough to give significant local gravity anomalies.

Pleistocene geology and location of profiles

The Pleistocene geology of the area situated around Flesberg is shown in Fig. 1.

We decided to measure two gravimetric profiles in the area. One was identical with a seismic refraction profile already shot by Norges Geologiske Undersøkelse, where the depths to bedrock had been interpreted (Fig. 2:

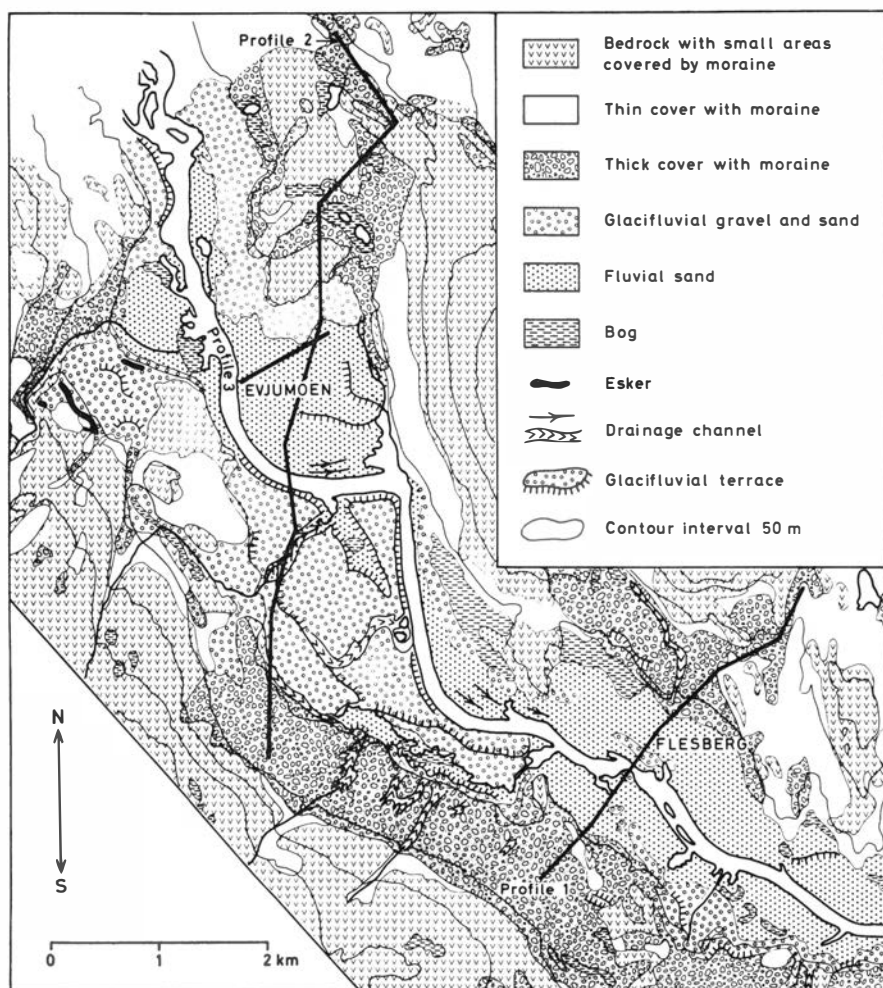


Fig. 1. Map showing the Pleistocene geology and location of the two gravimetric profiles.

profile 1). A comparison between the interpreted gravimetric profile and the seismic profile would then be a good check on the applicability of the method. The other profile (Fig. 3: profile 2) was measured across a large sedimentary basin with unknown depth to bedrock. The locations of the two profiles are shown in Fig. 1.

Gravity data

A total of 41 gravity stations were measured along profile 1. The intervals between the stations varied from about 50 m over the Quaternary deposits to

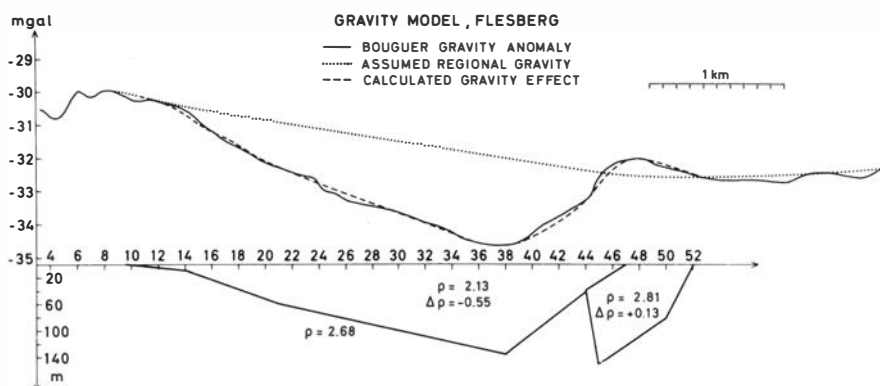


Fig. 3. Gravimetric profile (Fig. 1: profile 2).

field. This field is to be subtracted from the total observed field, thereby producing residual anomalies which are entirely due to the mass deficit caused by the lighter Quaternary deposits. The residual field in our study will be zero over exposed bedrock. Having a relatively large number of gravity stations on bedrock therefore gives a good foundation for choosing a correct regional gravity field. The stippled curve in Fig. 2 and dotted curve in Fig. 3 show our chosen regional gravity field for the two profiles.

Densities

The determined residual gravity field is a function of the density contrast between the bedrock and the Quaternary sediments and the thickness of the deposits. It is therefore important to have a good value for the density contrast since we are calculating the depth to bedrock.

The bedrock densities in the area range from 2.64 to 2.88 g cm⁻³ with a mean of 2.68 g cm⁻³ (12 samples). Attention is drawn to the dense gabbro ($\rho = 2.81$ g cm⁻³) producing the positive anomaly in Fig. 3.

The densities of the Quaternary deposits range from 2.1 to 2.25 g cm⁻³ for glaciofluvial and fluvial sand, depending mainly upon the porosity. For moraine, the densities range from 2.3 to 2.5 g cm⁻³ according to the degree of compaction and the clay content. For our models we have used average density contrasts of 0.45 to 0.55 g cm⁻³ (fluvial sand and bedrock) and 0.25 g cm⁻³ (moraine and bedrock), ignoring the thin top layer of partly saturated soils.

Results and discussion

Two dimensional gravity models for both profiles were calculated using the

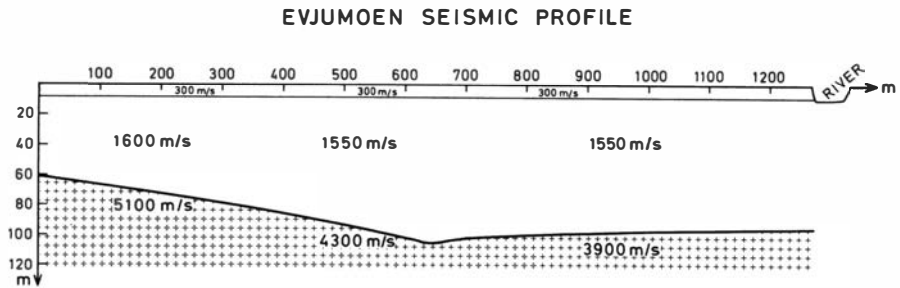


Fig. 4. Seismic refraction profile (Fig. 1: profile 3).

method of Talwani et al. (1959). In Fig. 2 the calculated gravity effect using both density contrasts (0.45 and 0.55 g cm^{-3}) for fluvial deposits is shown together with the corresponding gravity and seismic models. Good agreement between observed gravity and calculated gravity effect is found. The gravity model is also in good agreement with the seismic model, giving approximately the same depths to bedrock (maximum thickness of the deposit is about 55 m).

Fig. 3 shows the profile along the central part of the sedimentary basin. A maximum thickness of about 110 m is found using a density contrast of 0.55 g cm^{-3} . A smaller contrast would have given a thicker section. The positive gravity effect of the exposed gabbro massif ($\rho = 2.81 \text{ g cm}^{-3}$) has been allowed for. The total amount of fluvial and glaciofluvial sediments within this area was calculated by using the depth values given in Figs. 2 and 3, and the areas obtained from Fig. 1. The result is that the minimum amount is approximately 0.25 km^3 .

This study shows that a gravimetric survey aimed at determining the thickness of Quaternary deposits overlying denser bedrock is possible and gives depth values comparable in accuracy to those from seismic refraction surveys. A gravimetric survey will, however, depend strongly upon a good bedrock control for determination of a reliable regional gravity field, which in some cases can be an obstacle.

In our opinion the best results can be obtained if a gravimetric survey is combined with either a seismic or a drilling survey. A survey of the latter type, together with exposed bedrock, would give depth control points, and the gravity data would give the depths in between.

Appendix

Additional seismic refraction work was done by the authors last summer (1974) on Evjumoen (Fig. 1: profile 3). The new seismic results from this area (Fig. 4) confirm the depth estimates from the gravity profile.

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