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Some Notes on a Compiled Gravimetric Map of Southern Scandinavia

by

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Abstract.

A gravity map of southern Scandinavia shows six main trends which are closely connected to geological structures. The Caledonian and Dalslandian directions with gravity minima of ÷ 100 mgal must be explained by the relatively light roots of the Caledonian mountain chain. The Gotian direction with «trough» down to ÷ 20 mgal must be caused by the Precambrian granites. The Oslofjord and Kattegat directions are «highs» that must be explained by an intrusion of the substratum, just the opposite one should expect from graben structures. The Danian direction is made up of parallell trends of highs which must reflect the structure of the base of the Mesozoic sediments. Many other anomalies which cover smaller areas are usually related to rock masses with different density from the surrounding bedrock.

Introduction.

During the last years much effort has been expended by the Norges geografiske oppmåling, Geodetisk avdeling, to map the gravity field in Norway.

At present gravity maps of the Oslo region and of the Egersund area are published and the work is still in progress to make the Bouguer gravity map of Norway as complete as possible. Meanwhile I have had the opportunity to use the still unpublished preliminary data from southern Norway. Measurements have been made along the main roads with a station interval of 5 km or less, and total over 3000 measurements. The measurements were carried out with a Worden gravimeter, geodetic type. I have also used unpublished measurements done by Scott B. Smithson in the Hallingdal and Sørlandet area. Terrain corrections that in certain places may be as high as + 10 mgals, are not entered. Another error arises from the determination of the station heights, which is done by aneroid barometers checked by map points. They therefore may be

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up to 10–15 m wrong, which will cause an error of 2–3 mgal. Stations near each other are, however, often subject to almost the same terrain effects. The regional trends and gradients therefore are not disturbed notably by these errors.

The gravity data of Sweden are taken from a publication by Wideland (1946) which contains a gravity map of Sweden with a contour interval of 5 mgal. The gravity map of Denmark is taken from the publications of Nørgaard (1939) and Saxov (1945). Their maps have contour intervals of 2,5 mgal.

The present map shows six regional trends.

1. The Gotic direction.
2. The Dalslandic direction.
3. The Caledonian direction.
4. The Oslofjord direction.
5. The Kattegat direction.
6. The Danish direction.

We may notice that the anomalies are small over the southeastern part of the Precambrian of Sweden and over Denmark. This area therefore is in good isostatic equilibrium. Over the Caledonian mountains, the Oslofjord area, and the Kattegat, however, there are big gravity anomalies.

These anomalies may be termed regional because of their size which exceeds 40–50 mgal and covers big area.

Besides the map shows many local anomalies some of which are described. Many of these anomalies can be explained in terms of the known geology.

In addition to presenting this map the purpose of this note has been to call attention to gravity anomaly maps that may be very useful for geologists in structural interpretation.

The Gotic direction.

This gravity trend runs parallell to the southsoutheastern strike of the Gotic gneisses. One may notice how intimate this connection is in the area of Borås. The almost constant strike of the gneisses in the area there curves into an arc and the isoanomaly contours trend exactly parallell to them. In this way an anomaly of ÷ 10 mgal is formed. In this area one might suspect a granite to be situated not too deep beneath the surface.

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Younger Gotic granites are easily located on the gravity map. The Åmål granite is followed by an anomaly of ÷ 10 mgal. One may also notice a narrow positive trend crossing Vänern. This trend follows a tectonic border. The border between the Gotic gneisses and the Småland granites is followed by a negative trend.

The Dalslandic direction.

Over the Filipstad granite and the Dala sandstone in Värmland there is a gravity trough trending southeast. It goes down to ÷ 70 mgal in the central part. From the map one may see that this trough forks out from the Caledonian trough over the basin filled with Eocambrian arkoses. One trough is not cutting the other, because then there should be a gravity minimum at the intersection of the troughs. These structures are closely connected and might therefore be interpreted as being of the same age. To the northeast, however, we may see how closely the contours follow the border between the Dala sandstone and the porphyry. This fact implies that the anomaly is formed by the effect of different densities of the rocks on each side of the border. If this is true, the trough has to be of Gotian age. The most probable solution to this problem is that the trough was formed first in Gotian time. During crustal movements connected to the subsidence of the Eocambrian basin or connected to the Caledonian orogeny or both, it was deepened. The Dalslandic trough therefore apparently is caused both by structures in the crust and by structures at the surface. This is confirmed by the small gradient to the SSW-NNE.

The Caledonian direction.

In central Norway the gravity contours trend NNE, parallell to the strike of the Caledonian mountain chain. Along the thrust front of the Jotun nappes they form the bottom of a gravity «trough». The anomaly of the axis of the «low» descends to ÷ 100 mgal in three areas, viz. Eidfjord, Upper Hallingdal and the Helagfjället area. Besides there is an additional trough parallell to the main trend. It is found between Geiranger and Sunndal and has a minimum of ÷ 90 mgal. To the west the anomalies become gradually more positive according to the normal ocean effect, until they reach high positive values outside the coast. To the east the slope is much steeper, because the trough here is cut by the Oslofjord «high». The trough is also cut to the south by the high of the Norwegian channel (Den norske renne), an extension of the Oslofjord high. Any continuation of the Caledonian trough to the south postulated by Collette is not distinct (Collette 1960).

From the map we will find that the lowest values of the trough are situated to the southeast of the front of the Caledonian nappes, in fact, over the foreland to all appearance undisturbed by the Caledonian orogeny. If we compare the map to a map showing the deformation of the Subcambrian peneplane (Goldschmidt 1912) we discover that the maps seem to have little in common. These two facts seem to contradict the theory that the trough is formed by the roots of the Caledonian mountain chain. We therefore at first will discuss two other possible causes of the gravity trough:

1) That it is formed by some post-Caledonian sinking of the crust.
2) That it is formed by the still uncompensated loss of weight of the icecap that covered the area during the last glaciation.

There is ample evidence that Scandinavia is rising above the sea level with a velocity that varies from zero in the southern part to 1 cm per year in the northeastern part. This upheaval is produced by the isostatic compensation of the mass deficiency that arose when the ice cap formed during the last glaciation melted. Negative anomalies of about 50 mgal in Finland are attributed by Niskanen (1939) to this mass deficiency. His calculations show that western Finland is going to rise anofter 200 m. If we, however, compare the gravity map with the map showing the land uplift for Southern Scandinavia we see that the contours do not fit at all. The Caledonian trough therefore must be explained by causes other than this supposed mass deficiency.

It is supposed that other crustal movements took place during the Tertiary period. Remnants of the so-called Paleic surface (Ahlmann 1919) have convinced geomorphologists that western Norway has been elevated some 100 m during this period. Because an elevation of the crust would make the anomalies higher, this uplift cannot be the cause of the trough.

Therefore there seems to be no other explanation to the gravity trough than that it is the effect of the light roots of the mountain chain. The deep roots of the Caledonids, therefore, have an horizontal effect which makes the anomalies of the foreland lower.

Certain anomalies of a more local nature complicate the structure of the Caledonian gravity trough. Some of the biggest may be mentioned.

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1. The Trondhjem area high.

A high is found over the Trondhjem area syncline containing sedimentary rocks of lower metamorphic grade than the rocks around. The contours follow the borders of the syncline so exactly that it can scarcely be explained by other causes than the effect of the heavy greenstones in the sediment sequence.

2. The Egersund area high.

A syncline with rocks of noritic to monzonitic composition is here surrounded by anorthosites. The highest anomalies are found over the norite.

3. The Hallingdal area high.

Anomalies of + 50 mgal cut the Caledonian trend in the Hallingdal area. The bedrock consists of folded Cambro-Silurian sediments. Windows of Precambrian metamorphics show, however, that the sediment cover is not thick. Precambrian amphibolites may be responsible for this high.

4. The Bamble high.

In an area along the southeastern coast of Norway, there is found high positive anomalies. Near the coast it goes up to + 50 mgal. The anomaly has a constant gradient of about 1 mgal/km for about 40 km. This steep gradient begins near a fault trending parallell to the coast. This fault forms a border between the Telemark gneissgranites and the Bamble formation which is rich in quartzites and amfibolites. The high forms a continuation of the Oslofjord high. There may therefore be put forward three modes of formation of this high. It may be formed

1. by the same deepseated structure that produces the Oslofjord high.
2. by the heavy rocks in the Bamble formation,
3. or most probably by a combination of both effects.

The Oslofjord direction.

The Permian Oslo graben forms a very distinctive gravity high. This high is remarkable for two reasons.

First there is ample evidence that the Cambro-Silurian sediments were down-dropped over thousand metres during the Permian age so that Sialic rocks thus came in a level with the heavier substratum. A subsidence of the lighter outer crust in a graben structure ought to normally lead to negative anomalies. (Bullard 1936). The Permian intrusive rocks, which make up the bulk of the rocks in the graben are relatively light rocks. One of the most abundant is nordmarkite, which has a specific gravity of about 2,6 g/cm^3. The high therefore is neither explained by the relative weight of the exposed rocks in the area, nor by the graben structure.

Secondly, the symmetry of the anomaly surface does not fit the graben structure very well. Over the eastern shore of the Oslofjord which coincides with the big eastern fault, the gradient of the gravity field is little. On the contrary, the western side of the graben has a high gradient, even though the faulting here is inconsiderable.

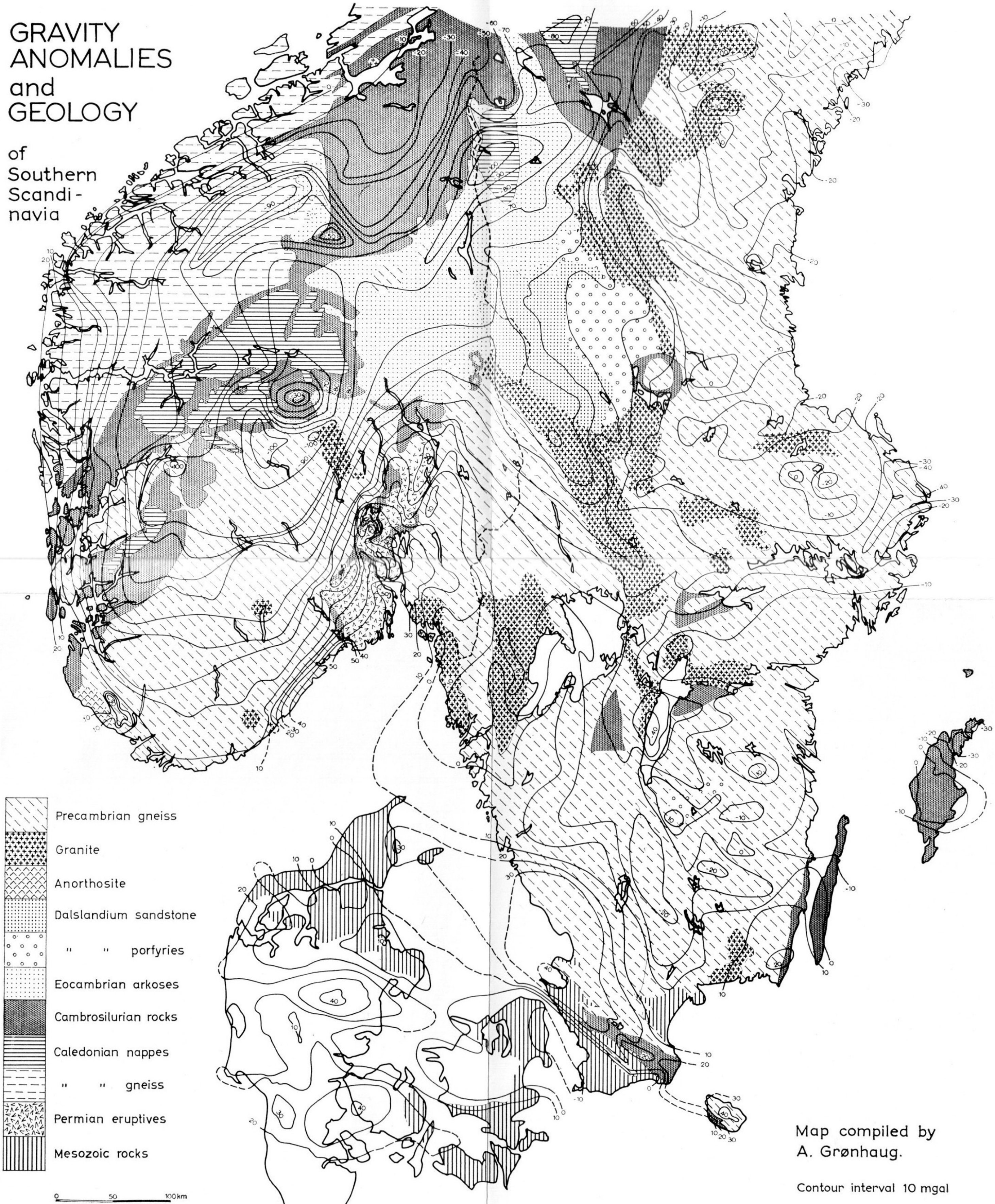
Both facts are inconsistent with what should be expected from surface geology. The cause of this gravity high therefore is to be situated beneath the surface. Schwinner (1928) has explained this as follows: There was a melting deep in the outer crust. During the crystallization there was a differentiation concentrating the heavy constituents at the bottom and the light at the top. The heavy rocks at depth should thus be responsible for the high. This explanation can, however, not be correct. A separation as postulated would have none effect other than moving the point of gravity downwards, which in turn would lead to negative anomalies. Even if we consider the rock masses moved by erosion this is not enough to explain the Oslofjord high amounting to + 50 mgal.

There is another explanation which should fit the geological and geophysical data better. The graben structure may be underlain by a structure of the opposite kind, namely an upbending of the basaltic substratum. The crust was intruded and melted from beneath, and the eruptives stoped their way upwards, pouring out on the surface as lavas, or congealing near the surface, the basaltic substratum moved upwards and during the eruptions the upper sial subsided and formed the graben structure. This explanation should be consistent with both geological and geophysical evidence. The Oslofjord high seems to continue over the Norwegian channel (Den norske renne), a depression of the Skagerak floor, probably formed during Tertiary. (Holtedahl 1960).

The high is modified by a great many anomalies of smaller size, most of them resulting from a variation of densities of the Permian eruptives and the Cambro-Silurian sedimentary rocks or Precambrian gneisses. Some of the most distinct may be mentioned.

GRAVITY ANOMALIES and GEOLOGY

of Southern Scandinavia



1. The nordmarkite low of about ÷ 20 mgal.
2. The Tyrifjord low about ÷ 20 mgal situated over the granite south of Tyrifjord.
3. The low over the southern larvikites.
4. The low over the Drammen granite.

The cause of some highs in the area is not so evident from the surface geology. They are:

1. The Kongsberg high.
2. The Asker high.
3. The Tyristrand high.
4. The Holmestrand high.

The Kattegat direction.

The border between the Mesozoic rocks of Skåne and the Precabrium to the north is of tectonic nature. Törnquist (1928) pointed out that this tectonic border could be followed to the southeast through Poland, along the Dnestr to the Black Sea. Southwest of this border the rocks are folded on axes parallell to this border. The border forms the southwestern frontier of the Russian platform covered with underformed Mesozoic rocks.

The present map shows that there are high positive anomalies which follow the tectonic border to the northwest. This is remarkable because drillings show that the Mesozoic rocks were faulted down over 2000 m.

The map implies that the Törnquist line proceeds into the Skagerak and disappears near the Norwegian coast. At the intersection with the Norwegian channel, this depression has its biggest depth, and most likely the anomalies have their highest value in the vicinity of this point.

The Danish direction.

Over Denmark there is an eastwest going gravimetric trend. These anomalies must reflect the structure of the basement as no other causes are revealed by the geologic map, which shows undeformed sedimentary rocks.

Litterature.

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