Part II

BLYKLIPPEN OCCURRENCE, STRUCTURE AND ITS INFLUENCE ON ORE DEPOSITION

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Introduction.

An essential preliminary to serious and extensive field exploration in a new field is an understanding of the geological occurrence of known deposits. It must be determined whether other similar deposits are likely to occur in the area, and which localities are the most favourable for investigation. Geological work is being directed towards these ends, at Blyklippen (fig. 4). In particular, the following subjects are under investigation:—

(1) The determination of the structural factors which have controlled the ore solutions and the deposition of the ore, in order that these may be recognised in further exploration and their significance understood.

(2) A study of the mineral distribution and its relationship to the structural controls, to determine whether the distribution is a consequence of depth (temperature) or is due to structural influences. Hence, whether the termination of mineralisation at a certain level represents the bottom of the ore horizon of the district, or whether further ore may be expected at a greater depth, on repetition of similar, favourable structural conditions.

(3) The determination of the temperature of formation of the ores and the paragenesis. These give an indication as to the probable source of the ores and their place relative to metallogenetic zoning.

This part of the paper forms an introduction to the geological occurrence of the Blyklippen deposit and deals, in a brief and elementary manner, with the chief influences which have controlled ore deposition, and with the distribution of the ore minerals. The mineralogy will be discussed, with further structural details, in a further paper.

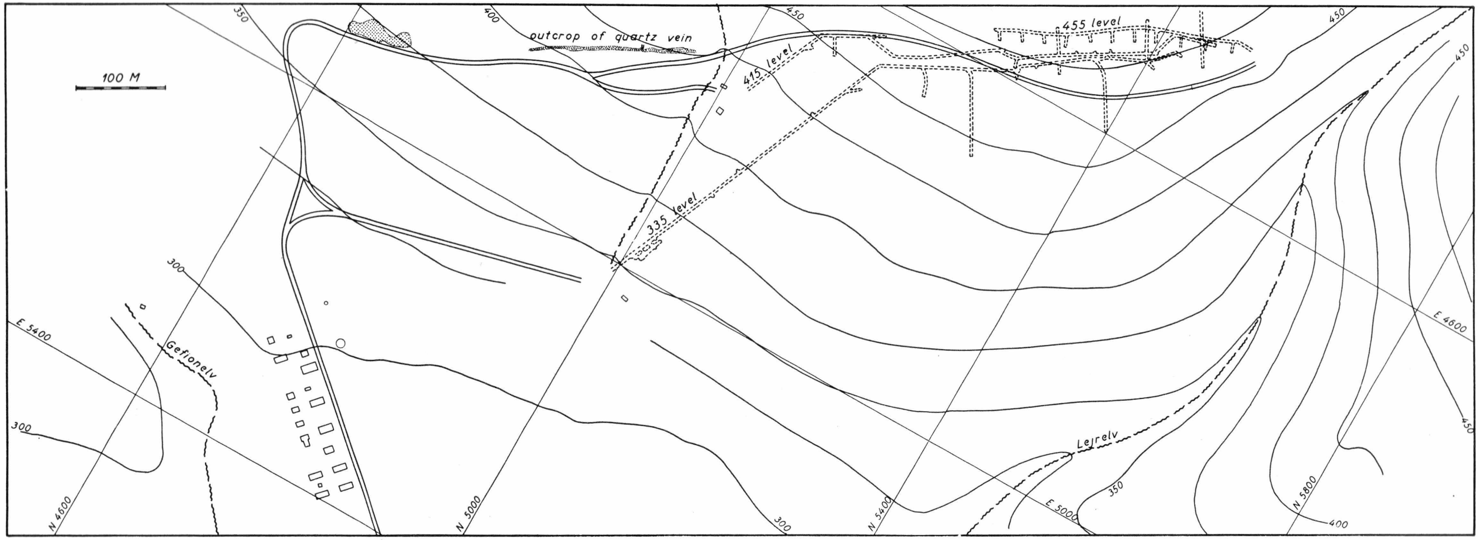

Fig. 4. Situation map of the Blyklippen Prospect, Mesters Vig, East Greenland.

1. Description of the Structural Features.

(1) Longitudinal Faults and Fractures. Faults and fractures which strike approximately 20° to 30° west of north are described as longitudinal. Their dip varies from about 40° easterly to vertical, with an average value of about 70°. The main longitudinal fault forms the hanging wall of the ore zone. As shown by the drawing, figure 5, this fault branches or splits at the northern end of the deposit. The vertical, transverse section shows that the fault becomes less steep with increase of depth, so that the faulted zone has a similar pattern in plan as in transverse section. The fault zone contains sandstone and shale which have been compressed and dragged down and along the fault. These materials are in a plastic or clayey form. The rock in the vicinity of the fault is brecciated, and subsidiary slips and fractures, parallel to the fault, in strike and in dip, extend into the sandstones, the interval between the fractures increasing with distance from the fault. In the brecciated and fractured sandstones have been deposited quartz, the ore and other minerals. The quartz zone is delimited definitely to the east by the main longitudinal fault, but its western limit is less definite, and depends upon the local extent and intensity of the fracturing. In agreement with the longitudinal fault, the longitudinal fractures change direction at the northern part of the deposit, swinging easterly.

In the areas of the constrictions, which will be described in the next section, similar fracturing is traversed by later fractures, striking more to the east and dipping westerly. These latter fractures contain quartz and barytes, and, in many cases, contain small cavities, lined with crystals of these minerals.

Fractures having the same attitude as those last described, but containing no minerals, cut across all other structures and mineralisation. These occur in and near to the constricted areas, and cause considerable brecciation of the vein material.

(2) The Constrictions. The width of the quartz zone is variable; this may be illustrated by reference to the longitudinal section, fig. 5. On this section have been plotted horizontal widths of the quartz zone. The plan indicates that a gradual narrowing of the zone takes place from south to north, to a section of minimum width, followed by a gradual widening of the zone to the north. The trace of the narrow zone, say 5 metres or less in width, in longitudinal section, plunges to the south and is horizontal, alternately. Fig. 6 is a plan of a part of the 415 level, showing the longitudinal fault and slips and the constricted section. As shown in the figure, between the points (6) and (7), the fault F 1 (2) undergoes a rapid change in strike direction.

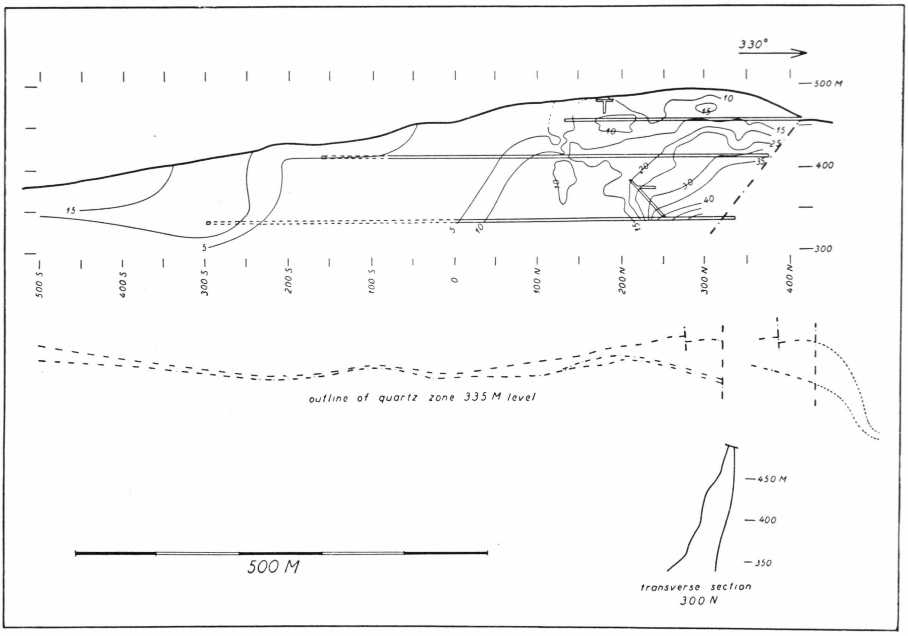

Fig. 5. Quartz Zone Widths, longitudinal Section, Blyklippen vein.

In a distance of about 15 metres in the general strike direction the displacement in the dip direction is 14 metres. The hanging wall fault, F 1 (1), makes a similar, but less marked, change. Fig. 6 (2) shows this feature on a larger scale.

The chief observed structural features between the points (11) and (12), fig. 6, are also shown on the larger scale in fig. 6 (5). It may be seen that a fault, F 1 (4), cuts the longitudinal fault, F 1 (3). On the west side of the drift, between point (11) and the fault F 1 (4), the longitudinal fractures parallel to the fault F 1 (3) terminate abruptly against the south side of the fault F 1 (4). Some of the quartz stringers are bent towards the east, against the fault. On the east side of the fault F 1 (3) the predominant fracturing and quartz stringers change in strike through a curved path, from a direction parallel to that fault, to a north-easterly direction, and back to their original direction, south of point (12). The fault, F 1 (2), indicates, in part, the path followed. On the north side of the fault F 1 (4), the dominant fracturing is parallel to the fault.

A comparison of the two features described above shows similarities in the directions of strike during the changes and in the displacement of the longitudinal system to the east. They are considered to be structures of the same type and formed in the same way. The fault F 1 (4) is interpreted as a further development in the formation of the structures, as described in paragraph 3.

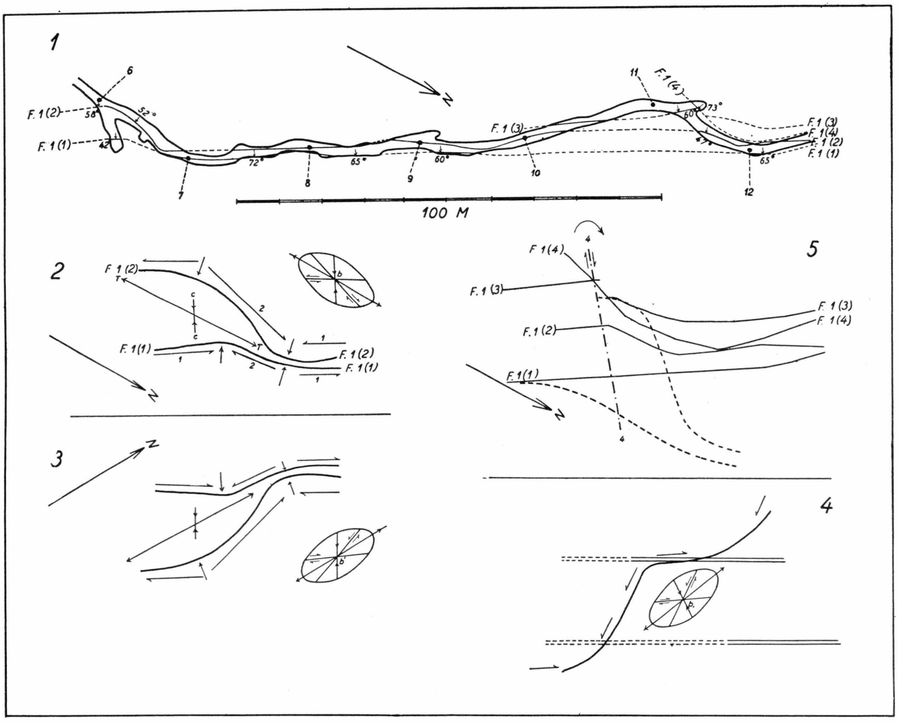

Fig. 6. Structural relations on the 415 m-level (detail).

(3) The Transverse Fault. This fault cuts and displaces the longitudinal fault and fracture systems, and the orebody. The fault is exposed in the 335 metre level, and it has been intersected by a drill hole from the surface to about the 445 metre horizon, and by drill holes U 50 and U 51 drilled from the 415 metre level. The fault dips at about 50° in a direction of about 10° east of south. A section of the fault is given in fig. (2) 4, and notes are below. Parallel in strike and dip are joints, best observed at the north end of the 335 level. These joints cut through, but do not displace, all other structures and minerals, and they themselves contain no minerals.

2. Formation of the Structures.

An understanding of the kind of forces which operated, and the manner in which the structural features were formed, may be obtained from an examination of the constrictions on the 415 metre level. Referring to fig. 6 (1), with the change in strike, there is a rapid convergence of the faults F 1 (1) and F 1 (2). This squeezing points to the operation of compressive forces acting normal to the local direction of strike.

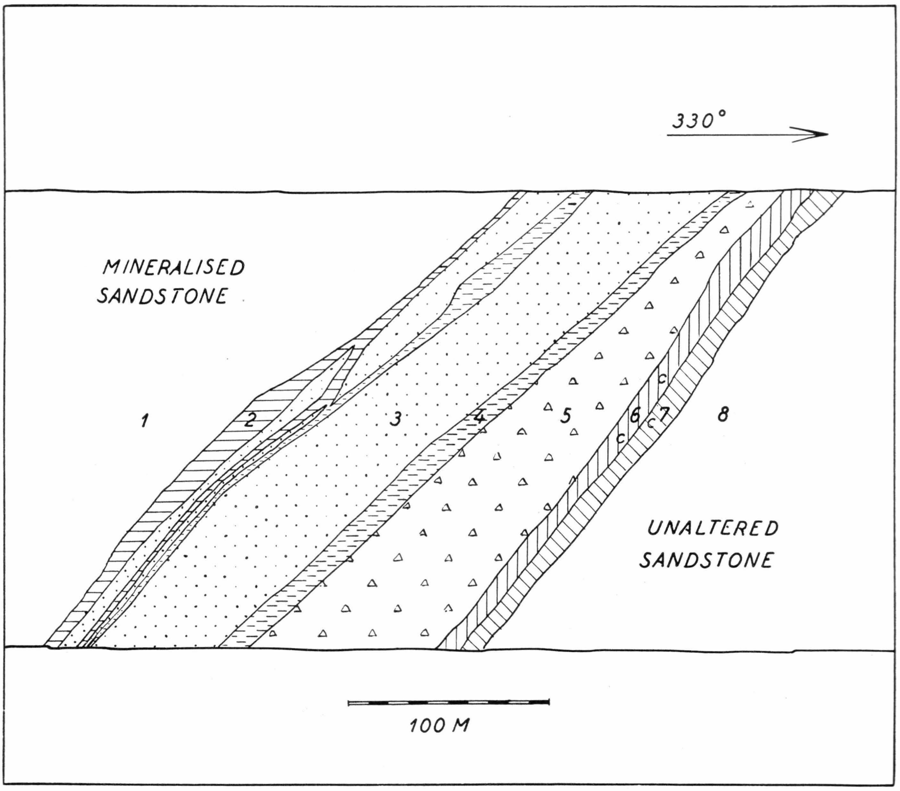

Fig. 7. Detail of transverse fault, 335 m-level.

Section of the 335 transverse fault.

1.	Grey sandstone, fractured and mineralised.	
2.	Black shale	20 cm.
	White, altered sandstone, iron stained	16 cm.
	Fault gouge—compressed sandstone and shale	3 cm.
	White altered sandstone	2 cm.
	Fault gouge	3 cm.
3.	White, altered sandstone. Crushed and compressed sandstone. Plastic consistency	70 cm.
4.	Fault gouge—sandstone and shale, etc.	15 cm.
5.	Brecciated quartz	57 cm.
6.	Quartz and fine-grained galena	15 cm.
7.	Quartz and normal galena and sphalerite	10 cm.
8.	Sandstone, unaltered.	

The fact that displacement to the east of the whole of the longitudinal system has occurred shows that the forces have not been entirely compressive. If that had been the case there would have been a constriction, but no lateral displacement. The effects observed may be explained by shearing forces. The diagram in fig. 6 (2) shows, approximately, the direction in which such forces would have acted. It is supposed that the forces (1) caused the longitudinal fracturing and faulting (F 1). In opposition to these forces, the reaction forces (2) were induced. Elongation occurred in the direction T-T, and compression approximately as C-C. The force (2), parallel to F 1 (2), was greater than that parallel to F 1 (1), so that clockwise rotation occurred, resulting in a gradually increasing convergence from south to north, until the latter force equalled the former, and equilibrium was restored. The orientation of the strain ellipsoid is indicated in the diagram, with the major axis plunging to the south, and the 'b' axis to the east.

Reference has been made to the alternate southerly plunge and the horizontal attitude of the constricted zone in longitudinal section. Orientation of the ellipsoid to obtain this pattern is indicated in fig. 6 (4), and it is seen to correspond to that in figure 6 (2). By projecting the plan, fig. 6 (2), on to the same vertical plane as the longitudinal section, as shown in the lower diagram, fig. 6 (3), it may be seen that both are part of the same structural pattern and have been formed by the same forces.

The second feature on the 415 metre level, to which reference has been made, and which is shown in fig. 6 (5), is regarded as having been formed in the same manner as the constriction described above. In this case, it is thought that the constriction had not fully developed before shearing occurred along the line 4-4 towards the eastern side of the zone. A further development of this structure is assumed, as indicated by the broken lines on the same figure. With clockwise rotation of the reaction, continued deflection of the longitudinal fractures, and of the shear plane 4-4, would occur to the east, resulting in the formation of a constriction at the northern end of the structure. Failure would naturally be expected to begin at the western side of the zone, as shown in the figure, where the rocks would be in tension.

The plan of the 335 metre level, fig. 5, shows the pronounced deflection towards the east of the longitudinal fracturing at the northern end of the level. The degree of the deflection increases from the western side of the zone. This structure is interpreted as being a part of a constriction-type structure, such as has been described above, and to have been formed by the same forces. A reconstruction of the pattern of the structure to the north of the transverse fault, before faulting occurred, is given in the diagram 5 (1).

The stage of development of the structure is more advanced than that of either of the two other structures, and the origin and development of the transverse faulting is indicated in fig. 8. The age of the final development, i. e. the displacement, of the transverse fault seems to be definitely established by the following:—

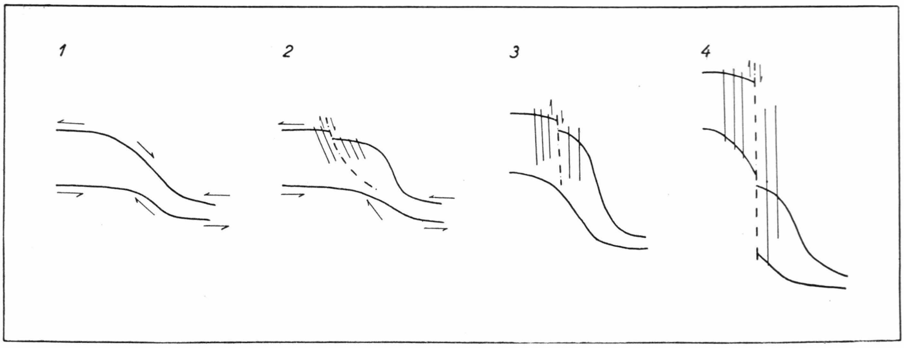

Fig. 8. Stages of development of transverse faulting.

(1) Strong and persistent fractures, seen on the 335 level, which are parallel to the transverse fault, and which were probably induced by the same forces which caused the faulting. These fractures contain no quartz or ore minerals, and are evidently later than any primary ore mineralisation.

(2) The transverse fault contains re-crystallised galena and brecciated normal galena and sphalerite, previously deposited minerals, rearranged by the shearing and its effects. The normal galena and the sphalerite occur in a breccia consisting of shale, cemented with quartz. The galena and sphalerite in this breccia appear to be broken pieces and grains from larger masses and to have been brought into their present position by the flow of „secondary“ quartz formed as a result of the movements. The normal galena occurs on the extreme limit of the faulted zone and is farthest from the planes on which shearing was most intense. It has suffered little deformation, therefore, and was further protected from the effects of shearing, including deformation and orientation, by the fluid quartz. The galena which was in close contact with the planes on which movement occurred was transformed to the fine-grained variety.

3. The Influence of Structure on Ore Deposition.

(1) Impermeable Fault Gouge and Shales. During the production of the longitudinal faulting, the sandstone and shale beds close to the fault were compressed to a plastic state and drawn down into the planes of movement. This plastic material on the hanging wall, or eastern side, of the zone acted as an impermeable barrier to the solutions, so that deposition occurred within the fractured zone, and escape of solutions was prevented. Very little silicification, and no ore is found beyond the hanging wall fault.

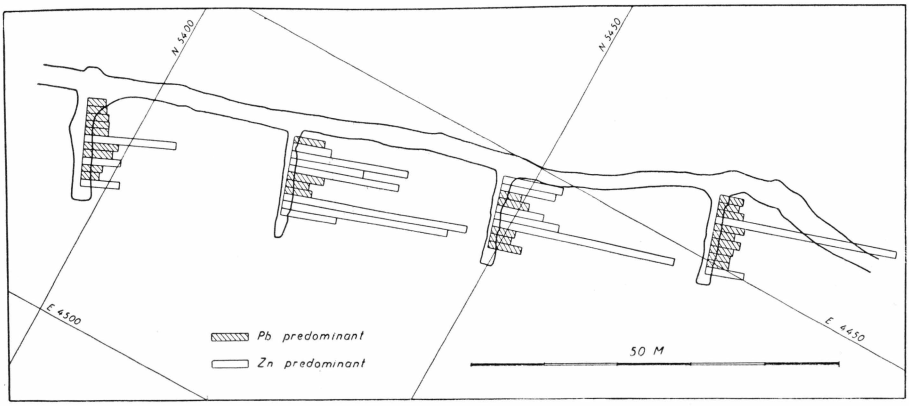

Fig. 9. Lateral distribution of the ore minerals; 455 m-level.

(2) The Longitudinal Fracturing. The effects of the longitudinal fracturing on lateral and on longitudinal mineral distribution are considered in brief in the following:—

(a) Lateral Distribution. As an example of the lateral distribution of the ore minerals, the results of the channel sampling at the 455 metre level may be examined. From the mean assay results, the ratios Pb + Zn/Pb have been plotted in fig. 9. The graphs show the abrupt changes in mineralogy transversely, lead and zinc predominating alternately across the zone. A similar arrangement is seen in practically all other cross cuts and in diamond drill holes which cross the zone. The explanation of these abrupt, lateral changes is that the ore minerals occur in fractures, parallel to the longitudinal faulting. The lateral control over the movement of the solutions was fairly rigid, due to their confinement between the longitudinal fault and slips and between the walls of the fractures. Variation of structural conditions, including the strike and dip and the size of opening, of the fractures, together with variation in the composition of the solutions in individual fractures, would determine whether lead-rich or zinc-rich ore would be precipitated at any particular section.

(b) Longitudinal Distribution. The longitudinal distribution of the ore minerals may be illustrated by reference to the 415 metre level. In fig. 10, two bodies of high grade lead ore, A-B and C-D, are shown. These bodies occur between the main constriction and the transverse fault. As the result of the reaction forces, a constriction occurred at "B", see figures 10 and 6. Ore solutions became confined between B and the neck A of the main constriction, and deposition of galena-rich ore occurred between A and B.

Passage of solutions through the constriction at B was controlled under high pressure, a gradual reduction in which took place northwards

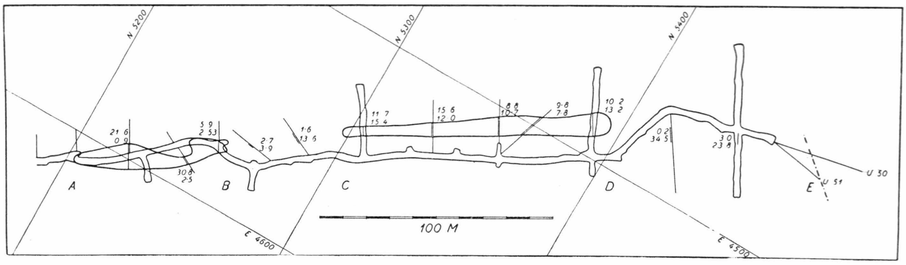

Fig. 10. Longitudinal distribution of the ore minerals; 415 m-level.

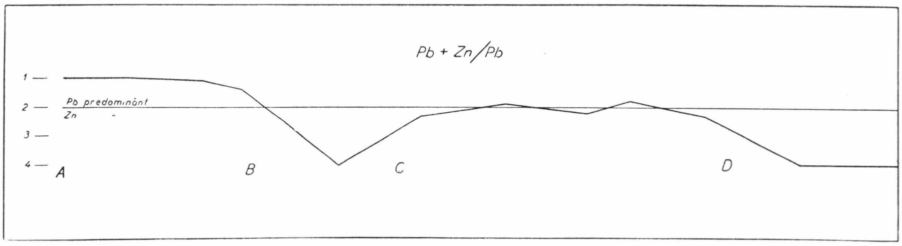

Fig. 11. Depositional variations longitudinally with changes in structural conditions, illustrated by the ratios of Pb + Zn/Pb; 415 m-level (compare fig. 10).

A. Neck of constriction. Passage of solutions blocked.
Solutions trapped between "A" and the constriction "B". Predominant lead precipitation.

B. Constriction formed initially, before development of the fault, F. 1 (4). Rapidly changing attitude of fractures. Passage of solutions controlled under high pressure. Gradual reduction of pressure, with widening of fractured zone and more consistent attitude of the fractures. First, zinc deposition predominant.

C. Second; with further reduction, pressures favourable to lead as well as to zinc deposition.

D. Pressure reduced to the point where lead deposition virtually ceased, but a marked increase of zinc mineralisation.
Fractured zone continues to widen and deflection to the east occurs.

from this section, with widening of the fractured zone and more consistent attitude of the fractures. Predominant zinc deposition occurred first. From C to D conditions of pressure were favourable for both lead and zinc, in about equal proportions, until, at D, with increasing width of the zone, and the resulting reduction of pressure on the solutions, galena deposition practically ceased, and zinc became strongly dominant. In fig. 11 have been plotted the ratios of lead plus zinc to lead, to illustrate the depositional variations longitudinally with changes in structural conditions.

In the section between A and B, there appear to have been two local influences on ore deposition.

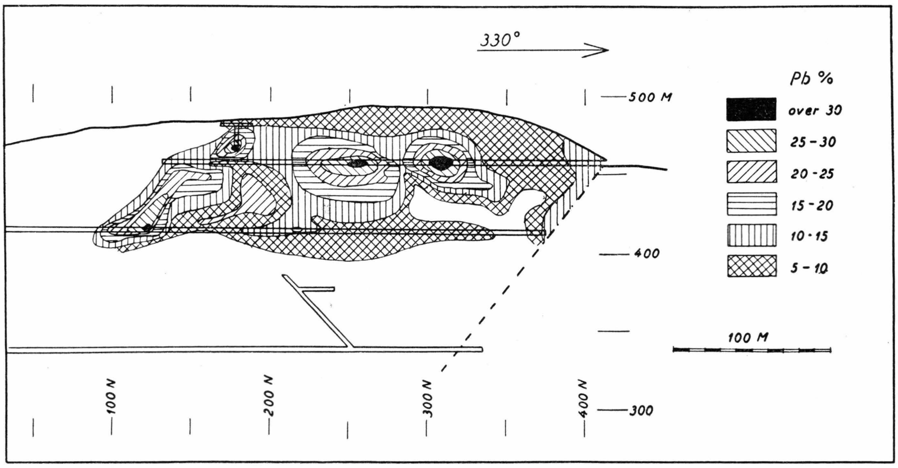

Fig. 12. Pb-distribution in longitudinal Section, Blyklippen vein.

(1) Due to the constriction at B, causing reduction in the volume of flow of the solutions, with a pressure gradient decreasing from the contraction southwards. Precipitation of galena would take place at sections where the pressure would be most suitable to promote reaction of the solutions with the wall rock. The more southerly part of this ore lens is attributed to this mode of formation.

(2) Due to the partial damming effect of the fault 4-4, which was formed during the ore formation period, by further development of the forces which caused the constriction at B. The concentration of galena just south of this fault is ascribed to this cause.

(3) The Constrictions. A comparison of the vertical, longitudinal sections of lead and of zinc values and of zone widths, figs. 5, 12 and 13, indicates that a definite relationship exists between ore deposition and the vein structure. The higher lead values occur where the zone width is moderate, between about 5 and 20 metres. Zinc is predominant in the zones of greater width. Where the zone is very wide, the tendency is for little or no deposition to occur. The most favourable position for the richest ore would appear to be, then, within the fractured zone of moderate width. There is a small occurrence of ore above the constriction, between sections 100 and 300 South. This may be explained by deposition resulting on the release of pressure on the solutions after passing through the constriction. To the north, the ore appears to occur beneath the narrowest part of the zone. If the interpretation of the development of the transverse fault is correct, and a constriction was formed, before faulting occurred, north of the present fault, then the Blyklippen orebody occupies the zone between two parallel constrictions.

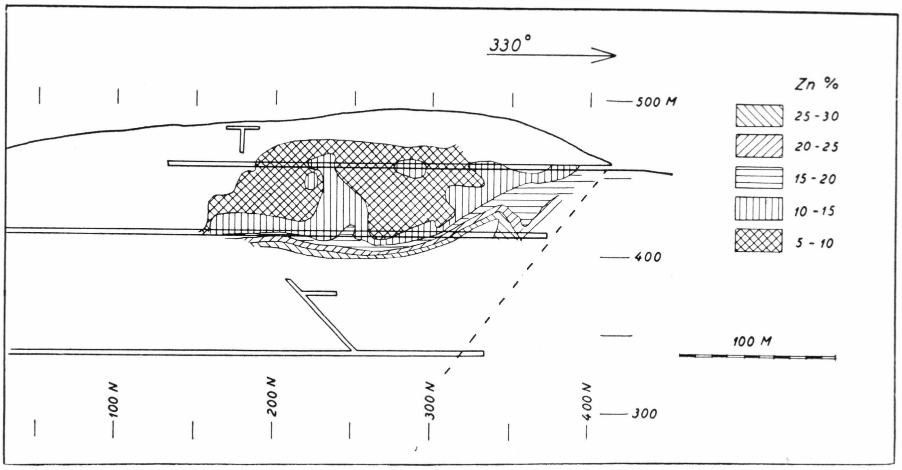

Fig. 13. Zn-distribution in longitudinal section, Blyklippen vein.

The longitudinal and vertical movements of the ore solutions were thus controlled by these constrictions.

The relative proportions of lead and zinc are shown in fig. 14. From this, two things are evident,

(1) Variations in the relative amounts of these two metals occur horizontally. The reason for this has been discussed above. It indicates that the lead-rich lenses shown in the figure have a zonal arrangement, with an increasing proportion of zinc outwards.

(2) Horizontally, from south to north, and vertically, with depth, there is an increase in the relative and actual amounts of zinc in the ore.

The fact that zinc increases longitudinally, as well as with depth, indicates that the zonal arrangement is not a result of temperature changes with depth, and that depth is not the determining factor in the mineral distribution. It is significant that the zinc/lead ratio lines are parallel to the southerly plunge of the constriction in the southern part of the deposit. The evidence is strongly in favour of a zonal arrangement due to the controlling influences of the constrictions.

4. Form of the Orebodies.

The structural controls discussed above have influenced the form of the orebodies. Bodies of ore which are greater in length than in height and in width are found. This is due to the rigid lateral control exercised by the walls of the longitudinal fractures and by the impermeable materials which lie parallel to these fractures, and to the less rigid

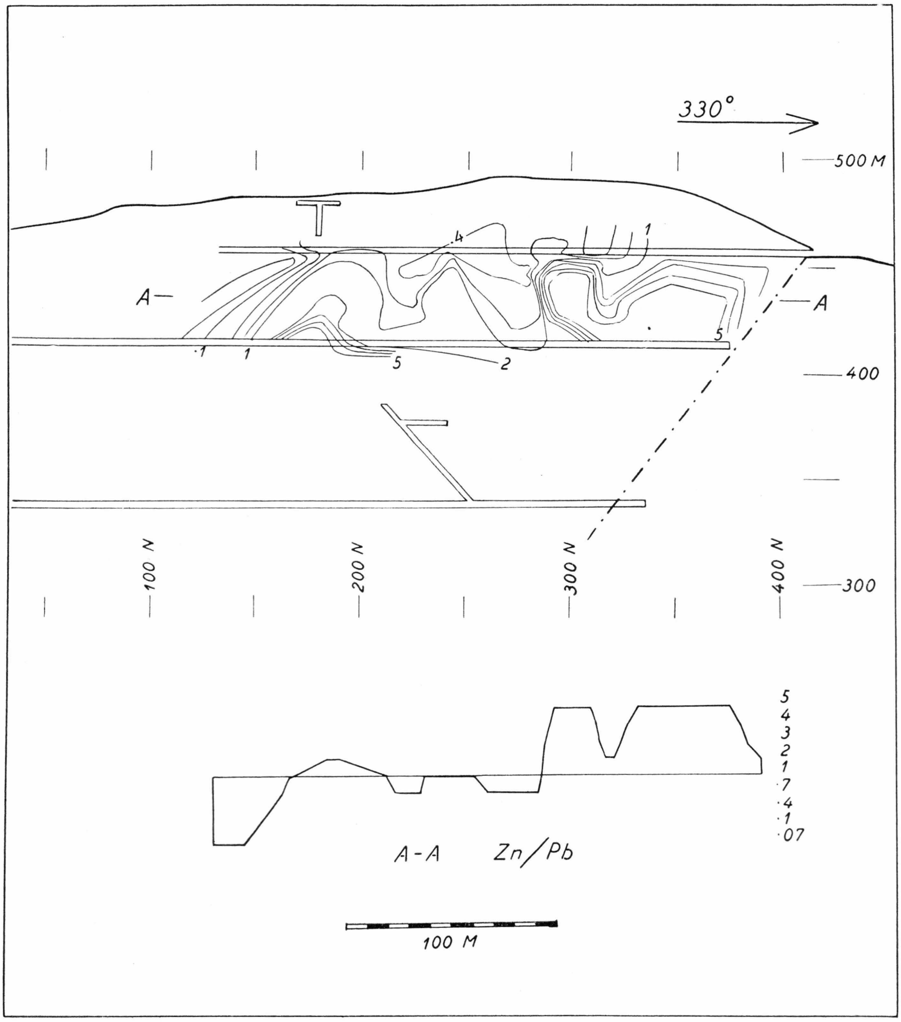

Fig. 14. Zn/Pb ratio in longitudinal section, Blyklippen vein.

control longitudinally, on account of the fractures being continuous, although variable in size and in attitude, in that direction.

The lenticular shape of the bodies may be seen in the longitudinal section, fig. 12. Two of these lenses of high grade material occur with their long axes nearly horizontal, i. e. parallel to the horizontal constriction, now eroded, under which deposition took place. The long axis, of another such lens, in the southern part of the orebody, also lies parallel to the constriction axis, the plunge being to the south.

The body to the north, lying against the transverse fault, by comparison with the others, appears to be part of a lens, the missing part of which has been displaced by the fault.

5. Sequence of Events.

The following summarises the chief events which occurred in the formation of the structures and the ore formation:—

1. Longitudinal Shearing, resulting in the longitudinal faulting, with the formation of fault gouges and plastic shales; brecciation near to the fault planes; longitudinal fractures, decreasing in intensity with distance from the fault. Introduction of quartz.

2. Reaction to the Longitudinal Faulting, causing brecciation of previously deposited quartz. The constrictions began to form and the ore minerals to be deposited.

3. Continued Reaction, with clockwise rotation, with formation of tension fractures and entry of quartz and barytes along them to seal brecciated ore and quartz.

4. Transverse Faulting and Fracturing, as a final development of the reaction forces. All mineralisation ceased before this stage.

6. Application to Further Exploration.

The structural features discussed in the foregoing form a part of the structural pattern in the Mesters Vig area, so that the results of work done at Blyklippen may be applied to further exploration in the faulted zones of that area.

The association of ore deposition with directional changes and with constrictions of the longitudinal fracturing constitutes a guide for conducting field exploration. The points where changes in direction of the longitudinal faults occur in the Mesters Vig area indicate localities for attention.

The possible development of the transverse faulting from the constriction feature also indicates that attention should be given to such faults, or, more correctly, the areas immediately to the south and north of them.

In regard to exploration in depth at Blyklippen, the conclusion reached, in paragraph 3, that mineral zoning is due, not to depth, but to structural causes, indicates that the Blyklippen deposit does not necessarily lie at the bottom of the ore zone, and that ore might be expected to occur associated with repetition of similar structural conditions at depth.

Færdig fra trykkeriet den 3. september 1955.