2. Some faults and fault depressions in relation to striated slickensides.

By

Erik Wiman.

(With Pl. I—II.)

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A. Areas investigated and the methods used.

During the summer of 1930 I had the pleasure of accompanying Prof. JOHN FRÖDIN, Upsala, on a scientific exploration in eastern Turkey. My journey was made possible by the LILJEWALCH and OTTERBORG scholarships. During the summer of 1931 I had the opportunity to bicycle around Lake Vättern in order to make the same kind of observations as in eastern Turkey and then along a typical and undisputable fault depression.

Some parts of the methods of investigation, which I intended to use in my work were developed in conference with Prof. H. BACKLUND, Upsala. I hoped to improve the methods I had already used in a previous work (48), by combining observations of movements recorded by faulted veins of different ages and faulted dikes with observations of striated slickensides. This expectation was justified, as I hoped to reach Lake Van in eastern Turkey, where a volcano with recent eruptions (and possibly recent veins) is situated along a fault. The salinity of the lakes of Van and Urmia (near Van) are so totally different (2 % and 21 %, p. 451, 43) that I had reason to investigate possible subterrestrial or quarternary outlets, especially as rivers have nowadays their sources very near Lake Van.

Prof. FRÖDIN has in a detailed report (12) explained the reasons why we did not reach Van, and it is not necessary to repeat them here.

The methods used in the present work are very simple and have a very limited application. I have mainly studied slickensides with striae (Rutschstreifen, Harnische, »fossile Seismogram» 34) along topographically visible fractures.

One might think, that if the lengths of the striae were measured in conveniant localities, a measurement of the vertical and horizontal movements would be obtained, but these measurements would with all certainty be of no value, as the lengths of the striae in most cases are directly dependant on the size of the road cuttings, the often quite accidental curvature of the rock wall and so on.

If the two walls of a fissure rub against each other, each of them may show any length of the striae, however small each displacement has been. If there are no strata containing fossils or, alternately, a number of dikes or veins along a fault, it is not easy to obtain the necessary control, and the faulting on separate sides of a fault depression may possibly have occurred at quite different periods. The danger in using this method is, that striae may only give evidence of smaller adjustments in the rocks, while larger, vertical movements may have occurred along open joints.

SALOMON and his pupils (37) have at an early date made observations of striae on fissure walls along the fault depression of the Rhine in order to interpret its secular development. A. G. HÖGBOM (20) has by his studies of the regeneration of breccias in Sweden shown that faulting occurs repeatedly along the same fractures.

My investigations give in the main the same results as those mentioned above, obtained by SALOMON (37) and HÖGBOM (20), but they are, I hope, of some value as the formation of the Rhine depression and certain other depressions need not necessarily be regarded as a model of a standard faulting in the earth's crust. I have therefor investigated two regions which are geologically so very different as eastern Turkey and southern Sweden. The Black Sea depression and the Erzindján depression in eastern Turkey are in their turn very different from each other, — the former having more the character of a geosyncline and the latter showing certain similarities with the Vätter depression.

The observations of striae at Lake Vättern have mostly been made on a chlorite coating but sometimes on prehnite (fusing and foaming in the blowpipe flame), in two cases on calcite and in one case on laumontite. The striae on the laumontite possibly indicate a very young move-

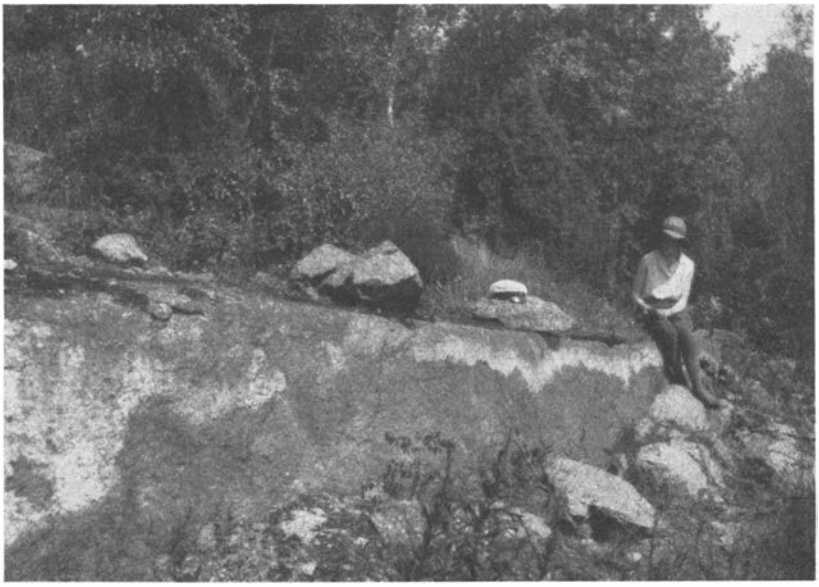

Photo. Wiman.

Fig. 1. Chlorite weathered to about 1 dm. in a joint of a coarse granite between Askersund and Karlsborg, NW of Lake Vättern.

ment as this mineral is so loose and easily crushed. Several striae have been observed in the very rock. It is then possible, that a thin mineral coating has been rubbed away due to the faulting. Generally I have made the observations in coarse-grained granites (Smålandsgraniter) composed of large felspar crystals, biotite and quartz. I have often observed, that sometimes the chlorite only coats the aggregates of biotite and not the larger felspar crystals. However, the smaller crystals of felspar are always coated and usually the larger ones also. The striae are in the first case recorded on the felspar itself.

I have not observed any striae on the few epidote coatings I have seen. Easily weathered minerals such as prehnite and chlorite are in the

Vätter rocks weathered in the fissures which are visible on the surface of the outcrops and often to a depth of 1—2 dm. (fig. 1, in the text) but sometimes to a depth of 1—2 m. It is only thanks the growth of motoring and to roadmaking for unemployment relief that fresh road cuttings have been made and perhaps the striae observed by me will in a few years have disappeared due to weathering and loosening of the mineral coating.

In eastern Turkey the roads often run as if on shelves in the mountains, and thanks to this, the escarpments of the shelves often slip or are blasted for road repair and more or less fresh cuttings seem always to occur. The striae were recorded on the rock itself and not on a mineral coating as at Lake Vättern. If there has been a coating on a the fissure walls in eastern Turkey, it has at any rate weathered very quickly. A thicker, weathered mineral coating must in such a case have been younger than the striae observed by me.

LEITH (27), BAILEY WILLIS (46), ASKLUND (2) and LJUNGNER (28) have studied the formation of joints and movements along them with regard to general tectonics and peneplains. HENDERSON (16), BARRINGTON, BROWN and DEBENHAM (3) have investigated the hrizontal and vertical movements along joints with regard to the formation of the landscape.

The geo-physicists HOBBS (18, 19), GUTENBERG (14) and others (7, 40, 49, 6, 22, 34, 44, 30, 26) have studied fractures and also striae from a geophysical point of view.

B. **A longitudinal and a transversal system of slickensides.**

LIND, a pupil of SALOMON (p. 515, 37) has discovered, that along the eastern escarpment of the Rhine depression, there are two systems of slickensides, — one longitudinal and one transversal. DINU (See SALOMON, p. 516, 37), who investigated the western escarpment of the depression opposite to Heidelberg, also observed two systems, — one striking N—S and one W—E. I attempt below to identify two such systems in the regions investigated by me.

The geology and geography of eastern Turkey have recently been dealt with in shorter papers by LILLY STAMER (41), ERNEST NOWACK (29), OTTO CYRÉN (8), R. BRUNK (6), and JOHN FRÖDIN (12, 13).

The same year as my visit to eastern Turkey, joints were formed in the earth's crust in Persia as described by BRUNK (6). FELIX OSWALD (31) has fairly exhaustively described the geology of eastern Turkey. According to him foldings have occurred during different geological periods including the miocen. During the middle-miocen period, intrusives forced their way, and they are marked on his geological map. They are in part altered into serpentine. I have, at Erzindján, made observations of striae on joints in coarse-grained gabbros of the above age. After miocen, a fracturing and faulting occurred during pliocen and pleistocen (p. 18—19, 31).

a. **The Black Sea depression.**

According to the map by OSWALD (textfig. 3) several fractures which are concave towards the north, run more or less along the Black Sea S of Trabzon. On comparing textfig. 3, with the international map text-

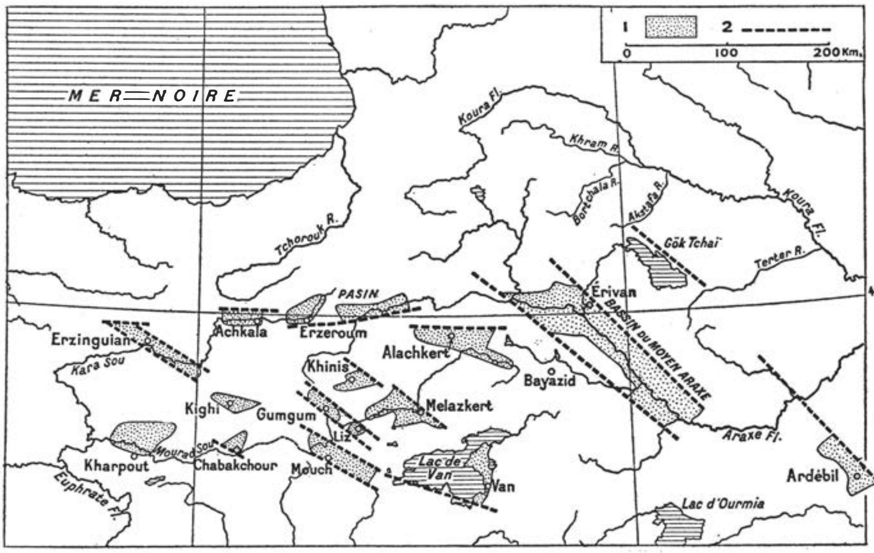

Fig. 2. Fault depressions in eastern Turkey according to Oswald (31). — Blanchard (p. 121, Geogr. Universelle. Tome VIII, 4). The Erzindján depression investigated by me.

fig. 4, it looks as if the fractures had been drawn with regard to the topography, which certainly can be regarded as correct in the present case, as the fracture-topography here seems to domineer. I have made my observations along two fractures through Sigana and Gümüsch hane (see textfig. 2—4), — each of my traverses having a length of 40 km. It would probably be better to mark these two fractures (textfig. 3) as one single fracture running in the valley of Kars hut (textfig. 3 and 4). OSWALD seems to have drawn the fractures along the summits of the mountain ridges and not along the valley between them (Compare textfig. 3 and 4). Observing the cutttings along the road from Sigana to Gümüsch hane it seemed to me as if the Karshut valley (textfig. 3 and 4) occurred in a zone of fracturing. However, as the two above-mentioned fractures have nearly the same direction, and the distance between them is not large (about 30 km.), it is not of great importance whether they are counted as one or two.

Joint planes with striae at Sigana occur mainly in a quartz-porphyry and at Gümüsch hane in a granite but in both localities in basic supra-

Fig. 3. The Black sea depression and the Erzindján depression according to Oswald (31). Scale 1 : 3 700 000. 1 cm. = 26 km.

crustals of doubtful age (OSWALD 31, ABICH 1). As, according to OSWALD's map (textfig. 3) and my observations, no fractures of importance occur at the actual coast of the more than 1000 m. deap sea, there is reason to believe that the bottom of the Black sea has at least in part sunk along the investigated curved fractures.

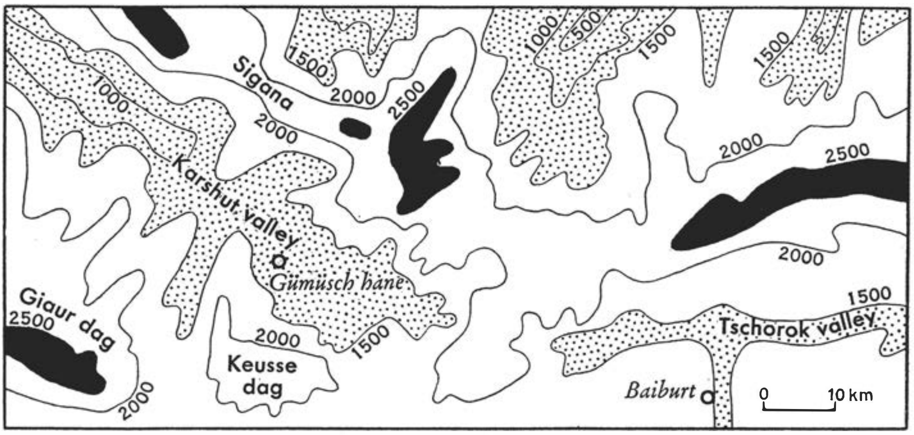

Fig. 4. Contours at 500 metre intervals at Sigana and Gümüsch hane. Eastern Turkey. Karshut valley = zone of faulting.

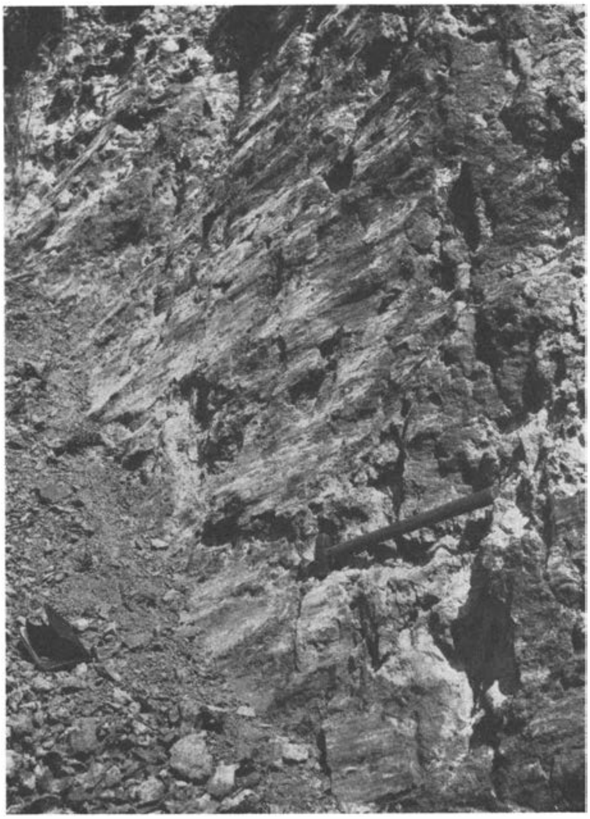

Photo. Wiman.

Fig. 5. Striae with an angle of 20° with the horizon. Rock = quartz-porphyry. About 10 km. S of Sigana along the road. Observation along curved fracture shown on map textfig. 3.

Strike and dip.

According to fig. 1 Pl. I the striated planes at Sigana (for orientation textfig. 4) strike mainly NW, NNW, N and NNE, — mostly N and

NW, — which perhaps indicates, that the movement here occurred partly at right angles to the mountain chain and the coast of the Black sea (transversal system) and partly along the fracture itself (longitudinal system).

According to the observations at Gümüsch hane (for orientation text-

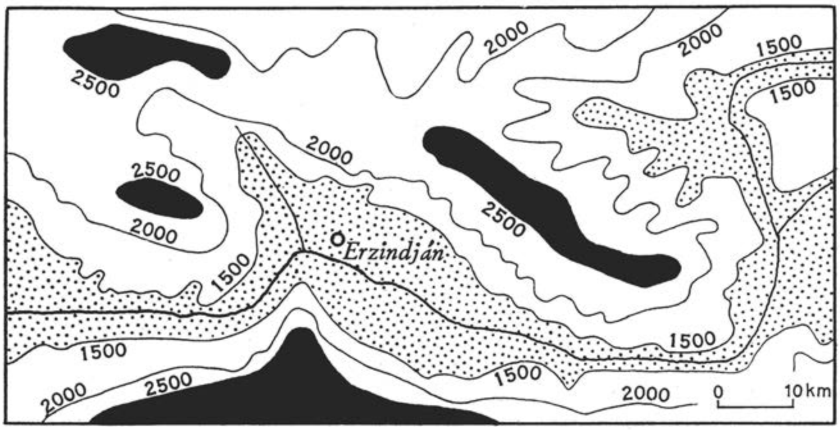

Fig. 6. The Erzindján depression according to the international map. The valley of Western Euphrates.

Photo. Wiman.

Fig. 7. The Erzindján depression viewed from the northern slope of the fault depression. In the background the southern slope. The town of Erzindján occurs on the bottom of the depression and 1420 m. above sea-level.

fig. 4), where the fracture strikes more in the direction of W—E than the one at Sigana, most of the striated planes strike mainly NW (fig. 2, Pl. I), possibly indicating a dominant transversal system of fractures.

Striated planes at both Sigana and Gümüsch hane have mainly a dip of 80°—90° (fig. 4 and fig. 5, Pl. I).

b. **The Erzindján depression.**

In the years 1045—1784 seventeen earthquakes took place near Erzindján according to ABICH (pp. 441—43, 1). My observations along the depression ($5 \times 1{,}5 = 7{,}5$ km.[2]) were made in a coarse-grained, partly brecciated gabbro. The gabbro-massives are marked on OSWALD's geological map (31) and have an orientation of ENE. The observations of striae were made about 20 km. N of the town of Erzindján and 1700 m. above sea-level (see textfig. 6) and 20 km. SW of Erzindján in the cutting of the Western Euphrates (photo textfig. 8) about 1420 m. above sea-level.

Photo. Wiman.

Fig. 8. The river-cutting of the Western Euphrates, SW of Erzindján. The camera was in the valley itself and directed toward the town of Erzindján (for orientation textfig. 6).

The observations N of the town were made in a genuine gabbro-breccia (textfig 9) built up of numerous striated slickensides, 0,5 dm. to 1 m. in size. The observations SW of the town were made in the same kind of gabbro as N of the depression, but the rock is not so abundantly fissured SW of the town that it can be called a breccia.

The hypothetical longitudinal system is possibly indicated by the joints striking (W—E? and) NW (fig. 3, Pl. I). As a transversal system we can perhaps with a greater degree of probability count the joints which have a strike of N 10° W and N 40° E (fig. 3, Pl. I). The transversal system would be mainly developed S of the depression and the longitudinal one N of the depression, indicating a possible assymetry in its structure.

c. The Vätter depression.

(Topographical sections Karlsborg, Hjo and Jönköping, geolog. sect. see 5, 23, 24, 25.)

Lake Vättern is the second largest lake in Sweden and has a long ovaloid form with a length of 128 km. and a maximum breadth of 31 km. Its level is 88,2 m. above the sea. For geological reasons, the Vätter depression has long been regarded as a typical fault depression.

Photo. Wiman.

Fig. 9. Breccia with striae on slickensided planes in coarse-grained gabbro. The northern fault of the Erzindján depression.

ASKLUND has quite recently (1931, 2) and LJUNGNER, earlier, (pp. 109—110, 28) made collocations of the forming of the structure and morphology of Southern Sweden. The lake is situated in a region chiefly composed of Archaean granites, which, near the lake are more or less in contact with the south-western gneisses of Sweden. Smaller areas of the hälleflint-leptite formation (definition p. 7, 48) occur along the lake. According to HÖGBOM (p. 166, 21) the age of down faulting of the Vätter depression cannot be regarded as settled. He is of the opinion that a tertiary one may have occurred (pp. 166—167, 21).

Post-glacial movements along the fractures of the lake seem to have

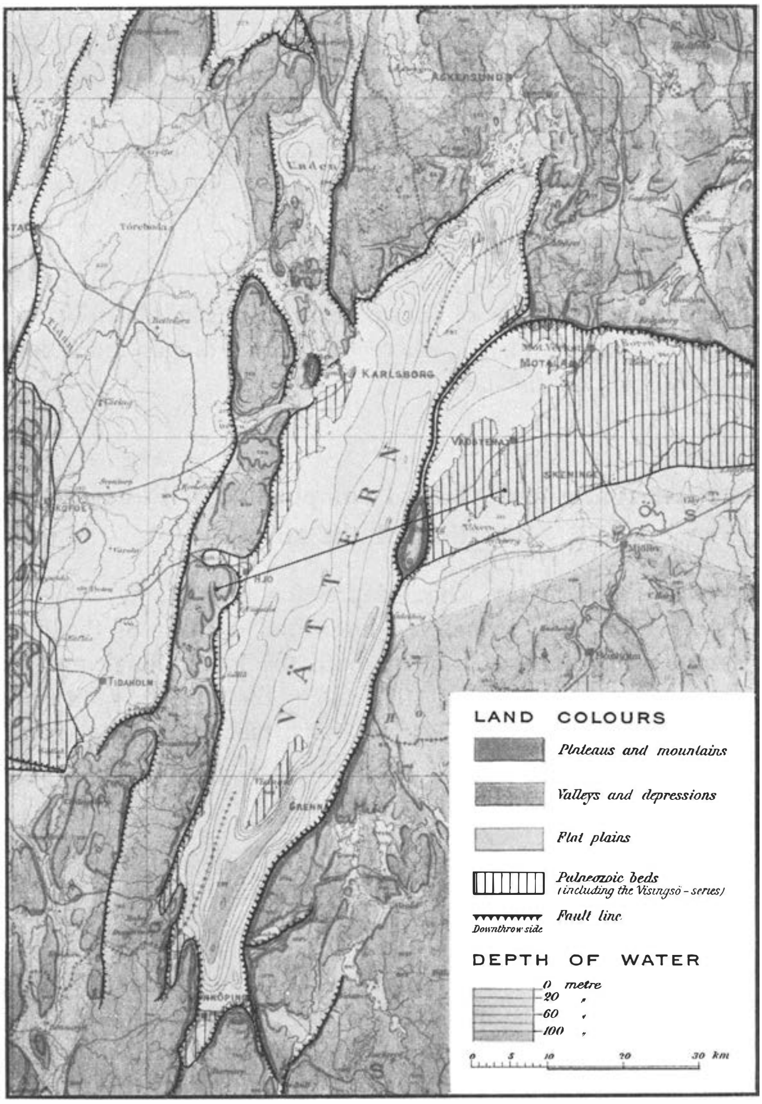

Fig. 10. Faults according to Sten De Geer (9, 10).

been demonstrated in the neighbourhood of Karlsborg (WESTERGÅRD, p. 65, 45) and for the Väner region, not far from Vättern, by SANDEGREN (pp. 11—12, 39) and v. POST (p. 201, 32). Regions of earthquakes have during the period 1907—1910 been mapped by SAHLSTRÖM (35), where the NNE-faults are cut by the W—E-faults at Motala E of the lake (for orientation fig. 1, Pl. II).

Strike of striated, slickensided planes along the Vätter depression (for situation of traverses see fig. 1, Pl. II).

The striated planes seem in the main to strike along the present limits of Vättern (black on fig. 2, Pl. II), and can be called the longitudinal system. A transversal system seems not to be so very dominant (white on fig. 2, Pl. II), but it is rather pronounced in the diagrams I, II, III, IV, V and VII, — especially in IV.

Dip of striated, slickensided planes at Vättern.

The striated planes mostly dip 50°—89° (fig. 3, Pl. II) towards Vättern except inside the area of the more pronounced schistosity indicated by III and IV (fig. 3, Pl. II), where the planes dip as much inwards as outwards in relation to the lake.

C. The horizontal and vertical components with regard to the direction of the striae.

LIND has found at the Rhine depression (p. 515, 37) that according to the evidence of the striae, the horizontal element of the movements have played an important rôle along both the longitudinal and the transversal joints. DINU has found, that along the western fault escarpment the horizontal component has a greater importance. He says (p. 516, 37) that 45,4 % of the slickensides of the transversal system show larger horizontal than vertical components.

a. The Black Sea depression.

Sigana.

A pronounced difference of angle between the striae and the horizon does not occur in the longitudinal and the transversal systems. Most of the striae run horizontally (fig. 7, Pl. I). The striae which form an angle with the horizon generally form an angle of 20° with it (fig. 7, Pl. I), but sometimes of 10°, and, exeptionally, (5 cases out of 57), 90°.

Gümüsch hane.

The striae mainly form a minimum angle with the horizon of 0°—30°, — a pronounced maximum is shown in fig. 8, Pl. I. Only 5 % show angles of 70°—90°. The striae are just as much direcred towards the west as towards the east (fig. 8, Pl. I).

b. The Erzindján depression.

Many of the striae on the slickensides run parallel (fig. 9, Pl. I) to the horizon, but most of them form an angle of 30° with it. The southern fault line of the depression having an orientation of NW runs nearest to the highest summits (textfig. 6, 3000 m. above sea-level) and the southern fracture nearest to the lower summits (textfig. 6, 2500 m. above sea-level). The bottom of the depression is situated 1420 m. above sea-level.

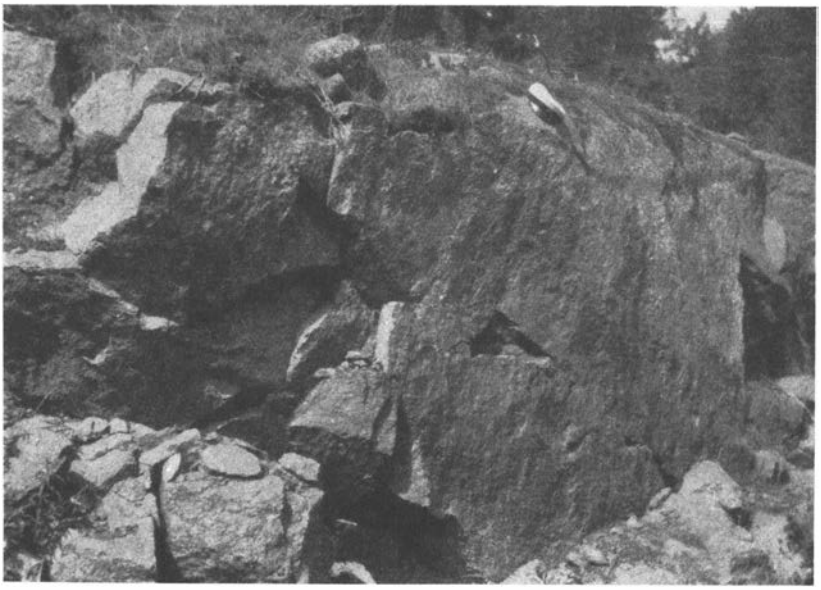

Photo. Wiman.

Fig. 11. Striated, slickensided plane with chlorite in a coarse granite at the north-western shore of lake Vättern between Askersund and Karlsborg.

c. The Vätter depression.

The minimum angle between the striae and the horizon has been recorded on textfig. 4, Pl. II. Where the lake shows its maximum depth (120 m. textfig. 10) the vertical components are rather dominant (black on fig. 4, Pl. II) and then along the eastern escarpment. The level of the lake is 88,2 m. above sea-level. The vertical measure between the greatest depth of the lake (120 m.) and the highest summits of the mountain (333,6 m. above sea-level) NNE of Stibbarp, is then 452,6 m. The Archaean table land at the lake shows an average height of 250—300 m. above sea-level.

Besides the deep-channel of the lake already mentioned, there is another at Omberg (textfig. 10) with a maximum depth of 100 m. The shallow Motala bay (textfig. 10) reaches a maximum depth of only 48 m., and, in all probability, it indicates the continuation of the Silurian strata present E of the lake.

Dominant vertical components are, — as was expected, — not present along the western escarpment (compare fig. 4, Pl. II and textfig. 10), and it is possible that the striae have here not so much to do with the formation of the depression. According to fig. 4, Pl. II, the striae along

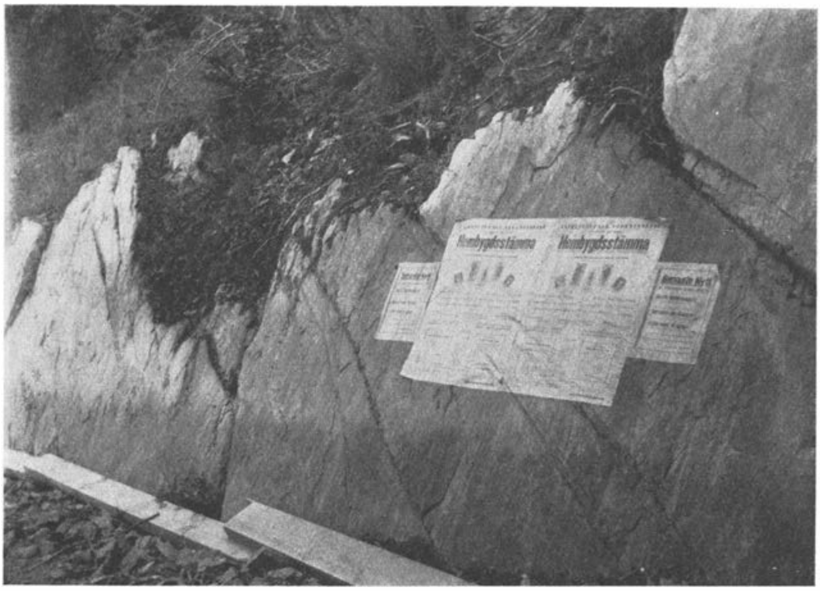

Photo. Wiman.

Fig. 12. Striated, slickensided plane about 1 km. NW of Norra kärr at the eastern shore of Lake Vättern.

the western escarpment generally form angles with the horizon which are less than 45° and along the eastern deep-channels 10°—65°, — but here they often reach 70°—80°.

The striae plotted in the diagram IV (fig. 4, Pl. II), which form a minimum angle with the horizon of often 40°—50°, are possibly caused by or accompanying the process of schistosity (protoginförskiffringen), which is especially pronounced just at IV (fig. 4, Pl. II).

As regards the character and the dominance of the different systems of striated slickensides, it may easily be seen that from Gränna towards S of Omberg (represented only in V fig. 4, Pl. II), a persistant system of striated planes (photo. textfig. 12) domineers, which, on the photograph also looks very different from the striated wall textfig. 11. On the photograph (textfig. 12) one can easily discern that the striae aro not deep and the wall looks more to have been polished than rubbed. The system is especially well developed about 1 km. NW of Norra kärr (between Gränna and Omberg), where a joint strikes N—S and dips 65° W. The striae, which are here at right angles to the line of intersection of the horizontal plane and the joint, then form a minimum angle of 65° with the horizontal plane. Provided that most of the striae along the Vätter depression have nothing to do with its formation, I believe that the above »polished» system indicates an extensive faulting.

D. On serveral systems of striae on the same slickenside and on the relationship between striae and breccias.

According to certain observations at Erzindján and Vättern the movements along faults seem to be zig-zag as several systems of striae running in different directions occur on the same wall. In the part of the present paper dealing with my methods I have already mentioned that the lengths of the striae do not give any information as to the extent of the movements. The lengths of the striae mentioned below change from 1 dm. to several metres. In the river-cutting SW of Erzindján (for orientation textfig. 6 and 8) several systems of striae on the same wall hardly indicate a tension but a fairly continuous compression.

On a slickenside 16 sq. m. in area, SW of Erzindján, striking N—S and dipping about 90° and gently curved, I have observed as many as 10 systems of striae (towards S: 55°, 20°, 45°, 70°, 60°, 10°, 30°, towards N: 15°, 0° and 90°). On a slickenside striking W—E and dipping 90° in the same cutting of the Western Euphrates I have also recorded the minimum angles between the horizontal plane and the striae, which are here represented by four systems (towards W: 75°, 15°, 30° and 90°). In the same valley on a slickenside striking N 10° E and dipping about vertically the striae fall towards S: 25°, 40°, 50° and 0°.

LJUNGNER (p. 207, 28) has shown that in Bohuslän a steeper system of striae cuts and is younger than a less steep one. West of Lake Vättern I have only observed one system on each separate slickenside but E of the lake 7 walls (out of 183) show 2 systems of striae. Of these 7 cases I could not observe any difference of age between the two systems as they only formed an angle of 10°, — one continuing into the other. Of the remaining 4 systems, 2 indicated that the steep striae are older, and 2, that the steeper are yonger than the others.

A. G. HÖGBOM (pp. 404—406, 20) has described regenerated breccias occurring at Lake Vättern, and he refers also to previous investigations here. HÖGBOM has pointed out as many as 5 or 6 generations of faulting, but of these 3 belong more to the class of eruptive breccias. The breccias along Vättern are, according to HÖGBOM, in all probability contemporaneous with the formation of the Vätter depression. According to my observations some of the striae are younger than the formation of breccias which I have observed W of Norra kärr. N of Erzindján almost all the pieces of the breccia are striated, and there is reason to believe that the brecciation and the striae are more or less contemporaneous.

E. Are the striae directed inwards or outwards in relation to the fault depressions investigated?

a. The Black Sea depression.

Along the wings of the curved fractures of the Black Sea (for orientation textfig. 2, 3, 4) the striae are directed inwards (towards the bottom of the depression) and the striae also fall inwards along the transversal system.

b. The Erzindján depression.

The striae are directed just as much towards W as towards E (fig. 9, Pl. I) in all the observations made near Erzindján. The transversal joint system shows striae, which run outwards at the southern escarpment (25 outwards and 4 inwards) and here 29 joints out of 50 can be regarded as transversal. The northern escarpment only shows 5 transversal joints with striae. The results are collected in the table below.

Southern escarpment. 50 observations.

Longitudinal. 21 observations (W—E- and NW-joints).

Transversal. 29 observations. (Joints striking N 10° W—N 40° E), of these: 25 outwards and 4 inwards.

Northern escarpment. 50 observations.

Longitudinal. (W—E- and NW-joints.) 45 observations.

Transversal. (Joints striking N 10° W—N 40° E). 5 observations and of these: 3 outwards and 2 inwards.

According to the above table it looks as if the structure of the depression were very assymetrical. Summarizing the above one can say, that a breccia indicates the nothern escarpment and along the southern escarpment the striae are directed outwards.

c. The Vätter depression.

In order to investigate how the striae are directed in relation to the Vätter depression, I have, as mentioned before, divided the material of observations into a longitudinal (black on fig. 2, Pl. II) and a transversal joint system (white on fig. 2, Pl. II). A table summarizes the results.

E of Vättern. 183 observations

Transversal striae = 69 (53 inwards and 16 outwards = $3_{,3}$ times more inwards than outwards).

Longitudinal striae = 114 (45 towards N and 37 towards S = $1_{,2}$ times more towards N than towards S. 10 horisontally. 22 along the dip of the striated planes and of these 16 inwards, 3 outwards and 3 quite vertically = 5 or possibly 4 times more inwards than outwards).

W of Vättern. 79 observations.

Transversal striae = 19 (13 inwards and 6 outwards = 2 times more inwards than outwards).

Longitudinal striae = 60 (20 towards N and 30 towards S = $1_{,5}$ times more towards S). 9 horizontally and 1 quite vertically.

$1_{,5}$ % of all the striae pitch quite vertically.

The diagrams fig. 5 and fig. 6, Pl. II are constructed directly according to the figures obtained in the above table.

F. **Summary.**

The vertical and horizontal components and resultants in continental movements have *inter alia* been laid stress upon by E. F. SUESS (42), and HAARMAN (15, 11). It is then of interest to investigate the facts obtained by the aid of 641 observations of striated slickensides along fault depressions.

The striae mainly occur on slickensides striking parallel and at right angles to the depressions investigated, which agrees with the findings of SALOMON (37).

According to the observations of striae I have made, it is only exceptionally that striae pitch quite vertically ($1_{,5}$ %). The striae generally form an angle with the horizontal of less than 90°. If one takes the trouble to make correct observations of the striae, which without a clinometer look as if they pitched quite vertically, one will find that in reality they form at least an angle of 10° and often much more with the plumb-line. In Asia Minor, where the movements ought to have been at least somewhat different from the movements in the fennoscandian Archaean shield, the striae generally form a smaller angle with the horizon than at Vättern. Besides my investigation along the Vätter depression, I have in Sweden observed striated slickensides at Bråviken (79 observations), Upsala (27 observations p. 117, 48) and at Skuru near Stockholm

(26 observations) and there the striae form angles with the horizontal of the same size as the ones observed at Vättern.

Striae of different ages have been recorded on the slickensides at Erzindján (10, 4 and 4 generations) and at Vättern (2 generations) indicating certain stages of the movements. Such a secular formation of fault depressions as may be suspected as a result of my observations of striae may in some cases explain antezendant (epigenetic) river cuttings (for orientation textfig. 2). The striae on the slickensides may indicate, though they do not prove, that the numerous river valleys (textfig. 2) between the fault depressions in eastern Turkey have been formed more or less as a result of such a faulting as I have sketched.

The striae are chiefly directed inwards along the Black Sea and the Vätter depressions but at the southern escarpment of the Erzindján depression outwards. At the northern escarpment of the latter the rock is so brecciated, that it is difficult to discern the direction of the chief movement. The Erzindján and the Vätter depressions seem to be rather asymmetrically built with regard to the striae observed.

Acknowledgements.

The tracing of the maps and diagrams have with usual skill been made by A.-B. KARTOGRAFISKA INSTITUTET. I wish to thank Mr R. MARSHALL for his work in reading through the manuscript and making the necessary corrections in it as regards grammatical errors.

Asymmetry instead of assymetry on pages 33 and 40.

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Maps of Turkey.

1. Eastern Turkey in Asia, compiled at the Intelligence Division, War Office, London. Scale = 1 : 250 000, 1 inch = 2,5 cm. or 1 cm. = 2,5 km., 1,014 inches = 4 miles.
2. International map of the world. K. 37 and J. 37. Scale 1 : 1 000 000. 1 cm. = 10 km. Agent for the sale of the map: London, E. Stanford Ltd 12. Long Acre. W. C.
3. Karte von Kleinasien. Rickard Kiepert. Scale 1 : 400 000. 1 cm. = 4 km. Geographische Verlagshandlung, Dietrich Reimer, Berlin. Wilhelmstrasse 29.
4. Carte geologique et minière de L'Asie Mineur par Ali Kénan et Ahmed Malik. Scale = 1 : 1 500 000. 2,3 cm. = 2 km. The map is according to the above mentioned gentlemen chiefly a copy of the international geological world-map, on which they have marked the ore occurences.
5. Geological map according to Abich (1). Useful when traversing from Trabzon to Erzerum. 1 verst = 1,067 km. or 1 km. = 0,9374 verst.

Printed 21/3 1932.

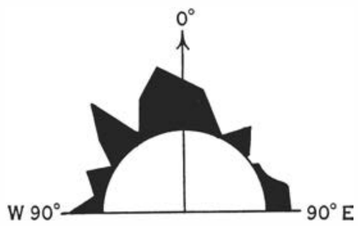

Fig. 1. Strike of slickensided planes along curved fault at Sigana. 57 observations.

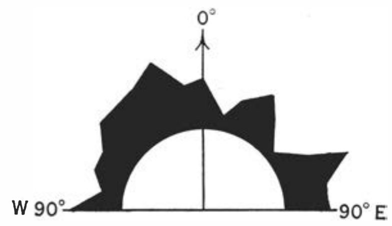

Fig. 2. Strike of striated, slickensided planes along curved fault at Gümüsch hane. 100 observations.

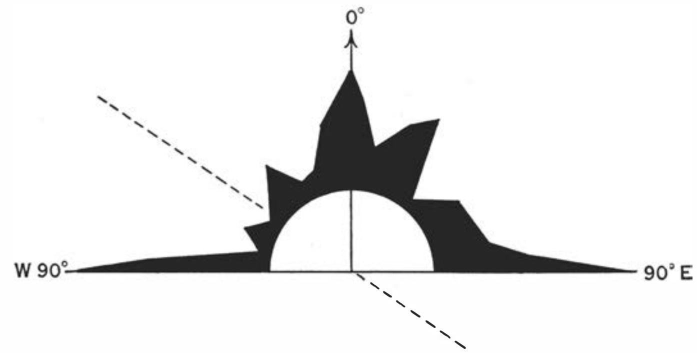

Fig. 3. Broken lines indicate the orientation of the Erzindján depression. Strike of striated, slickensided planes at Erzindján. 100 observations.

Fig. 4. Dip of slickensided planes along curved fault at Sigana. 57 observations.

Fig. 5. Dip of striated, slickensided planes along curved fault at Gümüsch hane. 100 observations.

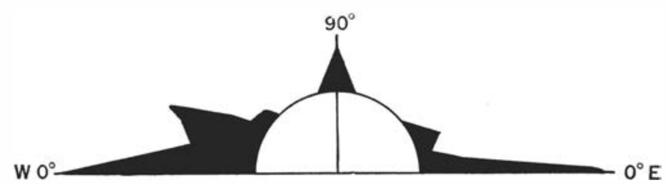

Fig. 7. Minimum angle between striae on slickensided planes and the horizontal plane along curved fault at Sigana, E Turkey. 57 observations.

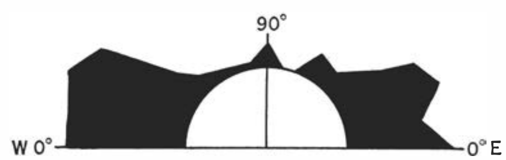

Fig: 8. Minimum angle between striae on slickensided planes and the horizontal plane along curved fault at Gümüsch hane, E Turkey. 100 observations.

Fig. 6. Dip of striated, slickensided planes at Erzindján. 100 observations.

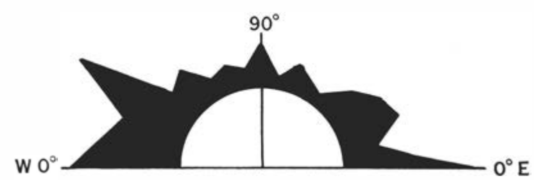

Fig. 9. Minimum angle between striae on slickensided planes and the horizontal plane at Erzindján. 100 observations.

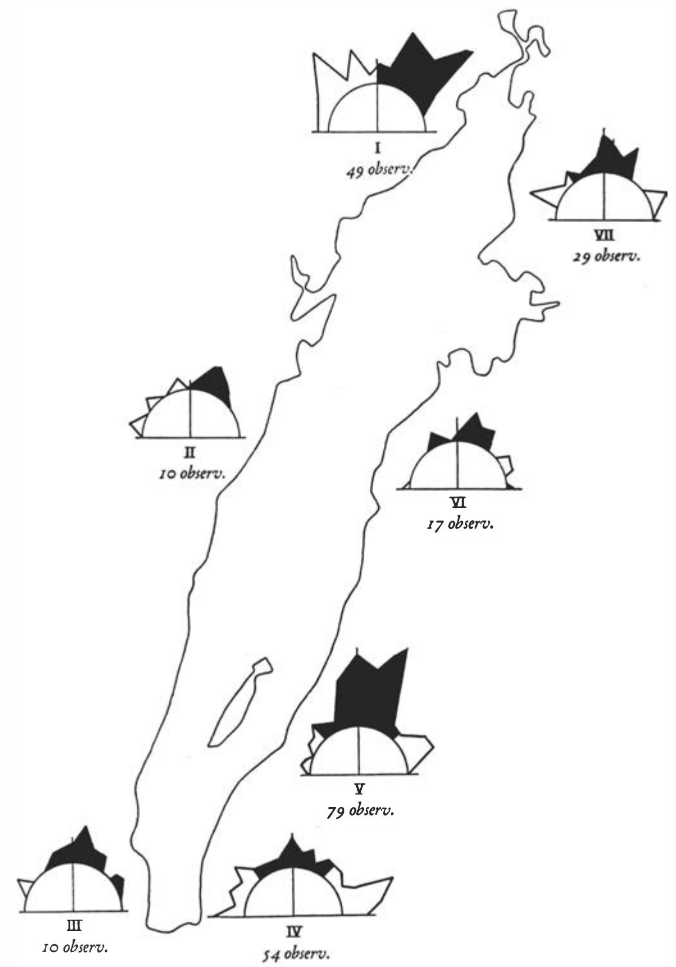

Fig. 2. Strike of striated, slickensided planes at Vättern. White is counted as a transversal and black as a longitudinal system.

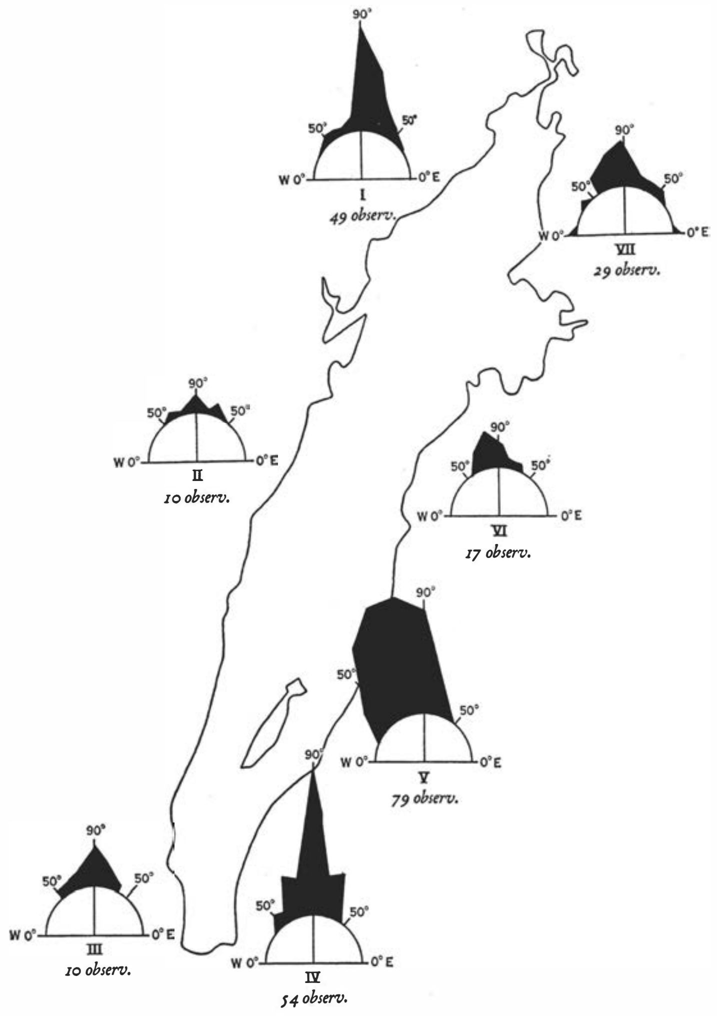

Fig. 3. Dip of striated, slickensided planes at Vättern.

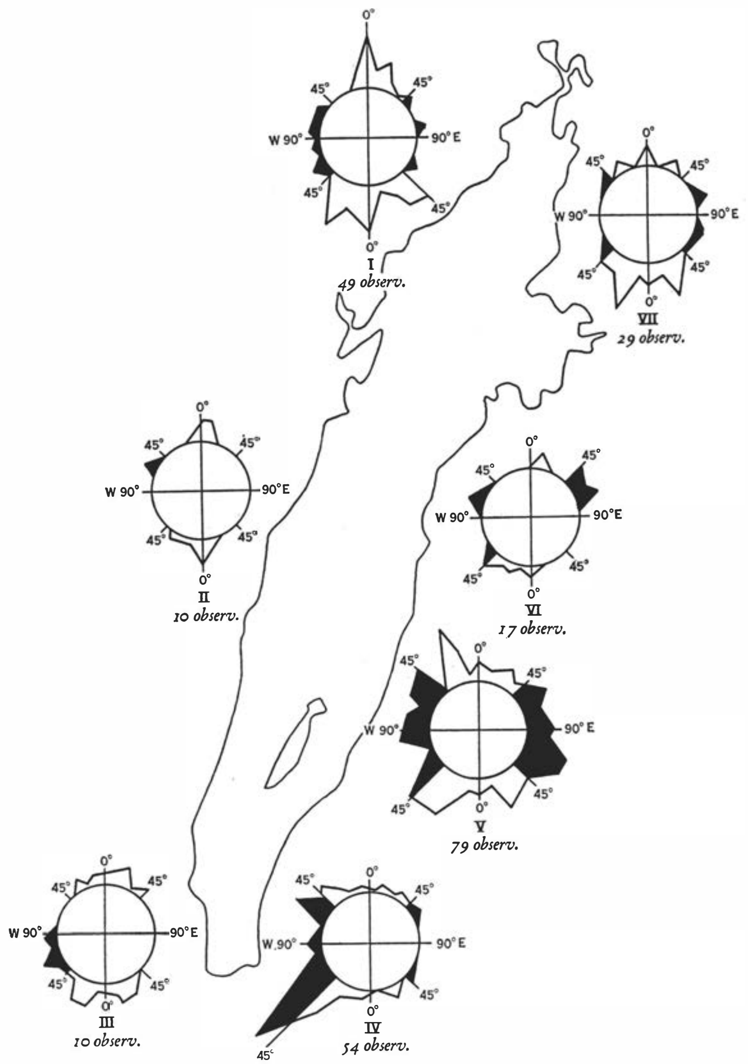

Fig. 4. Minimum angle between striae on slickensided planes and the horizontal plane at Vättern.

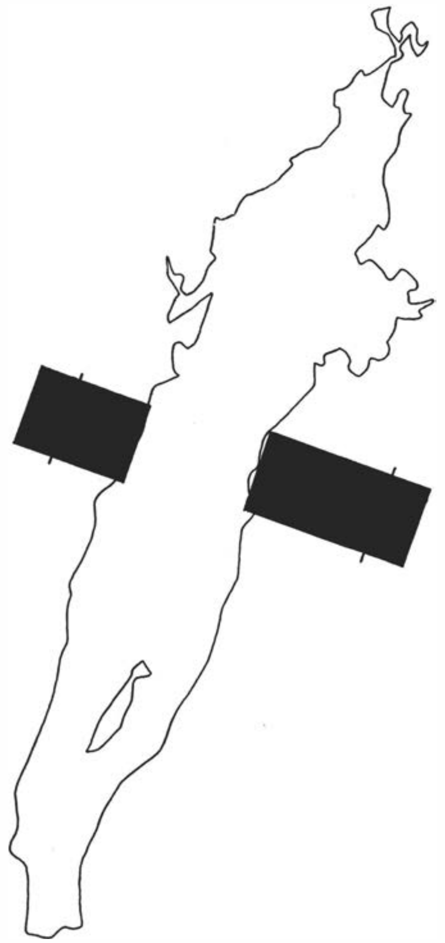

Fig. 5. Striae transversal to the Vätter depression. The striae are directed 2 and 3,3 times more inwards than outwards.

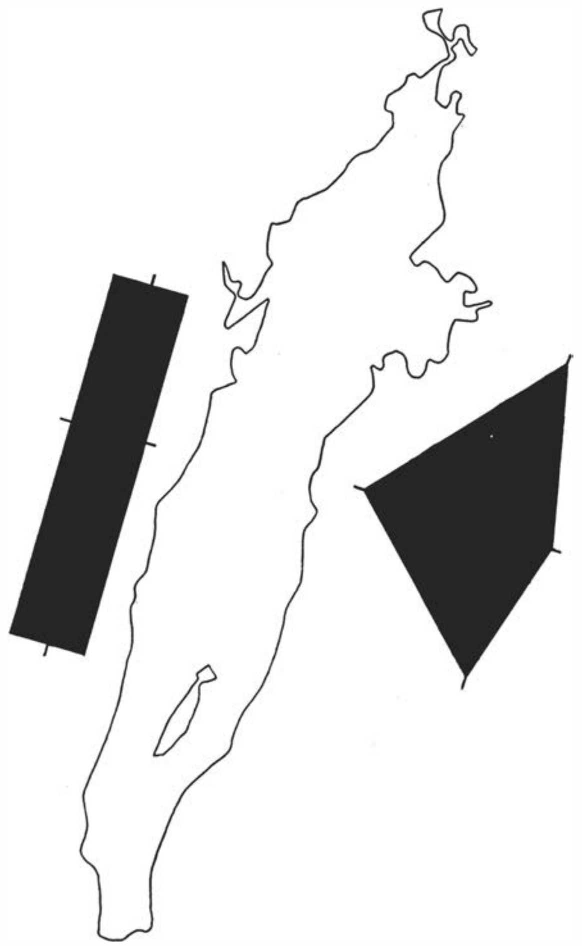

Fig. 6. Striae on slickensides longitudinal to the orientation of the orientation of the Vätter depression. The striae are directed 1,2 times (E of the lake) more towards the north and 1,5 more towards the south (W of the lake). Along the dip of the striated plane the striae are directed at least 4 times more inwards E of the lake. W of the lake it does not occur any striae along the dip.