GRAVITY MEASUREMENTS ON THE PAARUP SALT DOME

By

IVAR B. RAMBERG*) and GUSTAF LIND**)

Abstract

The Danish Salt Dome Province, a part of the North Sea Salt Dome Area, occurs in the deepest part of the Danish Embayment. Permian rock salt has risen almost to the present day surface at many places. The southern-most known dome is the Paarup Salt Dome, which constitutes the north-western part of an elongate gravity low on the south-western flank of the Silkeborg gravity high.

The Paarup anomaly is characterized by a sharp positive anomaly superimposed on a much wider gravity low. The low is ascribed to the mass deficiency caused by the underlying salt dome, while the positive effect is probably due to a relatively thick cap rock.

The interpretations are based on a total residual map, and residuals for the salt effect and cap rock effect, respectively. Different interpretational possibilities are shown, making use of the most reasonable and extreme density contrasts. The halokinesis of the Paarup salt dome and its possible relation to other salt domes in the Danish Salt Dome Province is discussed briefly.

INTRODUCTION

Present Work

In order to study the shape and size of salt domes the authors initiated a gravimetric investigation in the autum of 1967. The area for investigation was proposed by Professor S. SAXOV on the basis of a small positive anomaly that occurred on his Bouguer anomaly map of central Jutland (unpublished).

This paper presents and discusses the results of the gravity investigation. Calculations are based on 89 gravity stations measured with a Worden Master gravity meter (No. 779) plus Professor SAXOV's original measurements. The corrections are performed in the normal way, making use of a Bouguer density of 2.0 g/cm^3. Tidal gravity corrections are carried out, but no terrain corrections are applied. The mean error of the Bouguer anomalies is about ± 0.1 mgal. Some of the results presented here have earlier been given by LIND and RAMBERG (1968).

Previous work

Denmark belongs to the North European sedimentary basin from which it is partly separated by the WNW striking Fyn–Ringköbing high. The Danish Embayment is situated between this basement uplift and the Fennoscandian

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*) Present Address: Mineralogical-Geological Museum, University of Oslo, Norway.

**) Laboratory of Applied Geophysics, Aarhus University, Denmark.

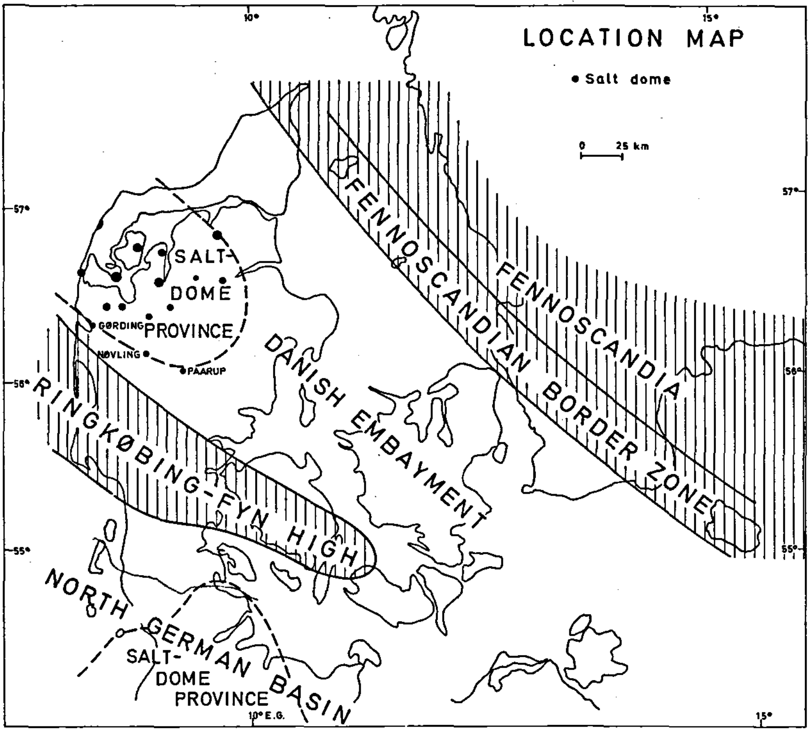

Fig. 1. Location map.

border zone (see Fig. 1). The Embayment is regarded as a non-orogenic trough with an increasing sedimentary thickness to the NW. It extends into the North Sea. The Danish Salt Dome Province occurs in the western and central part of the Embayment, where the Zechstein salt beds were thick enough to give rise to salt domes. Knowledge of the underground geology in Denmark chiefly comes from extensive prospecting activities.

In 1935, after the discovery of oil fields in Northern Germany, the Danish American Prospecting Company was founded. The activity of the company was continued – apart from the war years – until 1959 (see Ødum 1960). During this time geophysical surveys and drillings were carried out and some of the results have been published by Larsen and Buch (1960), Sorgenfrei and Buch (1964), Sorgenfrei (1966), and Larsen (1966). A compilation of the results for the Paarup regions is shown in Fig. 1.

The salt domes in the Danish Salt Dome Province were mainly discovered and located by gravity reconnaissance surveys. The Paarup salt dome was one of the domes thus discovered and one hole was drilled on its flank to a depth of 183 m, all of it in Quaternary. One drill hole was also made on the Herning (Növling) dome situated some 20 km to the west of Paarup and here cap rock was found at a depth of about 100 m (DGU file No.

1813–1–68e). For further details of these borings, see p. 259. As seen from Fig. 1 the salt domes of Paarup, Növling, and Görding all lie on one line which is roughly parallel with the outline of the salt province and parallel to the Fyn–Ringköbing high. The Vemb seismic profile (SORGENFREI, 1966) shows the size and geological setting of the Görding and Linde salt domes. The tops of these domes are respectively about 500 and 600 m below the present surface.

In 1962 a new exploration activity started, this time organized by Dansk Undergrunds Consortium (DUC), which mainly carried out seismic and aeromagnetic surveying of the country. New holes were also drilled, one of them again on Növling, but no results are available.

Salt doming

Salt structures which range from virtually cylindrical to completely asymmetrical have risen through younger sedimentary strata in many regions of the world. Considerable disagreements exist regarding the causes of this phenomenon. Most authors, however, agree that the three main contributing factors are tangential stress, high plasticity of the salt, and hydrostatic force due to the relative low density of the salt. It is a matter of observation that primary salt beds must be at least 300 m thick to initiate the process of flowing.

LACHMANN, as early as 1911, and ARRHENIUS (1912) proposed that salt doming was essentially a gravity phenomenon, while PUSTOWKA (1929) and in particular STILLE (1925) stressed the possible relation between tectonics and saltdiapirism with examples from the Transylvanian (Rumania) and North German basins. They considered the salt to have played only a passive role in the periodic folding. The salt beds were thrown into folds and the salt continued its uprise in anticlines, penetrating through the overburden which were dragged along. STILLE (op. cit.) and others considered both location and form of salt uprise to be structurally controlled. First by the works of BARTON (1933) and especially NETTLETON (1934, 1943) gravity was generally accepted to be the motivating force. NETTLETON demonstrated how salt dome structures could develop in models of two viscous fluids of dissimilar densities. NETTLETON's pioneer experiments with models were followed up by others using different model materials, for example DOBRIN (1941), PARKER and MAC-DOWELL (1955) and recently RAMBERG (1967). PARKER and MACDOWELL (op. cit.) who used light asphalt below heavier mud, could show such features as the control of dome initiation, production of fracture and fault systems in the overburden, geometry of domes, etc. A theoretical mathematical analysis of salt dome dynamics have been given by DANEŠ (1964) and SELIG (1965).

Modern experimental work and geophysical exploration have widened our knowledge of subsurface structures. Today it is generally accepted that the salt domes of epeirogenic regions have arisen as a result of buoyancy due to the negative density contrast between salt and overburden, while lateral compression has played an important role in orogenic regions. In all cases the plasticity of salt is of importance; rock salt crosses the boundary between the elastic and plastic condition at about 100 kg/cm³ confining pressure.

The formation of salt structures, or »halokinesis« (TRUSHEIM, 1957, 1960), may be initiated by a small dip in the pre-saline basement, by irregularities in the surface of the low-density layer, or by irregularities in the denser overburden, so called edge-discontinuities (RAMBERG, 1967 p. 98). The arrangement of salt structures in anticlines or salt walls (TRUSHEIM, 1960; CATER and ELSTON, 1963) may be due to lateral compression, fault systems in the basement or the outline of the source layer (see RAMBERG, op. cit. p. 54 etc.). The edge effect of the basin on the lineament of salt structures has been observed in many salt provinces, and, in fact, the distance from the basin edge may also affect halokinesis. Thus TRUSHEIM (1960, Fig. 4) has divided salt structures into »pillows«, »stocks«, and »walls« more or less dependent upon their position in the basin or vertical distance from the source layer.

Many salt domes are funnel or mushroom-shaped as a result of horizontal spreading of salt material in the top layers. This phenomenon has been attributed to salt extrusion, probably subaquatic (TRUSHEIM, 1960) or below a veneer of unconsolidated bottom sediments (GRIPP, 1958). The experiments by NETTLETON (1934) and RAMBERG (1967) demonstrate, however, that horizontal spreading will occur when the rising salt meets rigid strata in the overburden. The rigid overburden may later be penetrated, giving rise to new doming until the salt finally extrudes or is dissolved by the circulating ground water, leaving a result of insoluble components as a cap rock.

GRAVIMETRY

Introduction

As seen from Fig. 2 the Paarup salt dome is situated in a large elongate negative anomaly. This negative anomaly consists of at least three pronounced lows inside the large one, of which Paarup is the most northerly. From a regional point of view the Paarup anomaly lies on the SSW flank of the Silkeborg maximum, the most striking gravity anomaly in Denmark. This anomaly probably reflects deep-seated inhomogeneities within the Precambrian basement, but, the possibility that the feature is a basement uplift with an WNW – ESE trend parallel to the Fyn–Ringköbing high and the Paarup – Növling – Görding salt dome alignment cannot be excluded.

Density of Sediments

To choose the best density contrasts it was necessary to obtain some idea of the stratigraphical relations in the Paarup region. The depth of the basement in the Danish Embayment is not known, but is generally supposed to decrease in all directions, except towards NW, when moving away from the Salt Province. Thus, Carte Tectonique Internationale de l'Europe (1962) shows isodepth lines to the basement as half circles concentric around the

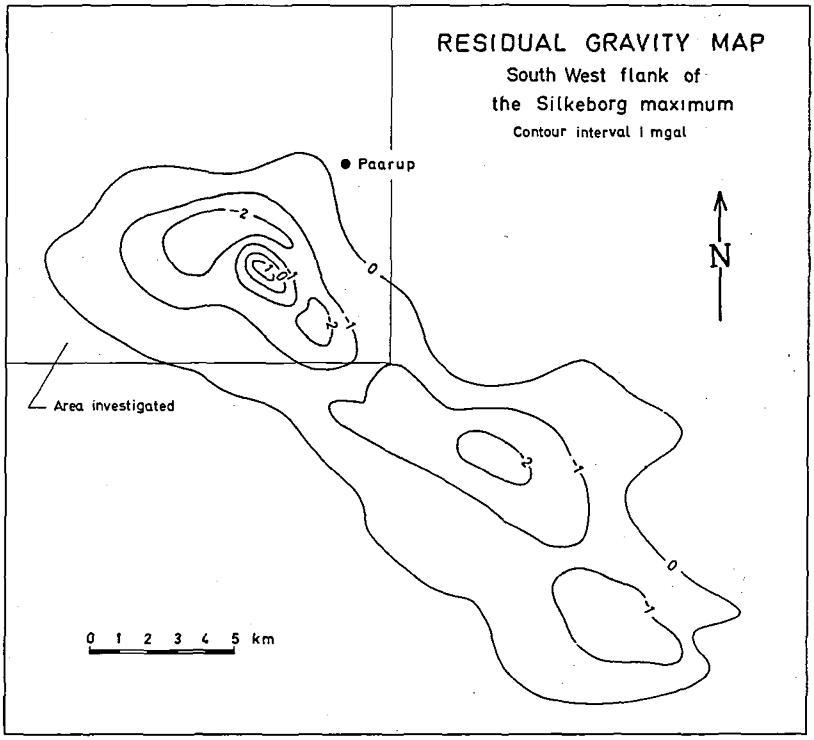

Fig. 2. Residual gravity map, Paarup area, derived from old measurements.

Salt Dome Province. The actual depths given on this map, however, are much less than those indicated by two recent drillholes in relatively marginal parts of the embayment (Növling, Rönde) which both penetrated more than 5000 m of sedimentary rocks without reaching the basement (Varv 1967). Larsen estimates the depth to be about 5 km (Larsen, 1966). The stratigraphical column shown in Fig. 11 is a hypothetical one since no data from deep borings in the neighbourhood of Paarup are published. The column is based on the available material from the nearest deep tests, particularly Gassum – Horsens – Vinding (Sorgenfrei and Buch, 1964; Sorgenfrei, 1966; and Larsen, 1966).

Sedimentary rocks cover a wide range of densities and they usually fall into four groups. In order of increasing density these are: soils and alluvia, sandstones, shales and clays, and calcareous rocks with limestones and dolomites (Grand and West, 1965). The questions of dry or wet bulk densities, compaction and silification of the sediments are of great importance when evaluating the densities of the sedimentary strata. Even though the depth of the watertable is not known in the present area, wet bulk densities have been used. In mineralogically homogeneous sediments it is a well-known fact that the density increases downwards with increasing compaction (HEDBERG, 1936, NETTLETON, 1934) and from the Gulf Coast NETTLETON (1940) concludes that it is only at a depth of about 650 m that sediments become heavier than rock salt, which then gives rise to lows in the gravity field. The lithological variations, however, produce much larger and more erratic variations in the density than the slowly increasing compaction. In recent years the density log has become a very useful tool in gravity interpretation. Density log (gamma ray) measurements have also been made in Danish drillholes (SORGENFREI and BUCH, 1964; SORGENFREI, 1966; LARSEN, 1966). Unforfunately, no density scale has been given, so it is only possible to estimate relative differences between the formations. In the following evaluation of the most probable density for each formation the figures are, therefore, chiefly based on values from BIRCH (1942).

Referring to the hypothetical stratigraphical column the uppermost 400 m is Quaternary and Tertiary. The Quaternary mainly consisting of sand with minor clay beds (DGU, written communication) and the most probable mean density for this formation is set at 2.0 g/cm^3. The Tertiary is dominantly a sand and clay series and a mean density for this lies in the interval 1.9–2.1 g/cm^3, the higher value being due to compaction at the bottom. The lithology of Danien, Senonian, and Lower Cretaceous is limestone, chalk, and claystone with density ranging from 2.0–2.5 g/cm^3. The dominance of limestone and chalk should give a mean density of about 2.3 g/cm^3. The Jurassic sequence consists of clay, shale, silt, and sand, and owing to compaction, a mean density of 2.3 g/cm^3 and a range of 2.2–2.4 g/cm^3 is highly probable. The silification presumably starts at the top of the Lias. From deep tests it is known that the stratigraphical level where lithified rocks occur varies considerably, but that the whole Triassic series is always consolidated. The Triassic consists of sandstones and siltstones with minor alternating beds of shale and claystone, and the average density is put at 2.5 g/cm^3 and the range at 2.3–2.6 g/cm^3

The Zechstein rock-salt is interbedded with anhydrite, dolomite, limestone, and clay as well as light K and Mg-salts. The density may consequently vary from place to place, but is generally considered to be close to that of halite, that is 2.2 g/cm^3. Salt upwarps in the Triassic should thus give density contrast of, mean – 0.3 g/cm^3, range ÷ 0.1 – ÷ 0.4 g/cm^3, and in Jurassic and higher mean ÷ 0.1 g/cm^3, range 0.0 – ÷ 0.2 g/cm^3. The cap rock probably formed above the so-called salt-mirror as a result of dissolution of soluble salt by circulating ground water leaving anhydrite, gypsum, dolomite, and clay as an insoluble residue. The problem of fixing a mean density for cap rock is difficult, because no data are available which show the relative percentages of the heavier compounds (anhydrite and dolomite) in relation to the lighter (gypsum and saltclay). We have chosen + 0.7 g/cm^3 as a mean density contrast and the range + 0.4 – + 0.9 g/cm^3. These density contrast figures are possible, when the cap rock is in the Upper Cretaceous or in the Tertiary. The last density contrast we can be dealing with is rock salt in the Tertiary, and in fact at this high level rock salt will give a positive contrast, not a negative one. For further comments on density contrast problems see p. 259 and 261.

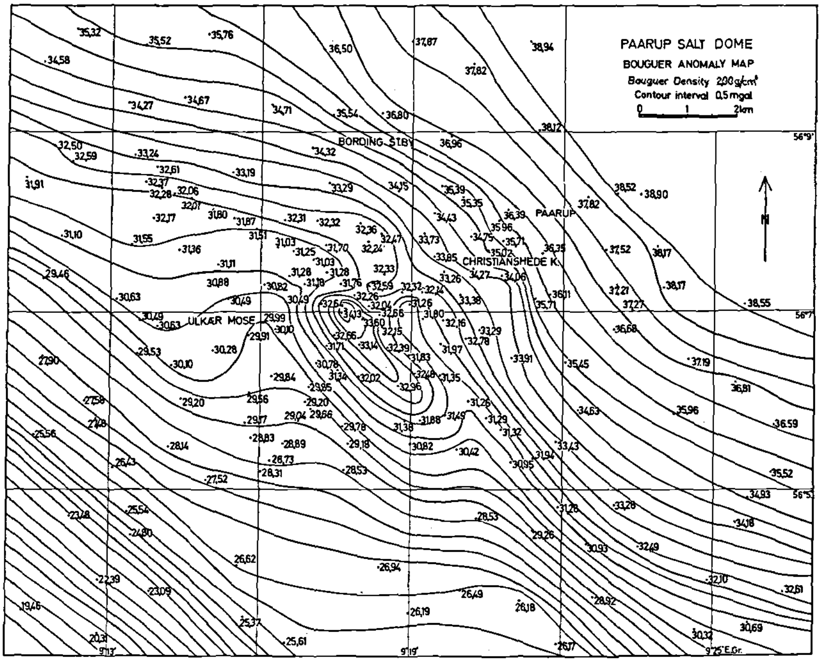

Fig. 3. Bouguer gravity map, Paarup area.

The Bouguer Anomaly Map

The Bouguer anomaly map, drawn with a contour interval of 0.5 mgal is based on 93 stations with an uneven geographical distribution. Our measurements were mainly concentrated around the central part of the map where the dome was known to occur; consequently, details in the marginal parts of the area investigated may have been omitted.

From this map (Fig. 3) three prominent features are apparent. The first is a NW-SE aligment of isoanomaly curves with a general increase in gravity towards the NE. This is a regional effect due to the Silkeborg gravity high. The gradient is somewhat undulatory, the cause of which should be the subject of another study treating the Silkeborg maximum.

Part of the map demonstrates a slight deflection of the isoanomaly curves from the Silkeborg direction. The deflection is due to an elongate gravity minimum superposed on the Silkeborg high and part of a much bigger trough continuing towards the SE (see Fig. 2). The mass deficiency thus revealed indicates relatively shallow inhomogeneities.

The third feature is a closed high, situated in the central part of the elongate low and just above the inferred salt dome. The small area covered by the anomaly and the steep gradients indicate that the mass surplus must

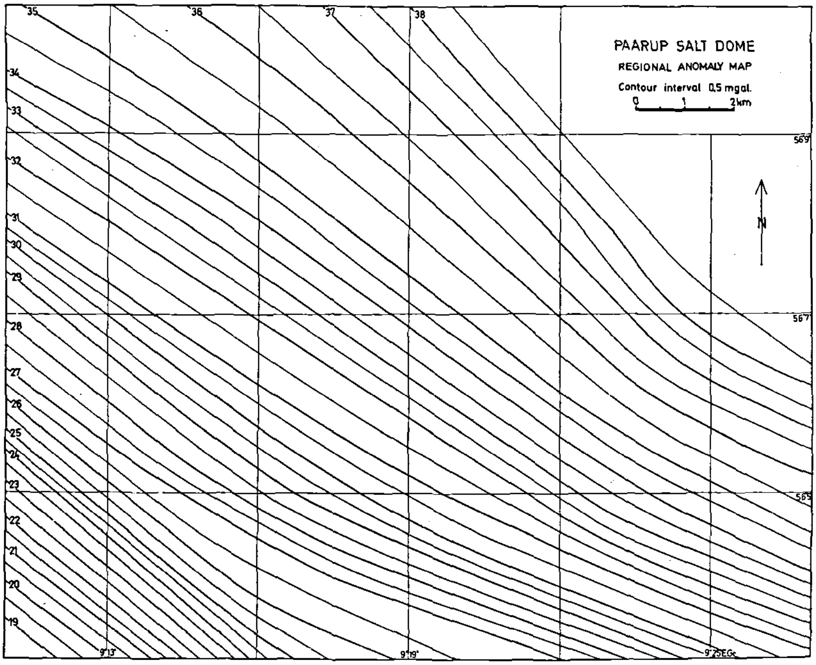

Fig. 4. Regional gravity map, Paarup area.

be sought at fairly shallow levels. It is also interesting to note that the sharp gravity maximum forms a distinct ridge whose axis lies in the same direction as both the broader low and the more regional Silkeborg high.

The Regional and Residual Anomaly Maps

The Bouguer anomaly map has been analyzed and redrawn into a regional anomaly map and a residual anomaly map. The Silkeborg gravity high has been regarded for the purpose as a regional effect in relation to the local variations in the gravity field caused by the Paarup dome. The regional map, therefore, includes all variations attributed to the deep, large-scale features of the Silkeborg high.

The separation has been performed in a graphical way taking into consideration the Bouguer anomalies in a much bigger area than shown in Fig. 3 (making use of Professor Saxov's unpublished Bouguer anomaly map with a contour interval of 1 mgal). The regional map (fig. 4) is consequently part of a larger smoothed Bouguer anomaly map of the Silkeborg high.

After removing the regional effect the residual Fig. 5) reveals an elongate low containing a distinct high. Separate depressions occur in the

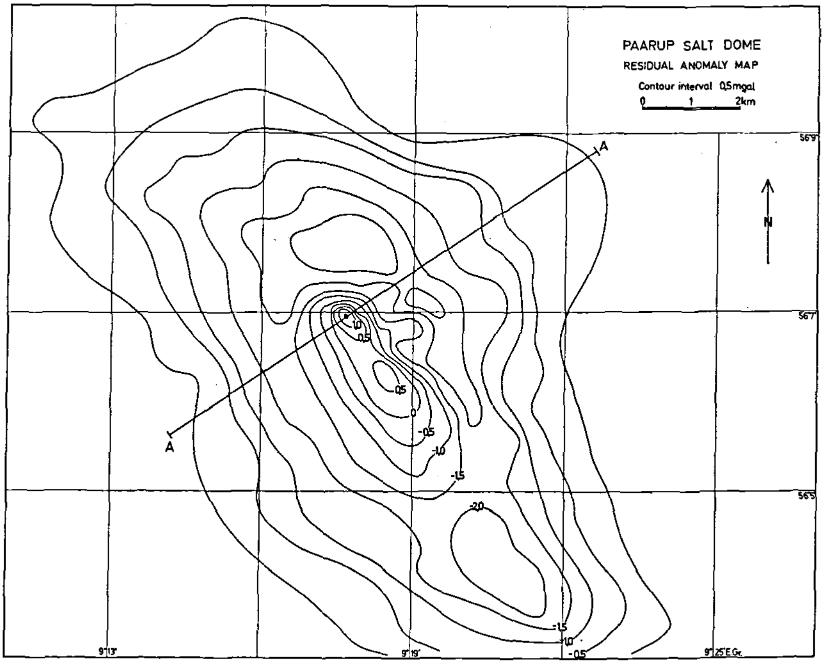

Fig. 5. Residual gravity map, Paarup area.

trough. NW and SE of this high less observations in the south-western part prevent us from detailed comments on the depression here. A possible superimposed, smaller gravity high should, however, not be excluded, see p. 263.

In order to facilitate interpretation the residual map is further split into sub-residuals, isolating the effect of the mass deficiency (salt) in one map and the effect of the mass surplus (cap rock) in another.

The construction of sub-residuals was carried out by means of a series of profiles drawn parallel and perpendicular to the profile AA in the residual map, Fig. 5 (the profile AA is shown in Fig. 6). Since only part of the gravity low is occupied by the gravity high, extrapolations from the unaffected negative anomaly gave a reliable basis for the calculation.

The resulting salt residual map (Fig. 7) shows an elongate trough with a main depression reaching a minimum value of – 3.5 mgals and a secondary depression reaching a minimum value of – 2.2 mgals. The cap rock residual (Fig. 8) reveals an irregular ridge mounting to a maximum value of + 4.7 mgals. The two subresiduals which are believed to represent the true shape and amount of the anomalies constitute the base for the following quantitative interpretations.

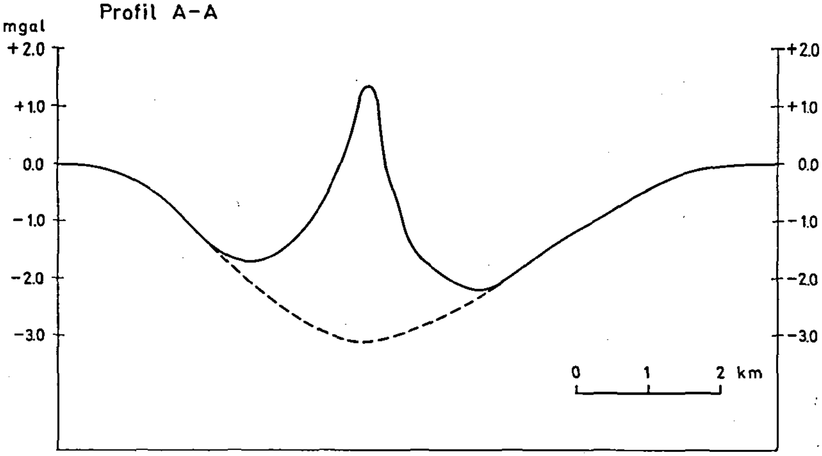

Fig. 6. Gravity profile, line A–A.

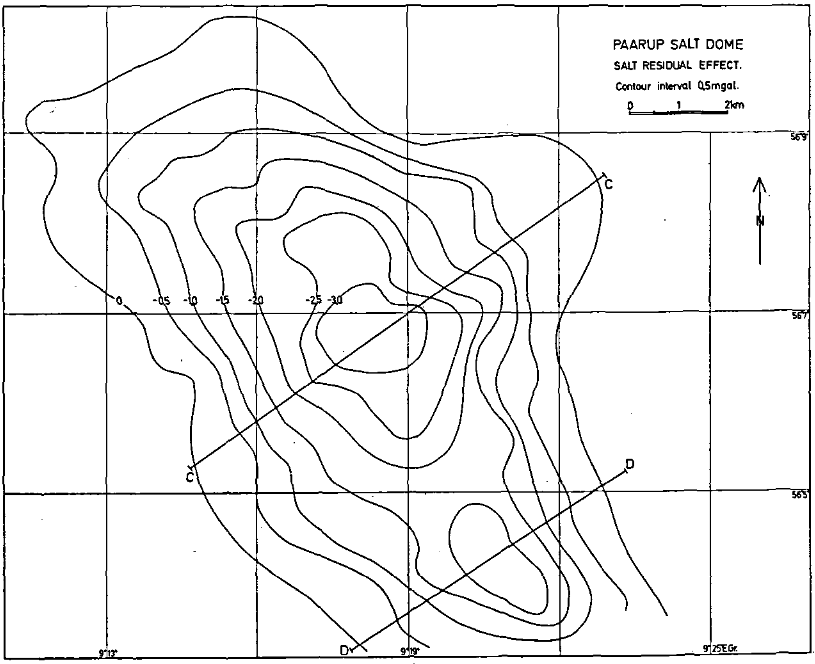

Fig. 7. Salt residual gravity map.

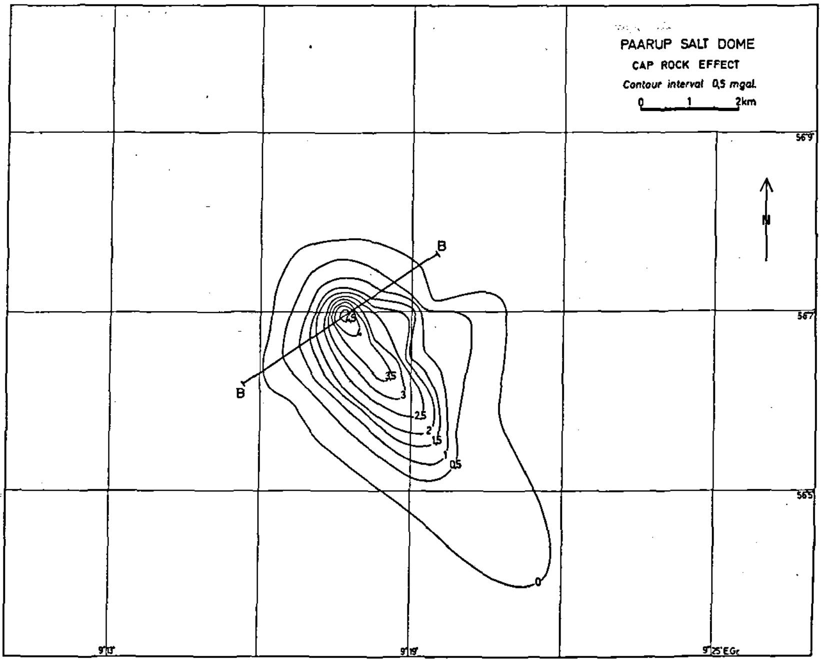

Fig. 8. Cap rock residual gravity map.

Geophysical Interpretation
From experience in other salt dome areas it is known that positive anomalies can exist inside wider negative ones. Those which have been checked by drilling have been shown to be salt domes with cap rocks (Barton, 1945). The shape and gradients of the present anomalies give every indication that this is also the current explanation in this case, in fact a salt dome with its cap rock is more or less the »only« explanation for the observed configuration.

CAP ROCK

A maximum value of + 4.7 mgals is an extremely high gravity anomaly for a cap rock. Nettleton (1940) says that cap rock anomalies are usually of the order of 1–2 mgals, but may occasionally reach 4–5 mgals.

The sharpness of the anomaly tells us that the body causing it is to be found at a shallow depth. By applying a maximum depth formula (e. g. Bott and Smith, 1959), we obtain a value of 450 m as a maximum depth value to the top of the disturbing body. Since a cap rock ought to occur within the zone of circulating ground water it is more likely that most of the cap rock is to be found above the maximum depth value. Tabel 1 shows depths to, and thicknesses of, some other Danish salt domes (Larsen, 1960).

Salt Dome	Depth to Cap Rock in Meter	Thickness of Cap Rock in Meter
Harboöre	82	84
Uglev	964	9
Vejrum	173	57
Batum	158	48
Mønsted	213	104
Tostrup	146	97
Hvornum	244	59
Suldrup	103	97

Two borings from Paarup and Herning (Növling) (DGU file No. 1813–1–68e and m, respectively) are both situated on the flanks of the domes. The drillhole at Paarup passed through 183 m of Quaternary and Miocene sand and clay. The Herning drillhole reaches 126 m, the uppermost 85 m consisting of glacial sand, but from this depth chips of gypsum get more and more abundant until, at a depth of about 120 m, the term »cap rock« is justified. The only seismic profile published over the Danish salt domes is from the Linde and Görding salt domes showing top of domes at a depth of 500–600 m (SORGENFREI, 1966).

Putting all the above mentioned figures together we have, as a first approximation, placed the salt mirror and the bottom of the cap rock at a depth of 450 m. The calculations were performed in the manner described by JUNG (1961, p. 160) and HUBBERT (1948, p. 220) considering the bodies to be two-dimensional and making use of end corrections following NETTLETON (1940, p. 117). The three models show that when using our mean density contrast (0.7 g/cm^3) we obtain a depth to the top of the cap rock of 125 m, while the minimum (0.4 g/cm^3) and maximum (0.9 g/cm^3) contrasts give 50 and 200 m to the top. The shape of the three bodies is more or less the same. The models are shown in Figs. 9 a, b, and c. Two more models, for the depth to the salt mirror of 300 m and 550 m, have been calculated. The mean density contrast $+ 0.7$ g/cm^3 has been used. Both models show almost the same shape as the body in Fig. 9 b. With the salt mirror at 300 m the cap rock reaches the surface and should also have been hit by the drillhole on the flank. This means that the salt mirror probably has to lie deeper than 300 m.

SALT DOME

A compilation of all available material suggests that the stratigraphical relations in the Paarup region may be as shown in Fig. 11. The disturbing Permian salt masses are consequently to be found between the top of Zechstein in situ at a depth of about 3800 m and the base of the cap rock.

In order to interprete the salt residual map we have drawn the profile CC (see Fig. 7) through the minimum value. To fit the anomaly we first tried rather simple models such as cylindrical stocks or two-dimensional vertical walls, but none of these were satisfactory. In all cases the calculated anomalies are much wider than the observed anomalies. Moreover the calculated curves get inflection points too near the centre if the gravity

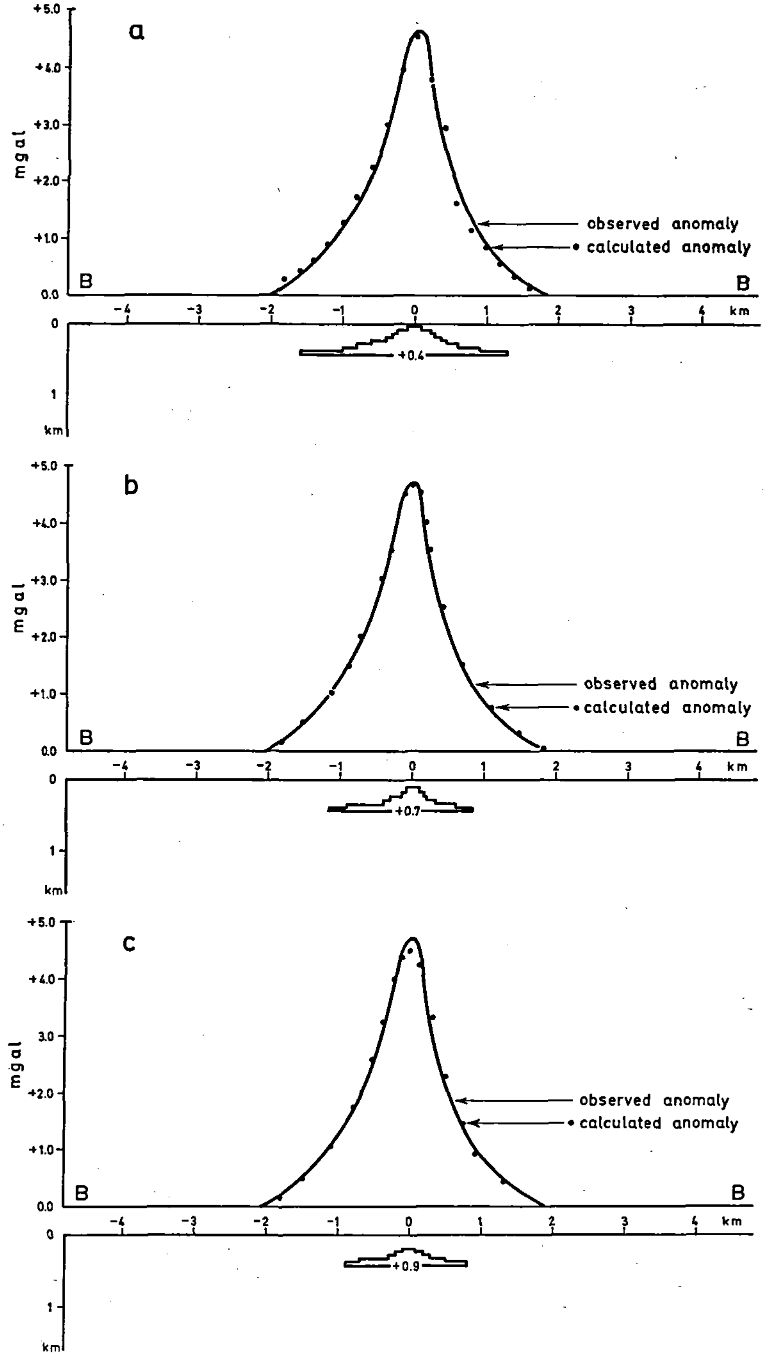

Fig. 9. Gravity profiles with calculated effects of the bodies shown.

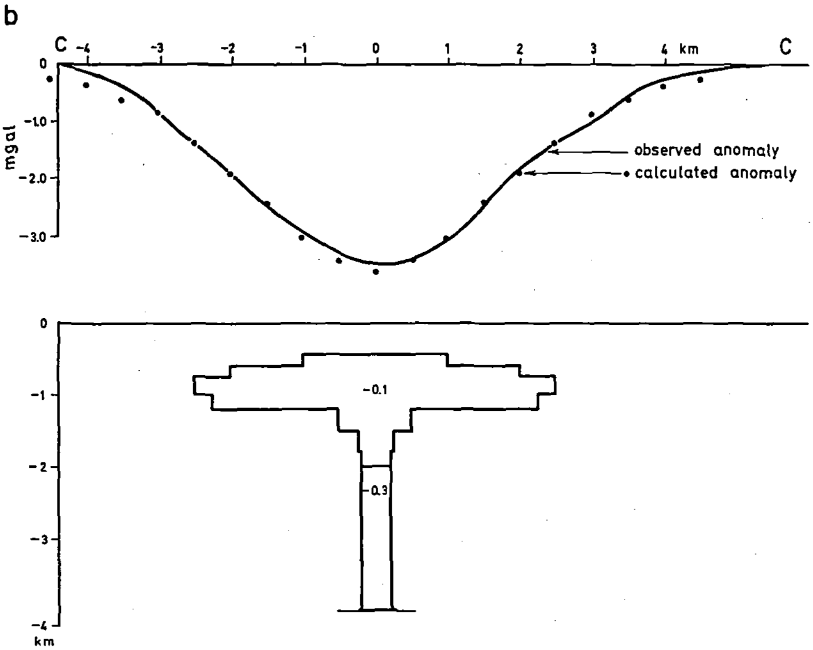

Fig. 10. Gravity profiles with calculated effect of the body.

values at the top point shall coincide. To obtain a better fit one has to move mass from the lower part to the upper part of the model and to spread the material laterally away from the central axis. The calculations were carried out as previously described for the cap rock.

The procedure mentioned was followed in three examples using the most probable density contrasts and also the most extreme possibilities (see p. 253). Assuming that the silification of the sediments starts at a depth of about 2000 m (in Sias), the most likely density contrasts to be used are 0.1 g/cm^3 for the upper part and 0.3 g/cm^3 for the lower part of the dome. The chosen values should be regarded as the mean of a variety of density contrasts the details of which are uncertain. In view of this uncertainty it is pointless at the present stage of our knowledge, to split up the models into many sub-bodies making use of different density contrasts in each. Since the variations are presumably small, the resulting anomalies should not differ very much from those given here.

The calculated models for the most reasonable and extreme density contrasts are presented in Figs. 10, 11, and 12, respectively. They all show the same reconstruction principally, the differences being clearly seen from the figures. The final choice of models must be delayed until other independent geophysical parametres are to hand.

Till now, all the models calculated had their salt mirror at about 450 m below surface – a depth chosen as the most reasonable (see p. 259). It is of

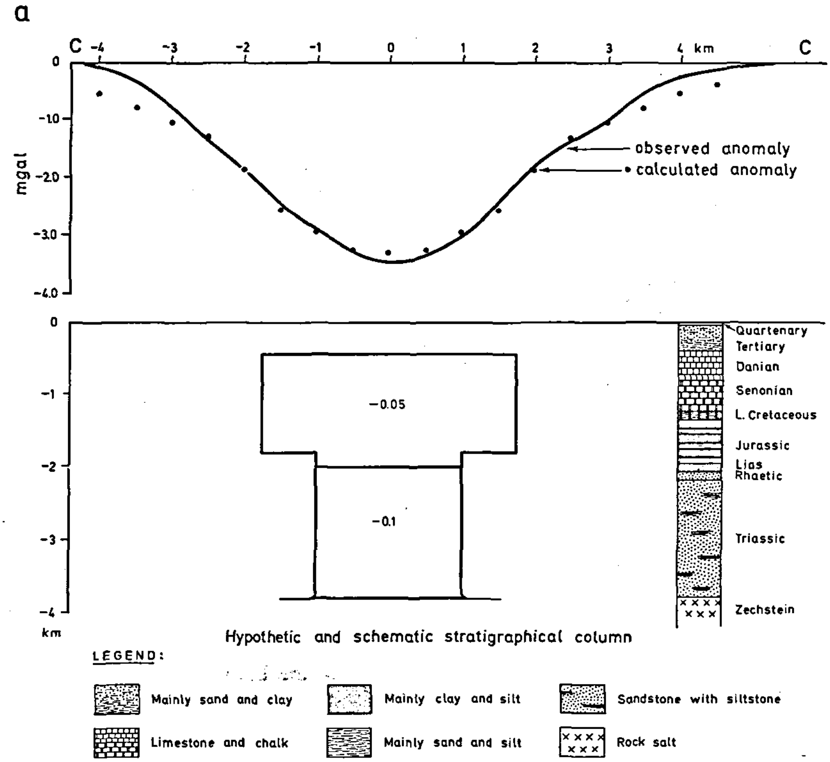

Fig. 11. Geological cross section and gravity profile with calculated effect of the body shown.

interest, however, to see what changes on the shape of the model will be caused by raising the salt mirror to about 300 m or by lowering it to about 550 m. In the first case less mass is required to fit the observed anomaly. The shape of the model will principally change towards the extreme »T-type« model earlier obtained when using the highest density contrasts (Fig. 12). When lowering the top of the salt dome, the opposite will occur. The model grows more and more stock-like, the radius of the crossbar on the »T« is reduced whilst the thicknesses increase. This is possibly a more plausible and expected shape than the extreme »T-type« models, but a probably conclusive objection is that the zone of circulating ground water can hardly reach a depth of 550 m (it may not even reach as low as 450 m).

For the profile DD through the secondary minimum in the salt residual map (Fig. 7) we have also calculated a geophysical model, Fig. 13, using the same density contrasts, 0.1 g/cm³ and 0.3 g/cm³, as in Fig. 10. The model demonstrate a less extreme horizontal spreading, but is principally of the same shape. It is probably in a less mature stage of development and

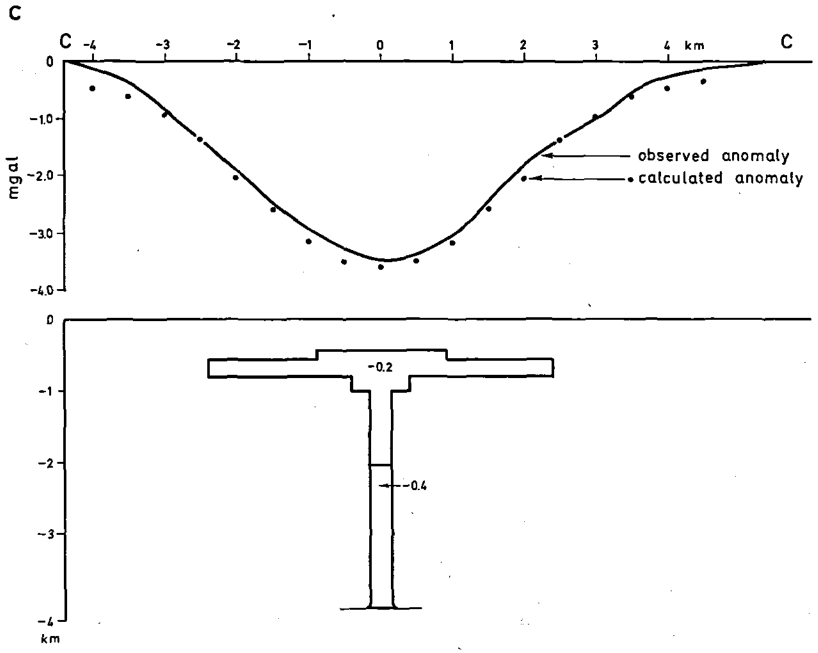

Fig. 12. Gravity profiles with calculated effect of the body.

the salt mirror is at a depth of 550 m, that is possibly below the zone of circulating ground water. No cap rock is calculated. The discrepancy between the observed anomaly curve and the calculated points near the central area indicates, however, that a small cap may exist. This can only be confirmed by dense gravity measurements over the anomaly.

GEOLOGICAL INTERPRETATION AND DISCUSSION

Gravity measurements alone never suffice to determine anomalous masses uniquely. Additional information from other geophysical or geological studies can reduce the ambiguity effectively. Thus, even if the different geophysical models presented above are based on parametres not exactly known, the various parametres chosen (depths and density contrasts) are on the basis of present geological knowledge (see p. 259) and seismic evidence (see p. 259) regarded as the most likely and extreme values. In section AA of Fig. 5 the most probable geological interpretation may, therefore, be schematical pictured by a smooth curve through the geophysical models and Figs. 9 b and 10, see Fig. 14. Density variations both within the rock salt and the side rocks will of course affect the model, and irregularities in the outline are expected. It is, however, the intention of the authors to make other geophysical studies since a final conclusion con-

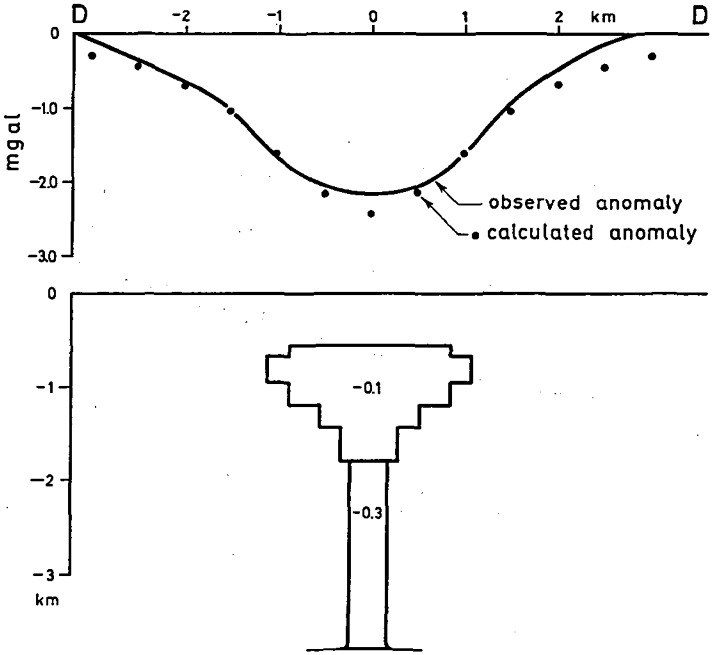

Fig. 13. Gravity profiles with calculated effect of the body.

cerning the shape and size of the Paarup salt dome cannot be reached until other independent geophysical and geological parametres are available.

The fact that the cap rock at Paarup is unusually thick (275 m) compared to other known thicknesses of cap rocks from salt domes in the Danish Salt Dome Province requires an explanation. Occurrence of anhydritic, dolomitic, and pelitic beds as well as layers of K and Mg-salts are known from the Danish Zechstein in situ (SORGENFREI and BUCH, 1964) and from several borings at the Suldrup salt dome (Saltudvalget 1959; Kaliboringerne 1962). From the North German basin such intercalations are known (TRUSHEIM, 1960) to be generally thickest at the edges of the basin. The fact that Paarup is the southernmost salt dome in the Danish embayment and situated well outside the main salt province (Fig. 1), indicates a possible relationship between the position of the dome in the saline basin and the thickness of the accompaying cap rock. From the Bouguer anomaly map of Professor S. SAXOV it can be seen that the Növling salt dome also exhibits an extreme cap rock gravity effect, possibly even higher than the one at Paarup.

The pronounced enlargement of the top of the Paarup dome has many parallels in the literature. In fact, similar structures have been especially explored because of the economical possibilities inherent in the »overhang« shape (e. g. RICHTER-BERNBURG und SCHOTT, 1959). Horizontal spreading of

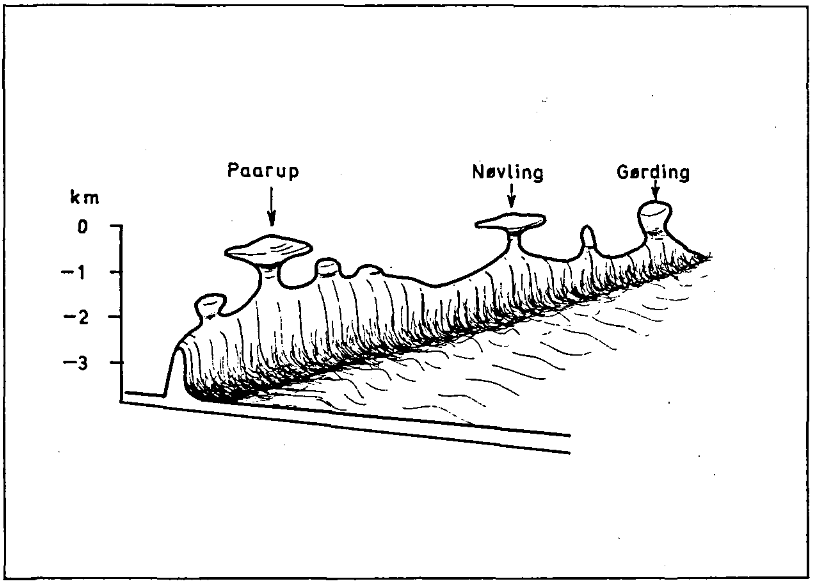

Fig. 14. Geological interpretation.

rising rock salt may, as earlier mentioned p. 251, be the result of (sub)surface extrusion or a roof effect from a strong sedimentary strata in the overburden. It is not possible to decide which of these two mechanisms is responsible in the present case without detailed information about the underground relations, but in this connection we would draw the readers attention to the fact that the tops of the salt domes of the Danish Salt Dome Province almost frequently lie at depths within the range 300–500 m, and that this range coincides with the known depth of permafrost in arctic regions not covered by ice (e. g. Spitsbergen). A permafrost layer was to be found in Denmark for long periods during Quaternary time. It could act as a roof possessing considerable strength, being much more effective than for example Eocene clay or other strata that might be capable of causing horizontal spreading of salt material.

The Paarup salt dome seems to consist of a more or less continuous salt wall running in a WSW – ESE direction, with stocks or funnel-shaped protuberances arising from the top of the wall (Fig. 14). This arrangement is consistent with the type of salt structure which TRUSHEIM (1957, 1960) regards as typical of intermediate basin depths.

As stated before the alignment Paarup – Növling – Görding salt domes is parallel to the rim of the basin. It is also parallel with the Fyn–Ringköbing high which reflects the northwest-striking tectonic alignment which predominates throughout central Europe. The direction of the Paarup – Növling – Görding-line is, therefore, observed in many European salt walls and anticlines even if the local basins have directions and outlines quite different from those of the Danish Salt Dome Province. Initiation of the salt movement in the Paarup region may, therefore, be ascribed to faults in the pre-saline basement. It may be noted that a line of seismic activity in Denmark runs through the center of the Danish Embayment (LEHMANN 1956) and parallel to the Paarup – Növling – Gördíng alignment.

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