A Pre-Cambrian Dome Structure at Tovqussaq, West Greenland.

By

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Abstract.

During survey work undertaken in the summer of 1949 for the Geological Survey of Greenland (G. G. U.) an interesting structure near the fishing port of Tovqussaq was investigated. The structure may be described as a tilted pressed-up dome ("an unborn diapire"). A description has been given of the various structural elements and the structural development.

During survey work for the Greenland Geological Survey in the summer of 1949 between Sukkertoppen and Godthaab under the leadership of Professor, Dr. phil. ARNE NOE-NYGAARD and Dr. phil. HANS RAMBERG, the author had the opportunity of investigating an interesting structural unit on the peninsula northwest of the Angmassivik fjord. This area will be spoken of as the Tovqussaq area after the fishing port of Tovqussaq. The map (Fig. 1) shows the geographical position of the Tovqussaq area.

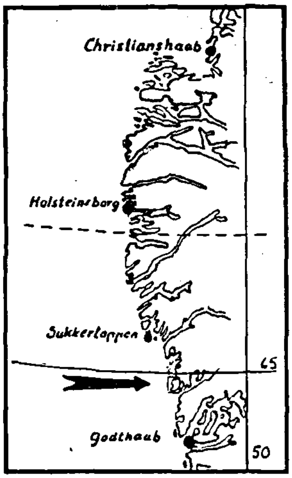

Fig. 1. The geographical position of the Tovqussaq area.

With a tent camp as base the author during a six days' stay mapped out the central part of the area and collected a number of rock samples. Later in the season another, shorter visit was made to some of the localities and further observations and samples were secured.

In addition to observations from the reconnaissance mapping work, results obtained by examination of aerial photographs kindly lent by Professor, Dr. phil. N. E. NØRLUND, head of the Danish Geodetic Institute, have been included in the preparation of the geological map (Fig. 11, a & b).

The present report only deals with the structure of the Tovqussaq area and the petrographical aspect has been included only as far as was strictly necessary for the understanding of the structure. It is hoped that the petrographical problems will be discussed at a later date.

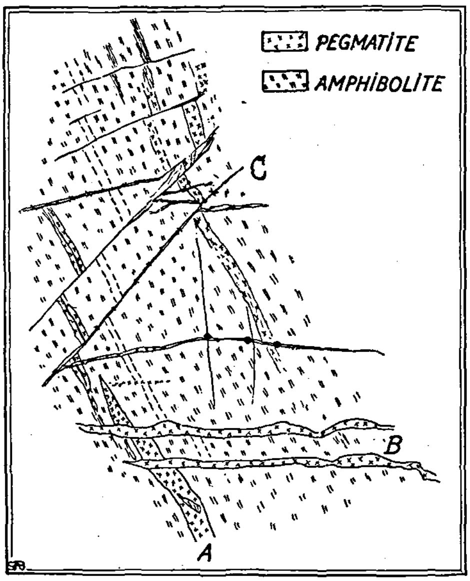

Fig. 2. The sketch shows three pegmatitic generations in amphibolite. (A: conformable, B and C: intersecting). A is the oldest and C the youngest. The transverse cracks at the top of the picture should also be noted; they have served as displacement planes.

As will be seen from the geological map (Fig. 11, a & b), the Tovqussaq area is built up chiefly of migmatitic rocks (occasionally agmatites), fairly homogenous gneiss granites and rather large amphibolites with ultra-basic variants.

A *provisional* investigation of the mineral facies (primarily of the index mineral hypersthene) showed it to be chiefly granulitic, sometimes, however, with transitions into amphibolite facies, which is typically represented through the more homogeneous gneiss granites. This change is not surprising as, facially, the Tovqussaq area lies in a border zone, amphibolite facies being prevalent north of the area until southern Isortoq and granulitic facies predominates in the coastal areas south of Tovqussaq.

The structure

may be seen in the stereogramme (Fig. 10) and can be described as a tilted, elevated dome.

To the north the structure conformly joins a field of *in situ* granitization, which during the survey was called the "Finnefjeld

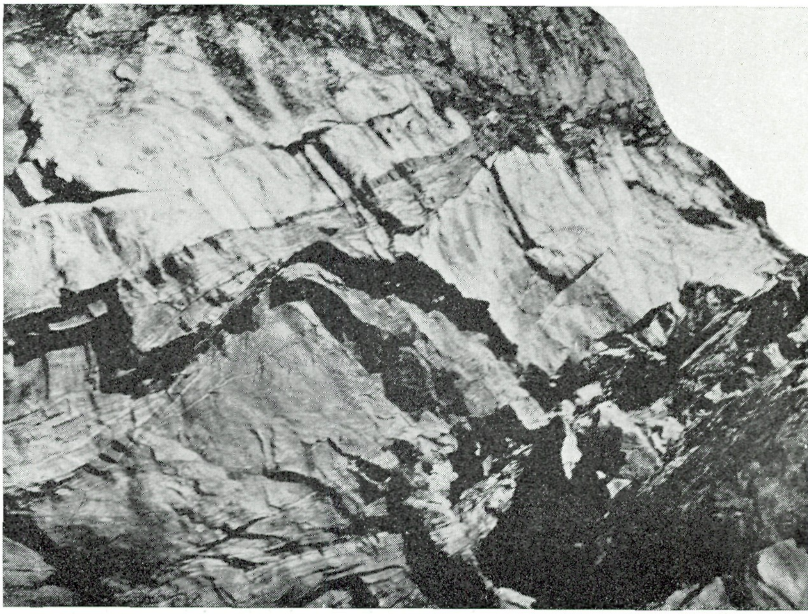

Fig. 3. The photo shows an intersecting mylonite which is cut by the same joints as the gneiss. The west coast south of the outer harbour.

complex" after the Finnefjeld, a mountain of 1047 metres on the north side of the Kangia Fjord where the granitization is almost complete. (Fig. 9). To the south the Tovqussaq area seems to be structurally connected with an anticline the axis of which has a south-south-easterly dip, and the east flank of which is the coastal area south of the Fiskefjord.

The structural elements (syn-, late-, and post-kinematic)

in the Tovqussaq area will be dealt with in their chronological order. A final summary will be given of the dome formation itself (p. 568).

a). Pegmatites occur in several generations, both synkinematic and postkinematic. They are particularly frequent in the amphibolites because of the comparatively great rigidity of the latter. A large number of the pegmatites are connected with minor dislocations (Fig. 2). In general the mineral facies of the pegmatites are in conformity with the adjacent rocks (cf. Ramberg 1949).

b). Mylonites (*Plastomylonites*). In the border zones of the area a strong mylonitization is seen, the age of which is indicated by the following observations:

1. The mylonites intersect the structure of the gneiss, but are often traversed by the same joints as the adjacent rock (Fig. 3).

2. The parageneses of the mylonitic rocks indicate that mylonitization has taken place while amphibolite facies was still prevalent.

3. In some exposures the mylonites pass smoothly downwards into a wedge-shaped upthrown root rich in granitic material (Fig. 4). This suggests that mylonitization is a later process than granitization but must have followed immediately upon the latter, being the last chance of a fairly plastic deformation. Later tensions in the region have only been released by deformation of a purely ruptive nature.

It should be noted that the strike of the mylonites varies chiefly from true north to true east so that the mylonites cut obliquely across the domed structure in Tovqussaq.

c). Epidote cracks. On the islands near the outlying station of Atangmik, epidote-carrying fissure veins as wide as 20 centimetres were found intersecting a mylonite, and at the head of a small fiord about 3 kilometres northwest of the station extensive impregnations of epidote in the rocks were observed. Thin intersecting cracks filled with epidote were also observed in highly granitized rocks at the head of Kangia Fiord. The mineral parageneses of the material of the dykes and cracks indicate that epidote-amphibolite facies has prevailed during the formation period.

d). Joints. This term includes all cracks and fracture zones whether or not they have served as planes of motion. From one or two fracture zones it has been possible to locate the latest metasomatic manifestations, and the rocks are characterized by an impregnation of pegmatitic material (microcline- and myrmekite formation).

The joints measured during the survey have been entered on the diagram (Fig. 5). There is a clear division into two groups (I and II). I includes joints, the strike of which varies round the direction of the folding axis. The joints are mostly vertical. II includes joints, the strike of which varies round a line at right angles to the direction of the folding axis and whose dip is more varied (II corresponds to *Q-klüfte* and *scherklüfte*).

An explanation of the fact that the northwestern component of the shear cleavages is further developed than the northeastern (see the tectonic general map, Fig. 11, a & b,) might be that the former

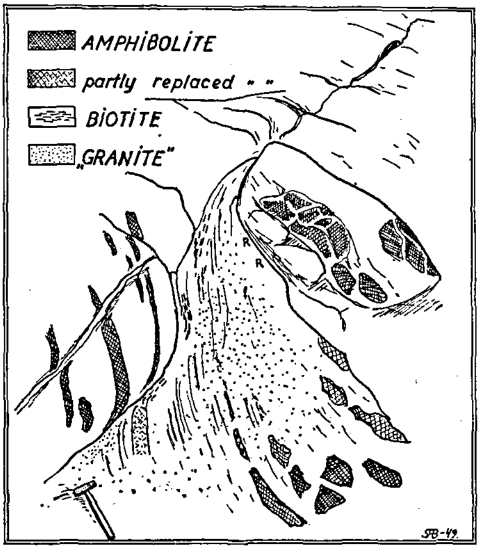

Fig. 4. The figure shows the "root" of a mylonite. Granitic material has been pressed into a wedge and has changed the agmatitic gneiss into a fairly homogeneous rock with a few nebulitic biotite schlieren. R. indicates a small zone of rust.

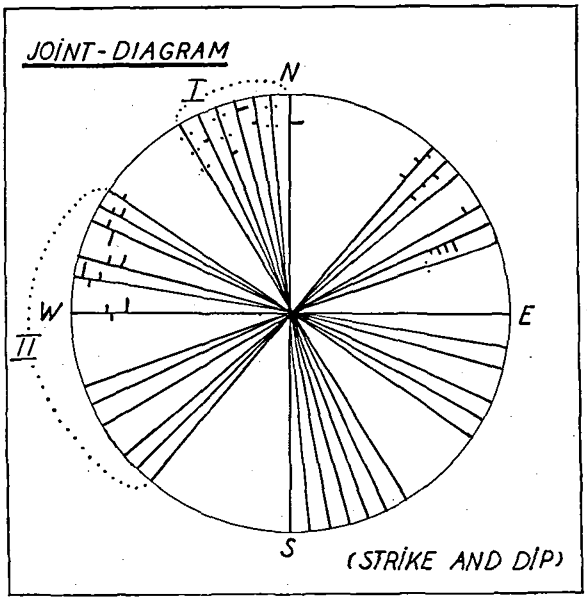

Fig. 5. The diagram shows the strike and the dip of the joints measured during the survey (37 in all). The small crosslines on the strike lines indicate the direction of the dip. Vertical joints are indicated by a pair of dots.

direction more readily has released an action by the horizontal pair of forces (rotation) which, according to the shape of the dome and certain details of the structure, have assisted in the deformation. If so, it is a case of "ungleichwertige Klüftpare" in the sense in which HANS CLOOS uses this term (CLOOS, 1936).

The orientation of the cleavages, mentioned above, shows that they must have been made originally after S-planes actually formed during the folding process.

At last a very common type of joints should be mentioned, sheeting joints (*Bankung*) which were observed elsewhere in West Greenland. Sheet-joints seem to be most highly developed in the migmatitic rocks where granitization has a tendency to homogenization. Thus, sheet joints are strongly developed in the comparatively homogeneous gneiss granites in the Tovqussaq area although absent from the surrounding amphibolites (Fig. 6 and 7). The dykes in the gneiss granites vary in thickness from 25 centimetres to 1 meter, but they may thin quite out on account of the somewhat irregular course of the cleavages. In the central area round the Tovqussaq mountain they help give the mountains their characteristic dome form (Fig. 6 and 8). In the "dyke-shaped" gneiss granites they fall slightly away from the amphibolites (Fig. 7), and so can hardly be explained as genuine L-Klüfte (CLOOS, 1936).

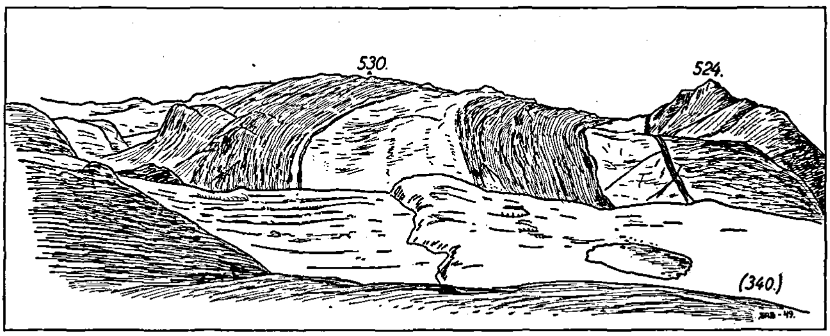

Fig. 6. The sketch shows the sequence of the strata in the east wall of the valley north of the inner harbour (cf. Fig. 11, a & b). The light-coloured strata are gneiss granites, the darker rocks have been built up from migmatitic to agmatitic rocks, and the steep dark strata are amphibolites. Note the lentils of ultra-basic rocks in the southern part of the central amphibolite (cross hatching). To the right is the Tovqussaq mountain (524 metres).

H. HAUSEN, who has worked on the problem of sheeting in the

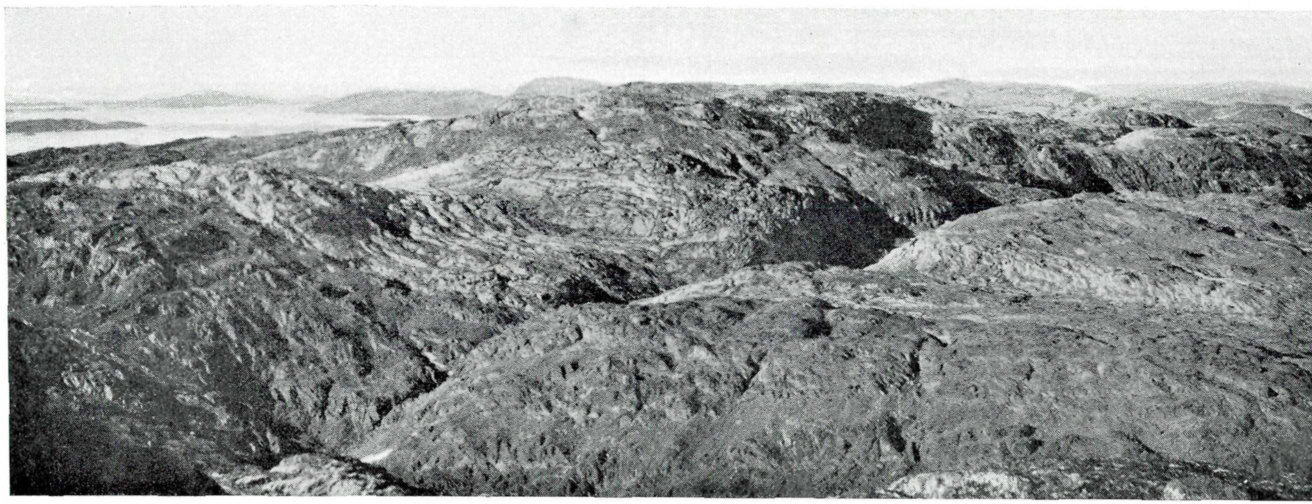

Fig. 7. The photo was taken northwards from the Tovqussaq mountain (524 metres). It shows two amphibolites and an intermediate streak with gneiss granite. Note also the typical jointing in the gneiss granites. The Finnefjeld may be seen dimly in the horizon as a protruding ridge.

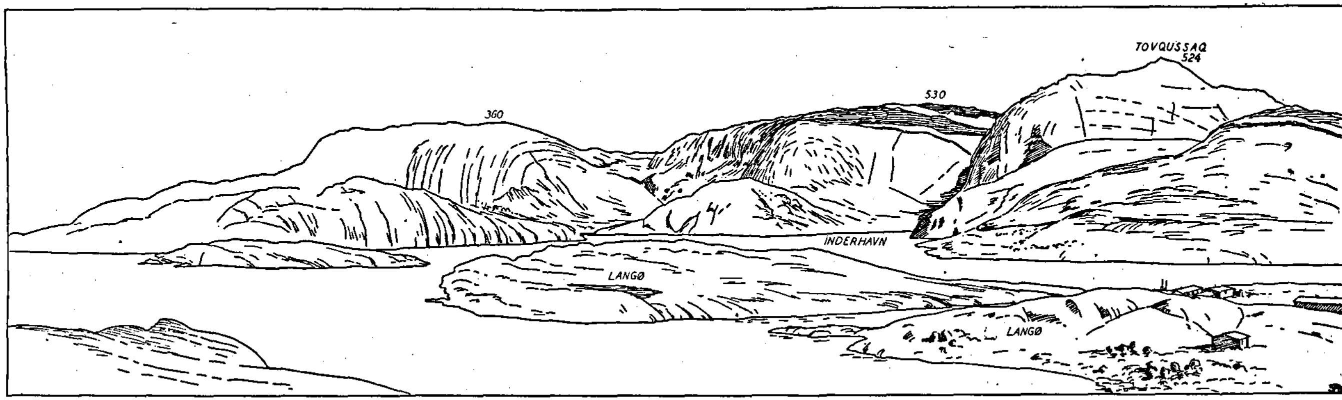

Fig. 8. View (from N to E) from the highest point of Langø showing the strata in the rocks round the inner harbour. On the right are some buildings near the fishing port.

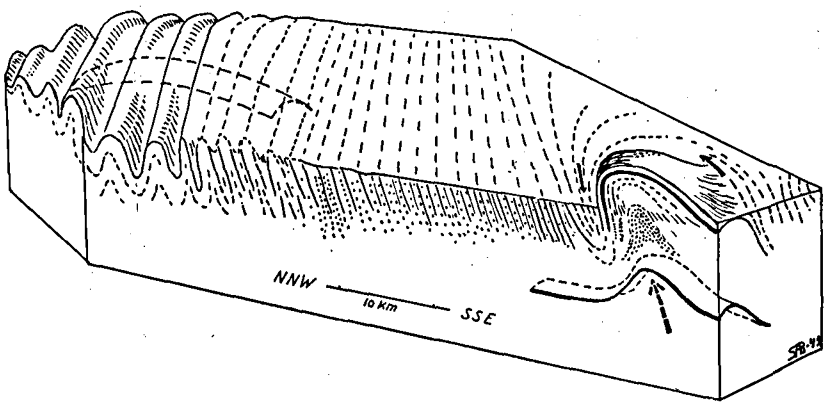

Fig. 9. A simplified outline of the structure of the Tovqussaq area and its formation (compare text). To the left in the block diagram is the highly folded Alangua area which passes smoothly into the Finnefjeld complex where the granitization has concealed the steep isoclinal folds. The dome structure is on the right.

Åbo skerries in Finland (HAUSEN, 1944), assumes that sheeting-joints (apart from genuine L-Klüfte in intrusive rocks) have been caused by expansion after the removal of overlying rocks. The author also accepts this explanation as the most probable for the area dealt with in the present paper. The initial set-up may, however, originate from tensions following cooling upon granitization (cf. WEGMANN, 1938).

e). Diabase dykes. Only three of such dykes were observed in the Tovqussaq area—and all in its border zone. This absence of diabases indicates that the area has not been subjected to very strong horizontal compression as the dilatation which usually follows and allows room for the dyke intrusion has been only slight. Apart from a certain rotational tendency, the forces at work during the deformation have rather been vertically directed. The Finnefjeld complex, however, is intersected by larger and smaller diabase dykes, which sometimes can be followed for long distances. This is consistent with the strong horizontal compression which seems characteristic of this area.

The Structural Development.

To meet the demand for an explanation of the vertically directed forces during the deformation, the cause of the structural formation of the Tovqussaq area should be looked for in "the deep".

The influence of:

1. a pre-orogenic "block",
2. a directional granitization ("granitization funnel")
3. a pre- or synorogenic axial culmination in an underlying structure

may all be possible causes of vertically directed forces. However, as far as the writer's observations go, there is nothing to suggest that pre-orogenic "blocks" have been instrumental in the deformation of the adjoining areas. The second possibility that the doming should be due to a highly localized, directional granitization was tested as a working hypothesis in the field but not confirmed. Nor can in my opinion such a directional granitization be considered possible with the p.t. conditions which correspond to the granulite facies and which must have prevailed on the level from where the action should come.

The writer proposes to leave this theory unproven for the time

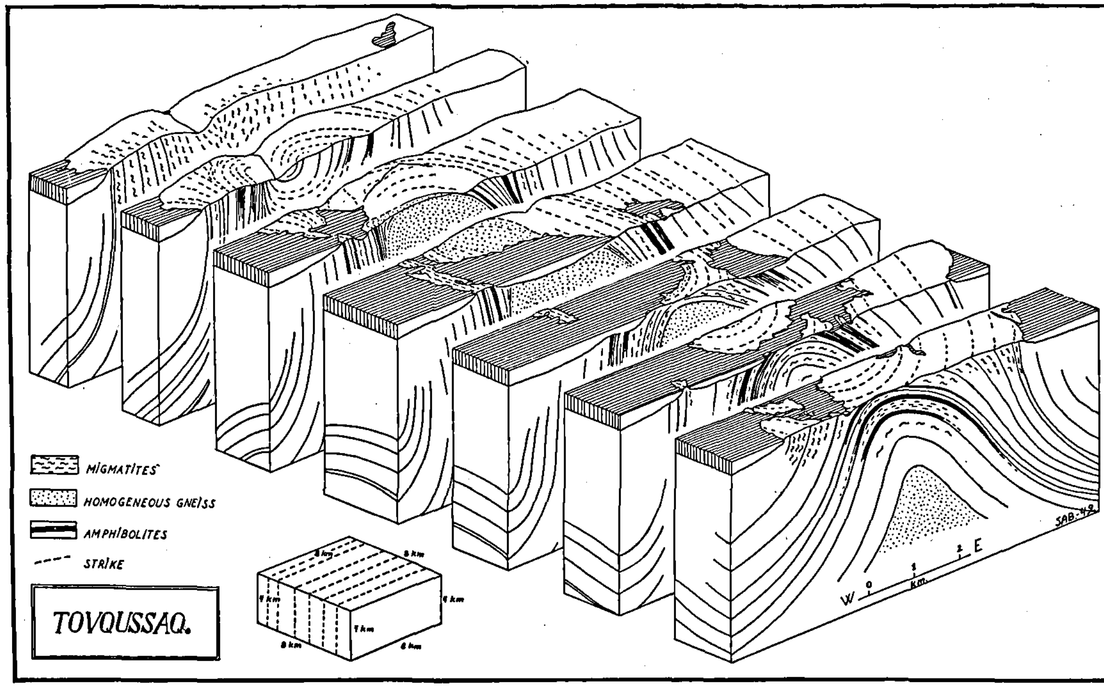

Fig. 10. The individual blocks in the stereogramme have been moved away from one another in order to obtain a series of cross sections (E–W). The topography has been taken from the maps of the Geodetic Institute. (1:200000). The structural guiding lines have been measured from the geological map (Pl. I). The dotted sign on the surface has been included to illustrate the beginning diapir formation. The guiding lines in the underground are extrapolations, and have only been sketched.

being but hopes to return to this interesting subject at a later date.

The possibility mentioned in 3) is presumably the most plausible explanation and will be dealt with in detail in the following passage.

An Underlying Structure.

The Kangamiut complex and its continuation southwards to Sukkertoppen (RAMBERG 1948, a and b) is characterized by a deformation with an axial direction NE–SW. This direction still predominates in an originally typically sedimentary complex (the Alangua area named after a fjord of the same name) north of the Finnefjeld complex, which is considered a granitized part of the northern Alangua area. The axial direction of the Tovqussaq area deviates slightly from this, being NNW–SSE. It is possible that the structure of the area has been partly determined by an underlying and, possibly, older structure, the axial direction of which must have been about NW–SE. This direction is also perceptible in the area between the Amitssuarsoralak Fjord and the Kangia Fjord as the folding axis there dips anticlinally away from a hypothetical axis going NW–SE. This has been outlined in Fig. 9. On the coast south of the Fiskefjord the direction of the folding axis seems to be about NNW–SSE (cf. p. 560). The mineral facies show that here is a more deeply eroded section than to the north (p. 559), for which reason it is natural to assume that the underlying structure should assert itself more in this place.

The question whether the underlying structure is pre- or synorogenic must remain unanswered until new investigations have been added to the material of observation.

The Doming.

The structural action of an axial culmination in an underlying structure, which seems to be discernible, must be regarded as the reason for the peculiar "closed" structure of the Tovqussaq area, as such an action is the best explanation of the upwards directed forces at work during the deformation. The strong metasomatism which has led to the formation of the comparatively homogeneous rocks in the central parts of the dome has presumably been catalytically accelerated by these forces. During the last phase of the formation of the dome the metasomatic processes have in all probability been the most important factor in the structural formation.

Assuming that this development, which may be compared to the formation and upward movement of a salt dome, continues until it stops at a much higher level, it may, theoretically, lead to the formation of a diapire (WEGMANN, 1930).

The less prominent rotational tendency of the dome may be explained as a consequence of the overlapping of two differently orientated structures. In Fig. 9 is an outline of the geometrical and vectorial conditions during the formation of the tilted pressed-up dome ("an unborn diapire"). In the figure is also indicated the orientation of the presumed underlying structure.

The structural elements described under b), c), d), and e) complete together with the weathering down to the present level the structural development of the Tovqussaq area.

I wish to thank Professor, Dr. phil. ARNE NOE-NYGAARD for giving me the opportunity to work up the material collected and for good advice and guidance during my work. My thanks are also due to Dr. phil. HANS RAMBERG and Mrs. M. L. RAMBERG who initiated me in the methods of field work and to stud. mag. MOGENS WALTHER who assisted me in the field. Mr. CHR. HALKIER, Conservator of the Mineralogical Museum, has kindly prepared the photographic plates for reproduction.

The preparation of the maps was made possible by the most obliging kindness and good will towards the Geological Survey shown by Professor, Dr. phil. N. E. NØRLUND, Director of the Geodetic Institute, and Lieutenant-Colonel HELK, the head of the photogrammetric section of this institute.

Copenhagen, Jan. 31st, 1950.

Dansk resumé.

Under kortlægningsarbejdet i sommeren 1949 for Grønlands Geologiske Undersøgelse havde jeg lejlighed til at undersøge en interessant struktur omkring fiskerihavnen Tovqussaq. I fig. 1 er med en pil vist det undersøgte områdes beliggenhed. Som det fremgår af det geologiske kort (Fig. 11, a & b), er området overvejende opbygget af migmatitiske bjergarter, temmelig homogene gnejsgraniter og ret mægtige amfiboliter. Bjergarternes mineralindhold viser, at der må have hersket tryk- og

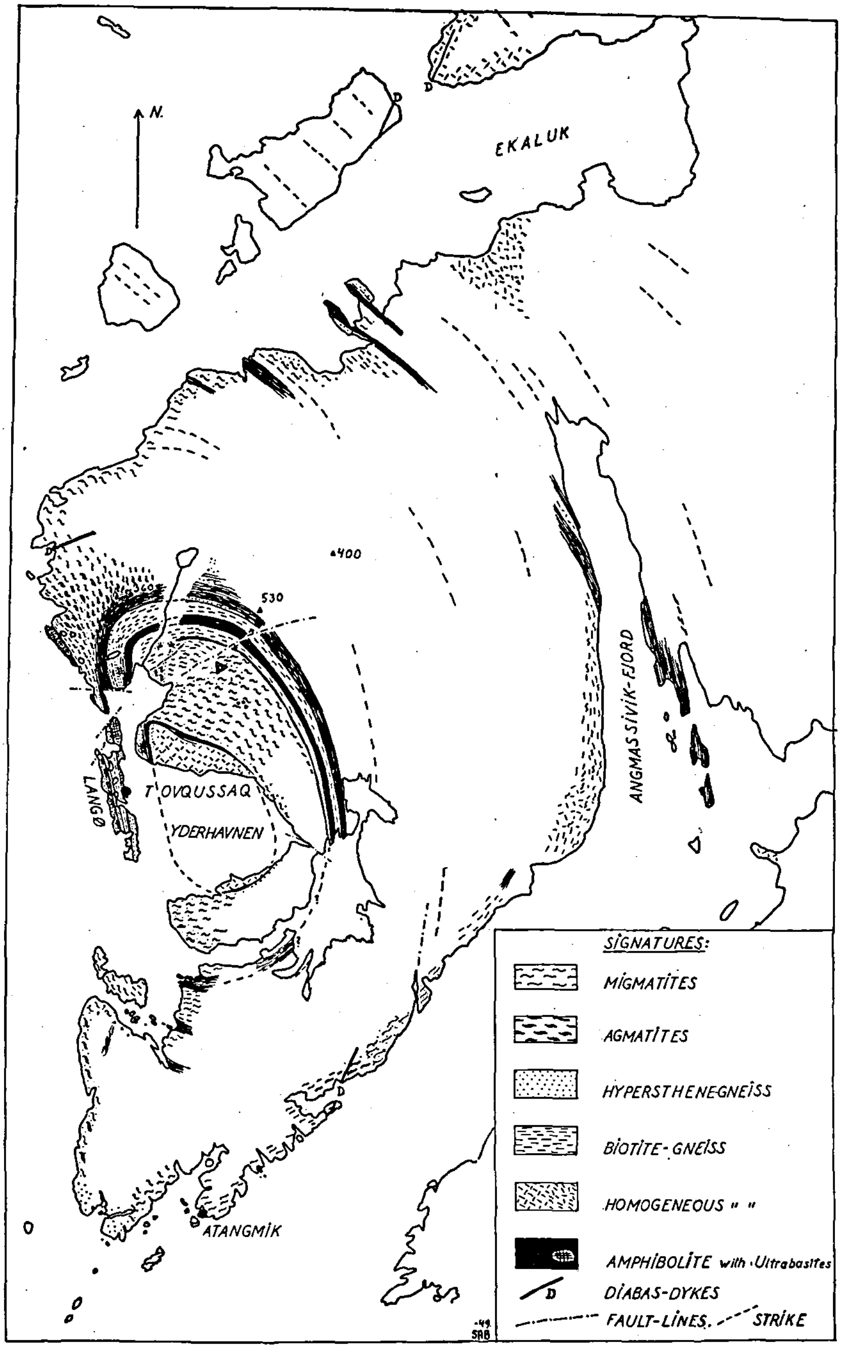
N.
EKALUK
400
530
ANGMASSIVIK-FJORD
LANGØ
TOVQUSSAQ
YDERHAVNEN
ATANGMIK
SIGNATURES:
MIGMATITES
AGMATITES
HYPERSTHENE-GNEISS
BIOTITE-GNEISS
HOMOGENEOUS " "
AMPHIBOLITE with Ultrabasites
DIABAS-DYKES
FAULT-LINES. STRIKE

Fig. 11 a.

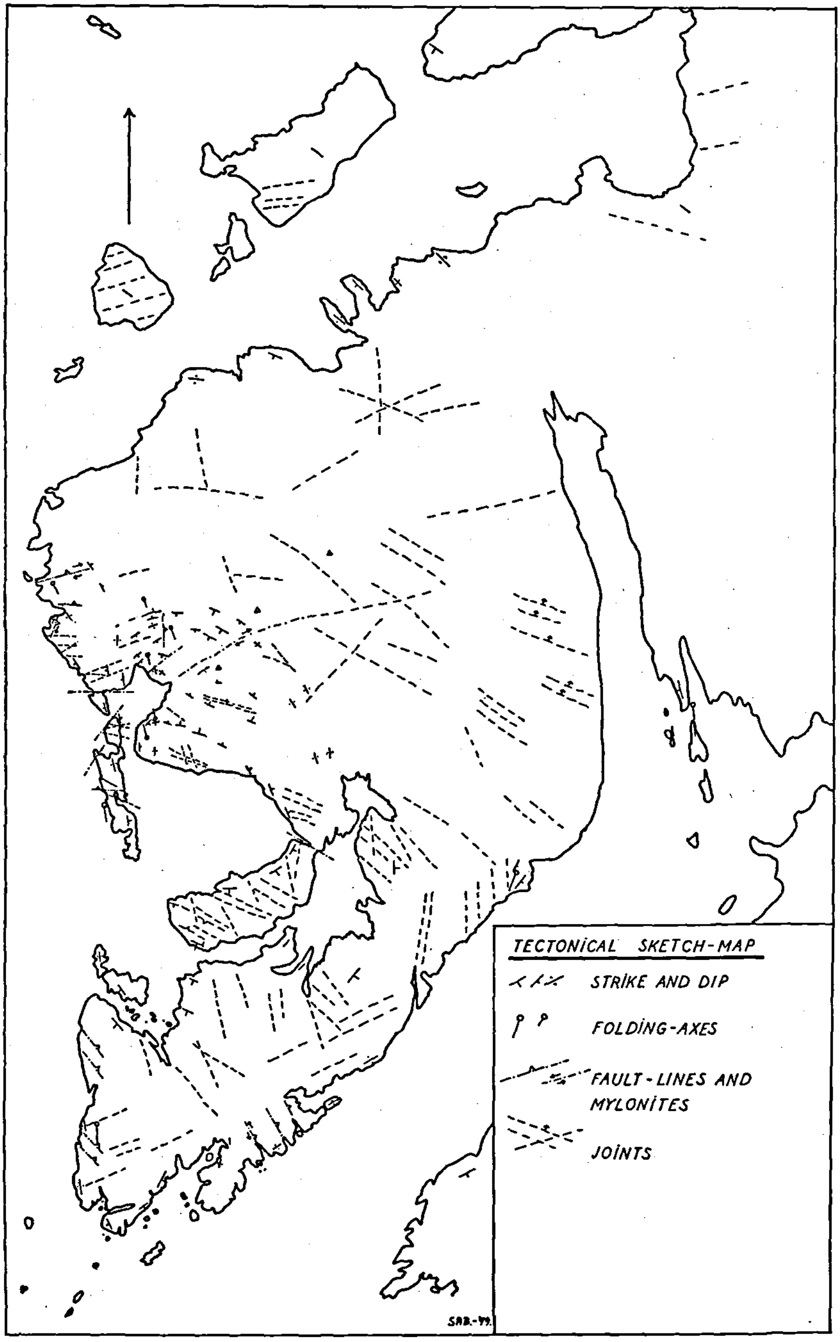
TECTONICAL SKETCH-MAP
STRIKE AND DIP
FOLDING-AXES
FAULT-LINES AND MYLONITES
JOINTS
SAB.-49.

Fig. 11 b.

temperaturbetingelser, der svarer til granulitfacies, dog undertiden stående på overgangen til — eller helt svarende til — amfibolitfacies.

Den strukturelle opbygning er søgt fremstillet i et stereogram (Fig. 10). Jeg betegner strukturen som en kippet oppresset dome.

Ved gennemgangen af de syn-, sen- og postkinematiske strukturelle elementer (pegmatitter, myloniter, epidotsprækker, joints og diabasgange) belyses de særlige vektorielle betingelser, der har ført til domedannelsen, som jeg beskriver i en afsluttende syntese.

Aarsagen til dannelsen af domestrukturen anses her for at være den strukturelle induktion fra en axialkulmination i en underliggende — muligvis ældre — struktur. I det skematiske blokdiagram i fig. 9 er vist denne virkning fra en underliggende struktur, som også lader sig spore længere mod nord. — Overgribningen mellem de to strukturer menes at have frembragt en mindre fremtrædende rotationel tendens. Samtidig med domedannelsen har en kraftig metasomatose homogeniseret bjergarterne i områdets centrale dele.

LITTERATURE

BALK, ROBERT, 1937: Structural Behaviour of Igneous Rocks. Geological Society of America, Memoir 5.

BARTH, T. F. W., CORRENS, C. W., ESKOLA, P., 1939: Die Entstehung der Gesteine. Berlin.

CLOOS, HANS, 1936: Einführung in die Geologie. Berlin.

HAUSEN, H., 1944: Die Bankung als regionale Oberflächenerscheinung im präkambrischen Felsgrund des Schärenhof im SW-Finnland. Fennia 68, Nr. 3.

PAULY, HANS, 1948: Calcite and Skarn Minerals in the Gneisses of the Holsteinsborg District, West Greenland. Meddelelser fra Dansk Geologisk Forening, Bind 11, Hefte 3.

RAMBERG, HANS, 1948: On Sapphirine-bearing Rocks in the Vicinity of Sukkertoppen (West-Greenland). Meddelelser om Grønland, Bind 142, Nr. 5.

— 1948: On the Petrogenesis of the Gneiss Complexes between Sukkertoppen and Christianshaab, West-Greenland. Meddelelser fra Dansk Geologisk Forening, Bind 11, Hefte 3.

— 1949: The Facies Classification of Rocks: A Clue to the Origin of Quartzofeldspathic Massifs and Veins. The Journal of Geology, Vol. 57, No. 1.

WEGMANN, C. E., 1930: Über Diapirismus, besonders im Grundgebirge. Comptes Rendus de la Société Géologique de Finlande, Nr. 92, III.

— 1932: Note sur le Boudinage. Bulletin de la Société géologique de France (5), vol. 2.

— 1935: Zur Deutung der Migmatite. Geologische Rundschau, vol. 26.

— 1938: Geological Investigations in Southern Greenland, Part I. On the Structural Division of Southern Greenland. Meddelelser om Grønland, Bind 113, Nr. 2.

— 1947: Note sur quelques problèmes de la tectonique superposée. Comptes Rendus de la Société Géologique de Finlande Nr. XX.