SUOMEN GEOLOGINEN TOIMIKUNTA

BULLETIN
DE LA
COMMISSION GÉOLOGIQUE
DE FINLANDE

N:o 123

SUOMEN GEOLOGISEN SEURAN JULKAISUJA
MEDDELANDEN FRÅN GEOLOGISKA SÄLLSKAPET I FINLAND
COMPTES RENDUS DE LA SOCIÉTÉ GÉOLOGIQUE DE FINLANDE

XII

AVEC 20 FIGURES DANS LE TEXTE ET 3 PLANCHES

HELSINKI
JUILLET 1938

Tekijät vastaavat yksin kirjoitustensa sisällyksestä.

Författarna äro ensamma ansvariga för sina uppsatsers innehåll.

Les auteurs sont seuls responsables de leurs articles.

SUOMEN GEOLOGINEN TOIMIKUNTA
BULLETIN DE LA COMMISSION GÉOLOGIQUE DE FINLANDE N:o 123

SUOMEN GEOLOGISEN SEURAN JULKAISUJA
MEDDELANDEN FRÅN GEOLOGISKA SÄLLSKAPET I FINLAND
COMPTES RENDUS DE LA SOCIÉTÉ GEOLOGIQUE DE FINLANDE

XII

AVEC 20 FIGURES DANS LE TEXTE ET 3 PLANCHES

HELSINKI
IMPRIMÉRIE DE L'ÉTAT

SISÄLLYSLUETTELO. — CONTENTS.

SUOMEN GEOLOGISEN SEURAN TOIMINTA VUONNA 1937.

Geologisella Seuralla on v. 1937 ollut 7 kokousta. Puheenjohtajana toimi toht. W. W. Wilkman, sihteerinä allekirjoittanut.

Uusiksi jäseniksi on valittu Miss A. Jean Hall (Cambridge, Englanti), maist. Karl Mölder (Eesti) ja Suomesta toht. A. Sirén, toht. Salli Eskola, ins. L. A. Levanto sekä ylioppilaat E. Austi, Eero Helkavaara, Reino Himmi, Oiva Joensuu, A. V. Kanula, Mauno Lehijärvi, Arvo Matisto, Kaarlo Simola ja Heikki Tuominen. Seurassa oli v. 1937 6 ulkomaalaista kirjeenvaihtajajäsentä sekä 105 muuta jäsentä, joista vakinaisia 16.

Jouluk. 26 päivänä kuoli vuoden puheenjohtaja, Suomen geologisessa tutkimuksessa ja etenkin kallioperäkartoituksessa suuresti ansioitunut valtiongeologi W. W. Wilkman.

Seuran julkaisuja ilmestyi vuoden aikana 10:s nide, joka sisältää 8 kirjoitusta ja on 170 sivun laajuinen. Vakinainen valtionavustus oli Smk 8,000: — ja ylimääräinen yhteensä Smk 20 000: —.

ACTIVITIES OF THE GEOLOGICAL SOCIETY OF FINLAND IN 1937.

During 1937, 7 meetings of the Geological Society were held. Dr. W. W. Wilkman acted as President; the duties of secretary were attended to by the undersigned.

The following new members were elected: Miss A. Jean Hall (Cambridge, England), Mr. Karl Mölder, M. A. (Esthonia), and from Finland Dr. A. Sirén, Miss Salli Eskola, Mr. L. A. Levanto, Civil Engineer, and Messrs. E. Austi, Eero Helkavaara, Reino Himmi, Oiva Joensuu, A. V. Kanula, Mauno Lehijärvi, Arvo Matisto, Kaarlo Simola, and Heikki Tuominen. The list of members included in 1937 6 foreign correspondent members and 105 other persons, of which 16 were members for life.

Dr. W. W. Wilkman, State Geologist and President for the current year, passed away on the 26th of December. He had gained a high reputation as a geologist, especially as a surveyor of the rock ground of his country.

The 10th volume of the Comptes Rendus of the Society was published during the year; it contains 8 papers totalling 170 pages. The ordinary Government subsidy was Fmk 8 000: —, the additional subvention Fmk. 20 000: —.

Vuoden 1937 lopussa Seuran taloudellinen asema oli seuraava:
At the close of 1937, the financial position of the Society was the following:

Saldo vuodelta 1936 — Brought forward from 1936	5 655: 95
Valtionavustus — Government subsidy	28 000: —
Jäsenmaksuja — Membership fees	4 277: 15
Korkoja — Interest	248: 65
Summa Smk. — Total Fmk.	38 181: 75

Painatuskuluja — Publishing costs	13 093: —
Toimistokuluja — Office costs	387: 25
Kirjeenvaihto — Correspondence	575: —
Sihteerin palkkio — Secretary's fee	1 000: —
Saldo vuodelle 1938 — Carried forward to 1938	23 126: 50
Summa Smk. — Total Fmk.	38 181: 75

KOKOUKSET — MEETINGS 1937.

4. II.

Maist. Antti Salminen: Savien raekokoomuksen alueellisesta vaihtelusta. — On the variation of the grain size of the clays within different areas.

Tutkimus aiheesta julkaistaan myöhemmin. — A study on the subject vill be published later.

Toht. Esa Hyyppä: Terijoen pohjavesipurkaus. — A heavy outpour of underground water at Terijoki.

Esa Hyyppä, Artesischer Grundwasserausbruch in Terijoki und einige Gesichtspunkte über die Struktur des Karelischen Isthmus. C. R. Soc. géol. Finl. N:o X, Bull. Comm. géol. Finl. N:o 119, 1937.

18. III.

Prof. E. H. Kranck: Om svecofenniderna i Sverige och Finland. — On the Sveco-Fennides in Sweden and Finland.

Tutkimus aiheesta julkaistaan myöhemmin. — A study on the subject will be published later.

Prof, P. Eskola: Rapakiven kiilteen rapautumisesta. — On the weathering of biotite in the rapakivi.

Rapautuneessa kiilteessä terveeseen verrattuna olivat tuntuvasti kohonneet rautaoksidin suhde oksiduliin ja vesipitoisuus, kun taas kalimäärä oli laskenut. — In the weathered biotite, the percentage of ferric oxide as compared with ferrous oxide, and the water content had greatly increased from their amounts in the mineral in an unaltered state, while the potassium, on the contrary, was lowered.

Prof. M. Sauramo: Hiili aineksena kerrallisessa savessa. — The nature of carbon occurring in the varved clay.

Matti Sauramo: The mode of occurrence of carbon in Quaternary deposits. Suomen Kemistilehti, B, XI, 11, 1938.

22. IV.

Toht. H. Väyrynen: Petsamon nikkelimalmin synnystä ja sijoittumisesta. — On the origin and emplacement of the nickel ores in Petsamo.

Heikki Väyrynen, Petrologie des Nickelerzgebietes Kaulatunturi—Kammikivitunturi in Petsamo. Bull. Comm. géol. Finl. N:o 116, 1938.

Prof. M. Sauramo: Muistelmia kansainvälisen kvartäärigeologiyhtymän kolmannesta kongressista Itävallassa syyskuussa 1936. — Recollections from the 3d meeting of l'Association International pour l'etude du Quaternaire Européen (Inqua), held in Austria in September 1936.

Katso siv. 9. — See page 9.

Prof, P. Eskola näytti S. Hitchen'in diagrammin kvartsin veteenliukenevaisuuden riippuvaisuudesta lämpötilasta. — Professor P. Eskola demonstrated the diagram by S. Hitchen, illustrating the solubility of quartz into water at different temperatures.

7. V.

Toht. H. Väyrynen: Petsamon alkalirikkaista kivilajeista. — On the syenitic supracrustal rocks in Petsamo.

Lyhyt kuvaus asiasta sisältyy tekijän edellä mainittuun tutkimukseen, Bull. Comm. géol. Finl. N:o 116. Kyseessä olevia kiviä tutkitaan hänen johdollaan edelleen. — A short description about the subject is included into the author's memoir quoted above, Bull. Comm. géol. Finl. N:o 116. The rocks in question are being studied further under his guidance.

Maist. Anna Hietanen: Lapuan Simsiönvuoren kvartsiitista. — On the quartzite of the Simsiönvuori Hill, Lapua.

Anna Hietanen, On the Petrology of Finnish Quartzites. Bull. Comm. géol. Finl. N:o 122, 1938.

Toht. Aaro Hellaakoski: Tiedonanto Vuoksen puhkeamisdeltasta. — Note concerning the delta accumulation at the Vuoksi River formed in connection with its coming into existence.

Katso siv. 51. — See page 51.

30. IX.

Toht. Thord Brenner: Tiedonanto harjusta löydetystä savikimpaleesta Jääskessä. — Communication and showing of a piece of clay found in an esker at Jääski.

Selostus ilmestyy seuraavassa niteessä. — A description about the matter will be published in the next volume.

Prof. P. Eskola: Moskovan geologikongressin Kuolan retkestä. — The excursion to the Kola Peninsula in connection with the 17th International Geological Congress in Moscow, 1937 (with showing of many rock specimens).

Toht. M. Saksela: Kesän 1937 malmitutkimuksista. — The ore prospectings carried out by the Geological Survey during the summer 1937.

M. Saksela, Katsaus viime kesän malmitutkimuksiin. Suomen Kemistilehti, A, X, 141, 1937.

30. X.

Toht. H. Väyrynen: Moskovan geologikongressin Karjalan retkestä. — The excursion to the East Karelia in connection with the 17th International Geological Congress in Moscow, 1937.

Katso siv. 65. — See page 65.

Prof. A. Laitakari: Havaintoja ja näytteitä eräistä Norjan kiisumalmeista. — Observations concerning some pyritic ore deposits of Norway, with showing of specimens (the nickel ores of Hosanger and Evje and the Stord pyrite mine).

X. XII.

Valittiin virkailijat vuodelle 1938, jolloin valituiksi tulivat: puheenjohtajaksi toht. E. Mikkola, varapuheenjohtajaksi toht. H. Väyrynen, sihteeriksi ja rahastonhoitajaksi toht. Th. G. Sahama, sekä tilintarkastajiksi prof. L. H. Borgström ja toht. S. Kilpi.

The Ballot for the officials was taken and the following Fellows were elected for the ensuing year, 1938: President, Dr. E. Mikkola, Vice President, Dr. H. Väyrynen, Secretary and Treasurer, Dr. Th. G. Sahama, Auditors, Professor L. H. Borgström and Dr. S. Kilpi.

Toht. E. Hyyppä: Etelä-Suomen postglasialisesta rannansiirtymisestä. — On the post-Glacial changes of the shore-line in South Finland.

Esa Hyyppä, Post-Glacial Changes of Shore-Line in South Finland. Bull. Comm. géol. Finl. B:o 120, 1937.

Ylipp. A. Simonen, Kemijärven pallograniitti. — The orbicular granite of Kemijärvi.

Katso siv. 47. — See page 47.

Maist. E. Savolainen: Jänisjärven dasiitista. — On the dacite of Jänisjärvi.

Puhuja ilmoitti löytäneensä Jänisjärven Selkäsaarten dasiittia kiintokalliosta myös järven W-rannalta Leppäniemen pohjoiskärjestä. — Mr. Savolainen reported a discovery of the post-Archaen dacite of Lake Jänisjärvi, formerly known in place only in the islands of Selkäsaaret, on the N. shore of the point of Leppäniemi at the W. shore of the lake.

Prof. A. Laitakari: Kuvia ja näytteitä Lammastenkosken hiekkakiviesiintymästä. — Photographs and specimens from the occurrence of Jotnian sandstone at the Lammastenkoski Rapids, Kokemäki River.

Katso siv. 10. — See page 10.

Helsinki 4. I. 1938.

In fidem

E. Hyyppä

SELOSTUKSIA. — SHORT REVIEWS.

INTERNATIONALE QUARTÄR-EXKURSION IN ÖSTERREICH IM HERBST 1936.

von

MATTI SAURAMO.

Von dem Vortragenden wurden einige mit zahlreichen Lichtbildern illustrierte Berichte über die dritte Sitzung der Internationalen Quartär-Vereinigung Inqua (in Wien vom 1.—6. September 1936) der Geologischen Gesellschaft vorgelegt. Auf dem Kongress wurden während drei Tage zahlreiche Vorträge teils allgemeiner Art, teils über das Quartär der Alpen gehalten; als der interessanteste Teil des Kongresses sind jedoch die zahlreichen Exkursionen zu betrachten, bei welchen die Teilnehmer eine persönliche Bekanntschaft mit den betr. Formationen machen konnten. Die ersten kurzen Ausflüge wurden zwischen den Kongresstagen nach dem Lössgebiet des Donautales, nach Laaerberg bei Wien sowie in die Drachenhöhle bei Mixnitz in Steiermark unternommen. Nach dem Kongress wurde Gelegenheit geboten, zuerst während zwei Tage das Lössgebiet des Niederösterreichischen Weinviertels zu besuchen. Danach wurde die Hauptexkursion vom 9.—23. September nach den Ostalpen und deren Vorland unternommen. Die interessantesten Stellen waren Steyr, Gmunden, Ischl, Vöcklabruck, Salzburg, Grossglockner, Zell am See und Innsbruck. Die Leiter dieser Exkursion und des ganzen Kongresses, Otto Ampferer und Gustav Götzinger, hatten keine Mühe gespart, um das Beste zeigen zu können, was Österreich auf dem Gebiete des Quartärs bieten kann. Das Quartär Österreichs stellt jedoch an vielen Orten das klassische Beobachtungsmaterial dar, auf das unsere jetzige Auffassung über die Vereisung der Alpen sich stützt. Die nordischen Quartärgeologen werden sich dankbar an das erinnern, was ihre österreichischen Kollegen mit ihrer bekannten Gemütlichkeit gezeigt haben: Die schönen dicht gebauten Lössgebiete Niederösterreichs an der Donau, die Moränenbögen im Vorlande ehemaliger Gletscher in Oberösterreich, die Zungenbecken in den heutzutage so wunderschönen Alpenseen und die Terrassensysteme als Widerspiegelung des Wechsels von Glazial- und Interglazialzeiten sowie das Zentrum der Alpen mit seinen Tälern, seinen stolzen Bergen und seinen ewigen Gletschern.

KUVIA JA NÄYTTEITÄ LAMMASTENKOSKEN HIEKKAKIVI-ESIINTYMÄSTÄ.

Kirj.
AARNE LAITAKARI.

Foto Roos 1937

Voimalaitoksen perustusta varten tehty kaivanto hiekkakivessä Lammastenkoskella. (Excavation in a gently-dipping Jotnian sandstone, the place where a new hydro-electric plant is being constructed at the Lammastenkoski Rapids, Kokemäenjoki River).

Lammastenkoski on puoliksi padottu ja lounaispuoleiselle rannalle on kosken pohjaan louhittu 16 m syvä kaivanto hiekkakiveen. Tässä kaivannossa on hiekkakivi hyvästi näkyvissä. Sen penkereitten kaade on noin 25° SW. Hiekkakivi on koko kaivannossa hyvin löyhää ja siinä on vähäväliä vetisiä saviliuskekerroksia, jotka märkinä ovat melkein plastillisia. Toisissa kohdin saviliuske on tiilenpunaista, toisissa vihreän harmaata. Hiekkakivessä on raesuuruudeltaan ja väriltään hyvin vaihtelevia kerroksia ja runsaasti virtakerrallisuutta näkyvissä. Esittäjän ollessa siellä 30. 11. ja 1. 12. 1937 oli lumi ja jää osittain vaikeuttamassa havaintojen tekoa. Paikka on tarkemmin tutkittava, sillä siitä voi saada hyvää valaistusta jotunikauden olosuhteisiin. Kosken kuivilla olevassa pohjassa oli näkyvillä runsaasti syviä hiidenkirnuja.

KIRJOITUKSIA. — PAPERS.

1.

OBSERVATIONS AND EXPERIMENTS ON PTYGMATIC FOLDING.

By

PH. H. KUENEN.

The first clear description and discussion of the curious veins, which Sederholm afterwards called ptygmatic folding, was given by Milch as early as 1900 (bibl. 3). His excellent illustrations are the only ones I have been able to find in which the structure of the surrounding rock is clearly and very carefully depicted. He concluded that the veins in the erratic he examined were originally plane, and were afterwards contorted by dynamometamorphism. He also found microscopic evidence of this metamorphism.

A few years later Sauer (bibl. 7, p. 599) came to the conclusion that the veins represent primary siliceous bands in the rock, which were subsequently folded.

Soon after, Sederholm took up this subject and in a series of publications he amassed a large number of instances, showing the frequent occurrence in the deeply eroded Finnish mountains. Generally the folds are shown by pegmatitic or aplitic veins, but basic dykes may be contorted in like manner. Often the vein is bent back again and again on itself, like an extreme case of meandering. Both astoundingly regular and highly aberrant cases are met with. He proposed the name »ptygmatic folding», a term that has since been generally adopted.

Sederholm first assumed that the veins had been folded by undulating more or less fluidal movements before crystallization had taken place, because the constituent minerals show no cataclasis. Sander (bibl. 6) pointed out that even if the contortion had taken place after the consolidation, subsequent recrystallization would efface the evidence of deformation. Sander's conclusion therefore is, that after injection and crystallization, deformation took place through tectonic movements, while the whole mass was in a plastic condition. Examples from the Alps were added to some from Finland.

In his last publication on this subject Sederholm is somewhat vague as to the exact mechanism. On the one hand he draws a parallel with streaks of foam in rapids: »In both cases there ought to have been an undulating action caused by movements to and fro, or by a different velocity of the current in different places» (bibl. 10, p. 81). But on the other hand he says of some specimens: »They have been compressed in such a degree that the thickness of the bundle is in part $^1/_6$ of the length of the veins which have been folded» (p. 76). Evidently he had come to a point of view that is nearer that of Sander's although he emphasizes that the deformation was more of a fluxional type than Sander assumed. This is not surprising as the experience of the two authors was mainly gained in different regions of which Finland was doubtless subjected to more extreme conditions than the Alps. The movements in the former were also in part due to injection of batholiths. Later Sederholm also accepted Wegmann's demonstration of normal tectonic structures in Finland; thereby he must indirectly have approached still further to Sander's view on ptygmatic folding.

Spurr (bibl. 11, p. 104—171) independently arrived at the same conclusion as Milch and Sander.

Holmquist (bibl. 2) also ascribes the folding to compression while the surrounding rock was in a plastic state. He only differs in believing that the magma was not intruded but formed in situ. We need not enter into this side of the problem. Both cases are substantially proved and do not exclude each other. In the matter of the origin of the folding Holmquist and Milch are agreed.

Suter (bibl. 12, p. 287—289) is slightly vague, but he evidently believed the ptygmatic folds of the Laufenburg region to be a primary feature caused by injection of plastic vein-material and not by subsequent deformation.

Read (bibl. 4 and 5) described and figured a number of cases from Sutherland. He found various difficulties in applying the explanations of Milch c. s., and therefore suggests that the »tortuous form results from the resistance to plane fissuring of the country-rock . . .» and that the Sutherland veins have their original form, never having been plane. The only difference with Suter is therefore, that the country-rock, not the injected material caused the contorted shapes.

The solution of this problem is not merely of academic interest. If it could be shown that the explanation through folding is correct, then an important set of data could be obtained to elucidate tectonic

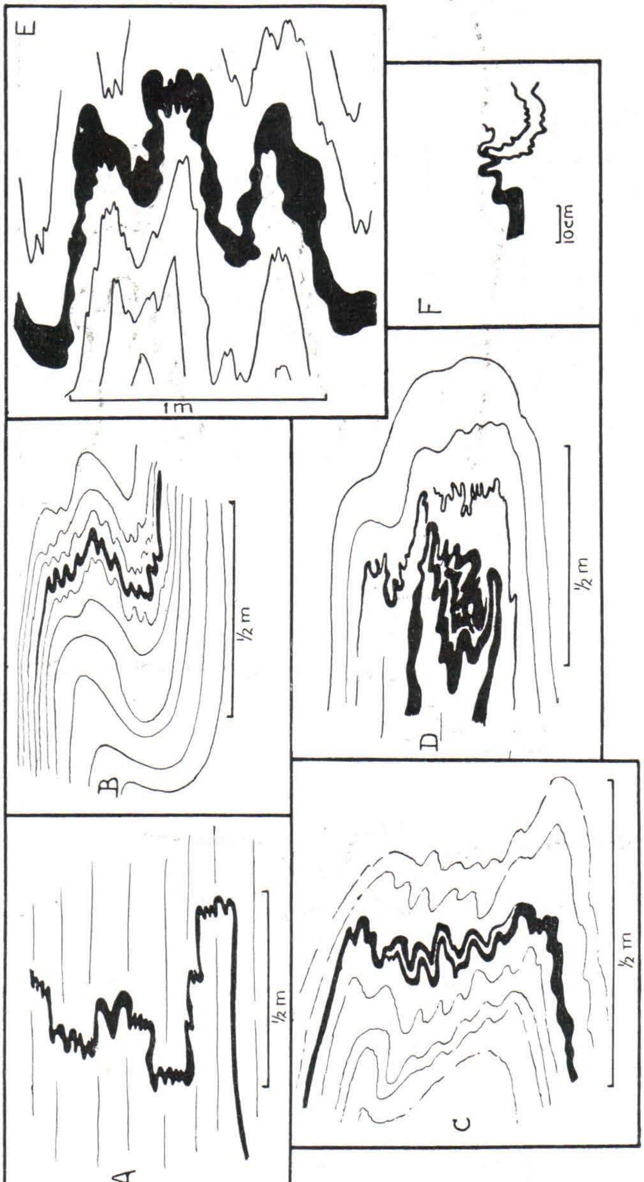


Fig. 1. Ptygmatic veins from southern Finland.
A Långholm, B, C and E Skata Ledholm, D Torrvedsholmarna, all near Pörtö;
F Inderskärs Vestgrund near Tvärminne.

structures. Not only would the high degree of plasticity of the rocks be proved, but a measure of the deformation could be obtained and

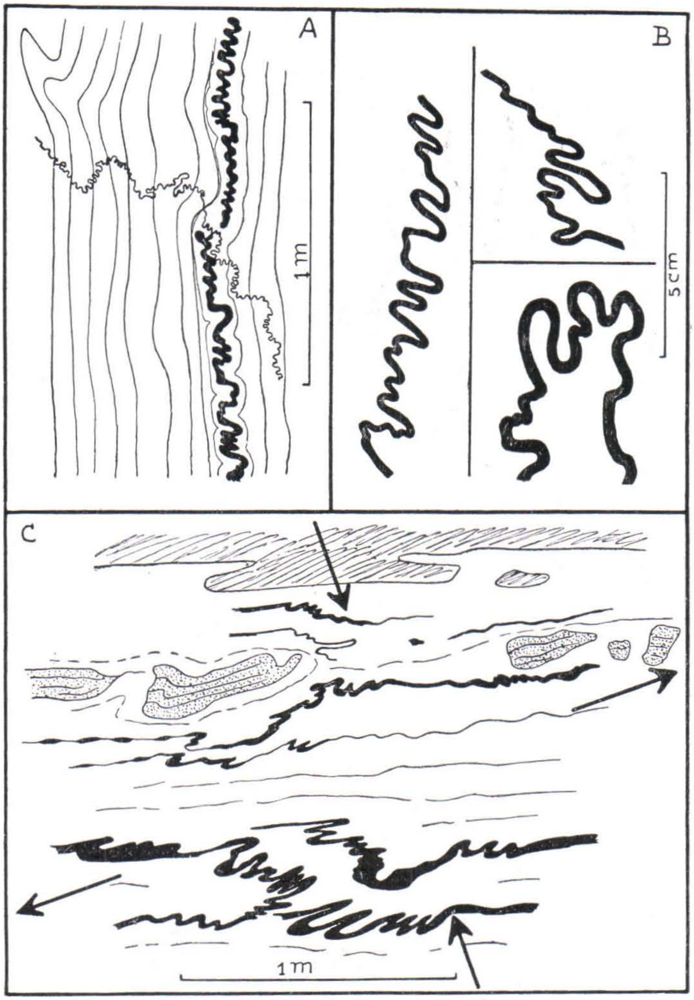


Fig. 2. Ptygmatic veins from the Pörtö archipelago in southern Finland. A and B Långholm, C Skata Ledholm; the arrows show the approximate directions of stretching and compression.

the result could be combined with observations of strike, etc. Further attempts at arriving at a conclusion are therefore warranted.

The present author had an opportunity to examine fine examples of ptygmatic folding during a visit to Finland in 1937. Although more extensive experience would have been desirable, the authors cited have so lavishly illustrated their papers, that a large mass of data is now at hand and most of the significant modes of occurrence must have been noted.

That normal folding of resistant rocks is ruled out is obvious when the figures of Sederholm, Read and this paper are examined. The absence of correlation between two neighbouring and roughly parallel dykes and between the dykes and surrounding country rock is obvious and excludes the possibility, that dykes and the enveloping rock reacted to the folding in the same manner.

First the arguments opposing Read's hypothesis of primary shape will be given.

---

1. Holmquist gives an example of a basic vein that has been first stretched and drawn out into separate parts, the interstices having been filled by aplitic ichor trickling in from the surroundings. This composite vein is folded by compression in the plane of the original stretching. The basic part must have been solid and in situ during the stretching, but it has partaken in the folding. The aplite was emplaced during the stretching of the basic dyke and is thus proved to have been contorted after the injection. For this case the original plane shape and subsequent folding are established beyond doubt.

2. There is a clear correlation between the width of the vein and the wavelength of the folds. The thicker the vein the larger the folds. Sederholm's figure 34, p. 73, bibl. 10 offers an example with 3 wavelengths, each restricted to a different width of vein. (See also my figures 1, D, and F; 2, B; and 5, B). When the magma is forcing its way into the rock the width that the consolidated intrusion will ultimately attain is not yet fixed, because at the time of consolidation the magma that first opened it at a given point, has flowed further on. In Read's conception the wavelength would therefore have to determine the extent of the subsequent intrusion, an entirely unwarranted assumption.

3. In some cases straight and folded veins are found in the same homogenous rock, for instance granite. The rocks were plane fissuring and yet they contain ptygmatic folds.

4. The veins are generally of uniform width over long distances and also in their sharpest bends. As a consequence the walls do not fit each other (see fig. 3, D I). When we try to pull the parts of a jigsaw puzzle apart, we do not obtain a shape like fig. 3, D I but II, yet I is the shape of a typical ptygmatic vein.

There is one observation that would be very strong evidence in favour of Read's theory. That would be if the structure of the wall rock depicted in fig. 3, D II could be found. It would definitely demonstrate that the country rock had split open along a meandering fissure and had not been deformed afterwards.

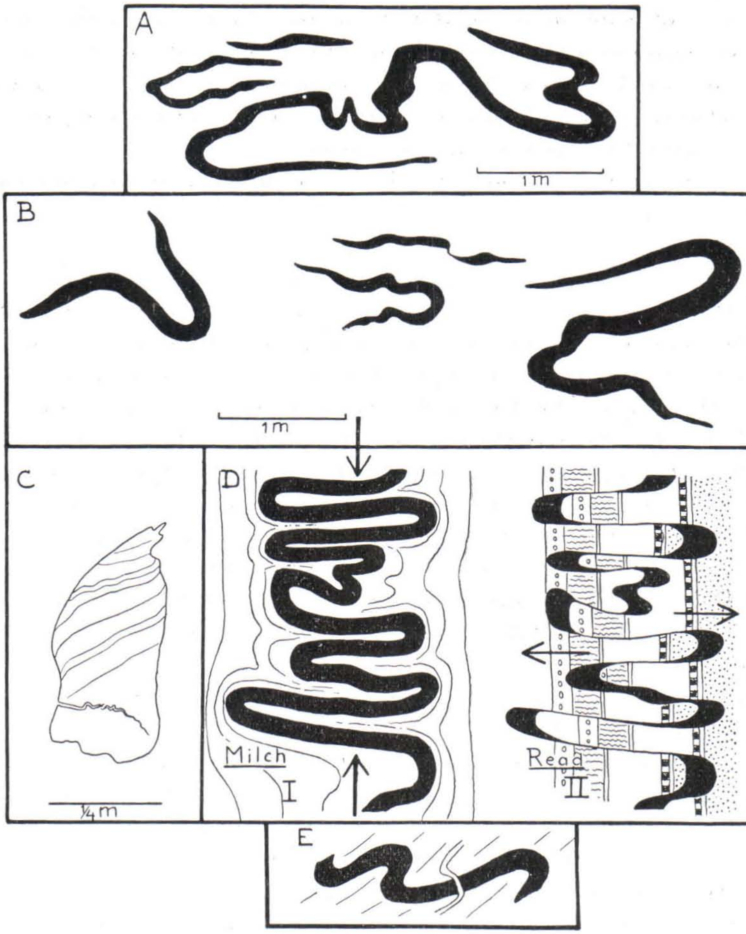


Fig. 3. A and B portions of a contorted basic dyke, S. Kittelskär, C ptygmatic vein in inclusion in granite, Östholm, both near Pörtö. D, I ptygmatic vein formed by compression, II theoretical shape formed by widening of sinuous fissure. E contortion of a thin vein by a thicker ptygmatic vein.

The stratification of the country-rock is nearly always vague and could not be followed with sufficient detail to make sure of its structure within the small meanderings of the veins in the field.

In this connection attention may be called to the case illustrated in fig. 3, A and B. A basic dyke has been distorted and drawn out in a spectacular fashion. B is found some 50 m away from A (but there may be missing links below sealevel in between). The enclosing rock is a kinzigite gneis giving evidence of strong deformation. But lacking the dark veins one would not perceive that it must have been kneaded as a chunck of putty.

In none of my specimens could I detect even indications of the structure shown in figure 3, D II. On the other hand several cases were found with the structure of I (fig. 1; 2, A; and 5 B, and C), where the wall rock is intensively deformed close up to the vein, but much less at a very short distance away from it. In the latter case one could easily be deceived into believing that the wall rocks show no deformation. Often there must have been unconformity between the vein and its wall to begin with. Especially with an irregularly shaped intrusion it will be difficult to ascertain whether our theoretical case II is actually represented. I admit that Suter's figure 39, although a »Schema» does suggest primary sinuous injection. I will return to this case presently. On the other hand nobody can doubt that Milch's drawing is accurate in this respect and here the theoretical case of fig. 3, D I is beautifully shown (fig. 5, A).

The case shown in fig. 3, E, that appears repeatedly in fig. 5, C is also significant. It shows how a thin vein is deflected and given a twist by the contortions of a thicker vein. The original cross-over remains at right angles to the less mobile thicker vein.

5. Presumably Read believes the magma to have flowed not up along the strike of the folds, but across from one to another, but he does not say so. In any case the magma would have to follow a long course, and a quantity would pass through each fold, yet the thin, sometimes almost cut off tongues of country-rock between the meanders have not been shifted out of place (fig. 2, C).

6. Fig. 1, C shows two veins separated by a thin screen. Straight screens are common and could be folded subsequently, but the direct formation without subsequent distortion is difficult to imagine.

7. As Read already remarked: »Time and again, veins have been observed that are perfectly plane »lits» when parallel to the bedding or foliation, but show marked tortuosity when they leave these controlling guides» — He believes that: »The absence of easily opened plane channels for the injected material thus affects the form of the veins».

In the direction of the »controlling guides» plane fissures were evidently readily formed. But why should the vein then continually leave these easily formed fissures and force its way across the »tough direction»? Fig. 1, A gives a good example.

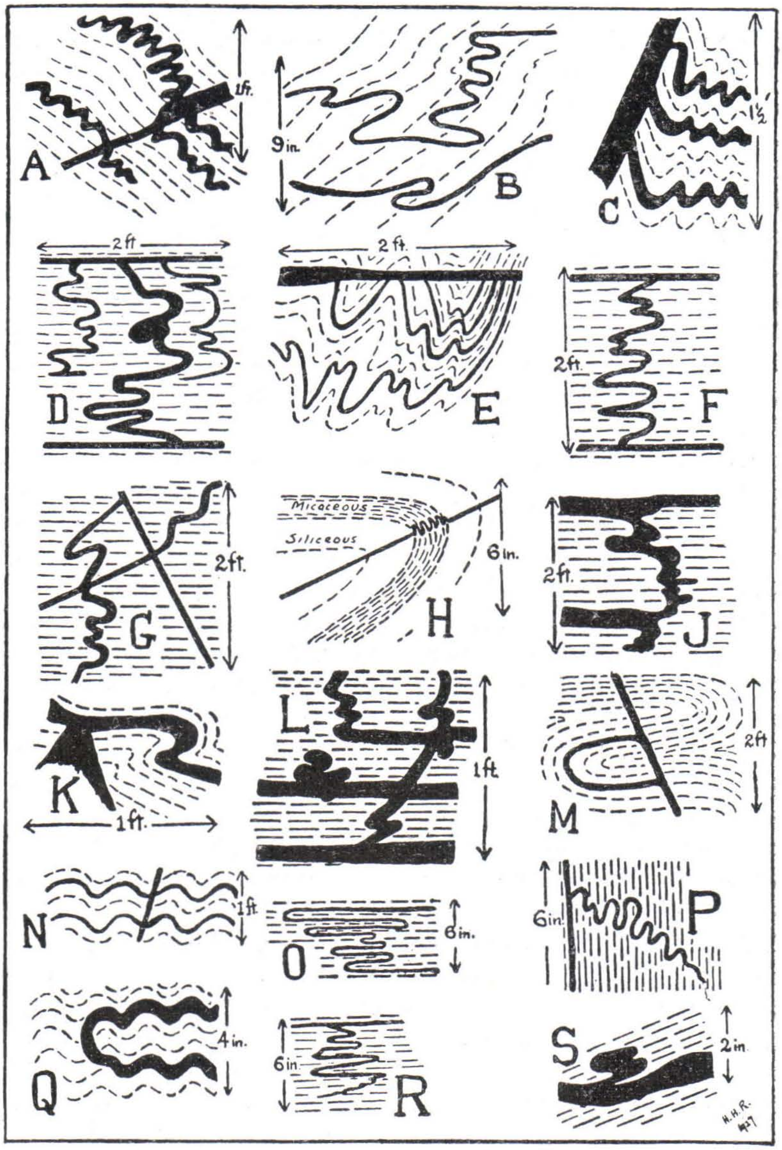


Fig. 4. Sketches of vein systems in Sutherland after Read (bibl. 4 or 5).

Moreover, the folds are generally very regular along their strike (see Holmquist, fig. 7). This is incompatible with a nature resisting plane fissuring; in fact the veins should be as tortuous in any plane at right angles to the schistosity.

8. It is not only under the described conditions that straight and meandering portions alternate. It is also the rule in strongly folded country rock. Here the ptygmatic portions are restricted to the anticlinal bends (fig. 1, B, C, D, and E) keeping closely to the identical

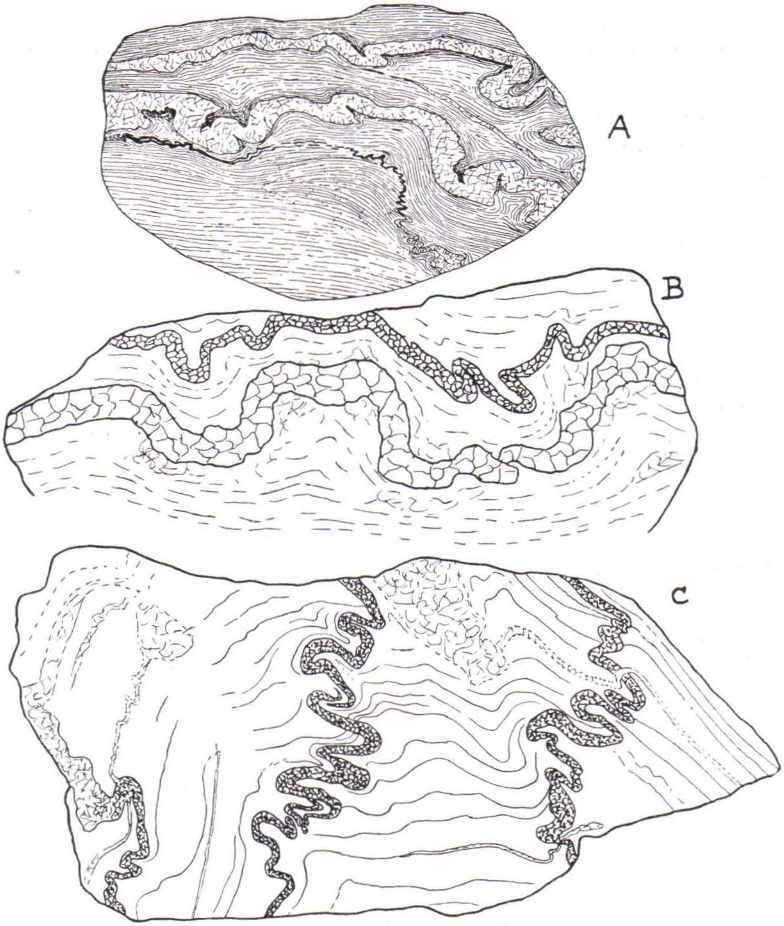


Fig. 5. Polished slabs, A ptygmatic veins after Milch, bibl. 3; B ptygmatic veins in gneiss from S. Kittelskär, Pörtö; C ptygmatic veins in gneissic rock, Långholm, Pörtö.

bedding plane. This plane is always the most highly contorted of the series. Outside these area's the veins are frequently drawn out to threadlike ribbons or disappear entirely. There is nothing suggesting injection after the folding for these cases.

The enumerated objections to Read's explanation do not appear to allow room for accepting it. There is of course no objection to the view that sometimes the primary injection followed plicated bedding planes and thus obtained a pseudo-ptygmatic shape. Some of Read's figures appear to fall under this class, especially E, M. For C, K, N and Q this may also be the case, but subsequent folding can also be accepted. However, at least this important point of view is gained by Read's exposition, that a distinction must be made between the amount of irregularity due to the folding and that which is primary. The latter is of quite subordinate importance for the Finnish occurrences, and I imagine the same, perhaps in less marked degree, to be the case for Sutherland in the absence of convincing evidence to the contrary.

Most of the objections raised against Read could also be brought against Suter. Besides, as he advocates an injection of fluid magma, that became viscous towards the end, the difficulty of imagining how the thin films between the meanders could have been left intact, becomes even more pronounced. Finally Suter's contention that the country-rock is undisturbed would be no less incompatible with his own theory than with that of folding. For in both views the folds are formed by viscous movements of the vein with respect to the country-rock, so in both the margins of the latter would have been deformed (otherwise Suter need not assume viscosity of the injection and his view would then be identical with that of Read). The only solution of the difficulty that Suter's figures show no distortion of the walls, is to assume that more minute investigation will disclose slight deformations of the wallrock in Suter's examples also, or that the schistosity was not finally developed until after the folding.

As stated above Sederholm did not entirely abandon his original conception of an undulating, flowing movement. This possibility must therefore also be examined. The observations that most strongly oppose it are:

1. The less contorted structure that generally prevails a short distance away from the ptygmatic vein. If the vein were the warped surface between two differentially moved parts, these parts should present internal evidence of fluxion.

2. The clear regular folds of the country rock, with ptygmatic

veins in the anticlinal and synclinal crests. Here folding is obvious and flowing is excluded.

3. The rule that the portions of veins traversing the schistosity are generally the only parts showing undulations. If flowage took place the schistosity proves that it must have occurred in the axial planes of the anticlines. In Sederholm's view the movement should have been across the strike from one fold to another if it were to explain the undulations.

4. The correlation between the wavelength and the thickness of the vein. In Sederholm's picture the undulations are caused by movements of the opposite walls of a vein with respect to each other, the vein material being passive. One would then hardly expect the thickness of the vein to control the size of the undulations.

We must now see what objections can be raised against the rival explanation through folding.

1. The surrounding rocks and the veins themselves generally show no signs of cataclasis, although Milch found some slight remains. Sander, Sederholm and Holmquist are of opinion that subsequent annealing has obliterated the effects of dynamometamorphism. For the Finnish and Scandinavian examples the great depth at which the process must have taken place warrants this conception. Read believes that for the Sutherland region the metamorphism is older. On the other hand he says: »The conditions requisite for this injection were activity of stress and prevalence of high temperatures in the country-rock of the complex», (bibl. 5, p. 146). Although the ptygmatic folds are shown by veins that are believed to be late, the plastic condition probably prevailed during their formation and subsequent annealing is not excluded in this case either.

2. Straight and meandering veins are sometimes found in combination. Extensive movements must have occurred between the injection of the two although they belong to the same period of intrusion or metamorphism and often show perfect synchronism of crystallization. Here too annealing must be invoked. Sederholm noted cases in which the bigger felspars of the older, folded veins have a continuation within the borders of the intersecting straighter veins. This proves that the last crystallization in both veins took place after the injection of the latest veins. But it shows also that they were not filled at the same moment by the same magma, otherwise they would contain the same rock. The annealing is here fairly obvious. Cloudlike portions

of aplite have sometimes gathered in the rock subsequent to the folding. Sederholm gave clear evidence to this effect and pointed out that it fits in satisfactorily with the conception, that the final crystallization came after the folding.

3. Read says concerning the country rock of Sutherland that »there is, however, no question of their having undergone any ultrametamorphic change or having attained any degree of plasticity», and »there is no evidence that the veined Moine sediments were ever in a softened or semi-molten condition» (bibl. 4, p. 76). But the strength of this argument is reduced by statements in his subsequent publication: »The injection is considered to have taken place during or immediately after the impression of the general metamorphism of the Moine and associated rocks, when high temperatures prevailed over great areas of Central Sutherland and directed pressures were operative» (bibl. 5, p. 12, see also the quotation above) and »the passage of these solutions into the country-rock either as discrete injections or in more tenuous forms leads to a recrystallization, with partial loss of directed structures» (p. 150).

As no alternative explanation can be given and as the objections raised are not too formidable, I feel confidant that the theory of folding by compression is correct.

We must now consider some details of the mechanism to show how the hypothesis should be applied. At the same time it must be tested for the objections raised against Read's suggestion. In the first place care must be taken when calculating the amount of compression from a ptygmatic fold, that the section is at right angles to the strike of the fold. (Most examples illustrated in this paper are oblique sections.) When very extreme cases are carefully examined it is generally found that the exposed section cuts obliquely through the folds and gives a greatly exaggerated impression of the compression. Nevertheless a reduction in length of 1 into 4 is not exceptional, as Sederholm noted.

In our theory the explanation of point 7 against Read is that the schistosity or bedding is at right angles to the compression. Only the veins running in the direction of the compression were contorted as Sander already explained. In Read's case H a straight vein traverses siliceous granulites but is tortuous in the »more resistant» micaceous bands. In my opinion the opposite is the case. The micaceous bands were more ductile and were compressed, the enclosed vein being contorted (fig. 1, A). This is especially probable for his fig. A. Read writes: »The tortuous side-veins shown in sketch A likewise traverse micaceous bands in the granulite» p. 76. But although the injection here followed along the direction of the bedding it is ptygmatic. Read points out that ptygmatic veins are more common in the metamorphic »hardened» rocks of the injection-complex proper than outside it. But to attain the present hardened structure the rocks had first to be heated until recrystallization or annealing took place. The ptygmatic veins belong to the close of the metamorphosing process and were therefore injected not into a hardened, but into a softened surrounding as Sederholm pointed out. Point 8 against Read is easily explained by the folding theory. The anticlinal limbs are at right angles to the compression and have been attenuated, the contortions in the crest are in the direction of the pressure.

Where the ptygmatic folds follow a general direction parallel to the schistosity (fig. 2, A) we must assume that the orientation of the rock-complex has changed with respect to the compression so as to reverse the sense of shortening. This may happen in strongly kneaded rocks, with overturned folds, etc. When it is parallel to the original bedding the change of orientation need not have occurred.

The combination of ptygmatic folds and phenomena denoting stretching are not uncommon. Fig. 2, C is an example. Following Sander, the lengthening at right angles to the compression can be read off from the broken and stretched basic stratum and pegmatitic veins. The arrows show the movements that may elucidate this case, but they were not necessarily in the plane of the section.

During compression the entire mass was at a high temperature. The country rock was slightly more plastic, due either to smaller grain or to chemical and mineralogical composition. The plasticity may have been due to recrystallization, especially when we are dealing with micaceous schists.

Sander supposed that the country rock was not exactly of the same degree of plasticity throughout. One might liken it to illmixed dough. The consequence of strong movements would be that some portions are deformed, while shortly after a neighbouring part was more severely distorted. In this manner complicated cases could arise of ptygmatically folded veins, cut by a straight younger generation. Subsequent annealing would obliterate evidence of the sequence.

In some cases, such as that described by Sederholm from the rapakivi contact in the Pellinge region, the deformation must be due to pressure exerted through the intruding magma.

It is sometimes found, that thick ptygmatic veins, for instance fig. 1, E, are highly irregular. This may be because the country rock resisted the formation of the large folds that would fit the thick vein. The latter is then crumpled into such short undulations that the normal regularity is suppressed.

As noted above, cases in which the vein is more strongly folded than the country rock are common. The opposite also occurs according to Read. This would be found when the injection took place after the country rock had undergone plication to a certain extent. The vein could then not catch up with the contortions of its surroundings during further deformation. It could also be due to the exposed section forming a more accute angle with the axis of the folds of the country rock then of the ptygmatic vein.

The close correlation between thickness and wavelength and the occurrence of thin screens are now easily understood phenomena and need no further explanation.

Conditions that bear a strong resemblance to those in deeper regions of the earth's crust are also encountered at shallow depths in salt domes. Ptygmatic folds of more resistant layers have often been found in salt mines and in the experiments Escher and Kuenen performed (bibl. 1) ptygmatic folds were also produced. In this case the material used was paraffine, the hard layer having a higher melting point (see their Pl. 34, fig. 38).

In conclusion some experiments may be described to illustrate the mechanism of ptygmatic folding. Those just mentioned gave fine results, but the mechanism was rather complicated because the plastic flow was directed towards a common centre. The folds were therefore irregular crumplings in all directions. A simpler set-up was desirable for the problem here discussed. The function of the experiment is to show the result of the simplest mechanism that can be devised. Only by this means can the more complicated case in nature be rendered clearer. My thanks are due to M. de Vries, for carrying out the experiments with great ability.

Some difficulty was experienced in evolving a suitable technique. Finally the following method was devised (fig. 6). An oblong box with large apertures at both ends was filled with plastic clay or vaselin. In the middle a thin sheet of paraffine or harder clay had been inserted at right angles to the longer axis, its upper and lower edge being held in place by slots in the wooden bottom and lid. The sides were coated with a sheet of celluloid. The loose lid was then gradually forced down in a strong press. The clay was thus squeezed out of the openings at the ends of the box and the whole block reduced to about $^1/_4$ of its original thickness. The pressure needed was a few kg/cm^2. The clay was then lifted out of the box. The sides or a section were then photographed. Plates I and II show the middle portion of some experiments.

When the paraffine layer remained in the centre it was crumpled up into folds that are identical with natural ptygmatic folds. Generally a slightly greater amount of clay flowed out of one of the apertures and the paraffine layer was then bent into a looped shape (Plate II, fig. 1). This case represents the mechanism of folding with a flat lying anticlinal axial plane. The result is similar to that of nature.

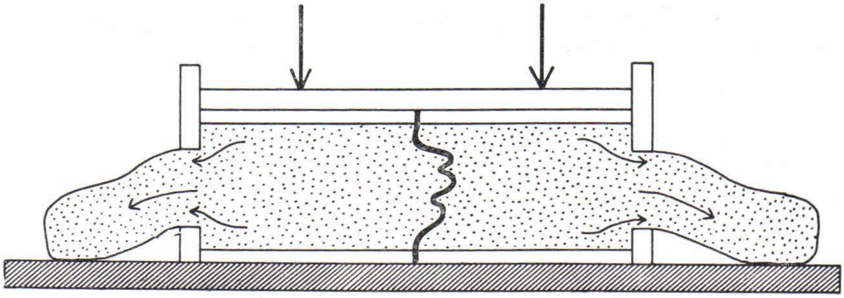


Fig. 6. Set-up of experiments on ptygmatic folding.
Experimental ptygmatic folding.

We find flat and even drawn out limbs (D) combined with a crumpled anticlinal apex (compare fig. 1). Inspection of Plate I, fig. 2, A shows that the wavelength of the folds increases with the thickness of the sheet of paraffine. By changing the consistency of this layer the wavelength can also easily be altered.

In fig. 2, Plate II the dark lines in C are the outcrop of originally plane surfaces parallel to the hard layer painted black. But the tendency of the clay to slip along horizontal shearing planes has given a stepped outline to the sections. In A and B the thick line shows the curve that would have ensued in perfectly plastic movement. The dying out of the contortions away from the controlling vein is well demonstrated.

Another inference can be drawn from the experiments. For simplicity I allowed only two opposing directions of escape for the clay. If the vein is placed in the plane containing the directions both of compression and elongation it is not folded. This is simply because it stretches together with the clay to compensate the compression. A more brittle layer, however, was not internally deformed but torn apart and the loose pieces were folded. Spurr thought the flow during gneissic deformation of the cases he described, had taken place parallel to the anticlinal axis of the ptygmatic folds. The experiments teach us that this is only possible if the folded veins were torn into separate strips along fissures parallel to the exposed surface. In most cases in nature the flowage will take place in all directions parallel to the schistosity.

The experiments further demonstrate, that a ptygmatically folded vein need not thicken at the bends, although this may be the case with a thick, soft vein (see fig. 2, Plate II).

Although these experiments cannot prove the folding-hypothesis to be right, it is hoped they may help to establish belief in this view on ptygmatic folding. The comparative simplicity of the mechanism will aid in interpreting the more elusive natural examples.

SUMMARY.

Ptygmatic folding was explained by Milch and Sander as the consequence of compression of plastic veins embedded in more ductile country rock.

Sederholm's hypothesis is slightly different, but he also believes the folding to follow after injection of plane veins. Read and Suter hold that they originate directly along meandering fissures. Objections to the last opinion are brought forward and an attempt is made to explain the observed phenomena by subsequent folding. It is admitted that in some cases the veins were probably injected along bedding planes or schistosity that had already been folded. The importance is shown of studying the structure of the wallrocks especially in between the meanders of the veins, and it is hoped others will contribute along these lines.

Experiments are described illustrating this point of view. It is pointed out that ptygmatic folds prove the large extent of plastic deformation that goes on in deep layers of the earth's crust and that they may be used to advantage in elucidating tectonic structures.

BIBLIOGRAPHY.

1. B. G. Escher and Ph. H. Kuenen: Experiments in connection with salt domes. Leidsche Geol. Med., III, 3, 1929, pp. 151—182.

2. P. J. Holmquist: Om pegmatitpalingenes och ptygmatisk veckning. Geol. Före. Förh., XLII, 1920, pp. 191—213.

3. L. Milch: Ueber dynamometamorphe Erscheinungen an einem Nordischen Granitgneiss. N. J. f. Min. etc., 1900, II, pp. 39—51.

4. H. H. Read: A note on »ptygmatic folding» in the Sutherland granite-complex. Summ. of Progress for 1927, Part II, Mem. Geol. Surv., 1928, pp. 72—77.

5. H. H. Read: The geology of Central Sutherland. Mem. Geol. Surv., Scotland, 1931.

6. B. Sander: Studienreisen im Grundgebirge Finnlands. Verh. k. k. geol. Reichsanst., Wien 1914, pp. 82—99.

7. A. Sauer: Das alte Grundgebirge Deutschlands. C. R. IX Congr. géol. Int. Vienne, 1903 Fas. II, pp. 587—602.

8. J. J. Sederholm: Om granit och gneis. Bull. Comm. géol. Finlande, 23, 1907, pp. 1—110.

9. J. J. Sederholm: Ueber ptygmatische Faltungen. N. J. f. Min. etc. BB. 26, 1913, pp. 491—512 (containing a bibliography of older references).

10. J. J. Sederholm: On migmatites and associated pre-Cambrian rocks of southwestern Finland, Part II, The Region around the Barösundsfjörd etc. Bull. Comm. géol. Finlande, 77, 1926 (see pp. 69—81).

11. J. S. Spurr: The Ore Magmas, Vol. I., New York 1923, pp. 164—167.

12. H. Suter: Zur Petrographie des Grundgebirges von Laufenburg und Umgebung. Schweiz. Min. Petr. Mittl., Bd. IV, 1924, pp. 288.

EXPLANATIONS TO THE PLATES.

Plate I.

Fig. 1. Ptygmatic folds of dark paraffin in lighter vaseline.

Fig. 2 A and B ptygmatic folds of dark paraffin in light clay. C light clay-paraffin in dark clay.

Plate II.

Fig. 1. Ptygmatic folds of dark paraffin in light clay. Note the concentration of contortions on the »crest of the anticline» and the attenuation and pulling apart of the limbs.

Fig. 2. Ptygmatic folds of dark clay embeded in light, softer clay. In A and B black lines show the approximate deformation of the wall rock if it had reacted solely by plastic deformation. In C the actual deformation is shown; the movements are seen to have been partly along gliding planes. These are the planes of schistosity in a schist.

PLATE I.

A B C

Fig. 2.

A B

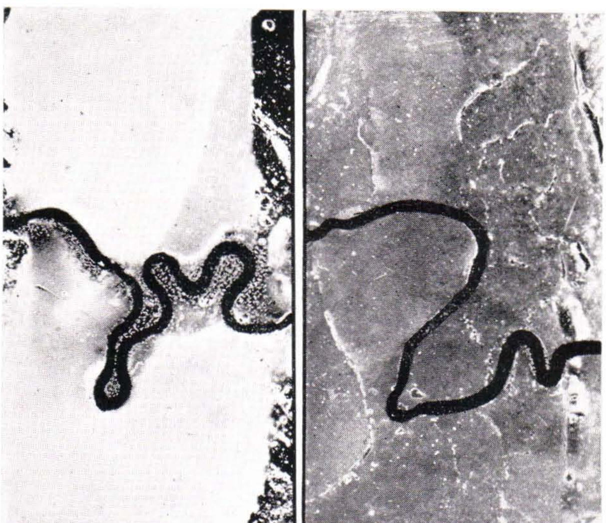


Fig. 1.

Ph. H. Kuenen, Experiments and Observations on Ptygmatic Folding.

PLATE II.

A B C

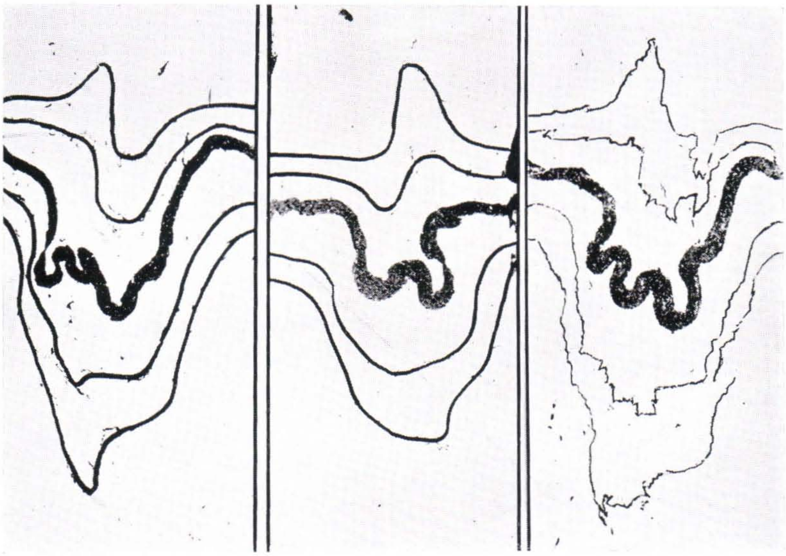


Fig. 2.

A B C D

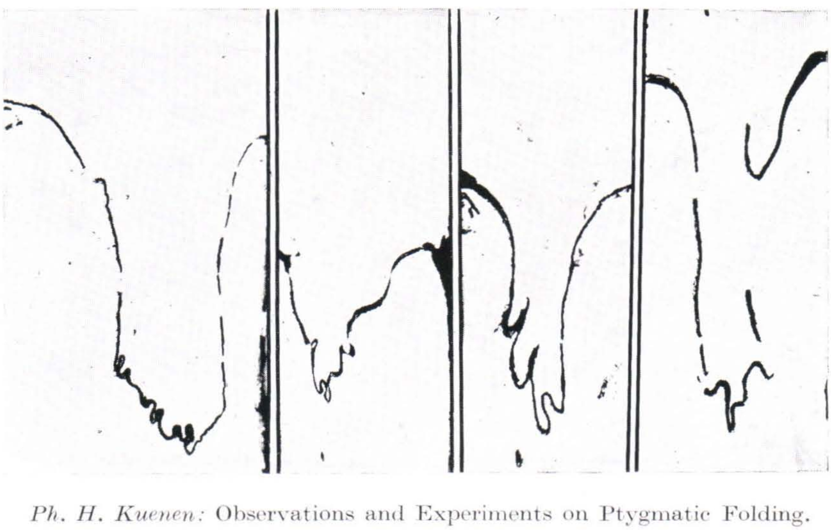


Fig. 1.

Ph. H. Kuenen: Observations and Experiments on Ptygmatic Folding.

2.

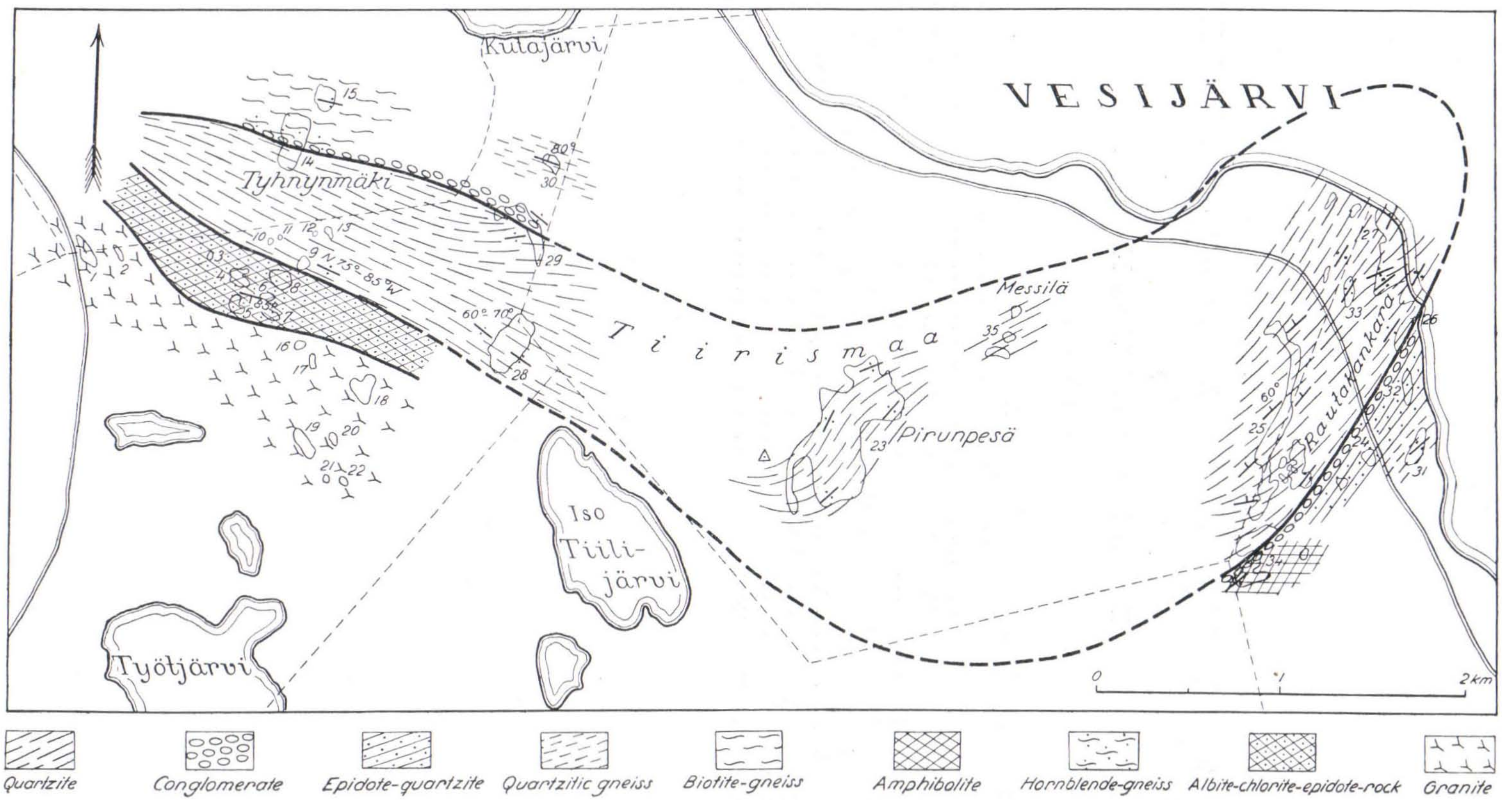
THE QUARTZITE AREA OF TIIRISMAA NEAR LAHTI.

By

PENTTI ESKOLA and EERO NIEMINEN.

Contents.

TIIRISMAA QUARTZITE AREA



INTRODUCTION.

In the Pre-Cambrian territory of Southwestern Finland, west of the zone of the Karelides, quartzites are rare and therefore attract special interest from geological, tectonical, and petrological points of view. In the following we shall present a short description of the largest area of pure quartzite within the said territory, viz. that of Tiirismaa in the parish of Hollola, immediately north of the marginal moraine ridge of Salpausselkä, which here expands into a wide plateau. The quartzite area stretches from the outskirts of the town Lahti in a westerly direction close to a highroad from the village of Hälvälä to the church of Hollola. The length of the quartzite area is about seven kilometers and its maximum breadth is a little more than two kilometers (see map).

The scenery in question is widely known in the sporting world, as the route of the famous Salpausselkä ski-races, annually held in Lahti, runs over the Tiirismaa heights.

So far this interesting area has been only summarily described in the explanation of the geological map-sheet 13 by A. F. Tigerstedt in 1890. In the summer 1935 the junior author carried out a field survey of the area and later a microscopic examination of the specimens collected. The field observations were revised during a common excursion by us in the same summer. In 1937 the junior author made some complementary field observations. The senior author has written the text, and he is responsible for the theoretical conclusions.

Geological investigation of Tiirismaa is greatly hampered by the scarcity of outcrops. Even the outline of the quartzite area, as shown on the map, could only in part be drawn on the basis of actual observations, being drawn for the most part from the observed strikes and the topography of the moraine-clad terrain where quartzite apparently underlies the higher parts of the country. While there is no reasonable doubt about the sedimentogeneous nature of the quartzite formation, its high grade metamorphism, which has obliterated all the finer features of stratification and primary structures, prevents any attempt at reconstructing with certainty the original stratigraphy. Certain facts indicate rather complicated tectonics, as will be pointed out below.

TOPOGRAPHY AND GENERAL FEATURES.

The topography has been influenced by the moraines of the Salpausselkä, but the Pre-Cambrian bed-rocks also must have a very uneven surface. The quartzite area has been split into three different heights, separated by deep valleys. The most westerly height is called Tyhnynmäki. It is a little higher than the Salpausselkä plateau (155 meters above sea-level). The central height is Tiirismaa, with which is connected the smaller height of Messilä. The highest point of Tiirismaa is 223 meters above sea-level, thus being the highest point in the whole of Southwestern Finland. It is a level but rather steeply sloping highland, of about 2.5 kilometers in length in an east-westerly direction. Both its ends are rocky. Near the east end there is a steep-sided rocky gorge called Pirunpesä (Devil's nest). The most easterly height, Rautakankara, runs from Lake Vesijärvi in a southwesterly direktion to the Salpausselkä, being a few meters higher than the glacifluvial plateau.

The quartzite area exhibits the horizontal cross-section of a lenticular body standing on its edge, more expanded (possibly by a complicated folding) in its eastern part. In the middle of Tiirismaa it is bent, the concave side of the gentle fold pointing towards the north. On Tyhnynmäki, in the west, the strike is N 75° or 85° W, vertical, at the west end of Tiirismaa (outcrop 29) it is still almost the same, N 70° W, with a steep northerly dip (70° N), but in the following outcrop towards the east, near Pirunpesä (no. 23), the strike has bent into N 50° E, vertical. On the height Rautakankara, near the east end of the area, the strike is a little more northerly, varying from N 30° E to N 35° E, and the dip from vertical to 60° NW (see map). Thus the bend seems to hide in the central part of Tiirismaa, where the bed-rock is covered by thick Quaternary deposits.

QUARTZITE.

The quartzite of the Tiirismaa area is for the most part red-coloured owing to pigmentary hematite, and distinctly schistose. The schistosity is marked especially at both ends of the lenticular area, while in the middle, at Pirunpesä near the bend, the plane schistosity is more indistinct, and in its stead a pronounced stretching, or linear schistosity in a vertical direction may be noticed. Generally the quartzite is highly metamorphosed, almost to an obliteration of the clastic structure. This is especially true of the more pure whitish varieties, exposed e. g. at the west end of Tiirismaa (outcrops 28 and 29), and on Rautakankara (outcrop 25). In the last-named locality the whitish quartzite forms a zone varying from 15 to 20 meters in breadth along the general strike, sharply bounded by the red quartzite. This variety is more impure, and a clastic structure is megascopically faintly perceptible, as clear quartz-grains are visible embedded in a red matrix. Under the microscope it may be seen to contain, besides iron ore as a fine pigment and separate grains, rather considerable quantities of sillimanite of the fibrolite type and scanty scales of sericite. The sillimanite is arranged, mainly along the schistosity, in bunches of minute fibres showing a brownish aggregate colour, but it also forms separate clear fibres. The bulk of the accessory minerals occupies the interstices between lenticularly elongated quartz-grains, though occasionally fibres of sillimanite have pierced through the grains. The outlines of the grains are fringed and sutured and granulated at the margins. They have been strongly deformed, showing marked strain shadows; but no regular lattice-orientation is noticeable by means of a gypsum plate. The petrofabrics of the Tiirismaa quartzite will be treated in a forthcoming memoir by Anna Hietanen.

There appears to be no doubt about the said distinction between the clear quartz-grains and the more impure matrix representing a relict clastic texture of a primary sandstone. The blastoclastic character of the quartzite is in good harmony with the fact that the quartzite at its boundary is frequently observed to pass over into distinct conglomerates, as will be described below. Still other relict features of a primary sedimentary nature may be observed in the quartzite itself. In the southwestern wall of the gorge Pirunpesä the quartzite shows ripple-marks standing almost vertically, but at an angle of about 15 degrees to the vertical stretching. They have been too poorly preserved to allow of a determination of the stratigraphical position, or the top side in the stratum. That they have been preserved at all seems to be due to a certain lamination in the primary sediment; especially sericite has been concentrated upon the wavy surfaces. Sericite and magnetite mostly occur in minute quantities only, but occasionally either of them may be concentrated in certain strata. Thus the quartzite near Pirunpesä contains in places darker layers stained with numerous magnetite grains. This is no doubt a primary layering.

Vertical jointings in directions at right angles to each other are well developed in the quartzite, one being parallel to the strike and the other perpendicular to it. The gorge of Pirunpesä has been carved out along joints in the latter direction.

An analysis of the quartzite from Pirunpesä, Tiirismaa, was executed by Miss Elsa Ståhlberg with the result quoted below. The analytical figures may well be accounted for by the observed mineral composition, except that the percentage of soda, twice as high as that of potash, is not consistent with the determination of the mica as sericite. The percentages of alkalies are, however, so small that this fact can hardly be regarded as an indication of the presence of paragonite. The composition shown by the analysis is such as can be expected and in fact frequently found in faintly argillaceous quartz sands and sandstones.

QUARTZITE.

SiO_2	94.52 %
Al_2O_3	2.38 »
Fe_2O_3	0.84 »
FeO	0.58 »
MnO	0.05 »
MgO	0.04 »
CaO	0.00 »
Na_2O	0.16 »
K_2O	0.08 »
TiO_2	0.01 »
H_2O+	1.15 »
H_2O-	0.21 »
	100.02 %

Cross-cutting dikes of pegmatite occur on Rautakankara, near the highroad.

CONGLOMERATE MANTLE AROUND THE QUARTZITE NORTH AND EAST OF THE AREA.

Owing to the poor exposition it is not possible to get any very exact idea about the character of the rocks surrounding the quartzite on every side of the area. The northern boundary is exposed only on Tyhnynmäki (outcrop 14) and at the west end of Tiirismaa (outcrop 29). In both these outcrops the quartzite is bounded by conglomerate.

Contrary to all expectation this conglomerate does not constitute the basal layer of the quartzitic strata but instead lies on top of them. The pebbles are for the most part formed of quartzite like the main variety of Tiirismaa quartzite. Besides these, only occasional dark grey pebbles of a fine-grained schistose rock have been observed. The cement may be described as quartzitic gneiss containing feldspar and mica, besides dominant quartz. The pebbles are strongly sheared and flattened out. Outcrop 29 is the largest one. Here may be seen how the conglomerate, away from the quartzite contact, becomes gradually more indistinct and its cementing mass less quartzite-like, whereas the pebbles decrease in number. At the point exposed farthest north of the contact-line the cement is gneissic in appearance and contains, besides quartz, light-coloured hornblende, rather anorthite-rich plagioclase (An_{46}), light-coloured or almost colourless biotite ($\gamma=\beta=1.592$), microcline, magnetite, titanite, and apatite. The comparatively large amount of titanite crystals arranged in rows parallel to the schistosity is especially striking.

South of Tyhnynmäki numerous big Glacial boulders of conglomerate occur. They have apparently been derived from the conglomerate horizon of the north side. Among these pebbles the greater part are drawn out and highly sheared, but in some conglomerate boulders they show well rounded shapes, and some ovoidal pebbles were seen lying across the general schistosity. Most pebbles consist of quartzite of the Tiirismaa type, containing much sillimanite, others, again, of pure quartz, like vein-quartz. The cementing matrix also is mostly very rich in quartz. One boulder was found in which well flattened quartzite pebbles, from one to three centimeters long, are evenly distributed in a reddish feldspar-bearing gneiss cement.

On close examination the conglomeratic structure is quite visible but, owing to the highly metamorphic character of both the matrix and the pebbles, it is not distinct enough to allow, for instance, the structure to be clearly reproduced in photographs. Some critical reader might therefore question the conglomerate character and suggest a »tectonic conglomerate». This possible explanation has been considered, but as might be gathered from the above description it does not seem probable.

Conglomerate is also exposed on Ŗautakankara southeast of the quartzite at the east end of the area, where the contact-line runs in a northeasterly direction. In outcrops 24 and 16 the immediate country-rock of the quartzite is conglomeratic, with pebbles almost exclusively of quartz within a narrow-boundary-zone. The cementing mass is quartzitic but rich in epidote like the epidote-quartzite following next to it in the same outcrops. The boundary is gradual, the number of pebbles decreasing outwards from the quartzite line.

EPIDOTE-QUARTZITE, QUARTZITIC GNEISS (INCL. CORDIERITE-GNEISS), AND BIOTITE-GNEISS FORMING OUTER MANTLES AROUND THE QUARTZITE LENS.

The epidote-quartzite is megascopically green in colour and banded, due to an unequal distribution of iron ore grains, especially on the lake-shore (outcrop 26). A specimen from this outcrop is composed of quartz, epidote, muscovite, chlorite, oxidic iron ore, and apatite. The epidote is fairly abundant and shows interference colours not higher than of the first order, indicating a composition rich in clinozoisite. Muscovite, or rather sericite, and chlorite are next in quantity. The chlorite is almost colourless, with a brownish tinge and distinct lavender-blue interference colours. The rock of point 24 is similar, though with smaller amounts of muscovite and iron ore. Frequent dikes of pegmatite cut the epidote-quartzite.

Miss Elsa Ståhlberg made an analysis of the epidote-quartzite from Rautakankara, Lahti (point 24) with the following result:

EPIDOTE-QUARTZITE, RAUTAKANKARA, LAHTI.

SiO_2	65.64 %
Al_2O_3	13.14 »
Fe_2O_3	5.04 »
FeO	1.08 »
MnO	0.08 »
MgO	2.27 »
CaO	8.44 »
Na_2O	0.37 »
K_2O	0.98 »
TiO_2	0.85 »
H_2O+	2.02 »
H_2O-	0.28 »
	100.19 %

The figures of the analysis can be well accounted for by the mineralogical composition and also agree with analyses of marly sandstones, considering that the rock has lost its original carbon dioxide by a reaction between quartz, alumina, iron oxide, lime, and alkalies during metamorphism.

A very peculiar rock is exposed at the farthest southeast corner of the quartzite area, in outcrop 34. It is a fine-grained amphibolite containing occasional fragments of quartzite wich are supposed to be origincal pebbles in a primary sediment. The rock is very nonhomogeneous, and its amphibole is seen, even by the naked eye, to be a light-coloured variety. A microscopical examination reveals the following mineral composition: quartz, bytownite, colourless amphibole, oxidic iron ore, titanite, epidote, and apatite. The bytownite shows, in sections ⊥ (010), extinction angles up to 45° and a markedly high relief. The colourless amphibole shows comparatively large extinction angles, $\gamma \wedge c = 27°$. Its indices of refraction determined by immersion were found to be $\gamma' = 1.647$, $\alpha' = 1.628$. It has been partly epidotized. From its short-prismatic habit it does not seem to be tremolitic but rather a pale-coloured hornblende, while its low refringence points to a very low iron-content. The rock is traversed by numerous dikes of pegmatite.

The next zone farther southeast of the epidote-quartzite and amphibolite zone on the slopes of Rautakankara consists of quartzitic gneiss, exposed in outcrop 31. It is composed of quartz, highly anorthitic plagioclase, pale-brown biotite ($\gamma = 1.591$), cordierite, oxidic iron ore, muscovite, epidote, apatite, and chlorite. The cordierite is unevenly distributed, being enriched in bands parallel to the schistosity, and has been much altered.

Let us now return to the rocks bounding the quartzite on the northern side. At the west end of Tiirismaa, in outcrop 29, only conglomerate is exposed, but farther north there is an outcrop of quartzitic gneiss (outcrop 30). It is a light-coloured banded and fine-grained rock. The banding is due to the arrangement of the dark constituents in rows parallel to the schistosity. Quartz is the most abundant constituent and shows a strongly undulose extinction. The other constituents are microcline, pale-brown biotite ($\gamma = 1.594$), anorthite-rich plagioclase ($\alpha > \varepsilon$ of quartz), abundant oxidic iron ore, titanite, apatite, and muscovite. Dikes of pegmatite are numerous.

In outcrop 14 a fine-grained gneissose rock is seen in direct contact with the conglomerate and appears to be very similar to the cement of the latter (cf. above p. 35), as though formed from the same sediment but without boulders. Its minerals are plagioclase (An_{36}), quartz, pale hornblende, oxidic iron ore, titanite, epidote, and apatite. The rather large quantity of titanite is characteristic, as in all the other rocks from the northern boundary zones and, to a certain extent, also in the rocks of Rautakankara in the east. The rock is granoblastic, but with serrated outlines of the grains. Towards the north this hornblende-bearing gneiss is followed by a biotite-plagioclase-gneiss which still occurs in outcrop 15 farther north. It is fine-grained, megascopically almost leptite-like, and composed of plagioclase (An_{20}), quartz, microcline, biotite, oxidic iron ore, chlorite, apatite, and zircon. In structure it is granoblastic and fairly distinctly schistose, the quartz showing strain shadows. The biotite is greenish brown and darker in colour than any of the varieties found in the immediate country-rocks of the quartzite. In this gneiss are intruded very numerous dikes and veins of pegmatite, making the rock on the whole rather migmatitic in character. It is in this respect similar to the dominant rock in the region all around the Tiirismaa quartzite area. There are neither relict structural nor mineralogical features giving any hint as to its original character, and it may have been considerably changed in composition by the influence of the incipient migmatization, but there is nothing in the way of assuming it to be a paragneiss like all the schistose rocks described so far from the eastern and northern boundary zone of the quartzite area.

GREENSCHIST SOUTH OF THE QUARTZITE.

The southern boundary of the quartzite is nowhere exposed, but south of Tyhnynmäki, in outcrops 3—8, a homogeneous rock, a greenschist, covering a rather large area was observed; in outcrop 8 it is exposed so close to the quartzite of outcrop 9 as to make it almost certain that it is here the immediate country-rock of the quartzite. In the south and west it is bordered by an intrusive granite which also forms intrusive dikes. Megascopically the rock looks like a common amphibolite, but in thin sections it is seen to be an albite-epidote-chlorite-rock, the constituents being: dominant albite (An_5), with chlorite, quartz, epidote, hornblende, apatite, oxidic iron ore, and zircon. The chlorite occurs as scales very perfectly arranged parallel to the schistosity. It is optically negative, green in colour and shows strong lavender-blue interference colours with pleochroic halos around inclusions of zircon. The hornblende has been partly well-preserved as idioblastic stout prisms of dark green colour, but most grains have been strongly altered into epidote, being stained with minute inclusions of the latter mineral. From these observations it is rather difficult to draw any conclusions as to the premetamorphic character of this schistose rock, whose mineral composition has finally almost reached equilibrium in the typical greenschist facies. Its present bulk composition, with a high percentage of soda present in the albite, which is by far the most abundant constituent, might point to an original spilite, but in the absence of any ophitic or amygdaloid relict structures this cannot be induced with certainty. The following chemical analysis by Miss Elsa Ståhlberg actually shows a composition typical of spilites, with a soda percentage higher than usual in normal amphibolites.

GREENSCHIST, S. W. OF TYHNYNMÄKI, HOLLOLA.

SiO_2	57.71 %
Al_2O_3	15.60 »
Fe_2O_3	2.40 »
FeO	7.99 »
MnO	0.12 »
MgO	2.76 »
CaO	4.22 »
Na_2O	4.48 »
K_2O	0.57 »
TiO_2	1.20 »
H_2O+	2.74 »
H_2O-	0.34 »
	100.13 %

On the other hand, it seems quite clear that the present low-temperature mineral facies must be due to a retrogressive or diaphtoretic metamorphism. The texture of the rock is characteristically granoblastic and equigranular, like that commonly observed in the Archaean amphibolites, with the difference that it is albite and not labradorite that forms the honey-combed pavement. What has escaped epidotization of the hornblende is exactly the common green variety found in ordinary amphibolites. Thus it is the amphibolite metamorphism, and not the greenschist metamorphism that has obliterated all the primary features of the rock, and it may well have been a spilite, as its bulk composition seems to indicate, before it became an amphibolite.

GRANITE.

Granite occurs west and south of the greenschist area. In the southern outcrops (16—22) the rock is reddish grey, medium-grained and slightly gneissose microcline-biotite-granite. The amount of microcline decreases towards the quartzite. The rock of the western outcrops (1 and 2) is light grey in colour and rather poor in microcline. The plagioclase in both groups of outcrops is almost the same, An_{26}. The biotite is dark brown as usual in granites. This granite area continues farther southwards.

The wider surroundings of the quartzite area are largely underlain by migmatites in which the older portions consist of various micaceous gneisses and the granitic veins are pegmatitic. As mentioned above, pegmatitic dikes intrude from all sides into the mantle-rocks around the quartzite, and on Rautakankara they have also succeeded in penetrating some way into the quartzite, whereas the quartzite has elsewhere resisted the attack of the migmatite front and the pegmatite intrusions. The dikes generally consist of red microcline-pegmatites containing biotite and some muscovite but no particular pegmatite minerals. Graphic intergrowth of quartz and microcline was observed in the pegmatites of Rautakankara.

SUMMARY AND CONCLUSIONS.

The Tiirismaa quartzite formation is early Archaean in age, older than the granites of Sederholm's second group in its surroundings, and probably even older than the granites of his first group. This would mean that it is older than all the known granites which have originated in connection with the Svecofennidic orogenesis.

In its few exposures the Tiirismaa area displays a monotonous appearance of reddish or greyish sillimanite-bearing or pure highly crystalline quartzite which, however, shows a blastoclastic relict texture and occasionally ripple-marks, or primary bedding. Intrusions of granite were not found in the inner parts of the quartzite, while dikes of pegmatite do occur near the eastern boundary on Rautakankara and are fairly numerous in the surrounding rocks wherever they are exposed.

On the north side of the western part, and in the same way on the southeast side of the eastern part, the quartzite is bounded by conglomerate containing pebbles of the Tiirismaa quartzite and passing over into epidote-quartzite, quartzitic gneiss, occasional cordierite-gneiss, and biotite-gneiss. This would seem to be a stratigraphic series in which quartzite forms the bottom and the conglomerate lies on top of it. Considered as rocks with their original bulk composition preserved, the epidote quartzite would represent an original quartz-sand mixed with some marly materials, more concentrated in the bytownite-amphibolite of outcrop 34 in the east, while the quartzitic cordierite-gneiss would correspond to sand with admixtures of highly aluminous clay.

Thus the top-side in the western part is directed towards the north and in the eastern part towards the southeast. This perhaps means an anticlinal folding of the series, the axis of folding standing almost vertical. It is regrettable that the exposures are so poor as actually is the case. Now this conclusion must remain very uncertain.

Apparently, however, the quartzite mass is unsymmetrical in structure, as the greenschist, or albite-chlorite-epidote-rock, exposed on the southern side of the west end is quite different from the rocks on the northern side, and no conglomerate occurs south of the quartzite. If the greenschist, as would seem probable, was originally a spilitic lava, it may have formed the base of the quartzite strata. With the present unsatisfactory information this conclusion, however, can be hardly more than a guess.

The conglomerate bed upon the quartzite, containing pebbles of the latter, of course means a hiatus in the sedimentation. Whether there is an angular unconformity between the quartzite and conglomerate, or not, cannot be said with certainty, as the stratification in the quartzite is not sufficiently distinct. At least on Rautakankara, in the east, the succession would seem to be conformable, as the intercalated white layer in the red quartzite is parallel to the contact line. However this may be, the interval in sedimentation must have been rather long, as the sandy sediment had time to harden at least into a sandstone before the rounded worn-out pebbles were formed during a new period of erosion. In old Archaean formations evidences of such incidents are not numerous. The Tiirismaa quartzite formation, being built up of products of weathering and subaerial exogeneous differentiation, is of considerable importance, testifying to the applicability of the actualistic principle to the oldest geological formations of our globe.

The quartzite is composed of quartz with subordinate sillimanite, sericite, and iron ore, but with no feldspar. Its prevalent reddish colour, due to a hematite pigment present in the primary cement, is presumably an intrinsic primary feature like that of the Jotnian, or »Oldest Red», and the Old Red and New Red sandstones, each of these formed at the close of an orogenic cycle. Backlund[1] has applied to such sandstones and associated feldspathiferous psephites and conglomerates the term molasse. If now the Tiirismaa quartzite formation be regarded as a molasse in this sense, we might be led to far-reaching geological speculations. It must be noted at once that the red colour and the other features of the Tiirismaa formation do not yield any sufficient evidence of their molasse character, especially as we have no arkose facies represented. Its characteristics can rather be regarded as indicating arid conditions during their stratification, and these are not by any means restricted to periods of detraction of mountain ranges alone. But in any ease, whether »molasse» or not, such mechanical sediments, where they occur at all, may be expected originally to have had a wide distribution and great thickness of strata.

[1] H. G. Backlund, Der Magmaaufstieg in Faltengebirgen. Bull. Comm. géol. Finl. N:o 115, pp. 293—347, 1936.

As mentioned at the outset, quartzites are rare in the Pre-Cambrian territory of Southwestern Finland and in the Pre-Karelidic Archaean in general. Paragneiss of an arkose-character are more common. Red quartzite of the Tiirismaa type has been found by the senior author in the parish of Kiikala, north of the Orijärvi area. This occurrence was recently mapped by Dr. E. Mikkola, who found its area to be only a few tens of meters in diameter. Most of the other small occurrences in Southwestern Finland present glassy, white or greyish quartzites, either pure like that of the island Tytärsaari in the Gulf or Finland, or feldspathiferous, in all probability originally arkosic, such as the quartzites of Taalikkala near Lappeenranta[1], the Rabbasö quartzite formation in the archipelago of Pellinge[2] and the quartzitic gneisses of the zone Örskär-Espskär-Röda Kon west of Helsinki[3]. More various though mostly pure quartzites occur in different areas in southern Ostrobothnia; these will be described in a forthcoming memoir by Anna Hietanen. In Central Sweden quartzites occur in the leptite region on a rather small scale in the Norberg district[4], N. W. of Fagersta near Malingsbo[5], at Nordmarken in the Filipstads Berglag[6] and Utö in the archipelago of Stockholm[7].

In his discussion of the significance of the quartzite occurrences in the leptite territory Geijer writes (op. cit. p. 155):

»The sedimentary quartzite appears to indicate the end of the volcanic period of the leptites. — — — — there occurs a band of quartzite apparently intercalated on the leptite series, but the situation also admits of an interpretation through faulting or overthrusting. In any case, the main mass of the quartzite is later than the associated leptites, and there are reasons to believe that it is the youngest member of the supracrustal formation of the district. It is improbable that this quartzite was built up of material derived

[1] Victor Hackman, Das Rapakiwirandgebiet der Gegend von Lappeenranta (Willmanstrand). Bull. Comm. géol. Finl. N:o 106, p. 54. 1934.

[2] J. J. Sederholm, On migmatites and associated pre-Cambrian rocks of Southwestern Finland. Part. I, the Pellinge region. Bull. Comm. géol. Finl. N:o 58, p. 68. 1923.

[3] E. H. Kranck, Beiträge zur Kenntnis der Svekofenniden in Finnland. IV. Über Intrusion und Tektonik im Küstengebiete zwischen Helsingfors und Porkala. Bull. Comm. géol. Finl. N:o 119, p. 78. 1937.

[4] Per Geijer, Norbergs berggrund och malmfyndigheter. Sveriges Geol. Undersökning, Ser. Ca. N:o 24, p. 52 and p. 155 (English summary). 1936.

[5] Alvar Högbom, Om förekomst av urbergssediment på geol. kartbladet Malingsbo. Geol. Fören. Förh. Bd. 51. p. 537. 1929.

[6] Nils H. Magnusson, Persbergs malmtrakt och berggrunden i de centrala dalarna av Filipstads bergslag. Kungl. Kommerskollegium, Beskr. över mineralfyndigheter, Nr. 2. Stockholm 1925.

[7] P. J. Holmquist, The Archaean geology of the coast-regions of Stockholm. Geol. Fören. Förh., Bd. 32, p. 789. 1910.

from the underlying leptites. Particularly the zircons rather point at granitic rocks as the source of this sediment. Possibly the material came from quite distant regions».

The Norberg quartzite is intruded by granite. In western Dalarna Archaean quartzites are accompanied by conglomerates containing pebbles of Archaean granite[1], thus affording a direct evidence that granites were exposed at the time of deposition of the quartzites. The same is also true of the Taalikkala area where, according to Hackman (op. cit. p. 65), a conglomerate occurs containing pebbles of arkose-like quartzite and, besides, such of a more dark-coloured, grey, small- or medium-grained rock that can be supposed to be a diorite or granodiorite. In the presence of quartzitic pebbles this conglomerate is similar to the Tiirismaa conglomerates described above, but we did not find any deep-seated rocks among the pebbles of the latter.

Metamorphic rocks of a primary argillaceous character are far more widely distributed in the Archaean than are quartzites. As we must suppose that quartzeous sediments also have once existed on a big scale in the old Archaean, the next question is, how to account for their disappearance.

Two ways are possible. Either the quartzites have been regionally granitized, or they have been eroded away before their folding in the Svecofennidic orogenesis. A few words may be said concerning the probability of a regional granitization of the quartzites.

The immediate country-rocks of the Tiirismaa quartzite, wherever exposed, are silicatic metamorphic rocks and, although they are intruded by dikes of granitic pegmatite, granite nowhere was found to meet quartzite. At a short distance from the quartzite boundary the surrounding rocks are migmatitic, but the quartzite itself seems to have been most resistant against granitization. The Tiirismaa quartzite area therefore rather offers an evidence against the thesis recently presented by Backlund[2]) that quartzites were originally widely spread in the Archaean of Fennoscandia but have been largely obliterated by regional granitization. Different areas display much variation in this respect, depending on special tectonical and geological conditions, but in Southwestern Finland the bulk of evidence is the same as at Tiirismaa: Quartzites, if they ever existed, have not been obliterated by granitization. The senior author hopes to return to this big problem in the near future.

[1] N. Sundius, Grythyttefältets geologi. Sveriges Geol. Undersökning, Ser. C, N:o 312, p. 219. 1923.

[2] H. G. Backlund, »Die Umgrenzung der Svecofenniden». Bull. Geol. Inst. Upsala, vol. 27. 1937.

It seems, therefore, that the hypothesis of a deep erosion in early Archaean periods, before the mise-en-place of the Svecofennidic granites, must be considered, although there is no direct evidence of such an event registered in the rocks. We know of no widely distributed conglomerates containing pebbles of deep-seated intrusive rocks, as might be expected, and we know of no great unconformities. Never the less, the existence of the quartzite formation is in itself an evidence of great things that have happened in those remote ages. Perhaps it represents occasional remains from times so remote that almost all geological record has been lost. We must remember the fact that we do not know with certainty any granites older than the leptite formation, to whose age-group the Tiirismaa quartzite as well as other remains of old Archaean quartzites would seem to belong. And yet there is good reason to maintain that the volcanics of the leptite formation have been erupted through a granitic crust. Great gaps must exist in the series of the oldest strata of our globe — as well as in the geological information about these things!

Quite another way to solve the riddle of the Tiirismaa quartzite would be to suppose it to be Karelidic in age, in which case the surrounding granites would be post-Karelidic. Such a hypothesis, however, is contradicted by the cardinal results of Finnish geology to such an extent that it can hardly be taken into consideration.

In their mineralogical development the supracrustal metamorphic rocks surrounding the quartzite represent two different kinds of mineral facies. The conglomerates, epidote-quartzites, and quartzitic gneisses in the east and northwest are characterized by epidote and pale-coloured iron-poor amphiboles, and comparatively much titanite, and chlorite. All the silicates, i. e. epidote, hornblende, and biotite, are poor in iron, a fact that cannot be merely accounted for by the absence of iron, as most of the rocks contain appreciable quantities of oxidic iron ore. The greenschist at the southwestern side of the quartzite contains deep green hornblende in process of alteration into epidote and chlorite. In both rocks the epidote-chlorite association is later than the hornblende with which anorthitic plagioclase, even bytownite, is found on the east side, while albite is the chief component of the greenschist on the soutwest side. These circumstances can only be interpreted by assuming two different processes of metamorphism, an earlier amphibolite metamorphism and a later retrogressive greenschist metamorphism. If the former is connected with the intrusion of granites and the migmatization, the latter must be due to a temperature that had fallen to a certain degree. It seems as if the quartzite which had succeeded in resisting the attack of the granite magma had absorbed and conducted heat also from the surrounding rocks. Has this been due to the better thermal conductivity of the quartzite as compared with the surroundic migmatites? This would seem quite probable if the quartzite, as a huge mass, was continuous up to the land-surface of that time. This hypothesis would gain in probability if it could be proven that big masses of quartzite in folded complexes are commonly associated with rock of some low temperature facies in their nearest surroundings. This possibility might be worth considering.

The Mineralogical and Geological Institute of the University, Helsinki, January 1938.

3.

CHEMICAL STUDY OF THE ORBICULAR ROCK IN KEMIJÄRVI.

By

AHTI SIMONEN

(Preliminary Report.)

During the prospecting work of Suomen Malmi O. Y. in the summer of 1937 the writer discovered, on the shore of Lake Kalliojärvi in the western part of the parish of Kemijärvi (in North Finland), a new occurrence of orbicular rock, the eleventh in our country. Most of the occurrences so far known have been found as Quaternary, glacial boulders. Formerly only those of Virvik and Esbo were known in place, and now the new find in Kemijärvi adds a third occurrence met with in the Pre-Cambrian rock crust of Finland.

In his treatise »On the Esboitic Crystallization of Orbicular Rocks» Eskola[1] has already given a short note and microscopical description of the Kemijärvi rock. The writer merely begs to recall the following points. The surrounding rock of this occurrence is a migmatitic granite and also in the matrix of the orbicular rock we can see, as a last crystallization, portions of light-red granite besides a granodioritic, hornblende-bearing rock forming an older, or »primary» matrix. According to the microscopical determinations the plagioclase of the nuclei of the spheroid (An_{17}) agrees better with the plagioclase of the migmatite-forming, granitic matrix (An_{16}) than with that of the primary, granodioritic matrix (An_{25}). Therefore it seems credible that the spheroids have been formed during the process of migmatitization.

In the chemical study of the orbicular rock of Kemijärvi four quantitative analyses were carried out by the writer with the following results (Table I).

[1] Journal of Geology, Jubileum volume in honour of Albert Johannsen 1938.

Table I. The chemical composition of the orbicular rock in Kemijärvi.

	I	II	I—II	III	IV
SiO_2	65.51	73.91	71.11	71.36	56.83
Al_2O_3	20.01	13.55	15.72	14.02	16.62
Fe_2O_3	0.67	0.31	0.38	0.56	3.20
FeO	0.52	—	0.23	1.82	5.11
MnO	—	—	—	—	0.91
MgO	0.02	< 0.01	0.01	0.59	3.29
CaO	3.24	0.07	1.13	1.39	5.36
Na_2O	7.66	1.89	3.81	3.82	4.63
K_2O	0.96	9.38	6.57	5.21	1.41
TiO_2	0.17	< 0.01	0.06	0.19	0.97
H_2O	1.02	0.80	0.87	1.21	1.24
	99.78	99.91	99.87	100.17	99.57

I. Nucleus of spheroid.
II. Outer zone of spheroid.
I—II. Average composition of spheroid (calculated).
III. Granitic matrix.
IV. Primary, granodioritic matrix.

From the results of the analyses we can see a very great difference between the nucleus and the outer zone of the spheroid. The spheroids are extremely sharply differentiated into an esboitic nucleus, mainly consisting of plagioclase, and a microclinic outer zone. The writer calculated the average chemical composition of the whole spheroid from the measured volumes[1] of the nucleus and the outer zone. It is very similar to the chemical composition of the migmatite-forming granitic matrix, while the primary, granodioritic matrix is more basic.

This result of the chemical study is in very good harmony with the conclusion drawn by Eskola in his memoir (l. c.), that the granitization has been of decisive importance in the origin of orbicular rocks. According to his opinion the granitization has played a significant rôle in the origin of the greatest part of the Finnish orbicular rocks; only a few of the more basic of these may be direct differentiation products of the primary matrix without the migmatitic phase. In the light of the microscopical and chemical study it seems very probable that the speroids of the orbicular rock in Kemijärvi are formed through a differentiation-process from the migmatite-forming granitic matrix.

[1] The radius of the nucleus is 4.7 cm and the thickness of the outer zone is 2.2 cm.

The present chemical study was made in the Petrographical Laboratory of the Mineralogical and Geological Institute. The writer wishes to express his deep gratitude to his esteemed teacher, Professor Pentti Eskola, for his valuable instruction during this work.

The Mineralogical and Geological Institute of the University, Helsinki, January 1938.

4.

ÜBER DAS VUOKSI-DELTA IN JÄÄSKI.

von
AARO HELLAAKOSKI.

1. Vorwort. — In einer früheren Untersuchung (1922) habe ich erwiesen, dass bei den Saimaa-Gewässern in postglazialer Zeit ein grosser Vorzeitsee gewesen ist, der anfangs nach Westen abfloss, bis die durch die Landhebung verursachte Transgression des Sees den Salpausselkä am Vuoksenniska durchbrach und der gegenwärtige Abfluss Vuoksi entstand. Gleichzeitig sank der Seespiegel um 2—2.5 m. Später bin ich in meinem Aufsatz: »Das Alter des Vuoksi» zu folgendem Ergebnis gekommen: »Als der Vuoksenniska durchbrach und der Wasserspiegel des Vor-Satanen um 2—2.5 m fiel, war die Zeit des Häufigwerdens von *Picea* am Saimaa, war die Hochstufe der steinzeitlichen typischen Kammkeramik, war die Zeit kurz vor der Mitte des Litorina, nach der gegenwärtigen archäologischen Datierung ca. 2500—2400 v. Chr., nach der Zeitkurve Ramsays ca. 2800 v. Chr.» Ferner wies ich auf die Möglichkeit hin, dass sich nach jener Bestimmung »vielleicht zu guter Letzt auch ein Durchbruchsdelta des Vuoksi auffinden» liesse. Sei es doch zu suchen in einer Höhe, die 72—71 % von der I. Litorinatransgression ausmache. Diese Höhe, die Höhe des Ufers der typischen Kammkeramik, beträgt in der Gegend von Viipuri ca. 15—17 m ü. M. Schliesslich wurde der Untersuchung ein kurzer Nachtrag beigegeben, in dem ich mitteilte, ein Durchbruchsdelta sei aufgefunden worden bei der Kirche von Jääski, wo es als Talterrasse am gegenwärtigen Vuoksi auftrete, an seinem Proximalende jedoch zu einer Höhe von 21—22 m ü. M. aufsteigend, d. h. 5—6 m höher, als auf Grund der archäologischen Konnektion geschlossen wurde.

Eine eingehendere Erforschung des Deltas ist vorläufig noch nicht über ihre ersten Anfänge hinausgekommen. Weder habe ich es überhaupt kartiert noch seine Stärke gemessen, ebensowenig weiss ich, auf welcherlei Schichten es ruht. Da ich jedoch einige vorbereitende Höhenmessungen und Bohrungen nebst Pollenanalysen angestellt habe, mag ich verpflichtet sein, kurz wiederzugeben, was ich weiss, sowie diejenigen Ursachen darzustellen, auf Grund deren ich geschlossen habe, dass das Delta im Zusammenhang mit der Durchbruchskatastrophe des Vuoksi entstanden sei.

2. Lage und Grösse des Deltas. — Das Delta liegt bei der Kirche von Jääski, an einer Stelle, wo das eigentliche Vuoksi-Tal endet und der Fluss in eine lange Seenkette übergeht. Hier ist schon früher (Schjerbeck 1925) das Vorhandensein eines Deltas vermutet worden.

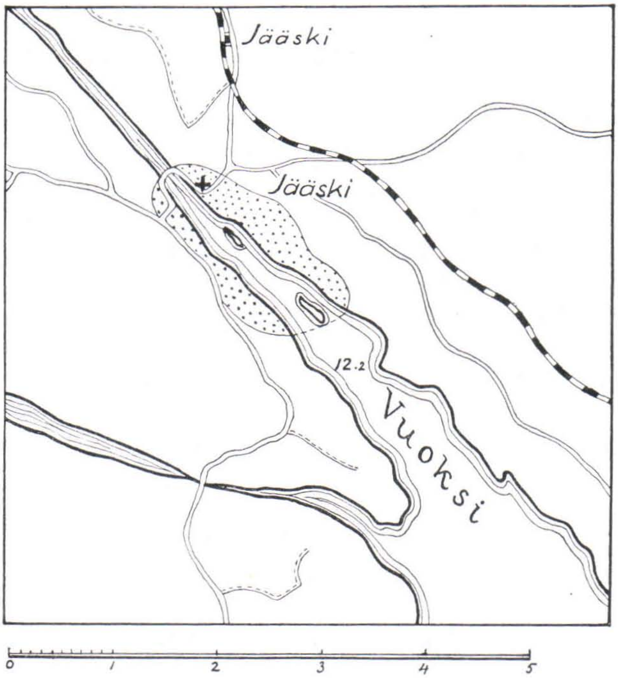


Abb. 1. Das Durchbruchsdelta in Jääski.

Auf der Karte Abb. 1 sieht man von diesen Seen den obersten, in 12.2 m Meereshöhe. Wie ersichtlich, öffnet sich das Flusstal nach dem See zu, allmählich erweitert es sich in einer ästuarartigen Mündung, wo sich zwei längliche Inseln erstrecken, die in ihrem Aussehen an Flussbarren erinnern. An einer derartigen Stelle, wo der fast 30 km lange Fluss sein Klärbecken erreicht, müssen gewiss irgendwelche Deltaaufschüttungen vorhanden sein. Doch überschreitet ihre Aufschüttung jegliche Masse, die eine den jetzigen Verhältnissen entsprechende friedliche Sedimentation erwartungsgemäss zustande zu bringen vermöchte.

Das Delta nimmt seinen Anfang bei der über den Vuoksi führenden Landstrassenbrücke. Am Proximalende liegen die Kirche und der alte Friedhof. Von dort aus setzt sich das Delta, morphologisch und in seinem Material deutlich erkennbar, nach SE an beiden Ufern des Flusses auf einer Strecke von etwa 2 km weiter fort, bis an das untere Ende der Insel Papinsaari. Die beiden Barreninseln, das genannte Papinsaari und das weiter aufwärts gelegene Niemensaari, scheinen ebenfalls hinsichtlich ihres Stoffes demselben Vorzeitdelta anzugehören. Misst man auf der Karte über dem 200—400 m breiten Fluss das Delta von Rand zu Rand, so ergeben sich als dessen ursprüngliche Breite Zahlen, die zwischen 0.8 und 1.0 km schwanken. Der grösste Teil des Deltas ist am NE-Ufer des Flusses gelegen; die Breite des am Westufer aufgeschütteten beträgt nur 200—300 m. Mit anderen Worten, der Fluss hat sich SW-seits der Deltamitte eingegraben.

Nach ganz ungefährer Schätzung macht der ursprüngliche Flächeninhalt des Deltas ca. 1.5—2.0 km^2 aus. Über den Kubikinhalt lässt sich vorläufig natürlich noch gar nichts aussagen. Doch ist aus den folgenden Seiten zu ersehen, dass das Delta vom Proximalrand bis um das untere Ende von Niemensaari, also in etwa halber Erstreckung, nächst der Flussrinne über 10 m, vielleicht sogar über 15 m mächtig sein muss. Eine bedeutende Stärke muss die Aufschüttung in ihrer Proximalhälfte auch weiter entfernt SW-seits vom Fluss erreichen, wo das Delta an verhältnismässig steile Felsflanken stösst. Dagegen scheint der umfangreichere NE-seits vom Flusse gelegene Deltateil von geringerer Mächtigkeit zu sein, desgleichen das Distalende des Deltas.

3. Topographie des Deltas. — Die morphologische Natur des Deltas ist recht gut zu erkennen, wenn man es von den die SW-Böschung des Flusstals umgürtenden hohen Felsen betrachtet. Das untenstehende aus freier Hand skizzierte Querprofil mag den Sachverhalt am besten erklären.

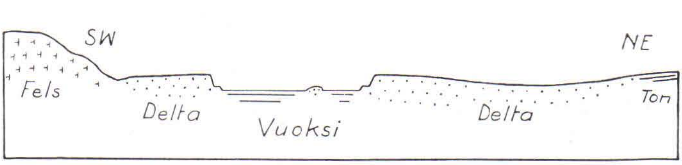


Abb. 2. Querprofil durch das Delta bei der Insel Niemensaari. Deltaaufschüttung punktiert. Massstab überhöht.

Das Flusstal trägt, wie zu erkennen, beim Delta den Charakter eines Terrassentales, und das Delta tritt als Flussterrasse auf. Der Fluss strömt zwischen den in sein früheres Sediment eingeschnitteten Erosionsabhängen. Diese steigen im allgemeinen nicht unmittelbar aus dem Fluss auf, vielmehr ist in ihnen ein kleiner Einschnitt zu erkennen, der zurückreicht in die Zeit vor 1857, als in der Seenkette des Vuoksi der Wasserspiegel künstlich gesenkt wurde (Palmén 1903). Der Oberrand der Kleinterrasse, der den früheren Wasserstand im See des Vuoksi markiert, liegt 15.5 m ü. M. An einigen Stellen im Oberteil des Deltas hat diese Kleinterrasse jedoch schon abgetragen werden können.

Die Plattform der grossen Terrasse breitet sich, leicht erkennbar, da sie von offenen Kulturflächen bedeckt ist, zu beiden Seiten des Flusses aus. Südwestlich vom Flusse tritt sie unter deutlicher Winkelbildung an die Felswandungen heran, nordwestlich geht sie in unschärferem Übergang in Tonebenen und flache Moränenhügel über. Die Oberfläche des Deltas flacht vom Proximalende her in der Distalrichtung leicht ab und schliesst sich in ihrem unteren Ende an die 1857 bei der Seesenkung freigelegten Schwemmböden an. Dort beträgt also die Höhe des Deltas 15.5 m ü. M. Weiter aufwärts beläuft sich die Maximalhöhe (= nahe der Flussrinne) bei der Insel Niemensaari auf 19—20 m und am Proximalende bei der Kirche auf 21—23 m ü. M. Für den Proximalteil des Deltas habe ich als Höhe 21—22 m angegeben, weil diese Höhe, gegenüber derjenigen von 22—23 m, allgemeiner ist und in weiteren ebenen Flächen auftritt.

Die Terrassenplattform des Deltas ist nicht ganz eben. Eine Abweichung von der Ebene ist in der Profilskizze zu erkennen: die Terrasse ist an den Rändern des gegenwärtigen Flusses am höchsten und senkt sich dort mit leichtem Gefälle nach beiden Seiten zu. Eine andere Unebenheit, die jedoch durch die Profilskizze nicht wiedergegeben werden kann, sind die Streifung und die Grubigkeit der Terrassenplattform. Dies ist vorzugsweise nordöstlich vom Flusse zu erkennen. Die Streifung verläuft in der Längsrichtung des Deltas und äussert sich als in die allgemeine Deltaebene eingetiefte flache Mulden. Die deutlichste von ihnen beginnt am Proximalteil des Deltas, wo sie als eine längliche Grube zu sehen ist, aber schon etwas weiter abwärts, wo die Landstrasse sie überquert, 20.7 m ü. M. liegt und weiterhin nach SE zu rascher als das allgemeine Niveau des Deltas abflacht. Die tiefste der Eindellungen ist der kleine Weiher Niemilampi. Er ist durch sekundäre Verschlämmung fast verlandet, aber nach meiner Bohrung reicht sein Grund 4 m unter den gegenwärtigen Wasserspiegel des Vuoksi, d. h. er liegt 8 m ü. M.

Es handelt sich wohl hier um eine Art Erosionskolk, bei der Delta-aufschüttung entstanden, einen Kolk, dessen Grund 23—24 m unterhalb der Deltaterrasse liegt.

Alles oben Beschriebene spricht offenbar für eine Deltatopographie. Der Wasserspiegel, in dem das Delta sich abgesetzt hat, muss jedoch mehrere Meter höher als der See des Vuoksi vor 1857 gestanden haben.

4. Material und Stratigraphie des Deltas. — Die Bebaubarkeit der Deltaterrasse weist auf ihre feine Bodenart

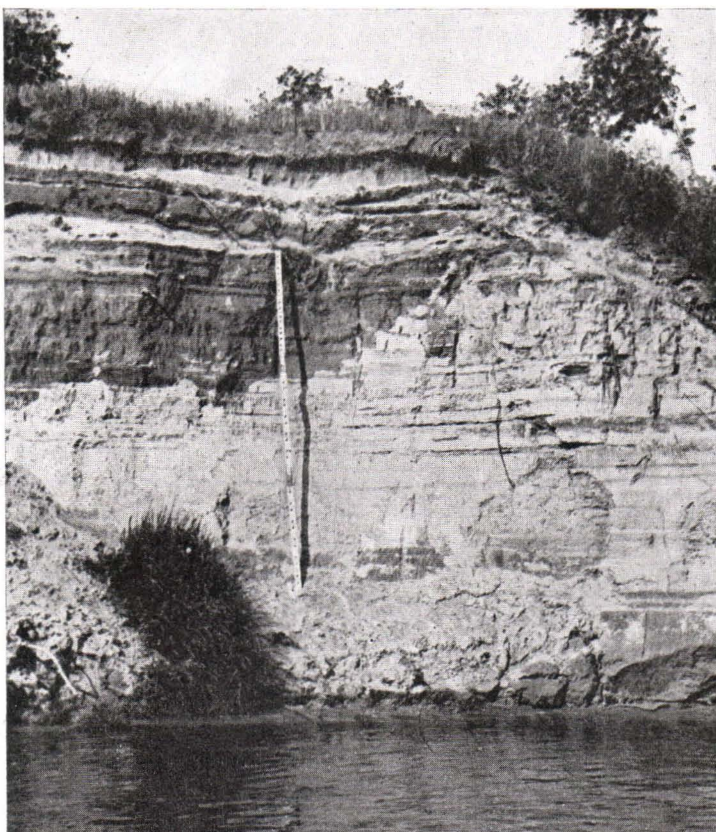


Abb. 3. Die Abrutschwand des Deltas von Jääski am SE-Ufer des Vuoksi, im Juni 1936. Als Massstab eine 4 m lange Latte.

hin. Die Proben, die ich aus den Flussabhängen und in zwei ausgehobenen Gruben in der Mitte des Deltas entnommen habe, sind

Abb. 4 Einzelheit zu der rechtsstehenden Hälfte des vorhergehenden Bildes. Die senkrechten Streifen sind Baumwurzeln. Von den horinzontalen Schichten sind einige ganz dünn, andere sogar fast 1 dm dick. Einige Schichten sind scharf begrenzt, andere unscharf abgehoben.

auch zur Hauptsache Schluff und Feinsand.[1] Ähnlich ist auch das Material der erwähnten Barren Niemensaari und Papinsaari. Der Proximalteil des Deltas ist eine vielleicht etwas gröbere Bodenart, da er als Friedhof brauchbar gewesen ist.

Der innere Bau des Deltas ist am besten zu erkennen bei Niemensaari, wo die frühere Terrasse des Vuoksi grossenteils abgetragen worden ist und die grosse Terrasse als 5—7 m hohe Abrutschwand in den Fluss abfällt. Das hohe Wasser des Sommers 1936 hatte die Steilhänge ständig ausgenagt, so dass an ihnen, vorwiegend am SW-Ufer, die frischen vertikalen Schnitte zu erkennen waren: Abb. 3 und 4.

Der überwiegende Teil der Schichten ist, wie ersichtlich, horizontal gelagert, jedoch ohne irgendwelche Regelmässigkeit im Wechsel der Stärke oder des Materials der Schichten. Zwischen den horizontal gerichteten Schluff- und Feinsandabsätzen waren in dem Abhang Diagonalschichten zu finden, deren Material häufig gröber, Feinsand oder Grobsand, war. In trockenem Zustande waren die dünnen Sandschichten teilweise weggebröckelt und treten dadurch auf den Photographien als dunkel beschattete Streifen hervor. Ausserdem war in der ganzen Lagerfolge, von unten nach oben, ein merkwürdigerer Bestandteil vertreten: lose Tonklumpen, Kleinsteine von der Korngrösse des Kieses und namentlich mancherlei Pflanzenreste wie aus Holz- und Borkenstückchen zusammengesetzte grobe Detritusmasse, ja sogar Kiefernzapfen und einige vermorschte Zweige wie auch Stämme. Die letzteren waren, soweit sie sich makroskopisch erkennen liessen, hauptsächlich Kiefer, seltener Fichte oder Birke. — Alle oben aufgezählten Einlagerungen im Delta, Kiessteine, Tonklumpen und Pflanzenreste, lagen teils hier und da vertsreut, vorwiegend aber angereichert in bestimmten dünneren Lagen, die meist das gröbste Material des Deltas, Sand, enthielten.

Dieselbe Struktur erkannte ich in zwei von mir ausgehobenen Gruben an der Seite des Niemilampi. Die Gruben setzte ich durch Bohren bis in eine Tiefe von 2.5—2.7 m unter den Wasserspiegel des Vuoksi fort, und durchgehend wechselten in ihnen Schluff- und Feinsandschichten sowie Grobdetritus wie auch Holzstückchen und Borke. Mit dem schwachkonstruierten Moorbohrer, der mir zur Verfügung stand, ist es mir weder in diesen Gruben noch anderswo gelungen, die ganze Deltaablagerung zu durchdringen, so dass ich vorläufig nicht sagen kann, was für Sedimente sie überlagert. Jedenfalls scheint

[1] Unter diesen Bezeichnungen verstehe ich die in Finnland allgemein benutzten, in Atterbergs Skala eingehenden Korngrössengruppen von 0.002—0.02 und 0.02—0.2 mm.

sie an ihren mächtigsten Stellen sogar über 10 m des oben beschriebenen Materials, also zweifellos ein Deltasediment, zu enthalten.

Dieses Sediment ist, wie aus Obigem ersichtlich, weder in seiner Beschaffenheit noch in seiner Fülle so geartet, wie wenn es sich unter gewöhnlichen friedlichen Verhältnissen in einer Flussmündung aufgeschichtet hätte. Vorläufig lässt sich zwar nicht durchaus die Möglichkeit leugnen, dass die Schichtung des Deltas den Wasserrhythmus mehrerer Sedimentationsjahre bedeutete. Doch weist alles, was bisher über das Delta bekannt ist, auf eine rasch erfolgte Aufschüttung in ganz schlammigem, trübem Wasser hin, in dem ausser den mineralischen Bestandteilen in reichlichen Mengen Grobdetritus und grössere Holzstücke trieben. Jedenfalls ist es gewiss, dass Menge und Beschaffenheit des Schlammes ruckweise stark gewechselt haben müssen.

Bei den Schlammanreicherungen, die ein auf das andere Mal das Delta überdeckt zu haben scheinen, wäre in erster Linie an Kleinkatastrophen zu denken, die weiter aufwärts am Flusslauf eingetreten sein müssen, als das entstehende Flusstal Moränenriegel auf seinem Wege durchbrach und wegräumte sowie sich in den zwischen ihnen gelegenen Senken in die Tone u. dgl. lose Bodenarten eingrub. Ausserdem konnte sich der ganze grosse und vielverzweigte Vor-Satanen nicht in einigen Tagen um 2.0—2.5 m senken. Es mussten mehrere Wochen vergehen, ehe die Wassermenge im Flusse sich ausgeglichen, die Rutschungen im Flusstale aufgehört hatten und die vielen Schwellenstellen des Flusses bis zum stabilen Boden abgetragen worden waren.

Abb. 5. Tal des Vuoksi, im Tongelände, oberhalb des Elektrizitätswerks von Rouhiala, im Sommer 1936; heute ist es von dem Wasserspiegel des Rouhiala-Stausees bedeckt. An dem hinteren Talhang Rawine und Abrutschnischen.

Weiss man doch, dass die durch Menschenhand eingeleitete Senkung des Sees Höytiäinen im J. 1859 zwei Wochen gedauert hat (Palmén 1903), obgleich das Durchbruchstal dort loser Sand und nur einige Kilometer lang war. Die Länge des Vuoksi-Tales beläuft sich jedoch auf fast 30 km, und auf dieser Strecke lagen, wie gesagt, einige Moränenriegel, der unterste 3.5 km oberhalb des Deltas, bei dem heutigen Elektrizitätswerk von Rouhiala. Und die zahlreichen Rawinen sowie durch Rutschungen entstandenen Zirkustäler zeugen davon, dass dort die Talform verändernde Bewegungen der Sedimentdecke längere Zeit als zwei Wochen lang stattgefunden haben.

5. Pollenbestimmungen. — Pollenanalysen kann ich vorläufig nur für die eine an der Seite des Niemilampi unternommene Bohrung darstellen. Die Proben stammen aus Detritusschichten, I lag 0.6 m unterhalb des Wasserspiegels des Vuoksi, die folgenden rühren aus Tiefen von 1.7, 2.0 und 2.2 m her. Alle vier Analysen sind unter Anwendung des Fluorwasserstoffverfahrens ausgeführt worden. Die tieferen Schichten derselben Grube, bis 2.7 m unter dem Wasserspiegel ausgehoben, waren ausgewaschener Feinsand, ohne mit blossem Auge sichtbare Pflanzenreste.

In der untenstehenden Tabelle sind zunächst das Pollenprozent der Hölzer in einer jeden Probe und schliesslich rechts der Mittelwert der prozentualen Anteile wiedergegeben.

	I —0.6	II —1.7	III —2.0	IV —2.2	Mittelwert
Alnus	1	7	3	6	4.25
Betula	3	13	14	23	13.25
Picea	43	12	10	6	17.75
Pinus	53	67	70	64	63.50
Corylus	—	—	1	—	0.25
Quercus	—	—	1	—	0.25
Tilia	—	—	1	—	0.25
Ulmus	—	1	—	1	0.50

Wie zu ersehen, ist nach diesen Proben der *Pinus*-Pollen mit seinen 53—70 % vorherrschend. Um die zweite Stelle ringen *Betula* und *Picea*, beide durchschnittlich mit ca. 10—20 Prozent, abgesehen von Probe I, die in aussergewöhnlich reichlichen Mengen *Picea* enthält. *Alnus* ist spärlich vorhanden, edle Laubbäume in noch geringerer Zahl, wenngleich auch sie immerhin (ausser Probe I) vertreten sind. Das Interessanteste an der Pollenflora sind das verhältnismässig hohe Prozent von *Picea* und die Anwesenheit von *Corylus* und der edlen Laubbäume. Diese beiden Tatsachen zusammen scheinen auf die Litorinazeit hinzuweisen. Begann doch *Picea* sich in Südfinnland erst in der Litorinazeit zu verhäufigen, und auf der anderen Seite weiss man, dass das Verschwinden der edlen Laubbäume, besonders von *Tilia*, aus der Reihe der Pollenprozente das Ende der Litorinazeit bedeutet. (Siehe z. B. Hyyppä 1932 & 1937, Hellaakoski 1936.)

Allerdings ist es sicher, dass, vergleicht man die Pollenprozente der Tabelle mit irgendeinem anderen aus Südfinnland dargestellten typischen Pollendiagramm, zu ersehen ist, wie bei uns aus keiner Zeit autochthone Ablagerungen vorliegen, die in ihren Pollenprozenten den Detritusablagerungen des Deltas von Jääski gleich kämen. Beispielsweise, obgleich oben angenommen worden ist, dass es sich wohl um die Litorinazeit handeln muss, weiss man, dass für die litorinazeitlichen Ablagerungen die hohen Pollenprozente der Laubhölzer und das entsprechend weit spärlichere Prozent des *Pinus*-Pollens kennzeichnend sind.

Doch ist es ganz ebenso offenbar, dass bei dem Delta von Jääski überhaupt nicht zu erwarten ist, dass man es mit einem autochthonen oder mit einem die Flora irgendeiner bestimmten Zeit vertretenden Pollengehalt zu tun hätte. Vielmehr ist vorauszusetzen, dass, da es sich nun einmal um ein bei einer Durchbruchskatastrophe des Vuoksi entstandenes Delta handelt, in dessen Pollengehalt auch ein Zusatz von Floren eingeht, die älter als die Entstehungszeit des Deltas erscheinen und die aus den am Oberlauf des Flusses erodierten Sedimenten talab verfrachtet worden sind. Mit anderen Worten, es ist anzunehmen, dass der Pollenbestand im Durchbruchsdelta des Vuoksi eine Mischung litorina- und vorlitorinazeitlicher Pollen sei. Demgemäss müsste das der Litorinazeit vorausgegangene Ancylus mit *Pinus*-Vorherrschaft in erster Linie mit seinem Pollengehalt an der Mischung beteiligt gewesen sein.

In diesem Lichte gesehen, sind die in der Tabelle angeführten Prozentsätze durchaus zu verstehen.

Ausserdem erscheint es wahrscheinlich, dass in allen analysierten Proben keine Pollen der Nachlitorinazeit vertreten waren. Allerdings könnte gewiss das hohe *Picea*-Prozent auch eine nachlitorinazeitliche Periode bedeuten, aber das Pollenprozent der edlen Laubbäume ist in Finnland im allgemeinen auch in der Litorinazeit so klein, dass sie, besonders *Tilia* und *Quercus*, sehr wenig Möglichkeiten hätten, in die Prozente einbezogen werden zu können, wenn die Pollenmischung des Deltas nach der Litorinazeit eingetreten wäre.

Soweit meine wenig zahlreichen Pollenanalysen als beweiskräftig anzusehen sind, scheinen sie also darauf hinzuweisen, dass wenigstens diejenigen Deltaschichten, aus denen die Proben entnommen worden sind, sich an ihrer gegenwärtigen Stelle in der Litorinazeit abgesetzt haben, und zwar beim Eintritt einer Katastrophe, die auch ältere Sedimente als das Litorina in das Delta mitzuführen vermocht hat. Und es ist gewiss, dass die Pollen des Deltas, soweit sie vorläufig bekannt sind, zum mindesten nicht gegen eine derartige Auslegung sprechen.

Ferner lässt sich das Minimalalter des Deltas nach dem oben angeführten Bohrungsprofil aus der Erosionsgrube am Niemilampi beleuchten. Das nach dem Profil gezeichnete Pollendiagramm habe ich in diesem Zusammenhang nicht vorgelegt, da es sehr ausdruckslos ist, indem es zeigt, wie in einer fast 4 m starken Ton- und Gyttjaablagerung ca. 20 % *Picea*, ca. 50—60 % *Pinus*, ca. 15—20 % *Betula*, ca. 5—10 % *Alnus* und ausserdem in der tieferen Hälfte fast stets 1 % *Ulmus* enthalten sind. Über die Ablagerung lässt sich also nur aussagen, dass sie wahrscheinlich in ihrer Gesamtheit dem Nachlitorina angehört. Doch gibt *Ulmus* im unteren Teil Anlass zu der Vermutung, dass die Litorinazeit dort sehr nahe ist. Die bedeutendste Grube des Deltas hat also wahrscheinlich bald nach beendeter Litorinazeit durch Ton und Feindetritus zu verschlicken begonnen.

6. Höhe des Deltas. — Auf Grund alles dessen, was über die in Jääski festgestellte Talterrasse des Vuoksi oben berichtet worden ist, kann keinerlei Zweifel darüber bestehen, dass sie ein postglaziales Flussmündungsdelta ist. Ferner wird durch alles, was vorläufig über das Delta bekannt ist, erwiesen, dass es wenigstens in seinen Hauptteilen beim Durchbruch des Flussteils des Vuoksi, in der Litorinazeit, entstanden ist.

Zu Beginn dieser Untersuchung wurde erwähnt, dass nach archäologischer Konnektion die gegenwärtige Höhe des Durchbruchsdeltas des Vuoksi 71—72 % vom Maximum der Litorinatransgression zu betragen oder, wenn dies auf die Umgebung von Viipuri angewandt wird, 15—17 m über dem Meere zu liegen habe. Dies stimmt gut überein mit der für den Distalteil des Deltas gemessenen Höhe, die, wie früher erwähnt, sich an die Höhe des Vuoksi-Seeteils vor der Seesenkung von 1857, d. h. 15.5 m ü. M., anschliesst. Doch die Wasserhöhe zur Entstehungszeit des Deltas bedeutet natürlich vor allem die für seine proximalen Ebenen ermittelte Höhe, die 21—22 m und somit 5—6 m mehr als die erwartete ausmacht.

Dies braucht jedoch nicht mit der archäologischen Konnektion in Widerspruch zu stehen, denn in der Tat kann Jääski nicht auf derselben Isobase wie Viipuri liegen. Betrachtet man die auf die neuesten Forschungen (z. B. Hyyppä 1937) gegründete Richtung der

Litorina-Isobasen im Hintergrunde des Finnischen Meerbusens, so ist zu ersehen, dass bei dem Delta von Jääski die der typischen Kammkeramik entsprechende Meereshöhe einige Meter, wahrscheinlich 2—3 m, höher als in der Gegend von Viipuri liegen muss.

Im Lichte der neuesten auf der Karelischen Landenge ausgeführten Untersuchungen sieht es allerdings nicht so aus, wie wenn das Meer zur Litorinazeit bis nach Jääski gereicht hätte. Wahrscheinlicher ist es, dass an der Stelle des Vuoksi-Seeteils bei der Entstehung des Deltas keine Meeresgebucht, sondern entweder ein vom Meere abgeschnürter See oder eine Bucht des transgressiven Laatokka (Ailio 1915) sich erstreckte. Hyyppä (1932) hat zwar eine solche Auffassung dargestellt, dass die Litorinatransgressionen über den Seeteil des Vuoksi an den Laatokka gereicht hätten, wo L III als identisch mit der von Ailio dargelegten Laatokka-Transgression zu betrachten wäre. Doch neuerdings hat Hyyppä diese Ansicht aufgegeben sowie unter anderm dargelegt (1937 S. 138): »In view of the low level of the Littorina maximum in the Viipuri district it seems certain that the Littorina Sea could never have extended its marine influence inside the Laatokka basin.» Dennoch mögen Ailios Laatokka-Transgression und Hyyppäs LIII als beide gleichaltrig, nämlich der steinzeitlichen typischen Kammkeramik chronologisch zugeordnet, anzusehen sein (Äyräpää 1934 S. 9, Hyyppä 1937 S. 190). Ihre Ufer sind jedoch an den verschiedenen Flanken der Karelischen Landenge in verschiedenen Höhen gelegen, nämlich L III einige Meter tiefer als jenes. Beide Ufer können als Ausgangspunkte dienen, wenn die in Jääski bestehende Wasserhöhe zur Durchbruchszeit des Vuoksi einzuschätzen ist, wobei ausserdem auch die theoretische Möglichkeit in Betracht zu ziehen ist, dass es sich um einen selbständigen, vom Meere und vom Laatokka gesonderten See gehandelt hätte.

Soweit sich eine Bucht des Litorinameeres nach Jääski erstreckt hätte, liesse sich für es nach Hyyppäs (1937) Isobasenkarte und Relationsdiagramm ungefähr dieselbe Höhe ermitteln wie in Virojoki, wo L I bei 22—23, L II 20—21 m und L III ca. 18 m liegt. In dem Fall, dass an der Stelle des Vuoksi-Seeteils ein vom Meere abgeschnürter See lag, muss angenommen werden, dass der See über die von Ailio (1915 S. 76—78) geschilderte Schwelle bei Heinjoki floss, deren Höhe ca. 15 m ausmacht; Jääski aber muss auf einer ca. 4 m höheren Isobase liegen, und der damalige Wasserspiegel in Jääski hätte bei ca. 19 m über dem heutigen Meeresspiegel gestanden. Wenn es sich hingegen, wie es am wahrscheinlichsten sein mag, um eine Bucht des transgressiven Laatokka handelte, war seine Maximalhöhe nach Ailio (1915 S. 82) in Antrea, das 18—19 km von Jääski nach SE gelegen ist, 21 m über dem jetzigen Meeresspiegel. Soweit diese Angabe zuverlässig ist,[1] müsste die entsprechende Uferhöhe in Jääski 22—23 m betragen.

Wie auch die hydrographischen Verhältnisse im Vuoksi-Seeteil bei dem Durchbruch des Flussteils gewesen sein mögen, so wurde es jedenfalls klar, dass der damalige Wasserstand in Jääski eine Höhenlage eingenommen haben muss, die der gegenwärtigen Höhe von 19—23 m ü. M. entspricht. Mit diesem Wasserstand stimmt die Höhe des Deltas völlig überein. Wenn auch der Proximalteil des Deltas vielleicht 1—2 m oberhalb des Wasserspiegels aufgeschüttet worden ist, müsste dies ausserordentlich gut mit der Tatsache übereinstimmen, dass es sich um ein Überschwemmungsdelta im Hintergrunde einer langen Bucht handelt. Diese Bucht war so klein und in ca. 10 km Entfernung, bei Antrea, so eng, dass die Wassermengen des Vor-Satanen den Wasserspiegel der Bucht merklich heben konnten. Hob doch z. B. der Durchbruch des Höytiäinen den 250 km² grossen Spiegel des Pyhäselkä über ein Meter (Palmén 1903).

LITERATUR.

Ailio, Julius (1915), Die geographische Entwicklung des Ladogasees in postglazialer Zeit. Fennia 38: 3 & Bull. Comm. géologique de Finlande 45.

Hellaakoski, Aaro (1922), Suursaimaa. Fennia 43: 4.

—»— (1936), Das Alter des Vuoksi. Bull. Comm. géologique de Finlande 115.

Hyyppä, Esa (1932), Die postglazialen Niveauverschiebungen auf der Karelischen Landenge. Fennia 56 : 1 & Ann. Acad. Scient. Fennicae A XXXVII.

—»— (1937), Post-Glacial Changes of Shore-Line in South Finland. Bull. Comm. géologique de Finlande 120.

Palmén, E. G. (1903), Äldre och nyare sjöfällningar och sjöfällningsförsök i Finland. Fennia 20 : 7.

Schjerfbeck, M. (1925), När uppstod Vuoksen? Fennia 45 : 16.

Äyräpää, Aarne (1934), Katsaus Suomen geologis-arkeologisiin ajanmääräyksiin ja esihistorialliseen antropologiseen aineistoon. Terra 46.

[1] Die Höhe mag nicht ganz genau auf das Meter zutreffen, denn sie ist schon im vorigen Jahrhundert und unter Benutzung der damaligen sehr unzuverlässigen Methoden gemessen worden (s. Erläuterung zu dem geol. Kartenblatt 35).

5.

NOTES ON THE GEOLOGY OF KARELIA AND THE ONEGA REGION IN THE SUMMER OF 1937.

By

HEIKKI VÄYRYNEN.

CONTENTS.

PREFACE.

In connection with the XVII International Geological Congress held in Moscow in the summer of 1937 an excursion was arranged before the meetings to the territory of the autonomous Republic of Karelia and to Kola Peninsula. The author took part in this excursion, from July 1st to 17th, and records the notes and main conclusions he made in the course of it.

In approaching the Onega Region and Karelia by rail from the south the geological systems of these territories, according to the Guide book of the Congress, are found to be in broad lines a succession from younger to older ones. We became acquainted with them in that order on this excursion. From Devonian ground there was a change to pre-Cambrian ground a short distance to the north of the Svir. The sandstones of the Onega Region that occur from there to Petrozavodsk are considered to belong to the Upper Jotnian. These are succeeded for a short distance beyond Kondopohja by rocks of the Suisaari volcanic complex representing the Lower Jotnian (Hoglandium), further up to the station of Karhumäki by sedimentary schists and intrusive bodies representing the Upper Jatulian (Onegium), in the districts of Tshobino, Seesjärvi and Uikujärvi by belts of Lower Jatulian quartzites and schists, and between them by a pre-Jatulian basement of a gneissose granite. Finally on the coast of the White Sea there are gneisses penetrated by these granites.

SANDSTONES OF THE ONEGA REGION.

In travelling by steamer along the western shore of Lake Onega we visited outcrops of Jotnian ground at three points on the shore: at Shoksha, Rop-Rutshei and Kamenny Bor.

At Shoksha the most beautiful red, fine-grained, bedded sandstone can be seen that has become famous for the reason that Napoleon's tomb was made of it. Besides red sandstone, grey also occurs at Shoksha. There are very few and tiny coarse-grained layers. They contain chalcedony grains. The strata dip here, on the eastern edge of the area, 10°—15° to the south-west, but on the western edge of the complex eastward, on its northern edge southward and on the southern edge northward, so that the sandstone sequence has the shape of a flat bowl. In addition a fairly clear pitch (Fig. 1) can be observed at Shoksha which dips 10° to the south-south-east. The transversal jointing almost perpendicular to this folding axis is also clearly visible (see the Fig.). This should not be confused with the fault lines which run in a north-westerly direction, according to

Fig. 1. The quarry of Shoksha showing the pitch, dipping S. S. W. and the transversal jointing almost at right angles to it.

Ramsay N. 20°—35° W., and along which the north-eastern side has always subsided or, which is the same thing, the western side has risen.

At Kamenny Bor, quite close to Petrozavodsk, there is grey sandstone which shows much greater variations than the former. It contains both finer, slaty, and coarser, conglomeratic layers. The coarse layers contain grains of chalcedony and of black, shungite-like shale. Wahl has furthermore found lapilli-like inclusions of a volcanic basic rock and concluded on the basis of them that there was no great unconformity between these sandstones and the extrusive diabase flows, defined by Sederholm in 1897 as Jotnian, on which they rest in the north, but that volcanic action still continued during the deposition of the sandstone of Petrozavodsk. Wahl is also of the opinion that the pieces of black shale, included in the sandstone are not identical with the shungite shale, but are cherts. In fact the contact discovered by Helmersen already in 1882 close to Ukshozero does not prove that there is any great unconformity between the sandstone series and the volcanic sequence below it. The conglomerate is only 3—5 cm thick according to Ramsay.

On the other hand the occurrence of chalcedony and black chert in the coarsest layers of Petrozavodsk sandstone, and even at Shoksha, is so common that it must imply an appreciable erosion of the volcanic rocks and a considerable transportation of material. No extrusive rocks have been found interbedding with this series of sandstone, so that the extrusive rocks of the Suisaari region lying north of the sandstone series and containing chalcedony as amygdules and filling of cavities should be considered the only source of the chalcedony grains. Carbonaceous chert has also been found in the cavities of these rocks, so that the origin of such fragments that occur in Kamenny Bor sandstone should lie in the same rocks. The present author, too, has discovered a similar chert also among the shungite slates of Shunga.

Eskola also found a contact that indicated unconformity at a railway crossing close to Petrozavodsk, and according to Ramsay (1918) there is sandstone at Pjalma, on the eastern shore of the bay of Povenetz, that overlies unconformably the folded strata of dolomite.

It would seem, therefore, that the unconformity between the volcanic rocks of Suisaari and the sandstones of the Onega Region is greater than was generally supposed formerly and this fact supports the Jotnian age of the sandstones. However, the mechanical deformation of the sandstone series, already referred to, should be borne in mind. Any pronounced deformation does not occur at many places in the Jatulian quartzites of the Koli area in Finland, in which an imbricate structure (Schuppenstruktur) has developed. Here, however, the folding of the Karelides has been much weaker, so that it cannot be expected that this deformation should have influenced such a thick quartzitic sandstone sequence more intensely. It would thus seem more natural to consider the sandstone series, too, older than the Rapakivi granite, either as a series corresponding to Sederholm's Hoglandium and differing from other Karelian systems or as a detrital (Molasse-like) deposit belonging to the Karelian. Its mechanical deformation may have been caused either by Karelian lateral folding or by movements that occurred in connection with the emplacement of the Rapakivi granites.

In other Jotnian sandstone occurrences no mechanical deformation worth mentioning has been found generally except in the Almesåkra series in Sweden which is ascribed to the Jotnian, but which is at the same time traversed by quartz dolerites and which is separated by Sederholm, at any rate partly, from the Jotnian and reckoned as also belonging to the Hoglandium (1927). Sederholm, however, did not define the bearing of the latter conception more exactly, merely reckoning this series as belonging to the long interval that must have elapsed between the folding of the Karelides and the eruption of the Rapakivi granites. According to this, too, they may belong either as Molasse-like sediments to the final phase of the Karelides (phase of revolution) or to a new cycle as a phase of evolution before the eruption of the Rapakivi granites (new revolution). It would be better, perhaps, to consider the Rapakivi granites, too, as »Molasse granites» belonging to the final phase of revolution of the Karelides (or Gothides). Judging by the dolerite conglomerates, the Almesåkra seıies appears to be at any rate a Molasse-like deposit which was still unconsolidated, when the dolerites erupted.

DOLERITES OF THE SANDSTONE AREA.

As the sandstone series have been classed as belonging to the Jotnian system, the doleritic rocks intruded in them have been classed as post-Jotnian dolerites (Särna-»diabases»). Already earlier (1892, p. 101—113) Sederholm had made the same assumption from the basic rocks occurring in Finland at Valamo, the Mantsinsaari etc. islands of Lake Ladoga, as they, too, appear to cut through the sandstone at the bottom of the lake. This sandstone has, however, only been found on the islands of Lake Ladoga in the form of loose boulders.

The relation of these dolerites to the Rapakivi granites should afford a surer basis for determining their age than their relation to the sandstone formations. This, however, has not been established. In the vicinity of the Salmi Rapakivi area no doleritic rock has been discovered except at one point in the Pitkäranta area. Trüstedt calls it augite-porphyrite (1907, p. 97) and quotes Wahl's verbal statement that it is a kind of rock analogous to the Valamo dolerite. It only occurs in a few outcrops, nor is its relation to Rapakivi granite to be seen.

Nevertheless it is worth noting that no basic dykes cutting through the Rapakivi granites have been found in the areas of Eastern Finland. Besides, the dolerites of Lake Ladoga and of the Onega Region are more analogous to the dolerites of Föglö both in their chemical composition, and in their petrographic properties than to those of Satakunta (Fig. 2). The former rocks generally contain quartz and their content of femic lime is usually lower, so that they contain also orthorhombic pyroxene (bronzite-diabases) or the pyroxene is pigeonitic, or uralitized (after pigeonite). Such kinds of rocks occur abundantly at any rate in the neighbourhood of the smaller Jaala and Mäntyharju bodies connected with the Viipuri massif.

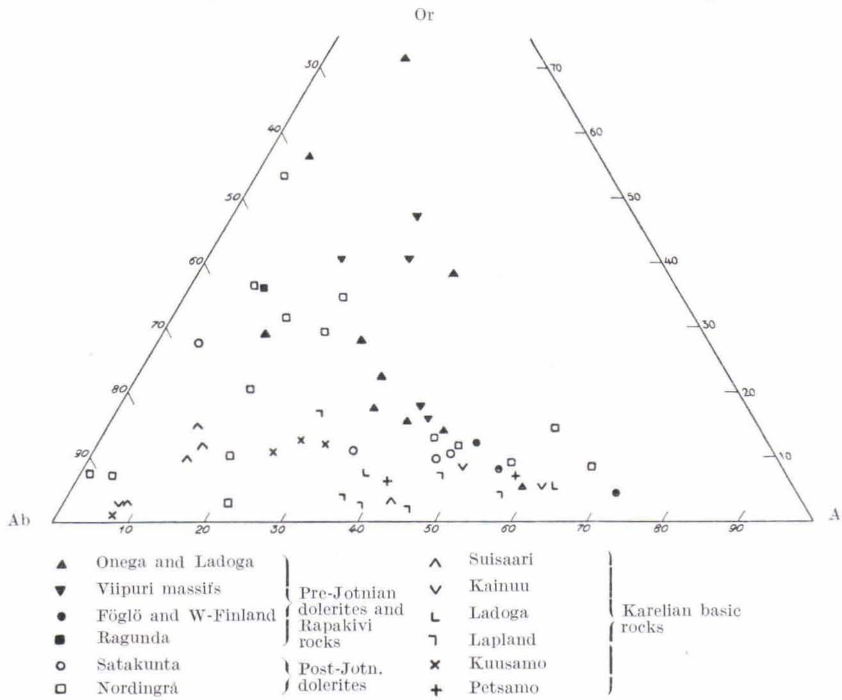


Fig. 2. Diagram showing the proportions of normative feldspars in the Jotnian and Karelian basic rocks.

In these, too, however, olivine occurs sometimes, and especially in the labradorites, plagioclase-porphyrites and ossipitic dolerites connected with them the content of lime, indeed, is higher, though not the content of femic lime. As, however, the Satakunta dolerites may also grade over into olivine-free types and even into acid varieties, the age of the sandstones referred to cannot be determined with certainty on the basis of the chemical composition of the dolerites. The post-Jotnian eruptions of the Nordingrå area in particular are entirely similar to the series of differentiation of the Rapakivi granites (Fig. 2).

As, at any rate, no definitely post-Jotnian dolerites have been found in Eastern Finland, it seems more credible that the basic rocks which are intruded in the sandstone series of Olonetz, such as the »Svir diabases» and the »Valamo diabases», are pre-Rapakivi dolerites and that the Onega and Ladoga sandstones are also older than the Rapakivi granites.

The formation of intrusive sills, in which form the »Svir diabases» occur, indicates certain, though weaker, horizontal movements, of the occurrence of which after the emplacement of the Rapakivi granites there are no signs in these areas. No such unconformity has been established anywhere in the whole system of the Onega supercrustal rocks, as such disturbances, as the intrusion of a large Rapakivi body about 60 km from the edge of the sandstone series would provide, nor have the detrital sediments, that its uncovering by erosion would presume, been found. These facts confirm the view expressed above and indicate that the Onega sandstone and perhaps also the rocks traversing them and even the Rapakivi granites may belong to the Karelian Molasse formations.

THE SUISAARI SERIES.

Below the Onega sandstones there is to the north of Petrozavodsk and from there to Kondopohja and still further north a volcanic complex that embraces a large number of different basic rocks, porphyrites, amygdaloids, pillow-lavas, agglomerates and tuffs. They have been investigated especially by Loewinson-Lessing, Ramsay, Wahl, Eskola and Timofeev. The volcanis are mostly spilitic and the felspar phenocrysts of the porphyrites are also mostly albitic (Eskola 1925). In the porphyrites the phenocrysts are felspar, felspar and augite, augite, and augite and olivine (picrites). The felspar- and felspar-augite-porphyrites also form pillow-lavas (Fig. 3, 4), volcanic breccias and tuffitic breccias and grade over into amygdaloids and variolites. In the amygdaloids the amygdules often consist of chalcedony.

The variolite parts occur in the form of ellipsoidal portions (Fig. 5), the white-ringed varioles being largest in the centre and surrounded by a dark matrix. The varioles may, however, also occur in the tuffite layers. According to the analyses the variolite rock contains more alkalies (up to 9 %) and silica (up to 61 %) than other rock. The most beautifully formed variolite rocks were to be seen at Jalguba.

These volcanis, as already mentioned, were considered by Sederholm in 1892 to belong to the Jotnian dolerites and later (1927) especially to pre-Rapakivi eruptions. Eskola, on the other hand, compared them in his researches to the Karelian basic metamorphic rocks (»metabasites») occurring on the Finnish side and considers

Fig. 3. Pillow-lava in a cross section. Petra Kara, Suisaari area.

Fig. 4. Surface forms of the pillow-lava at Petra Kara.

that they belong together. At that time, however, there was not sufficient material for comparison available of the Karelian basic rocks. Subsequently fresh investigations in various areas were published about them, and especially we now possess a number of chemical analyses, and are now in a better position to compare them and the Suisaari series. Hackman's investigations in Lapland and the

Kuusamo and Ladoga regions (1927, 1929 and 1933) and Väyrynen's in the Kainuu and Petsamo areas (1927 and 1938) should be taken into consideration in this connection. If the basic metamorphic rocks (Kalevian and Jatulian) of these regions and the rocks of the Suisaari sequence are compared with the rocks of the Rapakivi series (Fig. 2), it will be seen that these series, indeed, start from the same

Fig. 5. Mode of appearance of the varioles in the variolite of Jalguba. Scale ca. 1:10.

parental magma, but later their development proceeds along totally different lines. The composition of felspars of some Ortoaivi, Prolanvaara, Liejeenjoki and Hangasvaara (Karelian) and Eckerö, Svir and Nordingrå (pre-Jotnian and Jotnian) basic rocks is exactly the same, but then the development of the felspar of the latter rocks proceeds fairly straight-lined to the Or_{40} Ab_{60} point, whereas in the felspar of the Karelian »metabasites» the Or-percentage is much more irregular and remains all the time below Or_{15} (it rises a little above it in only one of 23 rocks). The varying amount of potash-felspar and ophitic texture in these Karelian basic rocks also seems to indicate that the composition of these rocks was a result of subsequent spilitic metamorphism, but as these compositions occur over such a large area, from Lake Ladoga to the Arctic Ocean and in both extrusive and intrusive rocks, frequently in intrusions that did not clearly differ originally very much from the manner of occurrence of the Svir dolerites, the question does not seem to be so simple. In these

Karelian basic rocks a kind of rock was formed as an extreme member which Eskola calls granophyre, Väyrynen albite rock (Albitfels) and quartz-keratophyre and Hackman leucodiabase. This kind of rock, which has an absolutely identical composition of felspars in all the three regions, Onega, Kainuu and Kuusamo, seems at any rate to be difficult to explain as a product of magmatic differentiation, as the amount of potash-felspar component in the albite is appreciably larger in all magmatic rocks. It is only at a very low temperature that the potash-felspar percentage of albite can be brougth down to such a low level. All the properties of this peculiar rock which Väyrynen has described (1927, pp. 41—43, 54—56) also point to the fact that these rocks are metasomatical low-temperature alteration products of extrusive basic rocks etc., possibly in some places even of gneissose granites. The most suitable name for them is therefore albite rock (Albitfels), or if a special designation is needed for this kind of rock occurring so frequently in connection with the Karelian basic rocks and making up an extreme member in the spilitic metamorphism, the present writer would propose the name *karjalite*, after the Finnish form of Karelia. The karjalite is thus associated with spilitized basic rocks and consists of albite very poor in potash, in addition containing variable amounts of quartz, carbonate, light-coloured amphibole, chlorite, and ore. The grain is variable being frequently coarse, but many times also very fine-grained types occur. Granophyric and mylonitic textures are sometimes met with.

The variolite formation also seems, in the opinion of the present writer, to be of the same nature.

At all events this group of rocks must have been formed at a much lower temperature than the pre-Jotnian and Jotnian dolerites. This is indicated by the fact that some pegmatitic and more acid dyke occurrences in these latter approach the Karelian spilitic rocks referred to fairly closely, and even the albite rocks.

In any case the difference between the Karelian »metabasites» and the later pre-Jotnian and Jotnian basic rocks is so great that there would seem to be no doubt as to the Suisaari volcanic rocks belonging to the former. They are therefore connected with the Zaonezhe Peninsula intrusions as an extrusive equivalent. Timofeev's observations of their folding also seem to point in the same direction. In making observations of flattened cavities and chalcedony stalactites he endeavoured to determine the original positions of these spilitic rocks and came to the conclusion that they were frequently inclined up to 60° from their original position.

The fact that the unconformity between these Suisaari Karelian extrusives and the Petrozavodsk sandstones is so unimportant, connects this sandstone series very closely to the Karelian rock complexes.

THE ONEGIAN SERIES.

On the large Zaonezhe Peninsula projecting into the northern part of Lake Onega, several zones of phyllites and black, highly carbonaceous slates, shungites, run in a north-westerly direction, and on the eastern shore of the peninsula and on the islands dolomites stand out from below the slate. These rocks overlie each other on the eastern

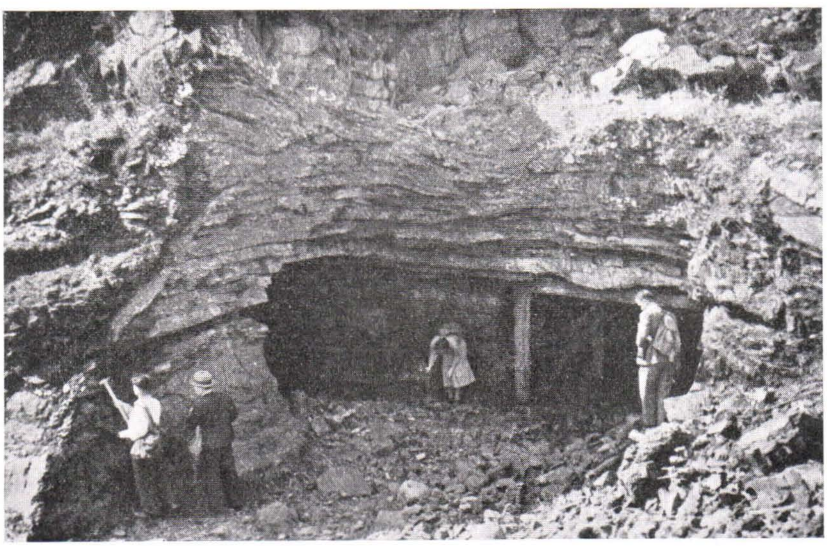


Fig. 6. Opening in shungite at Shunga.

shore, but at Shunga they alternate. For this reason Ramsay (1902) considered them to belong to a separate series, the Onegian system. Subsequently they were referred, as a rule, to the Jatulian. As quartzites still occur below them, the whole series here is the same as in the Suojärvi Jatulian, where the uppermost part corresponds to the Onegian (marine Jatulian, Metzger 1924). We were not able, however, to study these sedimentary rocks during the excursion last summer except the shungite beds of the village of Shunga. Since our fellow-countrymen inspected them, a great deal of prospecting work has been done on them. Experiments in mining have been made and deep-boring has been done. It has been established that the alternating succession of dolomites, slates and shungites is up to 50 m in thickness. This was, however, not the original thickness, the layers having been strongly compressed and tectonized. In some places the dolomite strata have been more resistant and the shungites more mobile, and it can be said that they have behaved like an eruptive intruding the strata lying above. In places a shiny, glassy material, shungite variety I, containing up to 98.77 % C has been formed, filling cavities and veins. The rising of the shungite thus seems to have obeyed the mechanics of the salt domes, though not in shape, as it has occurred along anticlines and this also explains the thickness of the shungite formation.

The rock complex is covered and intersected by a dolerite that appears generally to be intrusive in its origin.

The tectonics of the Onegian system on the Zaonezhe peninsula are very typical of the lateral folding of the Jura type and it therefore seems that the dolomite beds situated in the lower part of this succession and, as is evident from the above, perhaps even to a greater extent the shungite layers represented such a mobile horizon as made it possible for the rocks to slide along their basement.

THE LOWER JATULIAN ROCKS.

On this trip we were only made acquainted with quartzite and conglomerate occurrences comparable to the Karelian on the Finnish side in one district, the Tshobina-Pokrovskoye area to the west of Karhumäki station. Here a strongly folded belt of conglomerates, quartzites, dolomites and basic rocks exists running almost from east to west along the valley of the river Kumsa. South of the river sericite-quartzites occur in an almost vertical position close to the road and to the south of it conglomerates. In the bed of the river there is amphibolite and below it quartzite has been discovered by boring, dipping southward and at gentler inclination than on the south side, where there is usually an abrupt dip southward.

Near Padun we saw conglomerate at two points (Fig. 7). At one place (marked I a in the figure) there was coarse, polymict conglomerate, in which the pebbles were granite and small-grained amphibolite, finer grained than the basic rock in the Kumsa valley. No stratification is visible in the conglomerate. A short distance W.S.W. of this rock there is a small occurrence of schistose, tuffitic amphibolite near the path (I b in the figure), in which the fragments are of the same kind of rock as occurs in the form of pebbles in the conglomerate. Next to the house quite close to the road, south of it, there is a high ledge (I c in the figure), on the northern slope of which the same coarse conglomerate appears uppermost as in the occurrence referred to. To the north the conglomerate becomes sheared, the

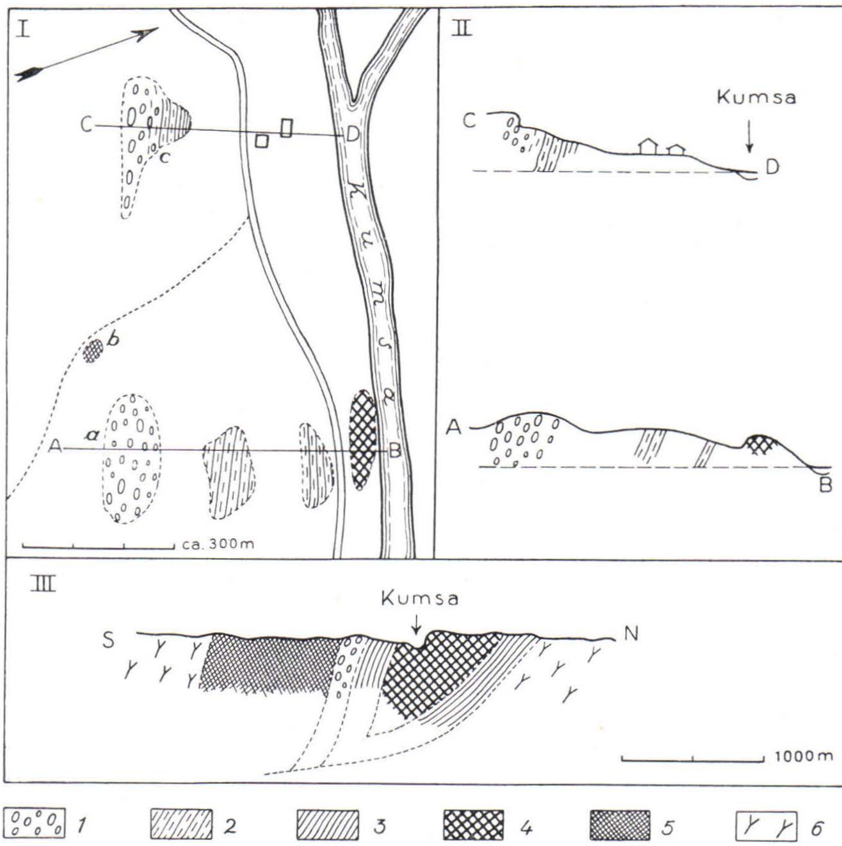


Fig. 7. Sketch map of the occurrence of Jatulian formations at Padun. 1 conglomerate, 2 sericite-schist, 3 quartzite, 4 dolerite, 5 amphibolite, and 6 gneissose granite.

pebbles assume lenticular shapes and their rocks become micaceous and finally contain much sericite. Nevertheless, quartz pebbles occur among them that are not at all flattened. Midway on the slope the conglomerate grades over to sericite-schist and a little lower to quartzite (see profile II C—D in the figure). In all the schistose conglomerate, the sericite-schist and the quartzite, dip is highly inclined southward.

It is obvious that the stratigraphical succession of the latter place can by no means be explained by the conglomerate having been unconformably deposited on top of the quartzite. The origin of the sericite-schist can be explained either by its having been formed by subsequent shearing or, as the present writer has explained similar phenomena in Kainuu (1924, 1928, 1929) and in Karelia (1933) in Finland, by the upper part of the conglomerate having at first after its deposition been subjected to atmospheric kaolinization and the sericite having been formed by metamorphism from this aluminous material. The occurrence of unflattened quartz pebbles provides evidence in favour of this latter manner of formation.

In the granite area S.W. of Tshobino quartzite occurs in quite horizontal layers. Below it there is conglomerate, the pebbles in which are not at all deformed, but their felspar has changed entirely into sericite. Thus the same kaolinization has occurred here after the formation of the conglomerate, but as the beds here are in a horizontal position and have therefore not been subject to dynamic influence, no shearing has occurred here and the pebbles have escaped deformation. In the lower parts of the conglomerate the felspar is still unchanged. In my opinion there is the same quartzite rock here in undisturbed layers that has been folded in the Kumsa valley to a narrow syncline.

It would be interesting to establish in this latter place that above the conglomerate there was quartzite, in which the coarseness varied and in which current bedding could be observed, but finally there followed a thin layer of conglomerate, about 30—40 cm thick, and above it there is only fine quartzite without any coarser layer whatever, a phenomenon that I established in Karelia and Kainuu (1927, p. 31) and explained according to Johannes Walther in the sense that this latter coarse conglomerate-like layer represents a »gepanzerte Wüste» (armoured desert) state, beneath which there are fluviatile deposits, but above only such material as has occurred as aeolian sand. Under such circumstances there are below the »gepanzerte Wüste» conglomerate, i. e. in the Sariolian strata, also fluviatile deposits here and not only tillite-like conglomerates.

In the syncline of the Kumsa valley phyllites and dolomites have also been found. Here, therefore, the Jatulian series has the same composition as at Suojärvi and Soanlahti in Finland. In these latter places shungite slates have also been found in connection with the Upper Jatulian rocks and it seems as if the Onegian rocks of the Zaonezhe Peninsula also belonged to these. At any rate no unconformity has been discovered between them and the Jatulian.

Nevertheless, their tectonics differ considerably from each other.

While there is distinct lateral folding in the Zaonezhe rocks, the Jatulian belts are folded between Archaean blocks which have been thrust over each other (Fig. 7 III), or these deposits have remained on top of the overthrust masses unfolded in their original position.

PRE-KARELIAN SCHISTS.

Below the Tshobina conglomerate that I have described fine-grained amphibolites, agglomerates and tuffaceous schists occur. The agglomerates show conglomerate-like appearance in some places, containing white fine-grained rocks in the shape of rounded pebbles. It seems that Ramsay ascribed at any rate these »diabase schists» to the Kalevian series that he distinguished here, but besides them also sericite-schists, sericite-quartzites etc. Later it seems that both Eskola and others considered these to belong together with the Jatulian systems. As these tuffaceous schists are cut by granites which in other places form the basement of the Jatulian conglomerate, Haritonov, as already stated, came to separate two Jatulian divisions.

It is more probable, however, that this is a case of a similar occurrence as discovered in various places in Finnish Karelia. The present writer has already dealt with them in the Koli region, on the eastern Ipatti slope, publishing a drawing, too, of the conglomerate-like agglomerates there (1933, Fig. 1). If these amphibole-schists etc. cut by granites are referred to the pre-Karelian systems, a complete counterpart is obtained between the Jatulian systems of the Onega region and Finnish Karelia except in tectonics. The Pre-Karelian supracrustal complexes also seem to be of the same nature in both regions.

As these rocks, at any rate, differ notably from the pre-Karelian series of schists occurring on Kola Peninsula, and designated by Polkanov as the Samian series, it would be suitable to designate this complex consisting of amphibole schists; leptitic gneisses, and phyllitic schists as the Ipatti series. At Havukkavaara, in the parish of Kontiolahti, this series also includes quartz-banded iron ores.

If these pre-Karelian rocks are considered to belong to the Karelian, the granites cutting them may be considered post-Karelian or inter-Karelian which separate the Karelian systems into two divisions: a lower division cut by granite and an upper division later than the granite.

For the same reason it follows, in my opinion, that large post-Karelian granite areas have been mapped further north, through which, however, Karelian quartzite ranges trend in the shape of straight and narrow belts. These we had no opportunity of examining closely on this excursion.

REFERENCES.

ESKOLA, PENTTI, Huvuddragen av Onega-Karelens geologi. Medd. Geol. Fören. Helsingfors 1917—18, 13—16.

—„— On the Petrology of Eastern Fennoskandia. I. The Mineral Development of Basic Rocks in the Karelian Formations. Fennia 45, N:o 19, 1925.

HACKMAN, V., Studien über den Gesteinsaufbau der Kittilä-Lappmark. Bull Comm. géol. Finlande, N:o 79, 1927.

—„— Kivilajikartan selitys, lehti D 2, Savonlinna. — Beskrivning till bergartskartan, sekt. D 2, Nyslott. Résumé en français. Helsinki 1933 and 1931.

—„— and WILKMAN, W. W., Kivilajikartan selitys, lehti D 6, Kuolajärvi. — Beskrivning till bergartskartan, sekt. D 6. Kuolajärvi. Résumé en français. Helsinki 1929 and 1926.

HELMERSEN, G. v., Geologische und physico-geographische Beobachtungen im Olonezer Bergrevier. Beiträge zur Kenntnis des russischen Reiches, zweite Folge V. St. Petersburg 1882.

METZGER, A. A. TH., Die Jatulischen Bildungen von Suojärvi in Ostfinnland. Bull. Comm. géol. Finlande, N:o 64, 1924.

POLKANOV, A. A., The Northern Excursion. The Karelian Autonomous Soviet Socialist Republic. Intern. Geol. Congr. XVII Sess., Moscow 1937.

RAMSAY, W., Om de prekambriska formationerna och bergveckningarna i den sydöstra delen af Fennoskandia. Geol. Fören. Stockholm Förh. 24, 1902, 28—36.

—„— Beiträge zur Geologie der präkambrischen Bildungen im Gouvernemente Olonez. I. Fennia 22, N:o 7, 1905.

—„— Statement by discussion. Medd. Geol. Fören. Helsingfors 1917—18, 16—17.

SEDERHOLM, J. J., Om bärggrunden i södra Finland. Fennia 8, N:o 3, 1892.

—„— Über eine archäische Sedimentformation im südwestlichen Finland und ihre Bedeutung für die Erklärung der Entstehungsweise des Grundgebirges. Bull. Comm. géol. Finlande, N:o 6, 1897.

—„— Om de jotniska och s. k. subjotniska bergarterna. Geol. Fören. Stockholm Förh. 49, 1937, 394—426.

SOBRAL, JOSÉ M., Contributions to the Geology of the Nordingrå Region. Dissertation. Upsala 1913.

TRÜSTEDT, OTTO, Die Erzlagerstätten von Pitkäranta am Ladoga See. Bull. Comm. géol. Finlande, N:o 19, 1907.

WAHL, W., Beiträge zur Geologie der präkambrischen Bildungen im Gouvernement Olonez. II. 3. Die Gesteine der Westküste des Onega-Sees. Fennia 24, N:o 3, 1908.

VÄYRYNEN, HEIKKI, Die geologischen Verhältnisse eines Vorkommens von Kaolin im finnischen Grundgebirge. Geol. Fören. Stockholm Förh. 46, 1924, 393—406.

—„— Geologische und petrographische Untersuchungen im Kainuugebiete. Bull. Comm. géol. Finlande, N:o 78, 1928.

—„— Über den Chemismus der finnischen Kaolinvorkommen verglichen mit Verwitterungsedimenten. Bull. Comm. géol. Finlande, N:o 87, 1929, 128—158.

—„— Über die Stratigraphie der karelischen Formationen. Bull. Comm. géol. Finlande, N:o 101, 1933, 54—78.

—„— Petrologie des Nickelerzfeldes Kaulatunturi—Kammikivitunturi. Bull. Comm. géol. Finlande N:o 116, 1938.

6.

ON THE MINERALOGY OF SOME MEMBERS OF THE HUMITE GROUP FOUND IN FINLAND.

By

KALERVO RANKAMA.

CONTENTS.

INTRODUCTION.

Chondrodite from Finland was mentioned in literature for the first time in 1817, when D'Ohsson (1), a Swedish scientist and diplomat, described a mineral occurring in the form of wine-yellow grains in crystalline limestone (together with pargasite and a green mica, evidently chlorite) at Parainen (Pargas) in south-western Finland. In accordance with its chemical composition D'Ohsson referred the mineral to the »talc silicates», and alluding to the granular appearance of the mineral he named it chondrodite.

Unfortunately, D'Ohsson did not detect the presence of fluorine in his chondrodite, and not till 1823 did Berzelius and Bonsdorff determine this constituent in a sample of chondrodite from Parainen.

Later on, based on the material from Parainen, some crystallographic and chemical studies have been carried out[1].

In addition to their classical occurrence at Parainen, the humite minerals (with the exception of clinohumite) very commonly occur also on other Finnish Archaean metamorphosed calcitic limestones. A large number of these occurrences has been described by Eskola, Hackman, Laitakari and Wilkman (3). As for their occurrence in connection with ore bodies, only one such case is known from Pitkäranta, where Trüstedt (4, pp. 175, 323) describes a highly serpentinized chondrodite, associated with sphalerite, occurring in dark serpentine.

The present study has been conducted in the Mineralogical and Geological Institute of the University of Helsinki under the guidance of Professor Pentti Eskola. The collections of the Institute were very kindly placed at the author's disposal by Professor Eskola, to whom the author is greatly indebted. The chemical part of this study has been carried out at the Chemical Laboratory of the University by the kind permission of Professor L. W. Öholm, to whom the author also wishes to express his thanks.

[1] These have been referred to by Laitakari (2, pp. 82—85).

THE METHODS.

The humite minerals in all the specimens examined occurred in calcitic crystalline limestones. The material for the analysis was separated from the crushed rock by means of acetylene tetrabromide and Clerici solution.

Ferrous iron was determined by the well-known Pratt method, and the values represent average results from repeated concordant determinations.

Manganous oxide was determined colorimetrically.

For the determination of fluorine, the lead chlorofluoride method was used instead of the old gravimetric method of Berzelius, because the results of several repeated determinations by the latter method were in no way satisfactory.

The specific gravities were determined by the Clerici solution and the Westphal balance at 20° C.

The determination of the indices of refraction was made by the immersion method in sodium light at 20° C. The values should be not more than $\pm$ 0.002 in error.

The axial angles were determined by the use of the universal stage and the Wulff stereographic net.

The analyses of the samples S. M. 1258, S. M. 1270, S. M. 3904, S. M. 4137, and S. M. 4139 are made by Mr. Olai Järnefelt, M. A. (5), and have been placed at the author's disposal by Professor Eskola.

THE MATERIAL.

PARAINEN.

Table I gives the chemical and optical properties for humite minerals examined, obtained from Parainen.

Notes on the samples.

S. M. 1258. Norbergite. Honey-yellow, irregular, rounded grains measuring up to 2 mms. No cleavage has been observed, and no twinning. The mineral is unaltered. In thin section the norbergite is colourless. Paragenesis: graphite, green spinel. The hand specimens also in some parts contain abundant colourless chondrodite with 2 V = 83°. The chondrodite often shows beautiful polysynthetic twinning lamellae, and is altered to greenish yellow chrysotile.

Table I. Chemical and optical properties of humite minerals from Parainen.

	1 Norbergite, Piukkala. S. M. 1258. Anal. by O. Järnefelt	2 Norbergite, Ersby. S. M. 4831.	3 Chondrodite, Ersby I. S. M. 5388.	4 Chondrodite, Ersby. S. M. 5625.	5 Chondrodite, Parainen 16. S. M. 1270. Anal. by O. Järnefelt	6 Chondrodite, S. M. 1267.	7 Chondrodite, Ersby. S. M. 1271.	8 Chondrodite, 4.
SiO_2	29.60			34.03	33.30		34.27	
Al_2O_3	0.53			0.43	1.42		0.22	
Fe_2O_3	0.60			0.12	0.69		0.36	
FeO	0.96	1.79	1.28	2.81	4.24	4.99	4.36	6.27
MnO	0.002 [1]	0.02	0.01	0.03	0.08	0.12	0.003	0.21
MgO	58.70			53.69	52.65		55.01	
CaO	n. d.			0.65	n. d.		0.04	
Na_2O	n. d.			0.08	0.98		0.13	
K_2O	n. d.			0.06	n. d.		0.07	
TiO_2	n. d.			0.12	n. d.		0.36	
H_2O	1.50			1.41	1.00		0.94	
F_2	13.55			7.93	8.03		6.99	
	105.44			101.36	102.69		102.75	
O for F_2	5.71			3.34	3.38		2.94	
	99.73			98.02	99.31		99.81	
Sp. Gr.	3.181	3.190	3.171	3.179	3.201	3.242	3.221	3.258
α	1.563	1.563	1.592	1.593	1.599	1.601	1.602	1.604
β	1.567	1.567	1.602	1.603	1.610	1.612	1.612	1.614
γ	1.590	1.590	1.621	1.623	1.630	1.632	1.633	1.635
$\gamma - \alpha$	0.027	0.027	0.029	0.030	0.031	0.031	0.031	0.031
2V (+) obs.	44°	45°	70°	71°	74°	76°	71°	78°
2V (+) calc.	47°	47°	72°30′	71°30′	73°30′	75°	71°	80°

[1] Determined by the author.

S. M. 4831. Norbergite. Yellowish brown, rounded grains measuring up to 2.5 mms. The grains are unaltered and show neither twinning nor crystal faces nor cleavages. In thin section pleochroic with α very faint yellow, β and γ colourless. Absorption $\alpha > \beta \sim \gamma$. Paragenesis: green spinel, chlorite, tremolite, and magnetite.

S. M. 5388. Chondrodite. Pale yellow, rounded grains sometimes showing poor, rounded crystal faces. No cleavage. Twinning rare. Some grains are partly altered to chrysotile. The grains measure up to 4 mms. in diameter. Colourless in thin section. Paragenesis: chlorite, pale violet spinel, tremolite, and magnetite. Occurs together with a little norbergite, which is untwinned and has $2V = 44°$.

S. M. 5625. Chondrodite. Pale yellow, rounded grains measuring up to 3 mms. Neither crystal faces nor cleavages could be observed. Twinning not very common. Colourless in thin section. Partly altered to chrysotile. Paragenesis: graphite, phlogopite, and green pargasite.

S. M. 1270. Chondrodite. The grayish yellow, rounded grains measure up to 5 mms. in diameter, and show neither crystal faces nor cleavages. Colourless in thin section. Twinning usual. The grains are wholly unaltered. Paragenesis: green spinel, phlogopite.

S. M. 1267. Chondrodite. Pale honey-yellow, rounded grains showing neither crystal faces nor cleavages. Usually twinned. The grains measure up to 3 mms. in diameter and are colourless in thin section. Chrysotile occurs as an alteration product. Paragenesis: graphite, pyrrhotite, pale green pargasite, phlogopite, and green chlorite.

S. M. 1271. Chondrodite. Rounded grains measuring up to 3 mms. in diameter and showing neither crystal faces nor cleavages. Usually twinned. Colour yellowish brown. Chrysotile occurs as alteration product of some grains. Faintly pleochroic in thin section with α pale yellow, β and γ colourless. Absorption: $\alpha > \beta \sim \gamma$. Paragenesis: green spinel, magnetite.

4. Chondrodite. Wine-yellow, rounded grains some of which show badly developed crystal faces. In a few grains an indistinct (001) cleavage. The grains are unaltered, commonly twinned, and measure up to 3.5 mms. Colourless in thin section. Paragenesis: green pargasite, magnetite.

Laitakari (2, p. 102) presents in a table of the Mineral Assemblages of Parainen the »chondrodite» paragenesis as follows:

chondrodite, calcite, phlogopite, pargasite, spinel.

His table is based on megascopic determinations only. The microscopic determinations referred to above add to the list the following minerals: graphite, pyrrhotite, magnetite, tremolite, and chlorite; the last-mentioned mineral occurring, however, always as an alteration product of phlogopite.

LOHJA.

The results of chemical and optical investigations are given in Table II.

Notes on the samples.

S. M. 4137. Chondrodite. Reddish brown, rounded grains showing no cleavages. Twinning rare. In some few grains badly developed crystal faces could be detected. The grains measure up to 6 mms. in diameter, and are unaltered. The colour of the mine-

Table II. Chemical and optical properties of humite minerals from Lohja.

	9 Chondrodite, Hermala S. M. 4137. Anal. by O. Järnefelt	10 Chondrodite, Ojamo. K. R. 15.	11 Humite, Hermala. S. M. 3904. Anal. by O. Järnefelt	12 Humite Hermala. S. M. 4139. Anal. by O. Järnefelt
SiO_2	33.60		33.80	34.56
Al_2O_3	0.18		2.94	1.46
Fe_2O_3	1.86		0.63	2.66
FeO	4.16	3.48	4.29	7.77
MnO	0.66	0.24	0.29	0.66
MgO	53.70		53.50	48.93
CaO	n. d.		n. d.	n. d.
Na_2O	n. d.		n. d.	n. d.
K_2O	n. d.		n. d.	n. d.
TiO_2	n. d.		n. d.	n. d.
H_2O	1.86		1.49	1.70
F_2	5.99		4.21	3.68
	102.01		101.15	101.42
O for F_2	2.52		1.77	1.55
	99.49		99.38	99.87
Sp. Gr.	3.201	3.229	3.202	3.273
α	1.613	1.635	1.607	1.643
β	1.623	1.645	1.619	1.653
γ	1.643	1.670	1.639	1.675
$\gamma - \alpha$	0.030	0.035	0.032	0.032
2V (+) obs.	70°	64°	77°	68°
2V (+) calc.	71°	65°30′	76°	67°30′

ral varies somewhat being at its deepest in the vicinity of spinel. This phenomenon has been observed already by von Eckermann (6, p. 383) in a Mansjö chondrodite. Paragenesis: black spinel (green under the microscope), chlorite, apatite, magnetite, and phlogopite. The chondrodite is distinctly pleochroic in thin section with α golden yellow, β nearly colourless, γ yellowish. Thus $\alpha > \gamma > \beta$. Dispersion very weak: $\varrho > \nu$.

K. R. 15. C h o n d r o d i t e. Red brown, somewhat rounded grains or short prismatic crystals with rounded crystal faces, both types showing twinning on (001). The grains measure up to 1.5 mms. in diameter. In some grains indistinct cleavages along (001). Partial alteration to chrysotile. Pleochroic in thin section with α golden yellow, β and γ colourless. Absorption: $\alpha > \beta \sim \gamma$. Paragenesis: green spinel, chlorite, magnetite, phlogopite, tremolite, and apatite.

S. M. 3904. H u m i t e. Rounded, brownish yellow grains showing neither crystal faces nor cleavages. No twinning. Pleochroic in thin section with α pale yellow, β nearly colourless, γ pale yellowish. Absorption: $\alpha > \gamma > \beta$. The hand specimen also contains some few grains of brownish yellow, twinned chondrodite.

S. M. 4139. H u m i t e. Deep reddish brown rounded grains in which no crystal faces could be observed, and no cleavages. The grains measure up to 10 mms. in diameter. No twinning. Pleochroic in thin section with α dark golden yellow, β pale yellow, γ golden yellow. Absorption: $\alpha > \gamma > \beta$. Very weak dispersion: $\varrho > \nu$. Paragenesis: dark green spinel, chlorite, magnetite, apatite.

According to the microscopic determinations listed above, the Mineral Paragenesis of the humite minerals at Lohja can be stated as follows:

magnetite, spinel, calcite, chondrodite or humite, tremolite, phlogopite, chlorite, and apatite.

OTHER LOCALITIES.

The results of investigation of four humite minerals from other localities are presented in Table III.

Notes on the samples.

K. R. 4a. H u m i t e. Yellowish brown rounded grains, some of which show partially rounded crystal faces. In some grains indistinct (001) cleavages. No twinning. The grains are unaltered and measure up to 3 mms. in diameter. Pleochroic in thin section with α pale yellowish, β and γ colourless. Absorption: $\alpha > \beta \sim \gamma$. Paragenesis: dark green spinel, magnetite, and chlorite. This occurrence has been described by Tammekann (7, p. 16) who gives for the refractive indices the following values: $\alpha' = 1.630$, $\gamma' = 1.655$. According to Tammekann the humite mineral in Sillböle is chondrodite, but as the extinction angle measured in a section parallel to (010) proved to be 0°, the mineral is humite.

P. E. 153. Chondrodite. Reddish brown, rounded grains showing neither crystal faces nor cleavages. The grains measure up to 2 mms. and are commonly twinned and wholly unaltered. Pleochroic in thin section with α bright golden yellow, β colourless, γ yellowish. Absorption: $\alpha > \gamma > \beta$. Very weak dispersion: $\varrho > \nu$. Paragenesis: phlogopite, tremolite, magnetite, and apatite. The occurrence is mentioned by Trüstedt (4, p. 323).

Table III. Chemical and optical properties of humite minerals from different localities.

	13 Humite, Sillböle, Helsingin pitäjä. K. R. 4 a.	14 Chondrodite, Ristiniemi, Impilahti. P. E. 153.	15 Chondrodite, Ahvensaari, Korppoo. S. M. 4012, 4017.	16 Humite, Pitkäjärvi, Perniö. S. M. 1275.
SiO_2		33.20		34.32
Al_2O_3		0.19		0.59
Fe_2O_3		0.30		0.48
FeO	4.78	8.70	4.23	5.40
MnO	0.59	0.42	0.06	0.01
MgO		50.47		53.17
CaO		0.06		trace
Na_2O		0.10		n. d.
K_2O		0.06		n. d.
TiO_2		0.41		0.25
H_2O		1.15		1.07
F_2		6.55		5.43
		101.61		100.72
		2.76		2.29
		98.85		98.43
Sp. Gr.	3.249	3.264	3.217	3.236
α	1.623	1.613	1.619	1.607
β	1.634	1.625	1.630	1.623
γ	1.655	1.646	1.650	1.643
$\gamma - \alpha$	0.032	0.033	0.031	0.036
2V (+) obs.	69°	78°	71°	81°
2V (+) calc.	73°	75°30′	74°30′	84°

S. M. 4012, 4017. Chondrodite. Red brown rounded grains, some of which show crystal faces. No cleavages. Usually twinned. The grains measure up to 4 mms., and are in some cases partly altered to chrysotile. In thin section pleochroic with α bright golden yellow, β nearly colourless, γ pale yellow. Absorption: $\alpha > \gamma > \beta$. Dispersion weak: $\varrho > \nu$. Paragenesis: green spinel, pyrrhotite, magnetite, chlorite. The occurrence has been described by Laitakari (8, p. 31).

S. M. 1275. Humite. Yellowish brown, rounded grains measuring up to 2 mms. and occasionally showing poor crystal faces and indistinct (001) cleavages. No twinning. The grains are wholly unaltered. Pleochroic in thin section with $\alpha > \beta \sim \gamma$. Paragenesis: tremolite, phlogopite, chlorite, apatite. Occurs together with a little twinned, yellowish brown chondrodite.

RELATIONS BETWEEN THE CHEMICAL COMPOSITION AND THE OPTICAL PROPERTIES IN THE HUMITE GROUP.

In a paper on the optical properties of the humite group Larsen (9, pp. 354—359) has tried to make an attempt to correlate the chemical composition of the humite minerals with their optical constants, expecting »a simple and systematic relation in which the indices of refraction increase with the iron and titanium content and decrease with the increase in fluorine». His results, however, showed only some tendency in this direction.

The humite family being closely related to the olivine group, one could except a close correspondence between the optics and the percentages of FeO and MnO in both groups. In the forsterite—fayalite series the investigations of Backlund (10) and Magnusson (11) showed that the refractive indices increase with the increase in FeO content and decrease with increasing MgO content. There is also an increase in the refractive indices with the increase in MnO, but the effect is weaker than that produced by FeO. We can thus state that the refractive indices in the olivine group increase with the increase in the sum FeO + MnO. The optic axial angle, on the contrary, decreases with increasing FeO + MnO.

In his study of the contact minerals of the Mansjö Mountain von Eckermann (6, pp. 381—382) supposes that in Mansjö chondrodite the refractive indices decrease with the decrease in FeO or increase in H_2O content. Also the optic axial angle decreases with the decrease in FeO. Mellis (12, pp. 220—228) in a paper on a chondrodite from Parainen pays regard also to this assumption of von Eckermann, but his results do not, however, throw any light on the problem.

Barth (13, pp. 94—96) states that von Eckermann's opinion that the small optic angle of the Mansjö chondrodite is due to the small percentage of iron is not verified in the case of the chondrodite from Christiansand.

Kunitz (14) has studied the rôle of titanium and Otto (15) that of manganese in the silicates. According to Kunitz titania replacing silica increases the refractive indices.[1] The results of Otto are similar to those obtained by Magnusson (11). According to Otto the optic axial angle increases with the increase in MnO.

In order to find out the suggested relationship between the chemical composition and the optics of the various humite minerals, Plate I is presented. It shows the highest refractive index γ in relation to the FeO + MnO, MnO, and F_2 contents.

Notes on Plate I.

The numbered white circles refer to the corresponding samples of the Tables I—III. The black circles represent the minerals in Larsen's (9) Tables I—III in the following order: 17: Warwick, N. Y. Brush 2054. 18: Monte Somma. Brush 2063. 19: Kafveltorp. Brush 2040. 20: Christiansand. Barth. 21: Mansjö. von Eckermann. 22: Nordmark, brown. Sjögren. 23: Tilly Foster. Brush 4813. (Table I); 24: Monte Somma. 25: Vesuvius, dark. Yale 4102 (Table II); 26: Vesuvius. Yale 4143. 27: Vesuvius. Brush 2046. 28: Piedmont (Table III). 29 is the chondrodite from Parainen, described by Mellis (12). 30 and 31 are the norbergites 1 (Franklin) and 3 (Norberg) as reported by Larsen, Bauer, and Berman (16, p. 350) in Table I. — The papers of Larsen (9) and Larsen, Bauer, and Berman (16) also contain other chemical and optical data for different humite minerals, together with references to the original papers, but since the data were incomplete for the purposes of the present paper, no regard was paid to them.

The light and dark varieties are marked with L and D whenever it has been possible to judge their colour from the notes in literature.

The division of the chondrodites into sub-groups according to the colour is established by Sjögren (17) and is presented by v. Eckermann (6, p. 379) for the Mansjö chondrodites, which are divided into B-type (brown) and G-type (yellow) minerals, both types showing well-marked differences in their optical properties.

---

[1] According to modern crystal chemistry titania in the silicates is found to replace alumina and ferric oxide, and not silica.

The following conclusions were made from the diagrams of Plate I:

1. Norbergite. Two varieties of norbergites can be distinguished according to the colour. The differences in colour are, however, not well marked. There seems to be some tendency in a direction in which the refractive indices slightly increase with increasing MnO tenor. As for the ferrous oxide and fluorine contents, no well-established differences in the γ of norbergites can be distinguished.

2. Chondrodite. The attempts to divide the chondrodites into two sub-groups according to their colour seem to fail entirely, as there are no marked chemical and optical differences between the suggested sub-divisions. The general tendency in both suggested sub-groups is for the increase in γ with the increase in FeO and MnO content and with the decrease in F_2 content. Only in the light-coloured chondrodites from Parainen does this tendency seem to be more regular, as shown by the two curves in the corresponding diagrams. It is the author's opinion that the colours of the humite minerals from different localities presented in literature are, generally, not well comparable with each other, according to the subjective determination of colour. In the determination of the refractive indices and in the analyses, also subjective errors are evident and the results are therefore not entirely comparable, though the errors may be small.

The general results for the chondrodites agree with the determinations from other minerals in which isomorphous replacement of magnesia by ferrous iron or by manganese is present. As to the optic axial angles, there is a certain tendency towards enlarging of 2V with the increase in FeO + MnO and MnO contents, when the chondrodites of Parainen (Table I) are surveyed.

3. Humite. We may briefly state that the ruling tendency for the humites is analogous to that for chondrodites.

4. Clinohumite. Excepting in the variety very rich in titania we find the same tendency for the clinohumites also.

From the above notes it is evident that a systematic relation between the chemical composition and the refractive index γ cannot be established. This is probably due to the fact that in the humite group there are too many factors co-operating: Increase in the FeO, MnO, and TiO_2 content enlarges the refractive indices whilst increase in the F_2 and H_2O content reduces them, the indices thus representing only the algebraic sum of the different factors.

In accordance with the above, we must state that it is not possible to determine *e. g.* the refractive indices of a chondrodite from its content of ferrous iron, or *vice versa*. What is possible in the olivine group is no longer possible in the humite family, though both groups structurally are closely related to each other.

Larsen (9, p. 358) presents in Table IV the general optical data for the humite group. From the determinations of the refractive indices of Finnish chondrodites and humites we may somewhat enlarge the areas occupied by these minerals:

	Chondrodite Larsen	Humite
α	1.592—1.643	1.607—1.643
β	1.602—1.655	1.619—1.653
γ	1.621—1.670	1.639—1.675

Geochemical Laboratory, The Mineralogical and Geological Institute of the University, Helsinki, May 1938.

REFERENCES.

1. D'Ohsson, C. M.: Undersökning Af några Mineralier. 3. En gul Sten ifrån Pargas. Kongl. Vet. Acad. Handl. 1817.
2. Laitakari, Aarne: Über die Petrographie und Mineralogie der Kalksteinlagerstätten von Parainen (Pargas). Bull. Comm. géol. Finlande, No. 54. 1921.
3. Eskola, Pentti; Hackman, Victor; Laitakari, Aarne and Wilkman, W. W.: Suomen Kalkkikivi (With an English Summary of the Contents: Limestones in Finland.) Suomen Geol. Toim. Geotekn. Tiedonantoja No. 21. 1919.
4. Trüstedt, Otto: Die Erzlagerstätten von Pitkäranta am Ladoga-See. Fennia, Vol. 25, No. 4. 1907.
5. Järnefelt, Olai: Tutkimuksia humiittiryhmästä. Manuscript in Finnish. 1933.
6. von Eckermann, Harry: The Rocks and Contact Minerals of the Mansjö Mountain. Geol. För. Förh., Bd. 44. 1922.
7. Tammekann, A.: Über die Petrographie des Grubenfeldes von Sillböle bei Helsinki (Helsingfors). Fennia, Vol. 45, No. 10. 1922.
8. Laitakari, Aarne: Le gisement de calcaire cristallin de Kirmonniemi à Korpo en Finlande. Bull. Comm. géol. Finlande, No. 46. 1916.
9. Larsen, Esper S.: The Optical Properties of the Humite Group. Amer. Min., Vol. 13. 1928.
10. Backlund, Helge: Über die Olivingruppe. Travaux Mus. Géol. Pierre le Grand, Acad. Imp. St.-Pétersbourg, Tome III. 1909.
11. Magnusson, Nils H.: Beitrag zur Kenntnis der optischen Eigenschaften der Olivingruppe. Geol. För. Förh., Bd. 40. 1918.
12. Mellis, Otto: Beitrag zur Kenntnis der optischen Eigenschaften des gesteinsbildenden Chondrodits von Pargas. Geol. För. Förh., Bd. 49. 1927.

13. BARTH, TOM: On Contact Minerals from Precambrian Limestones in Southern Norway. Norsk Geol. Tidsskr., Bd. 8. 1924.
14. KUNITZ, W.: Die Rolle des Titans in den Silikaten. Fortschr. d. Min., Bd. 13. 1929.
15. OTTO, HELMUT: Die Rolle des Mangans in den Mineralien. Min. petr. Mitt., Bd. 47. 1935.
16. LARSEN, ESPER S., BAUER, L. H., and BERMAN, H.: Norbergite from Franklin, New Jersey. Amer. Min., Vol. 13. 1928.
17. SJÖGREN, HJ.: Kristallografisk undersökning af Chondrodit och Humit från svenska fyndorter. Lunds Univ. Årsskrift, Tom. 17. 1880—1881.

Kalervo Rankama, On the Mineralogy of Some Members of the Humite Group found in Finland (cf. pp. 90—92.)

7.

ENTGEGNUNG AUF DR. E. HYYPPÄS KRITIK MEINER ABHANDLUNG »EIN INTERGLAZIALFUND BEI ROUHIALA IN SÜDOSTFINNLAND».

VON

G. BRANDER.

Im zehnten Band dieser Serie hat Dr. E. Hyyppä (1937) es für angebracht erachtet, das Ergebnis der Arbeit, die er in seiner Eigenschaft als offizieller Opponent meiner Lizentiatabhandlung »Ein Interglazialfund bei Rouhiala in Südostfinnland» (Brander 1937 b) geleistet hat, im Druck erscheinen zu lassen. Und ich konstatiere, dass der Inhalt seines Aufsatzes eine genaue Wiedergabe seines bei der Disputation erhobenen Einwandes ist. Kaum ein einziger m e i n e r Diskussionseinwürfe hat Berücksichtigung gefunden, ebensowenig scheint die seit der Disputation verflossene Zeit ihn belehrt zu haben. Alles geht wieder ins einzelne, von der Behauptung an, dass mein Untersuchungsmaterial aus z w e i Tonklumpen bestanden hätte, worauf er immer noch besteht, obgleich aus mehreren Stellen meiner Abhandlung hervorgeht, dass es sich nur um einen einzigen gehandelt hat, was ich jedoch für den geringsten in seinem Aufsatz vorkommenden Fehler halte, bis zu den ihm abgehenden Einsichten in die Ökologie der Kieselalgen und der geringen Vertrautheit mit Artenverzeichnisse bezeugenden Diatomeenstatistiken, auf welchen Punkt, wie ich verstehe, sich seine Kritik konzentriert. Ebensowenig hat Dr. Hyyppä sich bemüht, seinen Text zu ändern unter Beachtung dessen, dass das, was bei einer mündlichen Diskussion geäussert wird, nicht immer ohne weiteres für den Druck geeignet ist, und so findet der Leser den genannten Aufsatz überlastet mit einer Fülle von für eine sachliche Kritik belanglosen Einzelheiten, die ruhig hätten unbeachtet bleiben können.

Derartigen Belanglosigkeiten begegnet der Leser schon auf der ersten Seite des Aufsatzes. Hyyppäs sehr genaues Wiederholen der Art und Weise, in welcher der Fund gemacht wurde, und der Frage, wem ich für das Material zu danken habe, ist nur geeignet, dem Leser die Auffassung nahezulegen, dass Hyyppä es sich besonders angelegen sein lasse, hervorheben zu wollen, dass der Tonklumpen nicht von mir gefunden worden ist. Und etwas später findet er Anlass zu betonen, dass meine Artbestimmungen von Dr. Hustedt kontrolliert worden sind. Schon die blosse Aufnahme eines solchen Passus erscheint einer sachlichen Kritik durchaus belanglos. Der Sachverhalt ist jedoch bedenklicher als so, denn in der Weise, wie Hyyppäs Satz formuliert ist, ist er geeignet, eine falsche Vorstellung von dem Anteil, den Dr. Hustedt in der Bearbeitung des Diatomeenmaterials genommen hat, zu vermitteln. Der betreffende Satz muss von dem Leser so aufgefasst werden, wie wenn Dr. Hustedt meine Präparate und Artenverzeichnisse genau durchgesehen und kontrolliert hätte. Diese Verdrehung der Tatsachen muss ich als durchaus beabsichtigt bezeichnen, da ich in meinem Einleitungskapitel Dr. Hustedt ausdrücklich für die Kontrolle von e i n e r A n z a h l meiner Diagnosen danke.[1]

Dass ich mich überhaupt bemüht habe, das Unrichtige in Hyyppäs Darstellung in diesem Punkte richtigzustellen, liegt daran, dass der Schwerpunkt meiner Untersuchung gerade auf den Diatomeen ruht, mit deren Diagnose und Behandlung ich die grösste Arbeit gehabt habe.

Auf Seite 146 finden sich einige Sätze, die den Leser verwundern. Hyyppä weist darauf hin, dass ich das Zeugnis der Diatomeen für ein kaltes Meer unerwähnt lasse und dass ich erst im Zusammenhang mit den Silicoflagellaten zu diesem Schluss komme. Die Absicht mit der Kritik in dieser Hinsicht ist mir nicht ganz klar. Möchte Hyyppä damit nur für die Geologenwelt darauf hinweisen, dass ein Wort, kalt, das er in dem betreffenden Zusammenhang für angebracht hält, fehlt? Ein solcher Hinweis war vielleicht bei der Disputationsgelegenheit motiviert, doch erscheint es naiv vorauszusetzen, dass derartige Geringfügigkeiten ein grösseres Publikum interessieren sollten. Oder wollte Hyyppä etwa zu verstehen geben, ich gedächte zu verheimlichen, dass die Diatomeen für ein kaltes Meer zeugen? Der Auslassung des Wortes »kalt» in meiner Zusammenfassung über das Zeugnis der Diatomeen diese Deutung zu geben, ist jedoch absurd in Anbetracht dessen, dass ich später in meiner Abhandlung wiederholt darstelle, wie die Diatomeen auf ein arktisches Meer hindeuten. Die Sinnlosigkeit der »Kritik» tritt um so stärker hervor, als Hyyppä im nächsten Augenblick zuzugeben gezwungen ist, dass ich sowohl die Diatomeen als auch die Silicoflagellaten als Indikatoren für ein kaltes Meer erachte!

---

[1]) Die Anzahl der Diatomeenformen, auf die sich die betreffende »Kontrolle» bezieht, beläuft sich auf nur 27 der Gesamtzahl von 142 Formen!

Im Widerspruch zum Titel seiner Ausführungen geht Hyyppä auf Seite 147 dazu über, einen anderen meiner Aufsätze, »Zur Deutung der intramoränen Tonablagerung an der Mga, unweit von Leningrad» (Brander 1937 a) zu kritisieren. Da ich nicht die Arbeiten, die er wünscht, zitiere, zieht Hyyppä den Schluss, dass ich eine Reihe neuerer russischer Arbeiten und die in ihnen verfochtenen Ansichten, dass die Mga-Bildung interstadial, nicht interglazial wäre, nicht kenne, und da ich auch nicht auf diese eingehe, wirft er mir mangelnde Objektivität vor. Die letztere Beschuldigung muss ich entschieden zurückweisen. Ich hielt es keineswegs für nötig, im engen Rahmen meines Aufsatzes alles, was von verschiedenen Forschern zur Mga-Frage geäussert worden ist, zu behandeln, zumal die meisten von ihnen ihre Aussagen auf eine geringe Anzahl von Untersuchungen gegründet haben, welch letztere ausserdem in bezug auf den interstadialen oder interglazialen Charakter der Bildung keinen entscheidenden Beweis beigebracht haben. Den ersten Beweis liefert Pokrowskaja (1936) durch ihre Pollenuntersuchung, und gegen diese Argumentation ging ich vor auf ihrem eigenen Feld, dem der Pollenanalyse, wobei ich ausserdem meine Auffassung auf das Zeugnis der Diatomeen und der Silicoflagellaten stütze. Das einzige von allem, was bisher über Mga bekannt gewesen ist und zu entscheiden vermochte, ob die Bildung als interglazial oder interstadial bezeichnet werden soll, ist nämlich die Pollenflora, und hier glaubte ich einen sicheren Beweis für ihren interglazialen Charakter vorbringen zu können. Vielleicht wäre Hyyppäs Kritik in diesem Punkt weggefallen, wenn ich die Begriffe interglazial und interstadial näher definiert hätte, und ich bedaure, dass ich in den genannten Aufsätzen meine Auffassung in dieser Hinsicht nicht näher dargelegt habe. Diese Begriffe sind ja schwankend und schwer zu definieren, und zwar wegen Abweichungen in der Auffassung von der Temperatur des interglazialen bzw. interstadialen Klimas, ausserdem sind sie sehr relativ, da der regional-geographische Faktor hier ebenfalls in Betracht gezogen werden muss. Theoretisch kann man ja doch geführt werden zu einer Synchronisierung zwischen sicheren interglazialen Sedimenten in Mitteleuropa und Ablagerungen, die nahe der Rückzugsgrenze des Eisrandes in Nordeuropa abgesetzt worden sind und die dann einen Fossilbestand von unverkennbar »interstadialem» Gepräge führen. Was nun im besonderen eine Örtlichkeit mit der geographischen Lage von Mga im Verhältnis zum Zentrum des Vereisungsgebietes angeht, so halte ich dafür, dass dort angetroffene, zwischen zwei Glaziationen abgelagerte Sedimente als interglazial bezeichnet werden müssen, soweit ihre Fossilien ein Klima erkennen lassen, das zum mindesten ebenso günstig war wie dasjenige, das dort heutzutage herrscht. In dieser Hinsicht, glaube ich, werden mir die meisten zustimmen. Dieser Auffassung schliesst sich dagegen Sukatschew nicht an, wenn er, offenbar in erster Linie auf Grund der von Pokrowskaja dargestellten Analysenresultate, schreibt (1936, S. 84): »Indem wir annehmen, dass diese Flora aus Petrosawodsk und Mga sich in dem Interstadial der letzten Vereisung entwickelt hat, muss anerkannt werden, dass es dennoch keine Tundraflora war, sondern eine Waldflora, die dem Charakter der jetzigen Flora im mittleren Teil des Leningrader Gebiets entspricht.» Dieser Sachverhalt spreche jedoch nicht gegen den interstadialen Charakter der Ablagerungen, meint er, als er nach einer Erörterung über die Ergebnisse von verschiedenen Fundorten arktischer Pflanzenreste festgestellt hat (op. cit. S. 92), »dass an der Peripherie des pleistozänen Gletschers die Verhältnisse wenigstens stellenweise derartig waren, dass sich zu der arktischen Flora eine südlichere, darunter auch Waldvegetation, gesellen konnte.».

Ein Beweis für die interstadiale Natur von Mga sind, wie ersichtlich, diese Umstände indes nicht, und als einen solchen betrachtet auch Sukatschew sie nicht. Er stellt nur dar, dass die Übereinstimmung zwischen der Mga-Petrosawodsk-Flora und der gegenwärtigen im Leningrader Gebiet nicht daran hindert, die betreffenden Ablagerungen als interstadial anzusehen. Gegenüber der vollen Beweiskraft des beschränkten und unvollständigen Materials, das Sukatschew bei seiner Darlegung zur Verfügung stand, und auch gegenüber dem Berechtigten der daraus gezogenen Schlüsse, die bei ihm jene Ansicht befestigt haben, hat man sich jedoch vorläufig etwas skeptisch zu verhalten. Denn in Übereinstimmung damit könnte man also auf Grund einer Analyse der rezenten Pollenflora im Leningrader Gebiet das nun herrschende Klima recht gut als »interstadial» bezeichnen!

Nun sind jedoch die Umstände derart, dass ich in meinem Mga-Aufsatz ein Material vorgelegt habe, das deutlich erweist, dass das Klima wesentlich günstiger gewesen ist, als das Ergenbismaterial, mit denen die russischen Forscher zu arbeiten hatten, zu bezeugen vermochte. In erster Linie darauf gegründet ist meine Ansicht, dass Mga als interglazial, nicht als interstadial betrachtet werden muss.

Später gibt Hyyppä in seinem Aufsatz zu, dass das Klima zur Zeit der Ablagerung des Mga-Tons günstiger gewesen sein muss, als Pokrowskajas Analyse angibt. Die vollen Konsequenzen daraus hat er jedoch nicht zu ziehen gewagt.

Auf Seite 149 geht dann Hyyppä über zu einer Kritik meiner Art und Weise, Rouhiala und Mga auf der einen Seite mit den portlandischen Ablagerungen im Südbaltikum auf der anderen Seite zu parallelisieren. Da er mich beschuldigt, durch eine verfehlte Auswertung des durch die Diatomeen gewährten Zeugnisses eine »willkürliche Nebeneinanderstellung» von zwei Sedimenten erzwungen zu haben und da er auch im übrigen diesen Abschnitt als den schwächsten meiner Darstellung zu betrachten scheint, sehe ich mich gezwungen, in dieser Hinsicht etwas näher auf die Kritik einzugehen.

In meiner Rouhiala-Abhandlung stelle ich dar (S. 52—53), dass die obengenannten Ablagerungen wohl nebeneinandergestellt werden können, und zwar wegen reichlich vorkommender gemeinsamer, charakteristischer planktischer Diatomeen und auch einiger anderen gemeinsamen, aus dem postglazialen Baltikum unbekannten oder dort sehr spärlich angetroffenen Formen. Und ich lasse ebenso verstehen, dass diesen in Massen auftretenden p l a n k t o n i s c h e n Formen volle Beweiskraft beizumessen ist, nicht der an die Litoralzone gebundenen Aufwuchs- und Grundflora, die in grossem Formreichtum, aber meist in sehr geringer Individuenanzahl auftritt und deren Vertreter in geringem Grad den betreffenden Ablagerungen gemeinsam erscheinen können. Ohne diese Gesichtspunkte überhaupt in Erwägung zu ziehen, versucht nun Hyyppä, an Hand meines Artenverzeichnisses zu beweisen, dass meine Konnektierung auf unhaltbarer Grundlage ruhe, dass man bei »richtiger» Auswertung der Diatomeentabellen tatsächlich zu Schlüssen komme, die den von mir gezogenen durchaus entgegengesetzt seien. So weit gelangt Hyyppä auf rein statistischem Wege. Er unternimmt es nämlich, die für die verschiedenen Ablagerungen aufgezeichneten Formen zu addieren, findet, dass der Betrag der in Rouhiala-Mga und den südbaltischen Portlandia-Ablagerungen vorkommenden g e m e i n s a m e n Formen 25 % von deren Gesamtanzahl ausmache, und stellt fest, wie dieser geringe Zahlenwert vollauf b e w e i s e, dass die genannten Ablagerungen nicht miteinander identifiziert werden könnten! Ja, er konstatiert, dass Mga-Rouhiala dann eher mit den Eem-Ablagerungen zu konnektieren sei, da der Prozentsatz gemeinsamer Formen dort höher, 28 %, ausfalle.

Die Unhaltbarkeit der von Hyyppä dargestellten Beweisführung, die eine weitgehende Nichtkenntnis vom Wesen der Diatomeenassoziationen verrät und die ein gutes Beispiel dafür bietet, wie die Artenverzeichnisse n i c h t angewendet werden sollen, ist eigentlich so offensichtlich, dass sie keine Entgegnung verdiente. Dass ich überhaupt eine solche unternehme, ist dadurch geboten, dass jene Argumentation Geologen, denen die Mikropaläobotanik weniger vertraut sein sollte, etwa logisch und zutreffend erscheinen könnte.

Jeder, der selbst marine Lagerfolgen analysiert hat, weiss, dass man im Präparat regelmässig einige wenige, vielleicht 2, vielleicht 5, planktische Diatomeenformen, die indes in Massen auftreten, antrifft, desgleichen eine geringe Anzahl verschiedener, wenn auch ziemlich individuenreich vertretener, höchst gemeiner Aufwuchsformen und ebenso eine Menge, 20, 50, vielleicht noch mehr verschiedene, aber stets in sehr geringer Individuenanzahl auftretende Aufwuchs- und Grundformen. Gegebenenfalls gesellt sich dazu ein vereinzeltes Individuum oder Fragment einer zufällig eingeführten, der Assoziation sonst fremden planktischen Form. Diese in hohem Arten- aber geringem Individuenreichtum — oft nur e i n e Schale oder nur das Fragment einer solchen in einem im übrigen fossilreichen Präparat — vorkommenden Aufwuchs- und Grundformen sind oft zu einem grossen Teil nicht dieselben in lokal verschiedenen, wenn auch synchronen und in demselben Meere abgesetzten Ablagerungen. Je nach der Landnähe der Sedimentationsstelle und dem Charakter des nächstgelegenen Ufers können somit die Artenverzeichnisse ein sehr verschiedenes Aussehen annehmen. Ein Sandgrund führt eine teilweise andere Diatomeenvegetation als eine gyttjige. Bald ist das Ufer felsig, bald der Grund grusig, bald ziemlich steril, bald grasbewachsen. Bald ist die Bucht offen, bald durch Riffe oder Holme geschützt, oder es mündet etwa ein Bach oder Fluss an der Stelle, um eine Aussüssung des Wassers zu bewirken. Alles dies sind Gegebenheiten, die höchst wesentliche Verschiedenheiten im Aussehen der Artenlisten verursachen können, selbst wenn diese zwei einander nahegelegenen Ablagerungen zugehören, die dann ganz verschieden erscheinen können, s o w e i t m a n b e i d e n A r t e n v e r z e i c h n i s s e n n u r d i e Ü b e r e i n s t i m m u n g d e r A r t e n o d e r a l s o m. a. W. d e r l a t e i n i s c h e n N a m e n b e a c h t e t! Dass diese Verschiedenenheiten mit der Entfernung zwischen den Ablagerungen zunehmen sollten, ist nur zu erwarten, um so mehr, wenn diese in so verschiedenen geographischen Breiten gelegen sind, dass auch verschiedene Meerestemperaturen einwirken können. Der Betrag der Übereinstimmung zwischen den Formen zweier Artenlisten wird auch in wesentlichem Grade dadurch beeinflusst, inwieweit diese von einem und demselben oder mehreren Forschern aufgestellt worden sind. Der eine bestimmt eine Form anders als ein anderer, der eine unterscheidet eine Varietät, wo ein anderer sie unter die Hauptform begreift, der eine kann mit seiner grösseren Formenkenntnis oder bei Benutzung einer besseren optischen Ausrüstung, mit schärfer brechenden Einbettungsmitteln usw., seine Verzeichnisse bedeutend reichhaltiger als der andere gestalten. Dies alles sind Dinge, die in hohem Grade gerade auf die zufällig und mehr oder weniger willkürlich, artenreich und individuenarm vorkommenden Formen einwirken, also auf diejenigen, die in bezug auf die M e n g e der Arten in der Artenliste die absolute Mehrheit ausmachen.

Ganz anders verhält es sich mit dem Plankton, das im Präparat meist in einer geringen Anzahl von Arten, aber mit um so grösserem Individuenreichtum auftritt. Frei schwimmt es umher im g a n z e n Meer und ist gegenüber den Variationen in verschiedener ökologischer Hinsicht bedeutend weniger empfindlich als die Grundform- und die Epiphyten-Flora. In erster Linie sind also bei Versuchen, verschiedene Ablagerungen zu konnektieren, die Planktonarten zu berücksichtigen.

Die Diatomeen sind Lebewesen, die in regelmässiger Weise zusammen in Diatomeenassoziationen auftreten. Auch diese leben; empfindlich auf verschiedene Einflüsse reagierend, verändern sie Form und Charakter. Sie sind ein Teil der ständig wechselnden organischen Natur und dürfen daher nicht als tote Dinge betrachtet werden; eine Diatomee kann nicht wie eine tote Einheit, einzig und allein als Name in einem Verzeichnis behandelt werden. Das gerade ist es, was Hyyppä getan hat, wenn er, ohne auf die verschiedene Natur oder Frequenz der Arten Rücksicht zu nehmen, durch reine arithmetische Statistik, d. h. durch Addition lateinischer Namen und durch prozentuale Berechnung derjenigen, die in den Listen gemeinsam sind, meine Beweisführung umzuwerfen sucht!

Hyyppä erachtet den Prozentsatz gemeinsamer Formen, 25, für allzu niedrig, um Rouhiala-Mga mit dem südbaltischen Portlandia gleichstellen zu können. Aus Gründen, die ich oben angeführt habe, können die Artenverzeichnisse für Ablagerungen eines und desselben Meeres in der Anzahl gemeinsamer Formen sehr stark wechseln. Darüber weiss Hyyppä, offenbar wegen fehlender Kenntnis der Diatomeenökologie und geringer Vertrautheit mit der Diatomeenliteratur, wahrscheinlich nicht Bescheid. Doch müsste nicht der Sachverhalt, dass er nur 45 % gemeinsame Formen bei dem geringen Abstand Rouhiala—Mga herausgefunden hat, was ihm doch für die Nebeneinanderstellung dieser Ablagerungen genügt, ihn gewarnt haben! Und wenn der Prozentsatz gemeinsamer Formen zweier Ablagerungen, jede an ihrem eigenen Ufer einer sozusagen breiten Meeresenge und in ungefähr gleicher nördlicher Breite abgesetzt, nur 45 % ausmacht, dürfte es wohl nicht zu verwundern sein, dass dieser prozentuale Anteil in Sedimenten, die in f ü n f m a l s o g r o s s e m A b s t a n d und 5 geographische Breitengrade südlicher gelegen sind, auf nur 25 sinkt!

Wozu es führt, wenn die Diatomeenverzeichnisse in der unrichtigen Weise, deren Hyyppä sich bedient hat, benutzt werden, dürfte schon hervorgehen aus folgendem Beispiel von mit verhältnismässig wenigen gemeinsamen Formen ausgestatteten Artenverzeichnissen für in demselben Meere abgesetzte Sedimente. Es liessen sich mehrere Beispiele litorinaler Ablagerungen beibringen, doch möchte ich mich auf nur eines beschränken, bei dem das Material näher zur Hand liegt, nämlich in meinem Rouhiala-Aufsatz.

Wir berechnen an Hand meines Verzeichnisses die Prozentsätze gemeinsamer Formen der Portlandia-Ablagerungen in Reimannsfelde, Lenzen, Adlershorst, Hohenhaff und Cadinen. Tolkemit lassen wir ausser Betracht, da sein Artenverzeichnis bedeutend formenarmer als dasjenige der übrigen ist. Und wir finden, dass von insgesamt 120 verschiedenen Formen

18	Formen,	d. h.	15 %,	allen	5	Ablagerungen	gemeinsam	sind,
10	»	»	8 %,		4	»	»	»,
17	»	»	14 %,		3	»	»	»,
25	»	»	21 %,		2	»	»	»,
50	»	»	42 %,	in nur	1	»	vorkommen.	

Das Resultat ist ja bezeichnend genug. In diesen einander nahegelegenen Ablagerungen sind nur 15 % allen gemeinsame Formen anzutreffen, und bei der Betrachtung des Artenverzeichnisses finden wir, dass diese fast ausschliesslich aus p l a n k t o n i s c h e n oder höchst trivialen, in marinen Proben stets allgemein auftretenden, ihrem Substrat entrückten Aufwuchsformen bestehen. Auf der anderen Seite stellen wir fest, dass nicht weniger als 42 % von der Gesamtzahl der Formen in nur einer der Ablagerungen beobachtet worden sind!

Demgegenüber kann eingewandt werden, dass die Statistik nicht ganz objektiv ist, da die Flora, was den Formenreichtum anbelangt, verhältnismässig grosse Schwankungen in den verschiedenen Artenverzeichnissen aufweist. Gewiss, wir werden dann unter diesen diejenigen auswählen, welche die am besten übereinstimmenden Artenzahlen aufweisen, nämlich Lenzen mit 56 Formen und Hohenhaff mit 63. Diese Artenlisten umfassen insgesamt 83 verschiedene Formen, von denen nur 36, d. h. 40 %, gemeinsam sind! Und doch liegen diese Örtlichkeiten nur ca. 2.5 km voneinander entfernt, ausserdem ist die Artbestimmung von einer und derselben Person ausgeführt worden, so dass verschiedene Diagnostizierung ausgeschlossen ist!

Mit dem Obigen hoffe ich mit voller Evidenz erwiesen zu haben, dass Hyyppäs Beweisführung sich auf eine unrichtige Benutzung von Diatomeenverzeichnissen gründet, dass seinen mit grosser Mühe ausgearbeiteten Statistiken überhaupt kein Wert beigemessen werden kann sowie dass seine aus ihnen abgeleiteten Schlüsse daher auf unhaltbarer Grundlage ruhen. Ob die von mir vorgebrachten Beweise für die Nebeneinanderstellung der betreffenden Ablagerungen stichhaltig sind, mag eine sachkundige Kritik entscheiden. Mit seinen odiösen Statistiken vermag dagegen Hyyppä jedenfalls überhaupt nichts zu beweisen!

Gern gebe ich zu, dass die faktischen Übereinstimmungen zwischen den Floren von Rouhiala-Mga und dem südbaltischen Portlandia nicht durchaus so gut sind, wie es wünschenswert wäre. Nichtsdestoweniger halte ich aus den in meiner Abhandlung vorgebrachten Gründen daran fest, dass jene Parallelen für eine Nebeneinanderstellung durchaus genügen. Im Anschluss an meine oben gegebene Erklärung für die Ursachen dazu, dass die Artenverzeichnisse für in einem und demselben Meere abgesetzte Sedimente verhältnismässig wenige gemeinsame Arten aufweisen können, kann ich für den in Frage stehenden Fall mitteilen, dass ich die Anzahl der mit der Frequenzzahl 1 versehenen Formen, die in Mga-Rouhiala vorkommen, aber im Südbaltikum fehlen, auf nicht weniger als 36 berechnet habe. Das besagt, dass sie äusserst spärlich vorkommen, in einer oder höchstens einigen wenigen Schalen oder Fragmenten unter mehreren hunderttausend im Präparat beobachteten Individuen! Und diese ganz zufällig eingeschwemmten Exemplare tragen in hohem Grade dazu bei, dass der Prozentsatz der gemeinsamen Formen so niedrig ausfällt.

Hinsichtlich Hyyppäs Behauptung, dass Rouhiala-Mga ebensogut mit den Eem-Ablagerungen konnektiert werden könne, da der Prozentsatz gemeinsamer Formen hier ungefähr gleich sei, brauche ich wohl nicht mehr hervorzuheben, dass dies natürlich ebenso schwach begründet ist wie das früher angeführte Ergebnis seiner arithmetischen Beweisführung. Dass eine sogar etwas bessere Übereinstimmung in der Anzahl der gemeinsamen Arten erreicht worden ist, mag im Anschluss an die obigen Ausführungen gewiss Zufall sein. Irgendwelche haltbaren Vergleiche können in dieser Hinsicht leider nicht angestellt werden, da die Artenverzeichnisse für das südbaltische Portlandia, teilweise auch für das Eem, der Frequenzangaben entbehren. In bezug auf die Abweichungen im Fossilbestand des

Eem- und dem des Portlandiameeres möchte ich nur einige Arten anführen: *Actinoptychus aster* und *A. splendens*, *Cerataulus turgidus*, *Cyclotella striata* sowie drei *Triceratium*-Arten. Diese meist leicht erkennbaren Planktonarten oder unter dem Meeresplankton höchst allgemein vorkommenden, ihrem Substrat entrückten Aufwuchsformen finden sich reichlich bzw. allgemein im Eem, fehlen aber gänzlich im südbaltischen Portlandia und in Rouhiala-Mga!

Nicht zum mindesten in Anbetracht meiner arktischen Arten hat Hyyppä es schwer, sich mit dem Gedanken zu vergleichen, dass die betreffenden Ablagerungen einander gleichgestellt werden könnten. Findet er es denn so eigentümlich, dass das Meer in dem nahe dem eisigen Weissen Meer gelegenen Rouhiala-Mga kälter war als an den weit davon entfernt und beteutend südlicheren, nahe dem verhältnismässig warmen Nordseebecken gelegenen südbaltischen Portlandia-Örtlichkeiten? [1]

Für einen aufmerksamen Leser meiner Untersuchung braucht wohl kaum hingewiesen zu werden auf das völlig Unberechtigte in Hyyppäs auf S. 151 wiederzufinden Behauptung, dass ich es unterlasse, unter anderm die Silicoflagellaten zu berücksichtigen, »soweit sie die auf Grund der Diatomeen unternommene Verknüpfung von Mga und Rouhiala mit dem ostseeischen Portlandia in entschiedener Weise verhindern». Die wirklichen Ursachen dazu gehen vollauf aus meiner Abhandlung hervor. Ausserdem kann ich Hyyppä

---

[1]) Obgleich die Diatomeenfloren deutlich für ein kälteres Meer im NO als im SW sprechen, sind die Verschiedeheiten in dieser Hinsicht jedoch nicht in dem Grade beträchtlich, wie Hyyppä sie aufzufassen scheint. Betrachten wir Hyyppäs eigenes Verzeichnis der 7 Formen, die er für ganz sicher arktisch hält und die daher »als Belege für verschiedene klimatische Verhältnisse dienen können», so finden wir, dass unter ihnen *Campylodiscus angularis* und *Synedra camtschatica* als äusserst spärlich (niedrigste Frequenz!) angegeben sind, und zwar nur für Rouhiala und nicht für Mga, was auch mit *Dipl. bomboides v. media*, die jedoch etwas reichlicher vorkommt, der Fall ist. Dass diese spärlich auftretenden nichtplanktonischen Arten in Schulz' Portlandia-Verzeichnissen fehlen, ist nicht zu verwundern. Des weiteren konstatieren wir, dass die im Verzeichnis angegebene *Grammatophora arcuata* auch für einen portlandischen Fundort erwähnt ist! Da ich in Hyyppäs Verzeichnis ferner *Thalassiosira gravida*, die trotz ihrer Beheimatung zwischen den Eisschollen des Eismeeres jedoch nicht als ausschliesslich arktisch gelten kann, da Cleve-Euler (Cl. -E., 1937) sie im Öresundplankton aufgefunden hat, streiche, so finden wir, dass von den »sicheren arktischen Arten» aus Mga-Rouhiala nur die ziemlich spärlich vorkommenden *Coscinodiscus bathyomphalus* und *C. sublineatus* übrig sind, deren Fehlen in den südbaltischen portlandischen Artenverzeichnissen nach Hyyppä so stark gegen die Möglichkeit einer Nebeneinanderstellung spricht!

mitteilen, dass Schulz *Distephanus speculum* und *Dictyocha fibula* geradezu als Leitfossilien für die südbaltischen Portlandia-Ablagerungen betrachtet! Dass ich dies nicht ausgenutzt habe, hat seine Ursache darin, dass die genannten Silicoflagellaten trotz ihres in Mengen beobachteten Vorkommens zwischen den arktischen Eismassen dennoch als Ubiquisten gelten müssen.

Auf S. 152 geht Hyyppä dazu über, mein Kapitel über Klima und Vegetation zu kritisieren und ist der Ansicht, meine Auffassung, dass die Hagebuche niemals nach der Eiszeit in Finnland gewachsen sei, b e w e i s e, dass ich die neueste quartärgeologische Literatur Finnlands nicht vollauf kenne. Nach dieser an und für sich unberechtigten Behauptung erwartet der Leser von Hyyppä einen B e w e i s dafür, dass die Hagebuche nach der Eiszeit wirklich in Finnland g e w a c h s e n ist. Einen solchen kann er indes nicht führen! Dass *Carpinus*-Pollen in nacheiszeitlichen Bildungen des finnischen Festlandes sporadisch angetroffen wird, ist mir, trotz Hyyppäs »Beweis», wohlbekannt,[1] doch ist dies kein Beweis dafür, dass die Hagebuche wirklich im Lande g e w a c h s e n ist. Meine Ansicht, dass die Hagebuche in der I n t e r g l a z i a l z e i t in Finnland gewachsen ist, erscheint natürlich nicht unanfechtbar. Doch ist sie nicht so schwach begründet, wie Hyyppä zu verstehen geben möchte, sondern stützt sich darauf, dass das Verbreitungsgebiet von *Carpinus* nach Osten zu im letzten Interglazial weit grösser als nach der Eiszeit war (vgl. u.a. die Diagramme von Gams und Dokturowsky) — ich fand doch in Mga relativ hohe *Carpinus*-Prozente —, weshalb also die W a h r s c h e i n l i c h k e i t dessen, dass die genannte Holzart damals auch in Finnland wuchs, viel grösser ist, als die schwachen Anzeichen für deren postglaziales Auftreten im Lande zu bezeugen vermögen.

Nach einer längeren Beschreibung zweier interessanten südkarelischen Tonfunde, für welche Besprechung ich in jenem Zusammenhang die Veranlassung vermisse, setzt Hyyppä fort mit seiner Kritik, die diesmal wieder meinen Aufsatz über Mga betrifft. Auf S. 166 findet er meine Massnahme, die *Corylus*-Prozentsätze gesondert, ausserhalb der gemeinsamen Pollensumme, zu berechnen, »durchaus unbegründet». Diese Behauptung ist geeignet, einen jeden auch nur in gewissem Masse mit interglazialen Pollendiagrammen vertrauten Leser in höchstem Grade zu verwundern. Dass diese Verfahrensweise bei postglazialen Pollendiagrammen die gebräuchliche ist, weiss

[1]) Dass *Carpinus*-Pollen auf Åland angetroffen wird, ist mir ebenfalls bekannt; doch rechne ich Åland nicht zu dem finnischen Festland!

Hyyppä zweifellos recht wohl, doch scheine ich nicht umhin zu können, ihn darüber zu belehren, dass dasselbe auch bei den interglazialen Diagrammen der Fall ist. Ich brauche nur auf die grossen Diagramme von Jessen & Milthers, Dokturowsky oder Gams hinzuweisen. Da es mir nun darauf ankommt, Mga mit früher bekannten interglazialen Ablagerungen zu konnektieren, ist es wohl selbstverständlich, dass ich meine Spektren nach übereinstimmenden Prinzipien berechne! [1] Von Hyyppäs Parenthese »*Corylus* unter 20 %» erhält man die Auffassung, dass er meine Berechnungsweise verurteilt, weil dieser Prozentsatz zu niedrig wäre. Die prinzipielle Richtigkeit meiner Berechnung wird natürlich nicht verändert, so niedrig auch der betreffende prozentuale Anteil sein mag, aber hinsichtlich Hyyppäs Parenthese fragt man sich, w i e hoch der *Corylus*-Gehalt zu sein hat, damit eine Ausschaltung von der gemeinsamen Pollensumme unternommen werden dürfte. Wo soll die Grenze gezogen werden, frage ich Dr. Hyyppä. Reichen meine 35 Prozent *Corylus* in Rouhiala? Vermutlich hält er sie für ausreichend, da er nichts darüber erwähnt. Wie aber soll ich da meine Spektren von Rouhiala und Mga miteinander vergleichen, wenn sie nach verschiedenen Prinzipien zu berechnen wären?!

In seinem Eifer, in meiner Mga-Untersuchung Unrichtigkeiten herauszustellen, geht Hyyppä so weit, dass er einen Teil des Materials, dessen ich mich bedient habe, zur Kontrolle nochmals analysieren lässt! Dies motiviert er damit, dass es aus meinem Aufsatz hervorginge, wie ich die Pollenanalyse nicht vollständig beherrsche. Von dieser Ausdrucksweise hätte Hyyppä gern absehen können. Dass ich ein Präparat an Dr. Sandegren sandte, damit er die Richtigkeit meiner *Carpinus*-Bestimmung bestätige, darf nicht so aufgefasst werden, wie Hyyppä es getan hat. Dass ein Forscher einen anderen in w i c h t i g e n Fällen, wie z. B. dem vorliegenden, konsultiert, trotzdem er von der Richtigkeit seiner Diagnose fest überzeugt ist, dürfte Hyyppä nicht unbekannt sein. — Die Kontrollanalyse führte indes zu Ergebnissen, die mit den meinigen übereinstimmten!

[1]) Auch Pokrowskaja (1936) hat nach dem, was ich nach genauen Messungen an ihren Diagrammen gefunden habe, *Corylus* gewiss nicht unter die Holzpollen begriffen; vgl. z. B. das Spektrum aus 30 cm über dem Wasserspiegel in Pokrowskajas Diagramm über den Schnitt von Mga. Hyyppäs entgegengesetzte Auffassung darüber ist falsch, soweit das genannte Spektrum richtig gezeichnet ist!

LITERATUR.

BRANDER, G., 1937 a. Zur Deutung der intramoränen Tonablagerung an der Mga, unweit von Leningrad. C. R. Soc. géol. Finlande, N:o 10. Bull. Comm. géol. Finlande, N:o 119.

—»— 1937 b. Ein Interglazialfund bei Rouhiala in Südostfinnland. Bull. Comm. géol. Finlande, N:o 118.

CLEVE-EULER, ASTRID, 1937. Undersökningar över Öresund, XXIV. Sundets plankton. I. Sammansättning och fördelning. Lunds Universitets årsskrift, N. F., Avd. 2, Bd 33, N:o 9.

HYYPPÄ, E., 1937. Bemerkungen über G. Branders Aufsatz »Ein Interglazialfund bei Rouhiala in Südostfinnland», und zwei neue Tonfunde auf der karelischen Landenge. C. R. Soc. géol. Finlande, N:o 10.

ПОКРОВСКАЯ, И. М., 1936. О межморенных отложениях р. Мги. Abhandl. d. Sowjet-Sektion d. internat. Assoz. für d. Studium des Quartärs (INQUA). Leningrad-Moskau 1936.

SUKATSCHEW, W. N., 1936. Grundzüge der Entwicklung der Vegetation in der UdSSR im Pleistozän. Beiträge zur Kenntnis des Quartärs der UdSSR. Sowjet-Sektion der INQUA. Leningrad-Moskau 1936.

Uusia jäseniä Suomen Geologiseen Seuraan valitaan kahden jäsenen ehdotuksesta.

Seuran julkaisut ilmestyvät sarjassa *Bulletin de la Commission géologique de Finlande*, ja jaetaan

1. kaikille jäsenille,
2. niille, jotka saavat mainitun sarjan,
3. laitoksille ja yhdistyksille, jotka haluavat julkaisujen vaihtoa.

Suomen Geologisen Seuran osoite on Helsinki, Bulevardi 29.

Medlemmar i Geologiska Sällskapet i Finland inväljas på förslag av två av Sällskapets medlemmar.

Sällskapets publikationer utgivas i serien *Bulletin de la Commission géologique de Finlande* och utdelas till

1. Sällskapets medlemmar,
2. personer, som fått mottaga nämnda serie,
3. institutioner och sammanslutningar, vilka önska träda i skriftutbyte med Sällskapet.

Geologiska Sällskapets i Finland adress är Helsingfors, Boulevarden 29.

Pour devenir membre de la Société géologique de Finlande on doit être présenté par deux membres.

Les publications de la Société seront éditées dans la série *Bulletin de la Commission géologique de Finlande* et seront distribuées

1. aux membres de la Société,
2. aux personnes ayant reçues la présente série,
3. aux institutions et aux associations désirant entrer en échange des publications.

S'adresser à la Société géologique: Boulevard 29, Helsinki.