SUOMEN GEOLOGINEN TOIMIKUNTA

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

XIII

AVEC 45 FIGURES DANS LE TEXTE ET 1 PLANCHE

HELSINKI
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Kirjoituksia — Papers

1.

PRELIMINARY NOTES ON THE GEOCHEMICAL PROPERTIES OF THE MAARIANVAARA GRANITE

by

TH. G. SAHAMA and KALERVO RANKAMA.

The scope of the work. The fundamental laws governing the geochemical distribution of the most elements in nature are now known by the ingenious and elaborate work of V. M. Goldschmidt, and others. In this connection, the authors wish to refer only to Goldschmidt's recent paper (1937), in which he gives an epitome of the progress and of the results of modern geochemistry.

The ruling principles of the regional geochemistry, however, are less investigated. The only paper dealing with the regional geochemistry of Finnish rocks by comparing different areas with the aid of rarer elements is that of Erämetsä (1938). In this paper, Erämetsä alludes to the presence of two provinces, particularly rich in indium, in Finland.

One of the main tasks of the regional geochemistry is to divide the rocks into certain provinces, which show marked similarities when characterized by their content of the rarer elements. It is evident that such a division can be established only when a large number of rocks have been studied. To start with, the present authors wish to characterize the Maarianvaara granite, as an example of the Finnish Archaean granites, by means of some of its accessoric elements.

The Maarianvaara granite area is situated in East Finland, mainly in the parishes of Kaavi, Tuusniemi, Kuusjärvi, and Heinävesi. It is showed as »Postkalevian granite» on the Joensuu sheet (D 3) of the General Geological Map of Finland, published by the Geological Survey. The Maarianvaara granite appearing as one fairly large irregular massif and several small satellitic bodies, cuts trough the surrounding late-Karelidic and older rocks thus belonging to the group of the very youngest Finnish Archaean granites. The colour of the medium- or fine-grained main type is gray or red. Pegmatitic varieties are met with in abundance. They are even, in some places, the dominant type.

5172,—38

In the summer of 1938 the first author had an opportunity of visiting the Maarianvaara area under the kind guidance of Dr. Heikki Väyrynen and Dr. Erkki Aurola. Under these excursions hand specimens were collected for the present study.

The methods. The investigation of the rock specimens was carried out by means of optical spectrography in the geochemical laboratory which, under the leadership of Professor Pentti Eskola, newly has been established at the Mineralogical and Geological Institute of the University, Helsinki. The spectra were photographed with the Zeiss Quartz Spectrograph Qu 24 and with the Zeiss Three Prism Spectrograph using the wave-length range from 3 900 to 4 800 Å. The carbon arc was sharply projected on the slit of the spectrograph. By using the carbon arc cathode layer method, as developed by Mannkopff and Peters (1931), six subsequent exposures were made on the same photographic plate. An account of the spectrum lines used, together with a detailed description of the methods will be published in the succeeding papers.

Rare earths. The rare earths with few exceptions form, according to Goldschmidt (1937), the most coherent group of elements. The ratio of the concentrations of the different members in nature usually is constant. We, thus, can already expect a constant concentration ratio of the rare-earth elements in Finnish granites. On the contrary, it might be possible that there are fluctuations in the total amounts of these elements.

As shown by the preliminary studies of a number of the Finnish Archaean granites, made by the authors, the rare earths, including scandium and yttrium, may well serve as »Index Elements» when making a geochemical classification of the aforesaid rocks. This depends upon the fact that the occurrence of the rare earths in Finnish granites is relatively selective. The percentage of rare-earth elements in the granites of *e. g.* Bodom, Åva, and Nattanen is especially high. As to the Nattanen granite, this is due to the presence of orthite as one of its essential constituents, as pointed out by Mikkola (1928).

The presence of the following rare earths at the least has been determined by the authors in a material in which the chemical enrichment of the elements in no case was made: Sc, Y, La, Ce, Pr, Nd, and Eu. It now seems to be evident that the granites richest in the rare earths usually occur amongst the younger ones, although the older granites sometimes also contain relatively large amounts of the rare-earth elements (the granite of Finnbacka Lillsjö in Karjaa, and others). The granites of Kajaani and Maarianvaara, belonging to the youngest Archaean granites, however, show an exceptionally low content of the rare earths. Because of the frequent occurrence of pegmatitic varieties in these granites, especially in that of Maarianvaara, one could suspect that the rare earths were to be sought in these last crystallizing portions of the granitic magma. The pegmatites are, according to the observations, very poor in the rare earths indeed, and so the magma of the Maarianvaara granite must have been almost devoid of these elements.

Strontium and barium. These elements nearly always are present in Finnish granites. Only in some few cases their percentages are low (granites of Unonen in Kalvola, and Kajaani). It would be well to determine the strontia and the baria in rocks more than occasionally in order to gain new ideas regarding the geochemical classification of the rocks. The general rule in the Finnish granites seems to be, that when large amounts of rare-earth elements are present, the percentage of barium and, especially, that of strontium is high, but a considerable content of these alkaline earths does not necessarily imply any notable quantity of the lanthanides. The granite of Maarianvaara, *e. g.*, being very poor in the rare earths, nevertheless, contains appreciable amount of strontium and barium. We may, further, note that there is no constant concentration ratio of barium and strontium in the Maarianvaara granite. The barium is often strongly enriched especially in the pegmatitic varieties.

Chromium and vanadium. These elements always occurring together in the granites show marked variations in their amounts. The granites of Maarianvaara, Sassi in Tottijärvi, Salosaari in Mikkeli, and Lemland are relatively rich in vanadium and chromium, but those of Unonen and Taljala in Kalvola, Lietsaari in Lohja, Kajaani, Onas, Obbnäs, and others, show low percentages of these elements. It is evident that by means of accurate photometric measurements several differences might be found in the concentration ratio of chromium and vanadium. The qualitative determinations, however, already show the changes in the total amount of these elements. As compared with the Kajaani granite, the Maarianvaara granite is found to follow the same principles as for its strontium and barium contents.

Other elements. Gallium is always found to be present in the granites. According to Goldschmidt and Peters (1931) the amount of this element in minerals is largely variable. It might be possible, however, that the changes in gallium in the Finnish Archaean granites are relatively small. Thus there would be rather poor possibilities for the use of gallium as an Index Element.

Zinc and lead usually are present in the youngest Archaean granites of Finland. Zinc most probably would serve as an Index Element. As for lead, it may be mentioned that this element is especially enriched in the felspar of the pegmatite of Luikonlahti (which is a variety of the Maarianvaara granite). This phenomenon has been detected and accounted for by Goldschmidt (1937) in potash felspars.

The data given above might well serve for showing that it is possible, with the aid of the rarer elements, to divide the granites into separate groups. As pointed out by Eskola (1932) granitic magmas may also originate by partial re-fusion of older rocks. In other words, all the granites are not of purely magmatic origin. It is to be hoped, however, that the division of the Finnish Archaean granites pointed out above, being purely descriptive in its nature, can be used for the most rocks of granitic composition.

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

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2.

ÜBER EINIGE EISENERZE IM JUSSAARIGEBIET, SW-FINNLAND

VON

MARTTI SAKSELA

VORWORT.

Die folgende Darstellung handelt von den Eisenerzen auf den Inseln Iso Jussaari und Pieni Jussaari (Grosse und Kleine Jussaari) [1], von dem ausgedehnten untermeerischen Eisenerzvorkommen auf der SE-Seite von Iso Jussaari und von dem kleinen Magnetitvorkommen auf der Klippeninsel Hästö Utterharu, 11.3 km von Iso Jussaari nach SSW. Schon längst waren die Gegenden von Jussaari als gefährlich für die Seefahrt bekannt, und nicht am wenigsten darum, dass wegen magnetischer Störungen in grossen Gebieten auf den Kompass kein Verlass war. Diese Störungen, schon angegeben in der Seekarte über den westlichen Teil des Finnischen Meerbusens, die in dem zu Beginn des 16. Jahrhunderts in Amsterdam erschienenen Werke von Lucas Waghenaer »Den graten dobbelden nieuwe Spiegel der Zeelidert» etc. enthalten ist, haben Anlass zu mehreren genaueren magnetischen Untersuchungen gegeben (19). Die letzten und ausführlichsten Untersuchungen wurden gegen das Frühjahr 1898 vorgenommen, zu welcher Zeit A. F. Tigerstedt unter Mitwirkung von A. v. Julin und J. Boxström die beinahe 4 km lange magnetische Zone zwischen den kleinen Klippeninseln Lerharun, Orkobben und Stenlandet (das Jussaari — Segerstengebiet), das Väster-Gaddengebiet südwestlich von dem vorhergehenden und vergleichsweise noch das östliche Grubengebiet auf Iso Jussaari magnetometrisch aufnahm. Die Untersuchungen wurden mittels zweier Magnetomer und nach den von Thalen, Tiberg und Dahlblom entwickelten Methoden ausgeführt. Auf dem

[1] Gegenwärtig werden die Inseln oft Jussarö genannt, welche schwedische Benennung auch im Firmanamen einer Grubengesellschaft, die hier gearbeitet hat, vorkommt. Im folgenden wird nur der Name Jussaari gebraucht, wie früher die Inseln auch in der schwedischen Literatur oft genannt worden sind (vgl. Laine, Eevert, Jussaaren rautakaivos valtion käyttämänä vuosina 1834—1861. Hist. Ark. XXXVII, 3, Helsinki 1929).

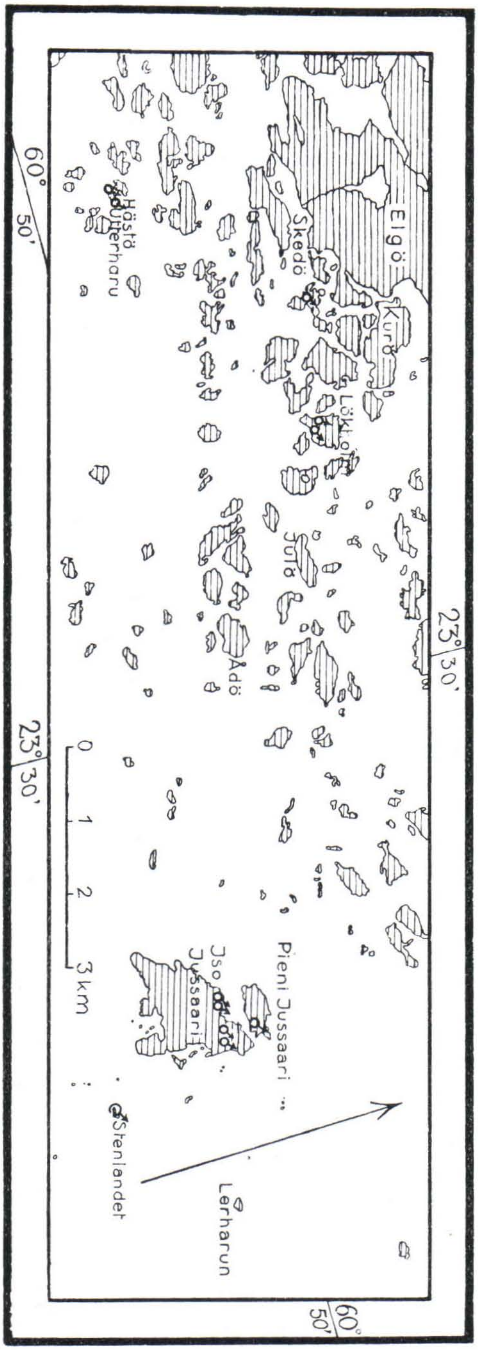

Abb. 1. Übersichtskarte des Jussaarigebietes. Die einzelnen Eisenerzvorkommen sind in die Karte eingetragen.

erstgenannten Gebiete waren die Störungen zusammenhängend und beteutend stärker als auf Iso Jussaari (G stellenweise grösser als 4 H). Es war offenbar, dass in diesem Gebiet bedeutende Erzmengen enthalten waren. Um die Beschaffenheit des Erzes einigermassen ausfindig zu machen, wurden gegen Ende der Untersuchungen, nach vorhergehenden Lotungen, Versuche gemacht, durch Taucher Proben vom Erz zu erhalten. In denjenigen Erzproben, welche vor dem Eisgang heraufgeholt wurden, variierte der Gehalt an Fe zwischen 20 und 35 % (19, S. 13). Im Rapport von Dr. E. Ganz (4) wird erwähnt: »Proben, welche durch Taucher vom Meeresgrunde im Mai 1898 heraufgeholt wurden, zeigten nach Analysen von C. G. Särnström, vom chem. Lab. der Kgl. Bergschule in Stockholm folgende Zusammensetzung: a) 35.2 % Fe, 0.031 % P und 0.005 % S; b) 34.4 % Fe, 0.023 % P und 0.007 % S.» Das Erz war also arm, obwohl, was die P- und S-Gehalte betrifft, ziemlich gutartig. Weil jedoch die Proben gering an Zahl und von solchen Stellen des Meeresgrundes genommen waren, die zufällig entblösst lagen, konnten sie natürlich kein zuverlässiges Bild über die Art des Erzes geben. Im Frühling 1898 wurde eine Gesellschaft gebildet zu dem Zwecke, mittels Schacht- und Ortarbeiten zuverlässige Kenntnisse von der Art des Erzes, von der Mächtigkeit des Erzkörpers usw. zu erhalten. Die Arbeit fing schon im August desselben Jahres an. Auf der 50 m breiten, 200 m langen und nur 2—3 m über die Wasserfläche aufragenden Insel Stenlandet wurde ein 60 m tiefer vertikaler Schacht abgeteuft und in einer Tiefe von 30 m ein 40 m langer Querort nach Süden getrieben. Der Querort hatte das Erz in 27 m Entfernung vom Schachte getroffen, aber auf der erwähnten Strecke von 40 m noch nicht den Erzkörper durchbrochen. Aus dem Erz wurde dann ein etwa 8 m breter, 13 m langer und 6 m hoher Raum herausgebrochen. — In seinen Erwartungen sah man sich jedoch getäuscht, was die Art des Erzes betraf. Nach den Analysen (im Jahre 1904 zusammengestellt) variierte namentlich der Eisengehalt zwischen 29 und 49 %, während er durchschnittlich nur 30—35 % war. In dieser Menge war auch dasjenige Eisen enthalten, das in den eisenhaltigen Silikatmineralen gebunden war. Die Grubenarbeit dauerte nicht lange. Von den 800 in den Jahren 1898—1901 herausbeförderten Tonnen Haufwerk waren ca. 250 Tonnen Eisenerz. — Im Jahre 1919 wurde die Arbeit wieder aufgenommen, dieses Mal auf die Initiative der Gesellschaft Jussarö gruva A. B. und unter Leitung von Ing. Y. Grönros. Der hauptsächliche Finanzier war die A. G. Fried. Krupp. Die Grube wurde lenz gemacht, und in einer Tiefe von 56 m wurde ein neuer Querort nach Süden getrieben. Armes Erz wurde in 9 m Entfernung vom Schachte angetroffen, reicheres Erz wiederum zwischen 12 und 15 m sowie zwischen 18 und 30 m. Die aus dem ersteren reicheren Erzlager genommene Generalprobe enthielt 24.9 % HCl-lösliches Eisen. Dem letzteren, 12 m mächtigen Erzlager wurden 100 kg schwere Mittelproben in jedem Längenmeter entnommen und von diesen Proben wieder eine Generalprobe. Diese enthielt 28.3 % HCl-lösliches Eisen. In 30 m-Sohle wurde der alte Querort um 5 m verlängert, wobei der Giebel des Ortes noch aus Erz bestand. Aus den Wänden des im Erz gesprengten Grubenzimmers wurden an 12 Stellen Proben entnommen. Diese enthielten 24.2—30.0 % HCl-lösliches Eisen. Durchschnittlich enthielten sie 26.3 % Magnetiteisen und 3.8 % Silikateisen. — Die Grubenarbeit war auch dieses Mal von kurzer Dauer. Schon im Jahre 1921 wurde die Arbeit eingestellt, und seitdem ist die Grube nicht mehr unter Arbeit gewesen. — Auch Aufbereitungsversuche sind mit dem Erze vorgenommen worden, und zwar von Ing. E. Pyhälä im Jahre 1904 und von Berging. Karl Sundberg während der letzten Tätigkeitsperiode der Grube. Die Versuche gaben wenig trostreiche Resultate (vgl. S. 21).

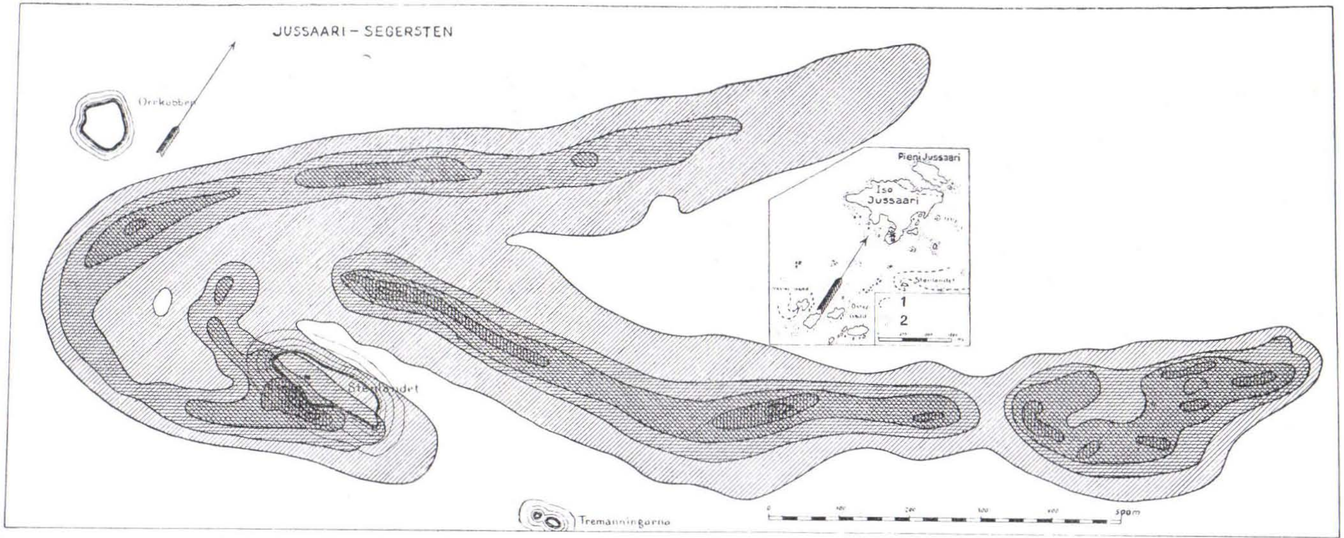

Abb. 2. Magnetische Karte des Jussaari-Segerstengebietes. Nach der Karte von A. F. Tigerstedt. Isodynamen für G = 0.2, 0.5, 1, 2 und 3 H. In der kleinen Karte bedeuten: 1. Magnetische Störungsgebiete (schematisch), 2. Untiefen.

Das Eisenerzvorkommen auf der Insel Iso Jussaari wurde im Sommer 1834 von Bergkadett E. J. Vestling entdeckt, als er hier auf Anregung von Oberintendant Nils Nordenskiöld Erz suchte. Die Erzzone zieht von Osten nach Westen im nördlichen Teil der Insel, und ist nach Vestling 380 Faden lang und höchstens 6 Ellen breit. Bei Schmelzversuchen wurden aus dem Erz 28 % Roheisen erhalten, das jedoch ziemlich langsam frischend war. Wenn dagegen in das Jussaari-Erz in passendem Verhältnis andere Eisenerze eingemengt wurden, erhielt man beim Schmelzen sehr gutes Stangeneisen. Nach Tigerstedt (19, S. 12) enthielt das Erz nur 25—29 % Eisen, aber sonst war es sehr gutartig, d. h. frei von Phosphor und Schwefel. Das Vorkommen wurde vom Staate gemutet, und die Grubenarbeit fing schon im Sommer desselben Jahres (1834) an. Die Arbeiten wurden dann bis 1861 fortgeführt und nur in den Jahren 1838—39 sowie während des Krimkrieges von März 1854 bis November 1856 eingestellt. Während dieser Zeit wurden im ganzen 187 576 Schiffspfunde (ung. 13 130 Tonnen) Erz aus neun Gruben gefördert. Am meisten, 15 388 Schiffspfunde, gewann man im Jahre 1851. Das Erz wurde an die einheimschen Hüttenwerkbesitzer verkauft. Der grösste Konsument (68 095 Schiffspfunde) war der Besitzer der Hochöfen von Vantaa und Teijo, Bergrat V. Z. Bremer. — Die Gruben (die Pingen) lagen in zwei Gruppen (im westlichen und östlichen Grubengebiet). Bevor man sie endgültig aufgab, wurden die Tiefe der Pingen, die Breite und Länge der Sohle sowie die Mächtigkeit des Erzlagers vom Grubenleiter K. Frey gemessen. Die Resultate sind aus der nachstehenden, von E. Laine (8, S. 60) zusammengestellten Tabelle ersichtlich:

Name der Grube (Pinge)	Tiefe in Fuss	Sohle		Breite des Erzlagers in Fuss	Bemerkungen
		Länge in Fuss	Breite in Fuss		
Itäinen uusi kaivos (*Die östliche neue Grube*)	124	140	11	7—8	
Itäinen pikku kaivos (*Die östliche kleine Grube*)	146				
Itäinen keskikaivos (*Die östliche mittlere Grube*)	146	80	11	7—8	Kein Erz in der Pingensohle sichtbar.
Itäinen syvä kaivos (*Die östliche tiefe Grube*)	136	86	11	7—8	
Itäinen rantakaivos (*Die östliche Ufergrube*)	136	76	11	7—8	
Läntinen keskikaivos (*Die westliche mittlere Grube*) .	174	104	6—8	2—4	
Läntinen syvä kaivos (*Die westliche tiefe Grube*)	158	100	6—8	2—4	
Läntinen rantakaivos (*Die westliche Ufergrube*)	84	60	5	3	Nur die östliche Hälfte der Sohle besteht aus Erz.
Läntinen merikaivos (*Die westliche Meergrube*)	119	80	5	3—4,5	

Die Grubenarbeit auf Iso Jussaari war nicht lohnend, trotzdem man vom Jahre 1841 Gefangene als Arbeitskräfte einstellte. In den 24 Jahren, in denen die Grube auf Rechnung des Staates betrieben wurde, hatte man nach Berechnungen des Oberintendanten G. Laurell ein Einkommen von 44 157 Rubel oder nur ung. die Hälfte der Unkosten gedeckt. — Was die Grubenarbeit auf Jussaari sonst betrifft, kann ich auf die ausführliche Beschreibung von Laine hinweisen (8).

Im vorigen Jahrhundert wurden auch auf Lerharun, Väster-Gadden und Pieni Jussaari in geringem Masse Schurfarbeiten ausgeführt, aber mit unbedeutendem Erfolg. Über die letztgenannten wird im Rapport von E. Ganz folgendes erwähnt: »In der östlichsten Landzunge finden sich einige Erzlinsen, von welchen drei durch Schurfen ausgebeutet wurden. Die westl. Pinge ist 7.5 m lang und 3 m breit, die östlichste 10 m lang und 1 m breit. Die Pingen sind nicht tief; es wurden kaum ein paar m^3 Haufwerk ausgebrochen». — Auf Hästö Utterharu ist keine Schurfarbeit ausgeführt worden.

GEOLOGISCHE BESCHREIBUNG DER LAGERSTÄTTEN.

HÄSTÖ UTTERHARU.

Der grösste Tei dieser kleinen Klippeninsel besteht aus grauem oder etwas rötlichem, meistens deutlich schiefrigem mittelkörnigem Granodiorit. Als Hauptbestandteile kommen Quarz, Plagioklas (An_{33}), Biotit und Hornblende, als Nebenbestandteile etwas Apatit, Titanit und Erzkörner vor. Das Gestein enthält ziemlich viel dunkle Bestandteile. Im Granodiorit kann man zahlreiche rote, mikroklinreiche, bis 2 m mächtige Pegmatitgänge beobachten. Diese verlaufen meistens parallel mit der Schiefrigkeit des Granodiorits, können aber stellenweise die Schiefrigkeitsrichtung auch in grossem Winkel durchschneiden. Ebenfalls enthält der Granodiorit längliche und schiefrige Bruchstücke von paragneisartigen, glimmerschieferartigen, amphibolitischen und uralitporphyritischen Gesteinen. Die Bruchstücke sind ziemlich genau parallel mit der Schiefrigkeit des Granodiorits geordnet.

Der Pegmatitgranit geht oft allmählich in einen kleinkörnigeren, rötlichen, aplitischen Granit über, der letztgenannte wiederum stellenweise in Granodiorit. Dies deutet offenbar darauf hin, dass alle oben erwähnten Magmengesteine zu derselben Eruptionsserie gehören und dass der Granodiorit nur etwas älter ist als die anderen. Aller Wahrscheinlichkeit nach gehören diese Gesteine zu der älteren, hochorogenen Gruppe des Gneisgranits (die Gruppe I Sederholms. Vgl. 14, 15, 16 und auch 7).

Der N-Strand der Insel besteht aus dunkelgrauen, feinkörnigen (Korndiameter durchschnittlich 0.15 mm) Hornblende-Biotitschiefern. Als Hauptbestandteile kommen gemeine grüne Hornblende, Biotit, Plagioklas und Quarz vor. In kleinen Mengen beobachtet man Apatit, Erzkörner, in den Biotitschuppen Zirkonkörner mit pleochroitischen Höfen und als Umwandlungsprodukt des Plagioklases ein wenig Serizit. Die Struktur ist schön kristallisationsschiefrig. Bei der Zunahme der relativen Hornblendemenge und der gleichzeitigen Abnahme der Quarzmenge geht der Schiefer in ein amphibolitisches Gestein über. Wenn die Menge des Biotits wieder der Hornblendemenge gegenüber zunimmt, geht er in ein paragneisartiges Gestein über. Die Zusammensetzung des Plagioklases ist in den hornblendereichen Schiefern An_{55-58}, in den hornblendearmen Varietäten An_{30}.

Die Achsialrichtung ist auf der Insel sehr konstant 60° nach N 80°—85°W. Das Streichen ist N 70°—80°E und das Fallen 70°—76° nach SSE.

M a g n e t i t v o r k o m m e n werden im W- und im E-Teil der Insel, und zwar in den Grenzgebieten zwischen den oben beschriebenen Gesteinskomplexen, angetroffen. Im W - E n d e der Insel ist das eigentliche Erzlager auf beiden Seiten von schmalen Zonen migmatitischer Gesteine umgeben. Diese bestehen aus roten pegmatitischen und aus dunklen biotitreichen glimmerschieferartigen Bändern. Jene enthalten vorzugsweise Mikroklin, Quarz und Plagioklas (An_{15-20}). Dazu kann man einzelne Körner von rotem Granat (Almandin), grüner Hornblende, Biotit, Magnetit und Apatit beobachten. Die dunklen Bänder bestehen hauptsächlich aus Biotit, Almandin, grüner Hornblende, Magnetit und Quarz in wechselnden Proportionen. Auch kann stellenweise Plagioklas (An_{30}) beobachtet werden. In den Granatkörnern sieht man sowohl Biotit- als auch Magnetiteinschlüsse. In denjenigen dunklen Bändern, die vom eigentlichen Erzlager weiter entfernt sind, ist der Biotit ziemlich grobkörnig und reichlich vertreten. Wenn man sich dem Erzlager nähert, nimmt allmählich die relative Menge des Magnetits und gewöhnlich auch die der Hornblende und des Granats zu. Gleichzeitig werden sowohl die dunklen als auch die hellen Bänder kleinkörniger und schmäler sowie die gegenseitigen Kontakte schärfer. Weiter vom Erz entfernt unterscheiden sich die dunklen Ränder oftmals gar nicht scharf vom granitischen Material, und sie enthalten nun auch Mikroklin und sauren Plagioklas in wechselnden Mengen.

Das Erz ist schön gebändert und aus 1—4 mm mächtigen rötlichen Quarz-Mikroklinbändern sowie aus dunklen, reichlich Magnetit, Granat, Quarz und grüne Hornblende oder farblosen Amphibol enthaltenden Bändern zusammengesetzt (Abb. 3). Die Mineralbestand-

Abb. 3. Gebändertes Erz. Die hellen Bänder bestehen aus Quarz und rotem Mikroklin. Hästö Utterharu. Nat. Grösse.

teile sind, ausser dem Granat, sehr unregelmässig geformt. Besonders die Magnetitkörner sind zerfetzt und in längliche, stellenweise beinahe haarförmige Streifchen ausgezogen (Abb. 4). Die Granatkörner sind

Abb. 4. Aus dem westlichen Erz von Hästö Utterharu. Magnetit (schwarz), Quarz (weiss) und trüber Amphibol (grau). Vergr. 32×. Nic. //.

unregelmässig rundlich, und man kann an ihnen nicht selten Kristallflächen beobachten. Der Quarz besitzt eine kräftig undulierende Auslöschung. Die Korngrösse des Magnetits (mit der Rosiwalschen Methode bestimmt) geht aus folgendem hervor.[1]

0.005—0.05 mm	29.2 %	0.1—0.3 mm	35.2 %
0.05 —0.1 mm	24.0 %	0.3—0.5 mm	11.6 %

Das Erzlager ist an der Stelle des magnetischen Maximums und längs einer Strecke von 18 m entblösst. Reicheres Erz, ung. 40 % Fe enthaltend, wird in einer Mächtigkeit von nur ca. 80 cm angetroffen.

Gemäss einer Analyse, die man im Renlundschen Berglaboratorium (E. J. Ingman) aus einem Handstück gemacht hat, enthält dieses Erz 0.2 % TiO_2.

Das reiche Erzlager grenzt auf beiden Seiten an ärmeres, vielleicht doch zur Aufbereitung taugliches Erz. Die totale Mächtigkeit der beiden Erzqualitäten beträgt höchstens 2 m. Die mineralogische Zusammensetzung beider ist ziemlich gleichartig. In letzterem werden doch stellenweise andesinischer Plagioklas und Biotit angetroffen.

Im E-Ende der Insel kommt das Erz ebenfalls in einer migmatitischen Zone vor, die einerseits an den Schiefer, anderseits an einen Pegmatitgang von einigen Metern Mächtigkeit grenzt. Das Erz ist im allgemeinen sehr arm. Es mag erwähnt werden, dass im Pegmatit, in der Nähe der Migmatitzone, hie und da unregelmässig geformte dunklere Klumpen oder Schlieren vorkommen, die (ausser den Hauptbestandteilen des Pegmatits) mehr als gewöhnlich grosse Magnetitkörner sowie im Zusammenhang mit diesen Granat, Biotit und auch ein wenig Apatit enthalten (Abb. 5). Die Kontakte gegen den umgebenden normalen Pegmatit sind sehr unscharf. — Ein Handstück des Erzes wurde im Renlundschen Berglaboratorium analysiert, und es enthielt u. a. 0.02 % P sowie 0.048 % S.

Die magnetischen Störungen erstrecken sich ausserhalb der Insel nach W und E und bilden ein ca. 1 200 m langes und durchschnittlich 60 m breites, einheitliches Gebiet. Die Störungen sind zum grössten Teil schwach (G ist gewöhnlich kleiner als 0.5 H). Seinen grössten Wert (4.5 H) erreicht G beim Ausgehenden des westlichen Erzkörpers.

ISO JUSSAARI.

Das westliche Grubengebiet: Wie auf Hästö Utterharu, kommt das Erzlager auch hier in einer migmatitischen Zone,

[1] Die Prozentzahlen geben also an, wieviel der ganzen Magnetitmenge in Körnern von bestimmter Grösse enthalten ist.

in Grenzgegenden zwischen einem am N-Ufer der Insel auftretenden Schiefergebiet und einem in der Richtung des Streichens der Schiefer langgestreckten Pegmatitgranitmassiv vor (vgl. 9). Der Schiefer ist ähnlich wie im vorigen Gebiete. Vielleicht ist jedoch die relative Menge der paragneisartigen Varietät grösser. An der Pegmatitgrenze weicht die Zusammensetzung des Schiefers oft vom normalen ab. Im Schiefer kommt ausser den erwähnten gewöhnlichen Bestandteilen mehr oder weniger Granat vor. Ebenfalls kann man in ihm mehr als

Abb. 5. Biotit-Granatschlieren in Pegmatit. Hästö-Utterharu. Vergr. 12×. Nic. //.

gewöhnlich Magnetitkörner beobachten und ist auch die relative Quarzmenge grösser als in normalen Fällen. Der Mikroklin scheint ganz zu fehlen. Ein solcher »vererzter Schiefer» geht allmählich in den normalen Schiefer über und kommt nur als dessen schmale Randzone vor. Gleichartiger »vererzter Schiefer» wird auch auf Hästö Utterharu angetroffen.

Der Pegmatit ist rötlich und sehr mikroklinreich.

Die dunklen Bänder der migmatitischen Gesteine und besonders deren Biotitmaterial sind ziemlich grobkörnig. Wie auf Hästö Utterharu nimmt die relative Biotitmenge ab, wenn man sich dem eigentlichen Erzlager nähert; gleichzeitig nehmen die relativen Magnetit-und Hornblendemengen zu. Auch die Menge des Quarzes ist jetzt erheblich.

Das Erz selbst ist meistenteils schön gebändert, was darauf beruht, dass die Granat- und Hornblendekörner sich in getrennte Bänder geordnet haben, zwischen denem wieder quarzreiche Bänder vorkommen (Abb. 6). (Quarz tritt auch in den ersteren Bändern auf). Die Bänderung wird noch durch die im Erz auftretenden schmäleren

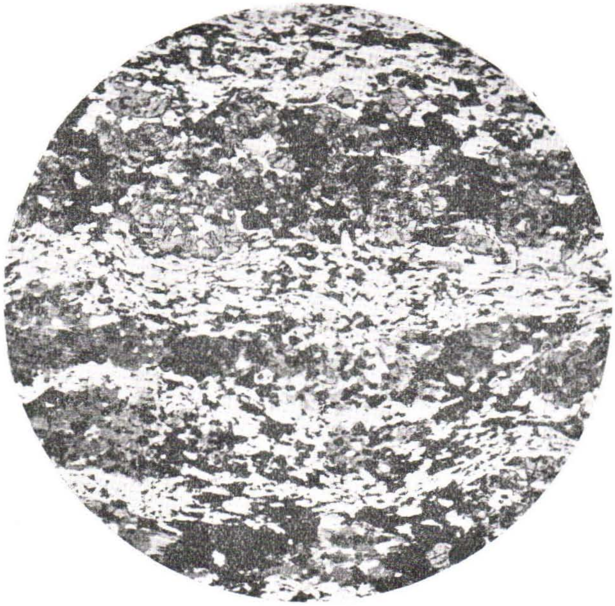

Abb. 6. Gebändertes Erz. Quarz-, amphibol- und granatreiche Bänder. Magnetit kommt in allen Bandarten vor. Das westliche Grubegebiet von Iso Jussaari. Vergr. 12×. Nic. //.

oder breiteren, parallelen Quarz-Mikroklin (Pegmatit-)adern hervorgehoben. Der Magnetit hat sich ziemlich gleichmässig in den quarz-, granat- und hornblendereichen Bänden verteilt. Ausser den oben erwähnten Mineralen kann man im Erz auch ein wenig Apatit beobachten. Alle Mineralindividuen sind ausserordentlich unregelmässig geformt. Die Magnetitkörner sind oft in langgestreckte Fetzen ausgezogen .Die Granat- und Hornblendekörner, deren Zerrissenheit noch durch die in ihnen vorkommenden zahlreichen Quarzeinschlüsse hervorgehoben wird, sind gewöhnlich grösser als die übrigen Mineralbestandteile und messen durchschnittlich ca. 1 mm im Durchmesser.

Die länglichen Magnetitindividuen sowie die Quarz-Magnetitbänder biegen sich sehr oft schön um diese Körner.

In den im Erz vorkommenden breiteren Pegmatitgängen beobachtet man stellenweise granat- und magnetitreiche Flecken, deren Kontakte gegen die umgebende Pegmatitmasse sehr unscharf sind. Der Granat bildet in diesen Flecken runde Körner, deren Zwischenräume mit einer Magnetit-Biotitmasse angefüllt sind (Abb. 7). Magnetit kommt oft innerhalb der Biotitschuppen vor, und zwar als

Abb. 7. Aus einem granat-, biotit- und magnetitreichen Klumpen in Pegmatit. Das westliche Grubengebiet von Iso Jussaari. Vergr. 13×. Nic. //.

schmale Streifen, die parallel mit den Spaltrissen des Biotits verlaufen. Ebenfalls füllt er Risse, die in den Granatkörnern auftreten. Offenbar gehört der Granat (und die Hornblende) zu den Mineralen des Pegmatits, die zuerst auskristallisiert sind. Erst nach diesen und nach dem Biotit scheint der Magnetit kristallisiert zu sein.

In einem aus dem Erz angefertigten Dünnschliffe wurden die Variationen der Korngrösse des Magnetits bestimmt:

0.005—0.05 mm	...... 41.5 %	0.1—0.3 mm	.... 21.5 %
0.05 —0.1 »	...... 23.3 »	0.3—0.5 »	.... 13.7 »

Südlich des Pegmatitgebiets, an das die Erzzone grenzt, wird ein graues oder schwach rötliches, mittelkörniges, dem Hästö Utterharu-

Granodiorit gleichendes Gestein angetroffen. Die gegenseitigen Verhältnisse zwischen ihm und dem Pegmatit konnten in diesem Gebiet nicht klargestellt werden.

Das allgemeine Streichen im westlichen Grubengebiet von Jussaari ist N 75°—80°E. Die Achsialrichtung ist 80° nach N 75° W.

Das Auftreten und die Beschaffenheit des Erzes ist sehr gleichartig auch im östlichen Grubengebiet von Jussaari. Es mag jedoch erwähnt werden, dass der Granatgehalt des Erzes oft sehr gross ist. In die Augen fallend sind die im Erz vorkommenden Granat-Quarzbänder. Aus diesen Bändern liessen sich leicht Splitter für die Bestimmung des Brechungsexponenten mittels Immersionsmethode losmachen. Als Immersionsflüssigkeiten wurden Lösungen von $AsBr_3$ und AsS in Methylenjodid verwendet (2):

$$n_{Na} = 1.796$$

Es handelt sich also um einen Granat der Almandin-Pyropserie, der nach Eskolas Diagramm (3) ca. 63 Mol. % FeO und 37 Mol. % MgO + CaO enthält.

Der Pegmatit besteht hauptsächlich aus Mikroklin, Quarz und albitreichem Plagioklas. Ringsum die grossen Mikroklinkörner kann man oft schöne Myrmekitbildung beobachten. Der Pegmatit geht, wie auf Hästö Utterharu, stellenweise in einen mittelkörnigen, aplitischen Granit über. Im Zusammenhang mit diesem kommt an einer Stelle in der Nähe der Pingen als schmales, mit dem allgemeinen Streichen paralleles Gebiet ein deutlich parallelstruierter, mittelkörniger Mikroklingranit vor, der scharf an den Aplitgranit grenzt. Sowohl im Pegmatit, Migmatit als auch in den Erzkonzentrationen kann oft ziemlich kräftig entwickelte Kataklasstruktur beobachtet werden. In letzterer sieht man noch »fluidalähnliche» Strukturzüge, von denen schon früher die Rede war.

In erzgenetischer Hinsicht ist noch diejenige kleine Klippeninsel beachtenswert, die in der Nähe des Ufers von Iso Jussaari gelegen ist und auf der die östliche Erzzone praktisch genommen endet (vgl. die Karte bei Tigerstedt, 19). Die Erzbildung ist hier schon ziemlich schwach. Der N-Teil der Insel ist aus Schiefern der oben geschilderten Art, der S-Teil wiederum hauptsächlich aus porphyrartigem und kräftig gepresstem Mikroklingranit aufgebaut. Zwischen diesen zwei Gesteinskomplexen findet sich »die Erzformation», d. h. eine mehr oder weniger migmatitisierte Pegmatitzone mit Magnetitkonzentrationen (Abb. 8 und 9).

Abb. 8. Der nördliche Teil der kleinen Klippeninsel im E-Ende des östlichen Grubengebietes von Iso Jussaari. Links ist ein Teil des Schiefergebietes sichtbar, rechts die Migmatitzone.

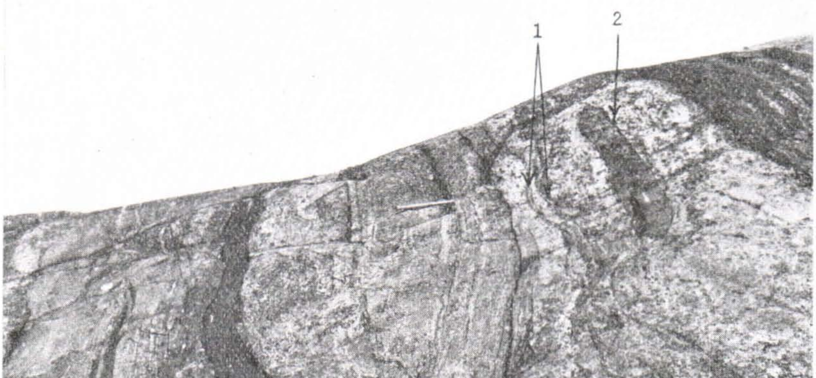

Abb. 9. Nahbild von der in der Abbildung 8 sichtbaren Migmatitzone mit Magnetitkonzentrationen. 1. Magnetitreiche Bänder in Pegmatit. 2. Schieferfragment mit Magnetitkonzentrationen längs der Kontaktlinie gegen den Pegmatit.

Der Magnetit tritt in dieser Zone in folgender Weise auf:

1. Als grössere, bis 0.5 cm im Durchmesser messende zerstreute Körner im Pegmatit.
2. In dunklen, quarzreichen, oft nur einige cm mächtigen Bändern im Pegmatit (1 in Abb. 9). Einige von diesen Bändern sind ziemlich grobkörnig (der Korndiameter durchschnittlich 0.5 cm) und enthalten in reichlichen Mengen gezahnte und kräftig undulierend auslöschende Quarzkörner (Abb. 10). In der Quarz-

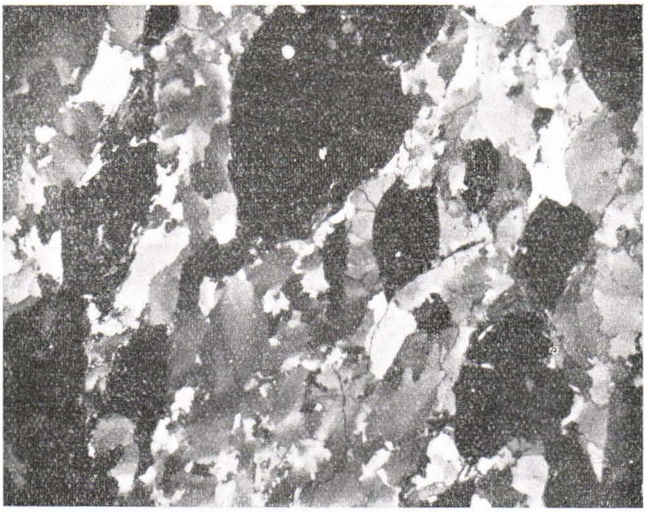

Abb. 10. Aus einem quarz- und magnetitreichen Band in Pegmatit. Die kleine Klippeninsel im E-Ende des östlichen Grubengebietes von Iso Jussaari. Vergr. 11×. Nic. +.

masse finden sich zerrissene Magnetitkörner und, meist im Zusammenhang mit ihnen, in wechselnden Mengen Granat und Biotit sowie sehr wenig albitreicher Plagioklas, Mikroklin und Muskovit. Biotit (und Muskovit) kommen auch sowohl in den Granat-als auch in den Magnetitkörnern vor, und sie besitzen dann in grossen Zügen dieselbe Orientierung wie auch die übrigen Biotitschuppen des Gesteins (helizitische Struktur). In den Magnetitkörnern beobachtet man bisweilen in schmalen Streifen eine braune Masse, die irgendein Zersetzungsprodukt des Biotits sein kann. Parallele magnetitfreie Mikroklinbänder zerlegen die Bandmasse stellenweise in schmälere Teile. — Andere Bänder wieder sind relativ feinkörnig (die Korngrösse durchschnittlich nur 0.06—0.08 mm) und erinnern auf den ersten Blick an die im N-Teile der Insel vorkommenden Schiefer. Sie enthalten hauptsächlich Magnetit, Quarz, Hornblende und Biotit sowie stellenweise auch Granat. Das Feldspatmaterial scheint gänzlich zu fehlen. Die Parallelstruktur ist in den Bändern gewöhnlich ziemlich deutlich, »die Bänderung» dagegen weniger in die Augen fallend. — Die letztgenannten Bänder grenzen meist scharf an den umgebenden Pegmatit; die Kontaktverhältnisse der erstgenannten sind undeutlicher.

3. An den Grenzlinien zwischen dem Pegmatit und einigen in diesem vorkommenden länglichen Schieferfragmenten als schmale, bis 3 cm mächtige bandförmige Konzentrationen (2 in Abb. 9).
4. In Randzonen der oben erwähnten Schieferfragmente, wenn jene auf die früher geschilderte Weise und offenbar durch den Einfluss des Pegmatits »vererzt» sind (vgl. die Beschreibung des östlichen Grubengebiets).

Der Pegmatit geht bisweilen allmählich in den parallelstruierten porphyrartigen Granit und dieser seinerseits in massigen, rötlichen porphyrartigen Granit über. Der letztgenante bildet das Hauptgestein der Insel Iso Jussaari südlich der Grubengebiete. Als grössere Körner treten in ihm Mikroklin, seltener Oligoklas auf. Die Kataklasstruktur ist im Gestein, wenigstens stellenweise, ziemlich kräftig entwickelt. — Alle oben erwähnten Magmengesteine gehören sehr wahrscheinlich zu der Serie des Gneisgranits (vgl. S. 7).

Das untermeerische Erzvorkommen von Jussaari-Segersten

hat nur in der Stenlandet-Grube näher untersucht werden können. Da die Grube gegenwärtig mit Wasser gefüllt ist, so ist man bei den Untersuchungen angewiesen auf die auf Stenlandet liegenden Halden sowie auf die knappen Mitteilungen, die in den kurzen Rapporten über die Grubenarbeit zu finden sind. In der nächsten Nähe des Erzgebietes ist der Felsgrund, ausser auf Stenlandet, auf den kleinen Klippeninseln Orrkobben und Tremänningarna entblösst. Das Gestein ist hier migmatitisch, mit rötlichen und grauen Pegmatitadern. Nach den technischen Rapporten von 1920 und 1921 (im Archiv der Gesellschaft O. Y. Telko A. B.) ist das Nebengestein des Erzes im Ort der 30 m-Sohle ein »amphibolitischer Gneis» (offenbar ein Hornblende-Biotitschiefer von oben geschilderter Art) und das Erz selbst hie und da von Pegmatitadern, die stellenweise Magnetit enthalten, durchschnitten. Im Ort der 56 m-Sohle befindet sich zwischen den früher erwähnten zwei reicheren Erzlagern ein Pegmatitzwischenlager von etwa 2 m Mächtigkeit.

Das Erz selbst ist seiner Mineralzusammensetzung nach sehr gleichartig wie in den oben geschilderten Vorkommen. Es ist verhältnismässig feinkörnig und meistens deutlich schiefrig. Die Bänderung ist dagegen, besonders makroskopisch, weniger in die Augen fallend. Als Hauptbestandteile kommen im Erz Quarz, Magnetit, Biotit, Hornblende und Granat vor (Abb. 12). Die relativen Mengen der Silikatminerale, besonders was den Granat betrifft, variieren innerhalb sehr weiter Grenzen. In der Regel scheint der Biotit in den ärmeren Erzqualitäten reichlicher vertreten zu sein als in den reicheren. Ausser den Hauptbestandteilen enthält das Erz etwas Apatit und stellenweise als schmale Bänder Plagioklas (An_{25-30}). Im ärmeren Erz werden ausserdem oft reichlich mikroklinreiche Bänder angetroffen. Nach Rosiwalscher Methode wurde in zwei Dünnschliffen die prozentuale Mineralzusammensetzung des Erzes bestimmt:

	Magnetit	Quarz	Hornblende	Biotit	Granat
1.	47.8 %	30.8 %	17.0 %	3.0 %	1.4 %
2.	51.4 »	28.1 »	8.5 »	10.0 »	2.0 »

Die meisten Mineralbestandteile bilden sehr unregelmässig geformte, zerrissene Körner. Dieser Umstand macht die Fuge zwischen den Körnern sehr fest, und folglich ist das Erz sehr schwer zu zermahlen. Nur der Granat ist mehr oder weniger idiomorph; die Körner sind gewöhnlich rundlich, und man kann an ihnen dann und wann Kristallflächen beobachten. Im Erz sieht man in reichlicher Menge Spuren mechanischer Deformation; die Biotitschuppen sind gebogen, die Quarzkörner sehr oft gebrochen und löschen kräftig undulierend aus. Bei der mikroskopischen Untersuchung wird die Aufmerksamkeit noch darauf gerichtet, dass die Magnetitkörner sehr gern die Gesellschaft eisenhaltiger Minerale, besonders des Granats, zu suchen scheinen. Der Magnetit kommt sowohl ringsum die Granatkörner als auch als feine Imprägnation innerhalb derselben vor. Diese Imprägnation ist bisweilen in bestimmter Weise regelmässig. Die rundlichen Granatkörner besitzen jetzt einen ebenfalls rundlichen, viele kleine Magnetitpartikel enthaltenden Kern, und um ihn herum lassen sich noch bisweilen feine, konzentrisch angeordnete magnetitreiche Ringe

Abb. 11. Magnetitreicher Migmatit. Stenlandet. Nat. Grösse.

Abb. 12. Das Stenlandet-Erz. Magnetit, Quarz, Hornblende, Biotit und rundliche Granate, voll von kleinen Magnetitkörnern. Verg. 13×. Nic. //.

erkennen (Abb. 13). Eine derartige Imprägnation könnte entstehen, wenn das Magnetit- und Granatmaterial teilweise gleichzeitig aus-

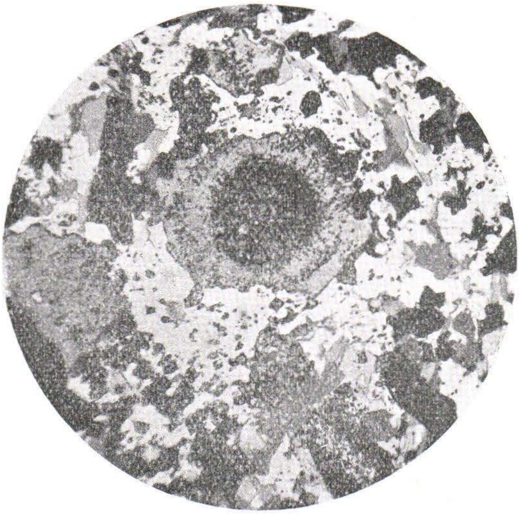

Abb. 13. Feines Magnetitpulver in Granatkörnern. Stenlandet-Erz. Vergr. 33×. Nic. //.

kristallisiert. In einigen mehr oder weniger länglichen Granatkörnern ist sehr feinkörniger Magnetit als parallele Streifen zu beobachten (Abb. 14) Es sieht beinahe so aus, als ob in diesen Fällen Granat in

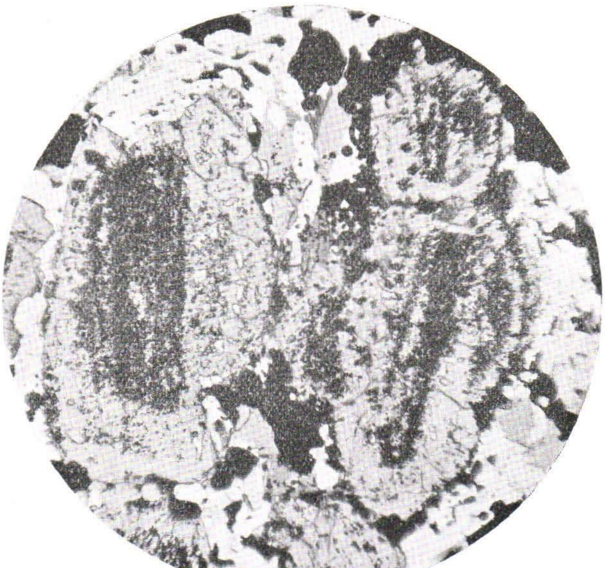

Abb. 14. Feines Magnetitpulver in Granatkörnern. Stenlandet-Erz. Vergr. 30×. Nic. //.

einem Gestein gebildet wäre, das ursprünglich dünne Magnetitlager enthalten hat. Die Sachlage scheint jedoch dieselbe zu sein wie im vorhergehenden Falle. Nur der Schnitt ist ein anderer. — In den Biotitschuppen sieht man Magnetit als Streifen, die parallel mit den Spaltrissen verlaufen.

Folgende technische Analysen beleuchten die chemische Zusammensetzung des Erzes:

	I	II	III
Fe_2O_3	29.14 %		
FeO	15.21 %		
Fe		29.5 % (HCl-lösl.)	31.93 %
P	0.032 %	0.044 %	?
S	0.081 %	0.116 %	0.027 %
MnO	1.2 %	3.5 %	
TiO_2			Spuren
SiO_2	45.17 %	48.2 %	47.73 %
Al_2O_3	2.87 %		3.31 %
CaO	2.25 %	2.1	
MgO		3.6 %	

I. Die Analyse ist in dem Werk Taalintehdas von einer im Jahre 1900 in der Stenlandet-Grube entnommene Erzprobe gemacht worden.

II. Eine ung. 500 Tonnen wiegende Generalprobe aus dem Erzhaufen auf Stenlandet im Jahre 1919 im Auftrage der Taalintehdas-Werke entnommen.

III. Eine von Dr. E. Ganz im Jahre 1918 auf Stenlandet genommene Erzstufe. Im Renlundschen Berglaboratorium analysiert.

Gemäss Analyse I enthält das Erz 42.2 % Magnetit (30.6 % Fe entsprechend) sowie 2.1 % FeO (1.6 % Fe entsprechend), das in den eisenhaltigen Silikaten verbunden ist. Das Erz könnte man »phosphorarm» nennen.

Die Variationen in der Korngrösse, die in aufbereitungstechnischer Hinsicht von Bedeutung sind, gehen aus der nachstehenden Tabelle hervor. (Die Bestimmungen sind mikroskopisch in vier Dünnschliffen ausgeführt.)

Korngrösse	I	II	III	IV	Mittelwert
0.005—0.03 mm	15.0 %	37.7 %	23.2 %	32.8 %	27.2 %
0.03 —0.05 mm	9.6 »	13.4 »	9.3 »	8.4 »	10.2 »
0.05 —0.08 mm	7.7 »	8.7 »	8.8 »	1.4 »	6.6 »
0.08 —0.10 mm	6.0 »	12.0 »	6.1 »	11.4 »	8.9 »
0.10 —0.16 mm	15.9 »	14.1 »	18.1 »	19.4 »	16.9 »
0.10 —0.3 mm	18.6 »	5.3 »	13.2 »	14.2 »	12.8 »
0.3 —0.5 mm	24.9 »	8.8 »	9.3 »	12.4 »	13.8 »
0.5 —1.0 mm	2.3 »	—	12.0 »	—	3.6 »

Die Aufmerksamkeit wird besonders darauf gerichtet, dass mehr als ein Viertel der ganzen Magnetitmenge in Körnern enthalten ist, die kleiner als 0.05 mm im Diameter sind. Dieser Umstand, wie auch für ihren Teil die früher erwähnte Festigkeit des Erzes, lässt die Herstellung von hochprozentigen Konzentraten teuer werden. — In Körnern von 0.1—0.5 mm Grösse sind durchschnittlich 43.5 % der Magnetitmenge enthalten.

Wie erwähnt, haben Ing. Karl Sundberg und E. Pyhälä magnetische Aufbereitungsversuche mit Stenlandet-Erz ausgeführt. Auf Grund der Versuche des erstgenannten könnte man aus dem Erz, wenn es unter 0.5 mm gemahlen ist, ein Konzentrat, das etwa 50 % Fe enthält, und einen Abfall, der 10—15 % Fe enthält, herstellen. Wenn das Erz unter 0.1 mm gemahlen ist, dürfte man ein Konzentrat, das etwa 60 % Fe enthält, und einen Abfall, in den 10—15 % Fe eingehen, erhalten können. Die Ausbeute beläuft sich im ersteren Falle auf 45 % und im letzteren auf etwa 70 %. Von dem reicheren Konzentrat ist nach Sundberg (technischer Rapport der Gesellschaft Jussarö gruva A. B. im Jahre 1920 eingereicht) folgende Analyse gemacht worden:

FeO	Fe_2O_3	MnO	P_2O_5	S	SiO_2	Al_2O_3	MgO	CaO	Insgesamt
28.01 %	54.71 %	1.44 %	0.055 %	0.075 %	13.26 %	1.06 %	0.61 %	0.92 %	100.14 %

Die Resultate der Aufbereitungsversuche von Ing. Pyhälä deuten ung. in dieselbe Richtung wie die obigen.

Die Erzzone von Jussaari-Segersten bildet nach der magnetischen Karte Tigerstedts (19) zwei ineinander liegende, nach Osten sich öffnende Bögen, deren südliche Enden auf der Südseite von Stenlandet sich vereinigen. In diesen Gegenden scheint das Erzlager eine sehr schroffe Biegung zu machen und deshalb gerade an der Stelle der Grube als doppeltes aufzutreten. Die Observationen, die man in der Grube und besonders im Ort der 56 m-Sohle gemacht hat, stützen diese Annahme.

In der Nachbarschaft der Erzzone sind folgende Observationen über das Streichen, das Fallen und die Achsialverhältnisse gemacht worden:

	Streichen	Fallen	Achsialrichtung
Stenlandet	W—E	ziemlich steil	—
Tremänningarna	W—E	vertikal	55° nach E
Orrkobben	N 10°—15°E	60° nach E	50° nach N 55°—62° E
Lerharun	N 80°—85° E	—	62°—65° nach N 70°—75° E

Die Erzzone bildet also eine enge »doppelte» Synklinale.

Auf Lerharun ist die Erzbildung sehr schwach. Der grösste Teil dieser kleinen Klippeninsel besteht aus grauem oder etwas rötlichem, biotitreichem und ziemlich deutlich parallelstruiertem Granodiorit. Im mittleren Teil der Insel sieht man eine Pegmatitzone, in der ähnliche schmälere oder breitere magnetitreiche Bänder angetroffen werden wie in der »Erzformation» der kleinen, im E-Ende des östlichen Grubengebiets von Iso Jussaari gelegenen Insel. Besonders die kleinkörnigeren, hornblendereichen Bänder erinnern in ihrer petrographischer Zusammensetzung auch sehr an das Stenlandet-Erz.
Der Granodiorit enthält hie und da Schieferfragmente.

Im E-Ende der Insel

PIENI JUSSAARI

kommen ein paar minimale und arme Erzlinsen vor (siehe S. 6). Die Erzformation weicht von den vorhergehenden darin ab, dass der Pegmatit praktisch genommen fehlt und das »Erz» unmittelbar in einem mittelkörnigen, dunkelgrauen und undeutlich parallelstruierten Quarzdiorit oder Granodiorit vorkommt. Dunkle Minerale, gemeine grüne Hornblende und Biotit, treten im letztgenannten Gestein ver-

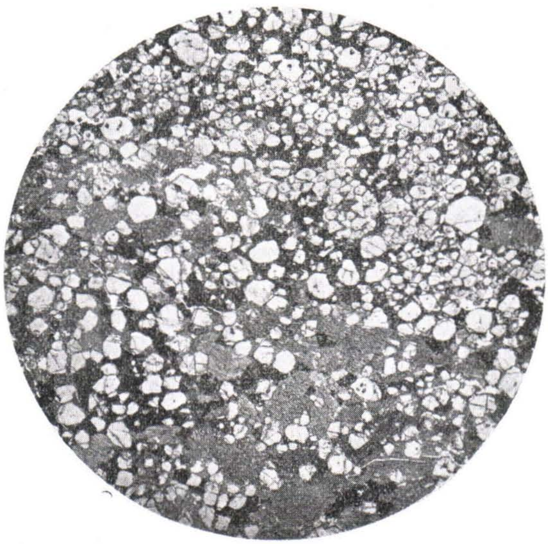

Abb. 15. Granat-, Hornblende-, Biotit-, Magnetitgestein. Das Erz von Pieni Jussaari. Vergr. 14 ×. Nic. //.

hältnismässig reichlich auf. Ausser diesen Mineralen enthält das Gestein andesinischen Plagioklas sowie auch ziemlich reichlich Quarz. In kleinen Mengen kommen Erzkörner, Granat und Apatit vor. In der Richtung gegen das Erz nehmen die relativen Mengen des Granats und des Magnetits allmählich stark zu, während besonders die relativen Mengen des Plagioklases und auch des Quarzes abnehmen. Das eigentliche Erz, in welches das Gestein zum Schluss übergeht, enthält in reichlichem Masse runde Granatkörner und zwischen diesen Hornblende, Magnetit, Biotit und ein wenig Quarz (Abb. 15). Die Struktur ist ziemlich massig. Bänderung ist nicht beobachtet worden.

DIE ENTSTEHUNG DER ERZE.

Am einfachsten dürfte sich die Entstehung der auf Pieni Jussaari gelegenen Erze erklären lassen. Es handelt sich aller Wahrscheinlichkeit nach um Differentiation des granodioritischen oder quartzdioritischen Magmas, und die Erzklumpen vertreten in jenen Gesteinen Stellen, an denen die Differentiationsprodukte, d. h. die eisenhaltigen Silikate und der Magnetit, in reichlicheren Mengen konzentriert sind.

Die Entstehung der übrigen geschilderten Erzvorkommen ist offenbar nicht so einfach. Weil diese alle in kräftig migmatitisierten Zonen gelegen sind, wäre es denkbar, dass die Erze genetisch in enger Beziehung zu der Migmatitbildung ständen. Am nächsten läge dann die Annahme, dass das Erzmaterial als Produkt einer, von dem als Intrusivteil des Migmatits (Arterits) vorkommenden Pegmatit verursachten Metasomatose gebildet wäre. Es gibt auch reichlich Beweise dafür, dass wenigstens e i n T e i l des Erzmaterials auf diese Weise entstanden ist. Es ist schon erwähnt worden, dass die grösseren Schieferfragmente und Schiefergebiete in ihren Randteilen, d. h. an den Kontaktstellen gegen den Pegmatit, eine vom Regelmässigen abweichende Mineralzusammensetzung besitzen. Die Erscheinungsweise derartiger Randzonen, die allmählich in normalen Schiefer übergehen, weist deutlich darauf hin, dass es sich um metasomatische Umwandlungen handelt. Eine weitere Stütze gibt die mikroskopische Untersuchung. Die Umwandlungen verlaufen hauptsächlich in der Richtung, dass das Feldspatmaterial allmählich verschwindet und als Neubildungen im Gestein Quarz, Granat und Magnetit entstehen.

Wo die Migmatitbildung mehr »intim» gewesen ist und die Schieferpartien schmäler ausfallen, sind diese völlig umgewandelt. In dieser »eigentlichen» Migmatitzone und besonders in der Nähe der Erzlager sind die Umwandlungen überhaupt kräftiger gewesen. Die Menge der neugebildeten Minerale ist so gross, dass die ursprünglichen Bestandteile gegen diese völlig zurücktreten. Ausserdem ist von den letzteren nicht nur der Feldspat zerstört worden, sondern offenbar teilweise auch der Biotit, wobei seine Bestandteile zu der Bildung von Granat und Magnetit verbraucht worden sind. Auf diesen Sachverhalt deuten folgende Umstände hin: In den beiden letztgenannten Mineralen sieht man stellenweise als Einschlüsse Biotitschuppen (die oft dieselbe Orientierung besitzen wie die übrigen Biotitschuppen), und in den grossen Magnetitkörnern lässt sich dann und wann eine dunkelbraune Masse beobachten, die offenbar, wie schon erwähnt, irgendein Zersetzungsprodukt des Biotits darstellt. Ebenfalls als umgewandelter Biotit (Biotit, dessen Eisengehalt ausgelaugt worden ist) dürften die hellen Glimmerschuppen angesehen werden, die in den genannten Magnetitkörnern wie auch an deren Rändern auftreten. — Wie erwähnt, ist das Biotitmaterial der Schieferpartien der Migmatite grobkörniger als in den Schiefern im allgemeinen. Vermutlich ist der ursprüngliche Biotit der Schiefer von den Magmalösungen absorbiert worden, und dann aufs neue kristallisiert (vgl. Grout, 5). — Auf Hästö Utterharu ist in solchen umgewandelten Schiefern stellenweise grauer, trüber Amphibol beobachtet worden. Ob dieses Mineral als ein Umwandlungsprodukt der gemeinen grünen Hornblende der normalen Schiefer anzusehen ist, hat als unsicher zu gelten. Stellenweise sieht es wiederum so aus, wie wenn die in den umgewandelten Schiefern und im Erz vorkommende grüne Hornblende, wie auch der Granat und der Magnetit, zur Generation der neugebildeten Minerale gehörte. Was die gegenseitige Kristallisationsfolge des Granats und Magnetits betrifft, so ist schon früher (S. 19) darauf hingedeutet worden, dass diese Minerale ziemlich gleichzeitig sind. Stellenweise scheint der Magnetit etwas später gebildet worden zu sein, danach zu schliessen, dass er als schmale Spaltenfüllungen im Granat (wie auch im Biotit) vorkommt.

Nach dem Obigen kommen wir zu dem Ergebnis, dass w e n i g s s t e n s e i n T e i l d e s E r z m a t e r i a l s auf folgende Weise entstanden ist. Vom Gneisgranit (oder dem porphyrartigen Granit der Insel Jussaari) sind bei seiner Erstarrung reichlich pegmatitische Lösungen emaniert worden, die auf weiten Gebieten Migmatitisierung der Schiefer verursacht haben. Zur Zeit der Migmatitbildung sind von diesen Pegmatiten kieselsäurereiche Lösungen zur Ausscheidung gelangt, Lösungen, in denen auch das Eisenmaterial des Pegmatits sich in grossen Mengen konzentriert hat. Diese Lösungen sind in die umgebenden Schiefer eingedrungen, metasomatische Umwandlungen und gleichzeitig Erzbildung verursachend. Was die Fixierung des Erzmaterials (des Magnetits) in den Schiefern betrifft, so ist sie also teilweise durch Vermittlung der Reaktionen zwischen den von aussen kommenden Lösungen und den eisenhaltigen Silikaten des Schiefers, hauptsächlich vielleicht jedoch durch die Verdrängung der ursprünglichen Minerale des Schiefers, in erster Linie der Feldspäte, geschehen. — Es ist gar nicht befremdend, dass vom Pegmatit Lösungen der oben erwähnten Art emaniert worden sind. Der Pegmatit selbst enthält auf diesem Gebiete — obgleich natürlich in ganz anderen Proportionen — dieselben Minerale, die in den Schiefern als Neubildungen auftreten. Dazu zeigen diese Minerale stellenweise das Streben, sich auch im Pegmatit selbst zu zerstreuten, unregelmässig geformten Klumpen und Bändern zu konzentrieren.

Es entsteht jetzt die Frage, ob das Erzmaterial im ganzen auf die oben geschilderte Weise entstanden ist. Betrachtet man z. B. einige reichere Erze von Iso Jussaari, in welchen die Bänderung ausgezeichnet entwickelt ist (S. 11 und Abb. 6), beginnt man wohl einen solchen Sachverhalt zu bezweifeln. Es lässt sich nämlich schwerlich behaupten, dass z. B. die Granat- und die Hornblendekörner sich in dem Masse wie z. B. Abbildung 6 zeigt haben, differentieren und in getrennten Bändern anordnen können, wenn sie als Produkte der Metasomatose der oben geschilderten Art entstanden wären. Ausserdem erinnert ein derartiges Erz sehr stark sowohl in seiner Struktur als auch in seiner Mineralzusammensetzung an geschichtete quarzitische Eisenerze. Auffallend ist unter anderem die Ähnlichkeit mit den Eisenerzen von Süd-Varanger, die zuletzt von Sederholm beschrieben und als sedimentogen erklärt worden sind (17). Vergleichspunkte finden sich auch in den Erzgebieten von Porkonen—Pahtavaara in Nord-Finnland (vgl. Hackman, 6) und von Dunderland, Norwegen (vgl. Nicolai, 10), obgleich die Gangart von einigermassen abweichender Beschaffenheit ist.

Trotz allem dürfte es allzu gewagt sein, auch die Erze des erwähnten Typus von Iso Jussaari für sedimentogen zu halten. Erstens erscheint es nicht glaubhaft, dass ein Teil der Erze von ganz anderem Ursprung wäre als die übrigen Erze des Gebietes, in denen die Bänderung weniger entwickelt ist, die aber, was die in ihnen enthaltenen Minerale betrifft, oftmals nicht besonders stark von den erstgenannten abweichen. Zweitens wäre zu erwarten, dass innerhalb der Erzzone wenigstens in gewissem Masse erzlose Quarzite vorkämen, wenn einmal erzhaltige Quarzite angetroffen werden. Es mag ausserdem berücksichtigt werden, dass die erwähnten gebänderten Erze auf Iso Jussaari gerade und ausschliesslich diejenigen Minerale enthalten, die in den umgewandelten Schiefern als Neubildungen auftreten. Dies gibt Anlass zu behaupten, dass das Erz auch in diesem Falle von den Lösungen, die von den Pegmatiten ausgeschieden worden sind, herstammen. Diese kieselsäure- und eisenreichen Lösungen sind jetzt jedoch nicht in das Nebengestein (in die Schiefer) eingedrungen und in ihm Umwandlungen verursacht, sondern wäre das Erz durch eine direkte Kristallisation aus diesen Lösungen entstanden. Die Bänderung des auf diese Weise gebildeten Erzes könnte man der fraktionierten Kristallisation und den kräftigen Strömungen während der Kristallisation zuschreiben. Derartige Strömungen sind übrigens sehr begreiflich, wenn

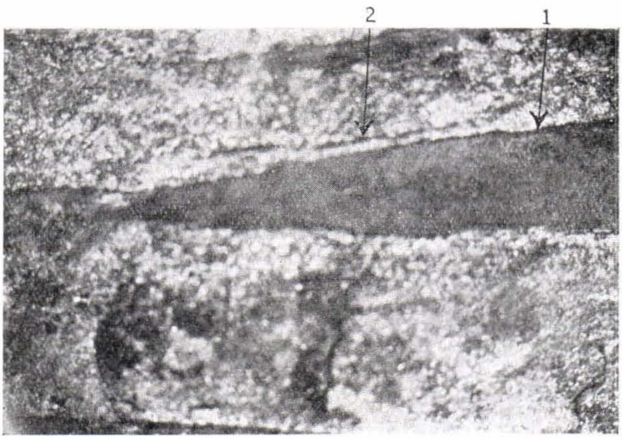

Abb. 16. Ein Schieferfragment (dunkelgrau) in Pegmatit. Streifenförmige Magnetitkonzentrationen längs der Kontaktlinie zwischen Schiefer und Pegmatit (1) sowie im Pegmatit in der Nähe der Kontaktlinie (2). Dorf Paimela, Kirchspiel Hollola. Aufn. O. V. Levander.

man in Betracht zieht, dass sowohl die Granodiorite und Granite, als auch die von diesen Gesteinen ausgeschiedenen Pegmatite, aus der tektonischer Erscheinungsweise zu schliessen, ihrer Natur nach hochorogen sind. — Die Verschiedenheiten in der Entstehungsweise der beiden oben geschilderten Erzsorten wären also prinzipiell dieselben wie diejenigen, die zwischen den karelischen reicheren Schwefelkieskonzentrationen und den sie umgebenden kiesimprägnierten Schiefern bestehen (Saksela 11, 12 und 13). In den letzteren ist das Kiesmaterial auf metasomatischem Wege, in den ersteren wiederum durch direkte Kristallisation aus denjenigen Lösungen, die im Nebengestein metasomatische Umwandlungen verursacht haben, gebildet worden.

VERGLEICHSPUNKTE AUS ANDEREN GEBIETEN.

Geeignete Vergleichspunkte sind in Finnland wie auch in den skandinavischen Ländern schwer zu finden. Die einzigen eigentlichen Eisenerzvorkommen, die in dieser Hinsicht vielleicht in gewissem Masse in Frage kommen könnten, sind die Erze der Lofoten, die nach Hj. Sjögren (18) irgendwelche quarzreiche Magnetitausscheidungen aus granitischem Magma darstellen. — Es mag jedoch erwähnt werden, dass u. a. die pegmatitischen Granite Finnlands nicht sehr selten magnetithaltig sind und — was an dieser Stelle interessiert — der Magnetit in diesen Gesteinen stellenweise das Streben zeigt, sich zu

Abb. 17. Schieferfragmente in Pegmatit. Ähnliche Magnetitkonzentrationen wie in der Abbildung 16. Dazu sieht man grössere zerstreute Magnetitkörner im Pegmatit. Aufn. O. V. Levander.

konzentrieren. Als Beispiel könnte man das ziemlich weite in den Dörfern Sarva und Paimela im Kirchspiel Hollola gelegene Migmatitgebiet anführen, auf dessen Magnetitgehalt Bankdirektor O. V. Levander meine Aufmerksamkeit gelenkt hat. Der Migmatit ist aus länglichen Glimmerschieferpartien und rötlichen Pegmatitadern oder -klumpen aufgebaut. Der Pegmatit ist im allgemeinen magnetithaltig, und der Magnetit kommt gewöhnlich als grosse zerstreute Körner, sehr oft aber auch in schmalen Bändern angeordnet vor. Magnetitbänder werden meistens längs der Kontaktlinie zwischen den Schieferfragmenten und dem Pegmatit oder im Pegmatit in der Nähe dieses Kontakts angetroffen (Abb. 16 und 17). Die Konzentrationen sind sehr ähnlich denjenigen auf der kleinen Klippeninsel im E-Ende des östlichen Grubengebiets von Iso Jussaari.

Schon auffallend viele Ähnlichkeiten, besonders in genetischer Hinsicht, findet man in dem bekannten Eisenerzgebiet von Adirondack. Ich weise in erster Linie auf Allings »Genesis of the Adirondack Magnetites» (1) hin, in der auch die früheren Schriften, die dieses Erzgebiet behandeln, kritisch analysiert sind. Das Nebengestein des Erzes ist hier stark gebändert und seiner Natur nach migmatitisch oder »syntektisch». Es ist aus einem Intrusivgestein der Syenit-Granitserie und aus älteren assimilierten und verdrängten (replaced) Grenville-Sedimenten zusammengesetzt. Sowohl das Erz als das Nebengestein sind von zahlreichen Pegmatit-, Silexit- und Quarzadern durchdrungen. Das Erz verdankt seine Entstehung der kontinuierlichen Differentiation des syenit-granitischen Magmas sowie der von den Differentiaten verursachten Verdrängung, der sowohl die Grenville-Sedimente als auch das früher erstarrte syenit-granitische Gestein ausgesetzt gewesen sind. In diesen Gesteinen sind besonders Quarz und Feldspat verdrängt worden. Alling erklärt die Adirondack-Erze in Kürze für Verdrängungs (replacement) vorkommen, die von den aus granitischem Magma emanierten magnetitreichen Lösungen gebildet worden sind. Er stellt in der Erzbildung auch mehrere verschiedenartige Phasen fest, von welchen folgende Hauptpunkte (mit den frühesten beginnend) erwähnt werden mögen:

1. Magnetite-rich differentiate of the syenite-granite series.

2. Encountered the overlying and highly foliated Grenville (and metagabbro) rocks, penetrated and soaked along the foliation planes, gradually saturated and replaced these ancient rocks, took on the structure possessed by them and became a syntectic.

3. Subdifferentiation of still liquid portions of the magma into
   a. pegmatite-rich and
   b. magnetite-rich fractions

5. Slight contact action took place between the differentiating magma and roof fragments of calcareous Grenville, or upon solidified portions of itself, producing local concentrations of magnetite.

6. The magnetite-rich aqueo-igneous solutions saturated and replaced the syntectic wall rock subject to the structural control of the superimposed foliation of the country rock, producing local concentrations of magnetite.

7. The pegmatite- rich fractions, by transference, concentrated the magnetite into the zones where they are found today.

8. Still later aqueo-igneous magnetite-rich solutions veined the wall-rock and the ore bodies.

Der Magnetit ist also verschiedenen Alters. Dem jüngsten Magnetitmaterial in den das Erz und das Nebengestein durchsetzenden Magnetit-, oder Magnetit-Quarzadern könnte möglicherweise dasjenige Jussaari-Erz entsprechen, das aller Wahrscheinlichkeit nach direkt aus den Lösungen herauskristallisiert ist. — Es mag noch erwähnt werden, dass durch den Kontakteinfluss der Intrusive stellenweise Granat, Skapolith, Titanit, diopsidischer Pyroxen und Kalzit gebildet worden sind. Ein gefundenes Stück war eine Zusammenwachsung von Granat und Magnetit.

Mehrere Beispiele von Eisenerzen im Zusammenhang mit den Pegmatiten könnten noch angeführt werden. In diesen gehört der Magnetit jedoch zu den primären und zuerst kristallisierten Bestandteilen des Pegmatits. So beschaffen sind u. a. die von Grout (5) beschriebenen Erze von Nord-Minnesota. Doch zeigt der Pegmatit stellenweise Neigung zu Differentiation, seine verschiedenen Bestandteile sind zu verschiedenen Bändern angeordnet. Magnetit kann man dann als schmale Bänder in den kieselsäurereichen, silexitischen Teilen des Pegmatits antreffen. Die Differetiation des Pegmatits ist jedoch relativ unbedeutend, und die metasomatischen Prozesse als Erzeuger der Erze sind gänzlich zurücktretend.

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3.

THE MODE OF THE LAND UPHEAVAL IN FENNOSCANDIA DURING LATE-QUATERNARY TIME.

by

Matti Sauramo.

Contents.

INTRODUCTION.

The changes of the relative level of land and sea can be studied in the deposits which have been laid down in Fennoscandia during Late-Quaternary time. At the end of the Ice Age the great central part of the glaciated area was depressed below sea-level and fine-grained sediments, such as silt, clay and mud, were deposited upon the sea-bottom. When, later on, the sea-bottom gradually rose, the old water-sediments were turned into dry land and became covered with forest and bog vegetation. From this organic matter peat was formed upon the water-sediments, and the contact between the aquatic and terrestrial sediments marks the decisive point of time when the place in question underwent transformation into dry land.

The elevation of this contact can be determined by the usual modes of measurement. Nowadays the dating of it is based upon the pollen-statistics, a micropalaeontological method developed by Lennart von Post (1928). By means of these statistics the sequence of strata is divided into time sections corresponding to the different stages in the history of forests and in the changes of climate.

When pollen is found not only in peat but also in water-sediments, the different stages of the development of forests can in Fennoscandia be correlated to the history of the Baltic Sea and to the late-Quaternary chronology by means of the annually varved sediments (G. De Geer 1910, Sandegren 1924, Lidén 1938, Fromm 1938). Thus in every perfect series of strata it is possible to say when the sea bottom at the place in question emerged above the water body.

In Finland about 400 profiles have been studied according to this method during the last ten years. These profiles have generally been taken from the coast region between the present littoral zone and the maximum limit of the former water cover. In connection with one another they give a detailed record of the changes of the shoreline during the post-glacial epoch, being of great value in the dating of the old raised beaches of the Baltic.

RAISED BEACHES OF THE BALTIC.

In the first place the pollen-statistics are well adapted for the dating of those levels which were formed (1) at the close of the Littorina time about 1 000 B. C., (Fromm 1938), (2) at the beginning of the same marine stage about 5 000 B. C., (3) at the beginning of the Ancylus Lake stage about 6 500 B. C. The determination is based upon the fact that the Littorina time is characterized by the occurrence of the mixed oak forests, the Ancylus time again, by the pre-

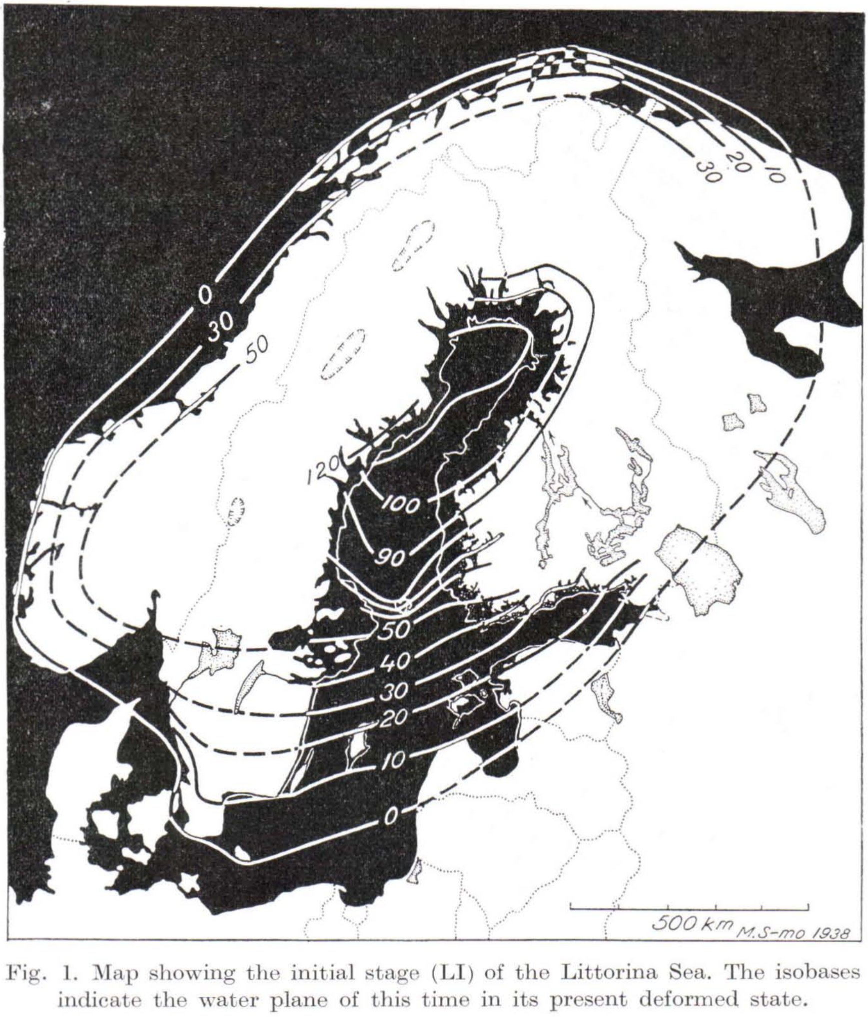

Fig. 1. Map showing the initial stage (LI) of the Littorina Sea. The isobases indicate the water plane of this time in its present deformed state.

dominance of the pine. The two last-mentioned levels can be distinguished quite accurately, because at these times great changes have taken place, not only in the composition of the forests, but also in the diatom flora of the Baltic basin. During the Ancylus time its water was fresh, but during the preceding and succeeding stages it was brackish.

In addition, during the Littorina time, five other well-marked beaches were formed and traced palaeontologically and also archaeologically. Distinct shore features have come into existence also during other times, namely three after the formation of the last Littorina

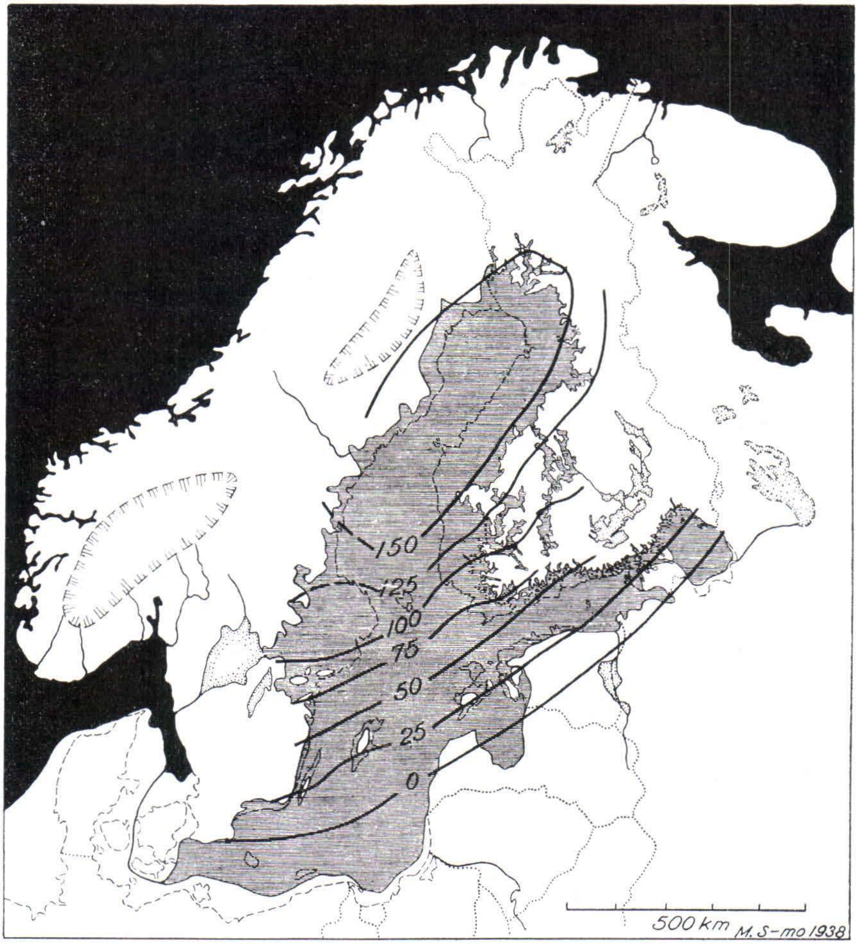

Fig. 2. Map of the initial stage of the Ancylus Lake.

shore-line, and four during the Ancylus period, besides the above mentioned highest shore-line of this stage (Fig. 2). Thus, no less than fifteen old water planes are known in the Baltic basin from the post-glacial epoch.

The late-glacial oscillations of level, again, are not recorded in detail by the pollen-statistics, because the formation of peat and mud during this time was very scanty. There is, however, another method available, basing itself upon the glacifluvial deposits which were formed in the marginal zone of the retreating land-ice. These deposits have the characteristic bedding of deltas, and the flat top shows the

Fig. 3. Map showing Fennoscandia during the first Rhabdonema Sea stage.

level which the water-cover had attained when the delta was built up. Chronologically every delta can be placed in correlation with the receding ice margin, with which the former have always stood in the closest contact. Further, the annually varved sediments in the neighbourhood of the delta afford a means of determining its place in the absolute time-scale of the Late-Quaternary Epoch. The dating can be established with a certainty at least of some centuries, but in most cases of some decades or even of a single year (Sauramo 1934, 1937).

There are a great number of glacifluvial deltas in Southern Finland. Most of them occur in several series corresponding to different ages and different raised levels. One of these well developed series stands in connection with the recessional moraine of the Second Salpausselkä, running throughout the whole of Southern Finland. It

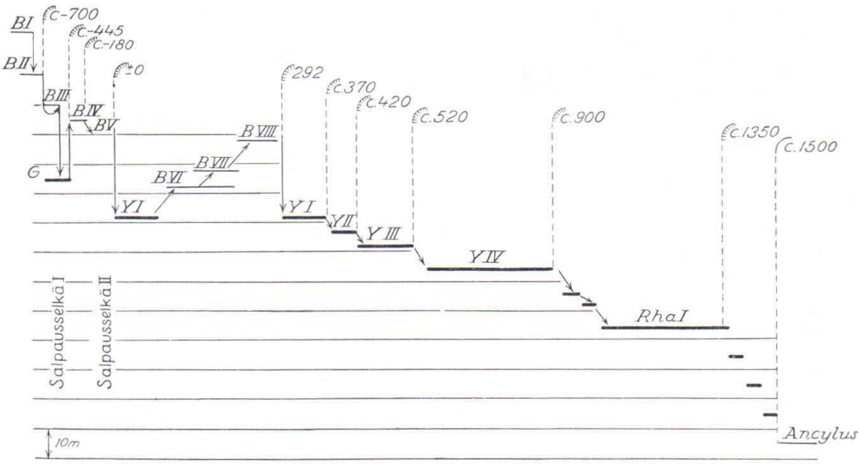

Fig. 4. Diagram of the late-glacial shore-lines in Western and Central Finland showing the direction, rate, and chronology of the intermittent changes of level at the retreating ice-margin. The figures in the upper margin give the age of the shore lines and also their relation in regard to the land ice. Marine stadia shown by thicker lines. The lettering is explained in the text. (Sauramo 1937).

has been built up at the level of the fifth stage of the ice-dammed Baltic Ice-lake (BV, = BIII Sauramo 1934), which cuts also a well-marked wave-cut bench south of the delta series, for instance in the First Salpausselkä moraine. Here the water plane in question lies at a level from 10 to 8 metres lower than the higher series of deltas corresponding chronologically with this end-moraine and belonging to the third stage of the Baltic Ice-lake (BIII, = BII, Sauramo 1934). The lower and younger delta series of the same end-moraine, again, lies about 15 m. below the first-named level of the fifth Ice-lake, and shows the height of the sea during the gotiglacial time (G, = Z, Sauramo 1934).

Before the Salpausselkä stages the Baltic Ice-lake stood at the oldest level BI. After the Salpausselkä stages, on the other hand, the ice-margin was withdrawing to the north-west, and during these times other beaches were formed, such as the glaci-lacustrine BVI, BVII, BVIII, the marine Yoldia I, Yoldia II, Yoldia III, Yoldia IV (= Rhoicosphoenia, Sauramo 1934), and, at the end of the Ice Age the Rhabdonema, the best developed shore-line of the Baltic (Fig. 3.). Altogether fifteen late-glacial raised beaches are known in Finland; their number thus being the same as that of the post-glacial shore-lines (see Fig. 4.). Their chronology is based upon the author's studies concerning the varved sediments of Finland. In this time-scale the last year of the Second Salpausselkä stage has been taken as zero (Sauramo 1918, 1923).

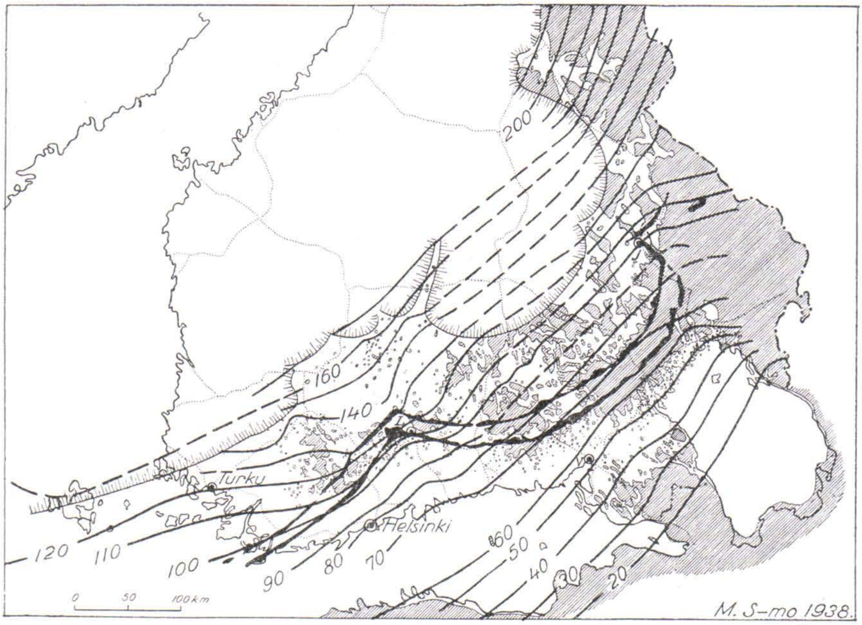

Fig. 5. Map showing Southern Finland at the end of the first Yoldia Sea stage. White = sea; striated area = dry land; black = Salpausselkä end-moraines and Selkäkangas in NW of Joensuu. Ice margin indicated by a toothed line. The isobases show the Yoldia water plane in its present deformed state. On the dry land in Eastern Finland the isobases are drawn in accordance with the shore-line of the first Baltic Ice-lake. J = Joensuu, L = Lahti, V = Viipuri.

Fig. 5 is a palaeogeographic map showing the conditions in Southern Finland in the year 370 after the Second Salpausselkä, or about 7 780 B. C. It shows the distribution of sea, land, and ice-sheet and also the plane of the shore-line of the First Yoldia sea (YI) in its recent deformed position. By the differential uplift of the earth-crust its elevation is far greater in the north-west than in the south-east. The warping and tilting are shown in detail by the isobases.

RECENT WARPING OF SOUTHERN FINLAND.

It is very interesting to compare this map with that [1]) showing the recent rise of land according to the renewed precise levelling made by Kukkamäki (1938) in the Geodetic Survey of Finland during recent years (see Fig. 6). At a first glance a pronounced similarity is seen not only in the greater features but also in the curvatures of the isobases, especially in the western part of the area, where the position of the Yoldia beach has been traced in detail. In some cases the curvature is quite identical, but in general a slight difference is seen, the curves of the recent time being sharper than those on the map of the Yoldia time. Thus, during the last 40 years the local differential uplift shows a tendency to vary more than is the case in the rate of the whole emergence which lasted at least 12 000 years! The contrary might have been expected.

This fact may apparently be explained in accordance with R. Witting's views regarding the nature of the recent upheaval of the

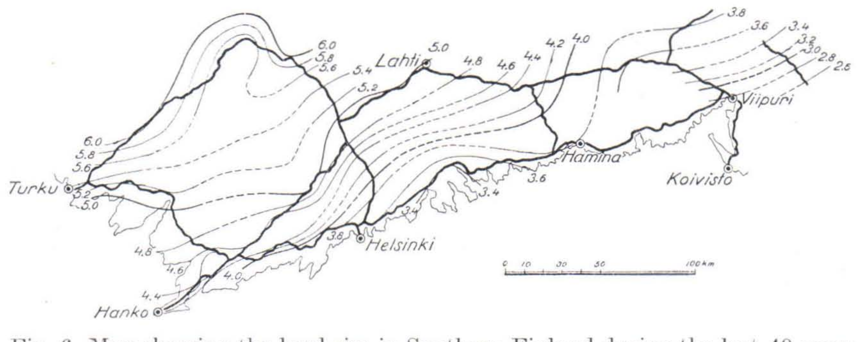

Fig. 6. Map showing the land rise in Southern Finland during the last 40 years, indicated in millimetres per year, according to precise levelling made by Dr. Kukkamäki and others in the Geodetic Survey of Finland. The fixed points of the precise levelling are situated along rail-roads and highways which are indicated by a thicker line.

[1]) This map was first presented at the meeting of the Geographical Society of Finland on the 21st October 1938, when Dr. Kukkamäki held a lecture on the recent uplift of land in Southern Finland on the base of renewed precise levelling. The author is indebted to Dr. Kukkamäki for his kindness in placing this map at his disposal. It is the first time we have an opportunity of seeing results obtained by this method.

coast in Fennoscandia (R. Witting 1918). The annual rates of upheaval in different localities are very unequal, but the mean upheaval is entirely compensated about every lustrum. According to Witting this is due to the fact, that the earth's crust rises not in the form of a rigid table and at an even velocity, but rather as a broken mosaic. Every block of the earth's crust rises in fits and starts, remaining thereafter for some years in its place. Consequently, after some length of time most of these differential movements compensate each other. Apparently this conception helps us to understand also the nature of the whole Late-Quaternary upheaval of Fennoscandia. Some of the differential movements have, however, escaped complete compensation and have preserved their individual character for thousands of years.

SYSTEM OF THE ANCIENT BEACHES OF THE BALTIC.

An exception to this rule is easily found in the diagram, Plate I. The lines, or rather curves in this graph represent, with greatly exaggerated inclination, the slopes of the planes of the shore-lines in the south-eastern section of Fennoscandia. The section in question contains not only the whole of Southern Finland, but also Ångermanland in the central area of land upheaval, and the Leningrad district in the periphery. The construction is based upon a straight line LI representing the above-mentioned initial stage of the Littorina sea (Fig. 1.). In the centre of Fennoscandia it has an elevation of 120 m; in the periphery, on the Carelian Isthmus at Terijoki, near to the eastern frontier of Finland, this shore-line dives beneath the present sea level. All other shore-lines are placed at heights which correspond to their real distances above and below the base line.

The first graph of this kind concerning the Baltic region was made by the author in 1934 (Sauramo 1934). It was based upon investigations by V. Auer (1924), E. Hyyppä (1932) on the Carelian Isthmus, A. Hellaakoski (1928) in Central Finland, L. Aario (1932) in North Satakunta, R. Lidén (1913) in Ångermanland, and K. K. Markow (1931) around Leningrad. The system of the late-glacial shore-lines was studied by the author, but the material concerning these stages has not yet been published.

In this diagram is seen a feature of particular significance bearing on the problem in question: The late-glacial beaches northwest, that is inside, of the great Salpausselkä recessional moraines are parallel with each other, whereas all other shore-lines have a different degree of tilting, the oldest invariably rising quickest when traced northwestwards. At that time it was not certain, if the parallelism of the late-glacial shore-lines occurs also south-east of Salpausselkä, because the relations between the different water planes were not yet adequately known.

Now, after five years, this lacune has been filled. A great number of papers dealing with the changes of level has since been published by L. Aario (1936), E. Aurola (1938), A. L. Backman (1936, 1937), Hellaakoski (1934), Sampo Kilpi (1937), K. K. Markow und Poretzky (1935) Karl Orviku (1934), P. W. Thomson (1935), K. Virkkala, and also some details and preliminary reports by the author (Sauramo 1936, 1937, 1938 a).

Among these Hyyppä's beautiful study concerning the post-glacial changes of shore-level in Southern Finland is of the greatest importance as regards the aforesaid problem. He brought to its solution the question concerning the complicated history of the Littorina sea in the periphery of the area of land-upheaval. Hyyppä established also the position of the highest limit of the Ancylus Lake in the Helsinki area. The preceding well-marked shore-line, formerly assumed to represent the initial stage of the Ancylus Lake, was found to be of marine origin. It is to be correlated with the Rhabdonema stage north-west of Salpausselkä, which consequently has now been traced throughout the whole of south-eastern Finland. By Hyyppä this shore-level is designated Lg VIII and Lg. IX, *i. e.*, the eighth and ninth late-glacial beach.

In conformity with these new results we can expect to find the counterparts also of the earlier late-glacial shore-lines of Western Finland south-west of the Salpausselkä moraines. As mentioned above, some of them have been determined by means of the glacifluvial deltas connected with the Salpausselkä moraines. Now, in the summers of 1937 and 1938, the author traced the wave-cut benches of the Yoldia and Rhabdonema Seas from the Salpausselkä zone southwards along the northern coast of Lake Ladoga, in the north-west of Viipuri, and on Suursaari (Hogland) Island, where all old shore-lines of the Baltic basin are visible in one place. Here, and in the whole zone investigated, the initial stage of the Littorina Sea lies at 22—23 metres, and the first Yoldia shore-line (YI, by Hyyppä designated Lg V) at 60—63 metres, as seen in the map Fig. 5.

Thus, the first Yoldia and consequently also the other Late-Quaternary beaches here above the Yoldia have an elevation of 20 metres more than was assumed by the author earlier; otherwise their places in Western and Central Finland have remained unchanged. Therefore they are not rectilinear, like the post-glacial shore-lines, but, as seen in the new diagram[1] Plate I, they are broken along a line running parallel and near to the isobase of 120 metres of the first Yoldia stage (Figs. 5 and 9). Within narrow limits this line coincides with the Salpausselkä zone, but elsewhere in Western Finland it remains inside it.

Such a line was called the hinge-line by Goldthwait (1908) in North America and was conceived by him to be a line of weakness in the earth's crust, thus acting like a hinge about which the tilting has taken place. The same term will be used here.

FINIGLACIAL HINGE-LINE.

To the north-west of the hinge-line in Western Finland the old water planes rise fairly rapidly and are parallel to each other. Southeast of this line the tilting of the shore-lines is far less marked and is also of different degrees. This exceptional warping of the earth's crust occurred at the end of the Ice Age, between the formation of the shoreline of the Rhabdonema Sea and the beginning of the Ancylus stage. Its progress can be followed in detail by means of two diagrams in Fig. 7. The first one shows that stage in late-glacial history, when the Rhabdonema beach was under formation at the sea-level of its own time. The older shore-lines had of course been formed earlier and raised to their respective places in relation to the Rhabdonema beach. In other words, they were horizontal north-west of the hinge-line, while in the south-east they were tilted. Thus, the first phase in the deformation was directed downwards.

The first diagram shows also five successive stages of retreat of the ice margin, and the position of the sea-level in regard to them. They show the relation between the decreasing ice-cover and the rising earth-crust. The whole of Southern Finland was during these times subjected to a slow and probably intermittent uplift, but otherwise the character of this movement was not everywhere the same. Southeast of the hinge-line the rise was differential, the shore-lines being tilted normally at the ice-load in the Salpausselkä zone as well

[1] This graph was made during the spring 1938 and was first presented at a meeting of the »Physikalisch-ökonomischen Gesellschaft zu Königsberg in Pr.» on the 30th May of the same year in Königsberg, where the author was called to hold a lecture on the latest progress in our studies concerning the Late-Quaternary history of the Baltic. Later on, in November, when R. Lidén (1938) and Erik Fromm (1938) had published their extremely interesting papers concerning the varved postglacial sediments in Ångermanland, several new datings were marked in the diagram.

as south thereof, in areas, which had been relieved of the ice already earlier. North-west of the hinge-line the centre of the uplifted area shows no departure from horizontality during the whole process of movement. The normal tilting was prevented there until almost all the ice had disappeared. Then the recovery was exceptionally rapid

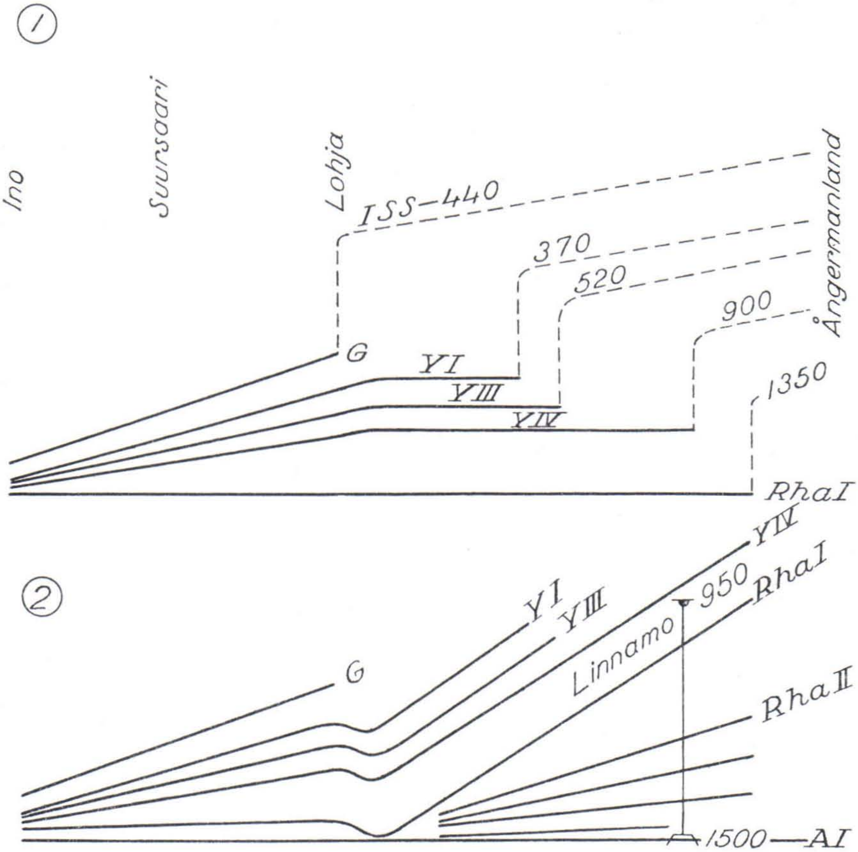

Fig. 7. Diagram showing the progress of the rapid tilting about the finiglacial hinge-line. 1. State at the close of the Rhabdonema stage, and 2, at the beginning of the Ancylus time.

up to the Ancylus time, and, as seen from Fromm's (1938) study, also later on during 150 years, when the normal rising and tilting of the whole glaciated area set in,

Diagram 2 in Fig. 7. shows this end-phase of the rapid tilting and also some chronological data concerning the uplift of Ångermanland at the end of the Ice Age, which has been studied by Lidén (1913).

By means of varved sediments he has accounted for the recession of the ice-border and also for the changes of level, when the delta-planes of the rivers during the regression moved from their highest position down the valleys. The oldest beach features formed on the coast of the Bothnian Gulf at the retreating land-ice represent chronologically and also in their relation to the first Littorina beach that stage, when the rapid regression after the fourth Yoldia set in from an elevation of about 270 m. at Linnamon. From this height the sea level has moved downwards 71 metres, near to the first beach of the Ancylus lake. This occurred about between the years 950 and 1 500 according to the Finnish chronology. Thus the mean velocity of the regression is 13 m. per century. This figure exceeds all other values relating to the land uplift in Fennoscandia and is in the opinion of the author valid only for Ångermanland at the close of the Ice Age. At the same time the zone of the hinge-line in Western Finland, lying at a distance of 400 km. from Ångermanland oscillated up and down within narrow limits, also later on still remaining at the same elevation, as seen from observations made by Aurola (1938) and the author (Sauramo 1936, Fig. 7). These facts give a striking conception of the great and abnormal temporary tilting in question. The eustatic rise of the sea-level has played no decisive rôle in this case.

We must, however, remember that the above mentioned figure relating to the regression in Ångermanland is the m e a n a m o u n t for 550 years. Actually, the change of level was not continuous, but intermittent, the formation of distinct beaches corresponding to pauses in the regression. The sea-level has thus for instance remained at the first Yoldia beach for about 400 years and at the fourth Yoldia for about 350 years. The above mentioned 550 years include the formation of the well marked Rhabdonema beach and also some other less distinct shore features. For these pauses in all about 400 years must be calculated. Consequently there remains only about 150 years for the movement itself, assuming that the land rise was not continuous as in the east of the Bothnian Gulf. Here, at Mount Lauhavuori, the above mentioned figures are in every case usable, being only a little smaller than in Ångermanland. This means that the actual velocity of regression was from 40 to 50 m. per century, or 0.5 m. in a single year! That is nothing less than earthquakes.

Such a conclusion is not at all surprising, considering that even now the centre of land-upheaval in Fennoscandia coincides with an area where the earthquakes are most numerous and strongest (Sahlström 1930). As supposed by Renquist (1930), they may be connected with the recent uplift of the earth's crust. At the end of the Ice Age these movements were apparently more severe, as may be concluded from the greater amount of the temporary uplift. Thus, we can say, that the Ice Age finished in Fennoscandia not only with a deluge, but also with extraordinarily great earthquakes.

ISOSTATIC RECOVERY.

The presence of elevated marine sediments and raised beaches in the centre of glaciation was first explained by Jamieson in the year 1865 by means of the theory of isostasy. He considered that the flexibility of the earth's crust was so great that it sank beneath the weight of the land-ice, and so became temporarily submerged, rising again on the melting of the ice-sheet. According to observations, the recovery from isostatic depression set in very soon during the removal of the load. It proceeded at first with relative rapidity, but ultimately slowed down and will reach its final completion only after a considerable lapse of time (W. B. Wright 1914, 1937, A. Penck 1922, R. Daly 1937). Thus, although the recovery in Fennoscandia started already 12 000 years ago, the recent land upheaval still shows youthful vigour, as seen above.

Moreover, evidence has been brought forward with a view to showing that the recovery progressed with a wave-like motion from the periphery to the centre, the uplift at any stage having always been considerably more advanced at the periphery than in the centre (Brögger 1901, Born 1923, Ramsay 1924). This conception, however, has not been confirmed by the detailed studies of Tanner (1930) in the northern part of Fennoscandia. In Southern Finland the author has found, that the changes of level and the uplift of the earth's crust have not been controlled in detail by the decreasing ice-load. The isobases of the late-glacial shore-lines have no definite relation to the protruding ice-lobes and incisions of the sea between them, as seen on the map Fig. 5. In fairly good congruence with the curves of the recent uplift they have their own local course, running in some places parallel to the ice-border lines, but in other places crossing these, as for instance within the great eastern ice-lobe of the Salpausselkä stages. This rule is confirmed by an exception near Lahti, where the isobases of the late-glacial uplift deviate in some degree from their recent counterparts and have a tendency to run parallel to the ice-border. The earth's crust seems to have had a limit as regards sensitiveness in the isostatic recovery in detail.

On the whole, however, there is a fairly pronounced relation between the decreasing ice-sheet and the upheaval of the earth's crust.

At the periphery the land emergence followed immediately on the retreat and the diminishing of the ice-sheet, even the oldest known shore-line of the Baltic Ice-lake having been tilted before the formation of the succeeding beaches of the same ice-lake. In the centre of glaciation the uplift apparently set in already during these early times. There is no reason to believe that such was not the case. This is, however, only an assumption. Of greater importance for our purpose is the progress of deformation of this area as actually established by means of the raised shore-lines. As long as there are greater remnants of unmelted ice the upheaval is fairly slow and equal throughout the whole area, and these remnants act as a brake, hindering the normal tilting upwards (Fig. 7). After the disappearance of this brake, the delay has been compensated by an abnormally rapid tilting about the hinge-line. The area inside the hinge-line bulged like a buckle on the surface of a rubber ball. We will call the limit of this buckle the finiglacial hinge-line.

GOTIGLACIAL HINGE-LINE.

Another hinge-line of gotiglacial age exists in the periphery of the glaciated area. It can be established by means of the oldest known shore-line (BI) of the Baltic Ice-lake. In the author's first diagram from the year 1934 he placed the line representing this water plane chiefly according to Munthe's investigations at Mount Billing in Central Sweden (Munthe 1928). In Finland only the region north-east of Lake Ladoga was studied in this respect, first by Ramsay (1931) and later on by the young geologist Sampo Kilpi (1932). In the summer of 1937 the author traced the shore-line in question in the whole of Eastern Finland, especially in Northern Carelia, checking there earlier observations (Wilkman 1912) and at the same time making new ones. According to the observations then made, unexpectedly large areas of this very thinly populated region have been submerged at the retreat of the land ice. Varved sediments occur in local basins, though they were later on almost entirely covered by peat bogs. The highest limit of the ice-lake is marked by shore features and also by glacifluvial deltas, one of these being the Selkäkangas, south of Lake Koitere and about 75 km. north-east of Joensuu. Among the fairly numerous glacifluvial terraces that the author has seen in Fennoscandia, Selkäkangas is the largest single one, being at the same time also the most beautiful in its features. The flat surface of the delta, which is 1 or 2 km broad and about 20 km. long, lies at an elevation of about 176 m.

Towards the north this water plane rises fairly rapidly, attaining a height of 200 m. within a zone where the first Yoldia lies at 120 m. Southwards it correspondingly sinks to 100 m. near Sortavala on the northern coast of Lake Ladoga, and to 50 m. in Salmi east of the same lake. At Sortavala the Yoldia again has a height of 50 m. As the shore-line in question has been marked in the new diagram according to these observations, it shows a fairly great degree of tilting in relation to the succeeding water planes, formed during the Salpausselkä stages. One would perhaps expect to find in this wide angle a great difference in age between the shore-lines; but such is not the case. During the first ice-lake stage the ice margin had retreated already very near to the first Salpausselkä moraine. Thereafter the water

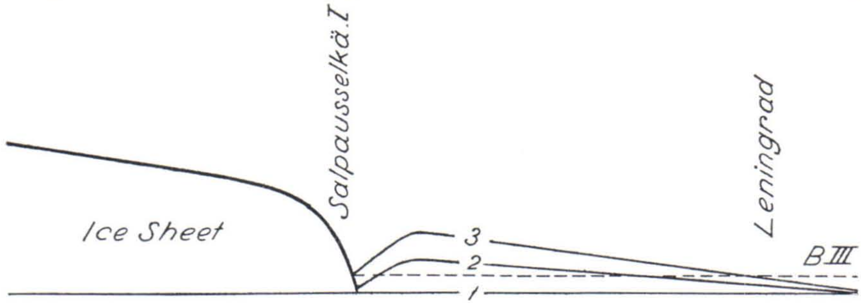

Fig. 8. Diagram showing the rapid tilting at the beginning of the first Salpausselkä stage. 1 shows a horisontal level before the tilting, 2 and 3 the successive stages in its deformation. The line BIII indicates the level of the third Baltic Ice-lake formed after the tilting. The inclinations are greatly exaggerated.

level suddenly dropped considerably at two stages when a new outlet was opened to the White Sea in Northern Finland (Hyyppä 1936). Some fifty or, as a maximum, a hundred years later the first Salpausselkä stage set in about the year -660, lasting somewhat longer than two centuries, to the year -445. In this year the water plane of the third Baltic Ice-lake (BIII) abandoned the upper series of the marginal deltas of the first Salpausselkä. Thus, the time-interval between the formation of the shore-line BI and BIII is somewhat more than three centuries. This short time by no means corresponds to the degree of tilting of the shore-line BI, when one considers that the succeeding late-glacial beaches of the same region have in their tilting differentiated far less during the lapse of 1 500 years.

The area in question must consequently have been subjected to a rapid deformation of the same character as that in the centre of Fennoscandia at the end of the Ice Age. The tilting has taken place before the end of the first Salpausselkä stage about a hinge-line situated somewhere south-east of Leningrad (Fig. 8.) The north-western limit of the tilted area has been limited by the great ice-lobes of the first Salpausselkä stage, see Fig. 9. Inside this limit the load of the stagnant and probably also increasing ice, caused according to Hyyppä (1933, 1936) by the rising moisture during the last maximum of the solar radiation (Milankovitch 1930, 1938, W. Köppen 1934, Sauramo 1938 b, Ahlmann 1938), seems to have put a brake on the uplift, whereas the sudden thinning of the water-cover outside the same limit may have facilitated the tilting, as in the case of Lake Bonneville in North America.

ABNORMAL UPLIFT OF EASTERN CARELIA.

However, the deformed area has also a northern limit, to the east of Joensuu. There the isobases split into two groups, as seen on the map Fig. 5, the northern ones following the general direction to the north-east, while the southern group turns to the east, describing a wide bow, which probably comprises also the area of Lake Segosero (Seesjärvi) and the northern end of Lake Onega in Eastern Carelia. This form of the isobases is seen already on some earlier maps (S. B. Jakowleva 1932). The course of the isobases suggests, that the area in question has warped along a line running parallel with the axle of the old Archaean mountain ridge, thereby uplifting the eastern side of the area to an abnormal height in relation to the Leningrad district.

In the basin of Lake Segosero (Seesjärvi) and also south of it varved marine late-glacial sediments occur, containing *i. a.* fossil shells of *Yoldia* (Djakonova-Saveljeva 1929, S. B. Jakowleva 1932). Therefore the corresponding marine stage has been called the Yoldia Sea. It has also been correlated with a stage of the same name in the development of the Baltic Sea. With regard to this dating it must be remembered that the Baltic Yoldia in our system is of finiglacial age, and that at this stage the land-ice had already entirely withdrawn into the Baltic basin and inside the Salpausselkä moraines. The area east of this ice-border line again was freed from ice during the later part of the gotiglacial time (BI) and the Onega district still earlier. Consequently, the above-mentioned Yoldia-bearing sediments are of gotiglacial age or still older, corresponding to the shore-lines *g*, *h* or, perhaps, *i* in Tanner's (1930) system. It would be of great interest to know if the finiglacial Yoldia Sea also extended to Lake Segosero. In that case it would be possible to follow the progress of the abnormal deformation of the area in question more in detail.

LAND RISE IN NORTHERN FINLAD.

Let us now see whether the two hinge-lines found in the south-eastern section of the glaciated area are traceable also in other parts of Fennoscandia.

In the Sotkamo area (Kilpi 1937) and in the northern part of the Baltic basin (Hyyppä 1936), the late-glacial changes of level have taken place quite in the same manner as in Western Finland, the uplift of the earth's crust having been intermittent and equal everywhere. These areas consequently lie inside the finiglacial hinge-line. This can, however, not be placed here in detail, because the changes of level have not been accurately studied east of the water-shed and the Finnish frontier. We can only state that the eastern limit of the equally uplifted central area on the whole coincides with the ice-border line corresponding to the Salpausselkä moraines (Fig. 9). Thus, its relation to the retreating land-ice is the same as in Western Finland.

On the coast of the Arctic Ocean Tanner (1930) has studied the changes of level in great detail. His diagram shows a great similarity to that of the author as regards the later marine shore-lines counted from the end of the gotiglacial time. During the earlier stages, from *h* to *l* in Tanner's system, Southern Finland was not yet uncovered. Tanner's water planes *e* + *f* correspond in Southern Finland to YI + YII + YIII, and the line *c* to the metachronous highest limit of the postglacial transgression indicated by the beaches LI, LII, LIII, LIV, LV, and, LVI in the Baltic basin. According to this connection the Arctic coast, submerged by the Late-Quaternary Sea, corresponds to that part of Southern Finland which lies south-east of the finiglacial hinge-line. The differential tilting is characteristic for both areas. The limit against the equally uplifted central area must therefore lie farther south in Lapland. As there are only high supramarine lands in this territory it is, however, impossible to trace the hinge-line in detail.

In Tanner's diagram the oldest raised shore-lines on the ocean coast show different degrees of inclination. The greater differences may of course be due either to a rapid temporary tilting or to a slow differential uplift during a longer time. As, however, the more accurate time relations are quite unknown there, we cannot answer the question about the presence or absence of the gotiglacial hinge-line. Instead, we find that the most peripheral zone is faulted, the Cambrian sediments of the Fishers' Peninsula having dropped about 15 m. in relation to the Archaean continent. This occurred, not at the retreating ice margin, but later on, chiefly during a time when the shore-line in Central Finland moved from the fourth Yoldia down to the Rhabdonema beach.

HINGE-LINES IN SWEDEN.

The two hinge-lines found in Finland are perhaps traceable also in Sweden. During excursions arranged there by the Geological Society of Stockholm last summer the author had the opportunity of becoming acquainted with Mr. and Mrs. Sten Florin and their archaeological and geological studies in the surroundings of Lake Hjälmaren, and then arrived at the conception that the highest limit of the Ancylus Lake would have a much greater gradient there than in Southern Sweden and that it consequently was warped abnormally, as was the case in Western Finland, at the finiglacial hinge-line. According to this assumption, the hinge-line in question should run in the zone of the great Swedish lakes north of the Fennoscandian end-moraines. Apparently the tilting is connected with the local displacements characteristic of this area (L. von Post, 1929).

In the area of Lake Vettern the late-glacial changes of level during and after the Salpausselkä stages have recently been studied by Bergsten (1936) and Erik Nilsson (1936). Their results agree fairly well with those obtained in Finland, and afford a ground for correlating the named late-glacial shore-lines in our system. Now, according to Henr. Munthe (1925), and E. Granlund (1936, Fig. 99) also a higher water plane of great inclination representing the first shore-line of the Baltic ice-dammed lake exists there. It coincides with the author's BI in Eastern Finland and consequently implies also the occurrence of a rapid tilting south of the great end-moraines in Sweden. Thus the gotiglacial hinge-line ought to be found in Southern Sweden.

In Gotland (L. von Post etc. 1925) and in Öland (G. Lundqvist, 1928) the changes of level during post-glacial time are quite similar to those on the Carelian Isthmus (Hyyppä 1938), but the earlier shore-lines have not been studied in detail. Therefore we can only state, that the gotiglacial hinge-line probably lies more southward, perhaps in Scania, near to the outer limit of Fennoscandia, where displacements have occurred also during Quaternary time. This can be seen from Hyyppä's (1938) diagram, which is the only suitable one showing the latest changes of level at Limhamn, in southern

Scandia, whereas the earlier shore-lines have been deformed irregularly, as in Eastern Carelia and Fishers' Peninsula[1].

DISCONTINUOUS NATURE OF UPLIFT.

It would appear, therefore, that the Fennoscandian uplift area is characterized by two concentric hinge-lines (Fig. 9). The more central and later one encircles the buckle which developed at the end of the Ice Age. The peripheral and earlier hinge-line again shows the outer limit of a zone which tilted at the beginning of the Salpausselkä stages. The inner limit of this tilted zone runs near and parallel to the ice border line of that time. Consequently there is a fairly pronounced relation between the retreating ice margin and the isostatic rise of

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[1] After this paper was ready for print, the author received L .von Post's (1938) preliminary report concerning the isobase surfaces in the late-Quaternary Viska fiord in Western Sweden. Assuming that the diagram showing the relations and the chronology of the shore-lines is in the main correct, the vertical distances between the earlier late-glacial and post-glacial shore-lines in Western Sweden differ greatly from those observed in the Baltic basin and on the coast of the Arctic ocean. Consequently also the mode of the land upheaval took place in another manner. In fact, von Post sets forth that the isostatic land rise has been twice interrupted by a retardation or a real sinking of the earth's crust. The intermissions are assumed to have been caused by a temporary increase of the ice load especially at the end of the gotiglacial time and also afterwards.

The old and well-known idea of land sinkings and transgressions during the late-glacial epoch has not been supported by investigations in the Baltic basin, at least not in the Finnish part of it. On the contrary the land near the ice-sheet has always had a tendency to rise also during the Salpausselkä stages, as clearly seen by the relative position of the successive marine shore-lines G and YI. Moreover, our fairly rich stratigraphical, phytopalaeontological and morphological material does not provide any evidence whatever in favour of the view that the Yoldia Sea of our system might have been transgressive. Only the Rhabdonema Sea seems to have in some degree submerged the southern coast of Finland, probably due to the eustatic rise of the sea level at the close of the Ice Age, as was the case during the Littorina time (Hyyppä 1939).

Von Post particularly emphasizes the preliminary character of his diagram. In the opinion of the author especially the datings of the late-glacial shore-lines may undergo changes and therefore also the conclusions based upon these must be somewhat modified in future. At present the author of this paper suggests that the changes of level followed the same rule in Western Sweden as in other parts of Fennoscandia so far investigated in detail. This assumption is supported by the fine observations which von Post with his young colleagues has made in the picturesque Viska valley and which he showed during and after the above mentioned excursions last summer. The map of the Baltic Rhabdonema Sea (Fig. 3) has been drawn in accordance with this view as regaıds Western Sweden.

the earth's crust, the diminishing ice-sheet having chiefly controlled the rate and mode of the land uplift. The isostatic recovery has, however, not progressed like a wave after the retreating ice margin; it is discontinuous in another manner. There are two limited areas

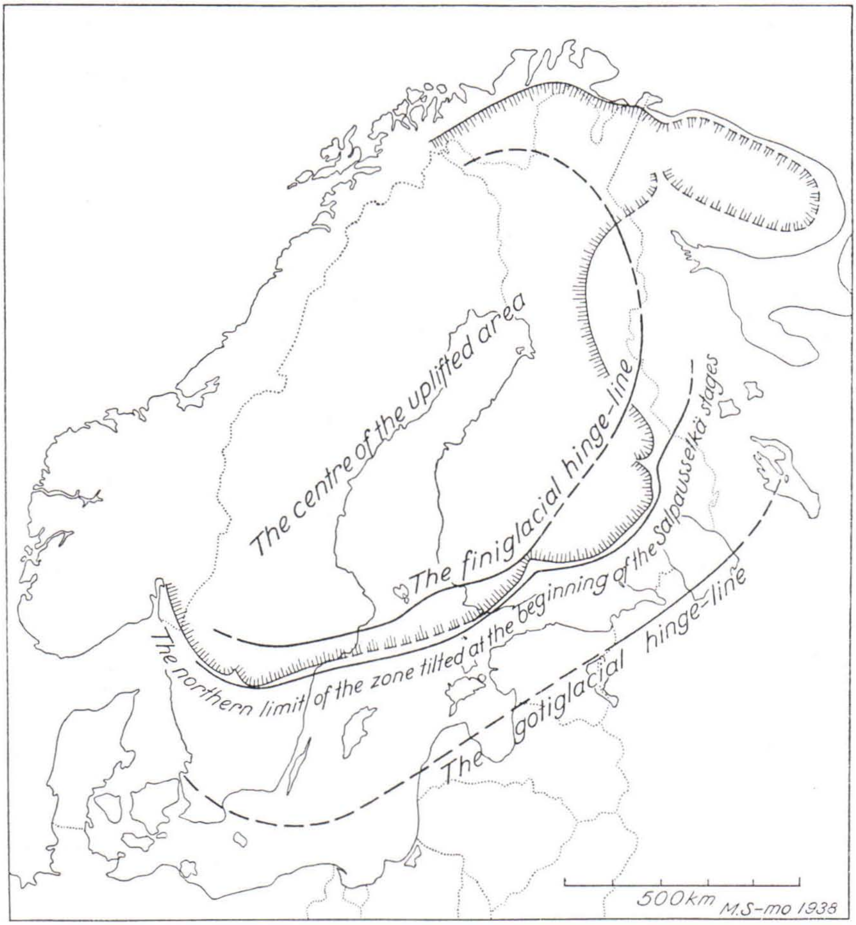

Fig. 9. Map showing some of the most important structures in the deformation of the earth's crust during late-glacial time. The toothed line indicates the ice margin at the close of the first Salpausselkä stage.

which have been tilted separately one after the other during a relatively short time; hence the uplift of the earth's crust took place at a slower rate throughout the uncovered area. Moreover, the hinge-lines run in the first place parallel with the isobases, but at the same time they show a tendency to be in harmony with some local structure of the earth's crust.

The discontinuous uplift appears in the diagram, Plate I, the shore-lines being divided into three groups according to their degree of tilting. The first and most tilted group consists of BI only. The second group is formed by the succeeding and, in the central area, parallel late-glacial shore-lines (BIII—Rha I), whereas all post-glacial water planes counted from AII belong to the third group. The groups are separated from each other by some intermediate shore-lines of short duration, as for instance BII between the first and second group, and, Rhabdonema II, Rhabdonema III and also the first Ancylus between the second and third group. The whole system shows clearly that the degree of tilting of a shore-line is no measure of its age. Instead the intermissions of the relative land uplift have followed a regular time-table, the longer pauses during the late-glacial time, G, YI, YIV, and Rha, having a periodicity of about four or three centuries.

In the third group there is seen an unusually wide angle between the second and third Littorina shore-line. In this case Lidén's (1938) admirable curve showing the rate of the regression in Ångermanland is not suggestive, because its form between the stages LII (4 500 B. C.) and LIII (3 300 B. C.) happens to be based upon interpolation. Future researches will show whether the regression during this time was gradually diminishing or implies retardations and accelerations corresponding chronologically to that part of the post-glacial epoch, when the peripheral zone of the isostatically uplifted area was temporarily resubmerged by the eustatic rise of the sea-level.

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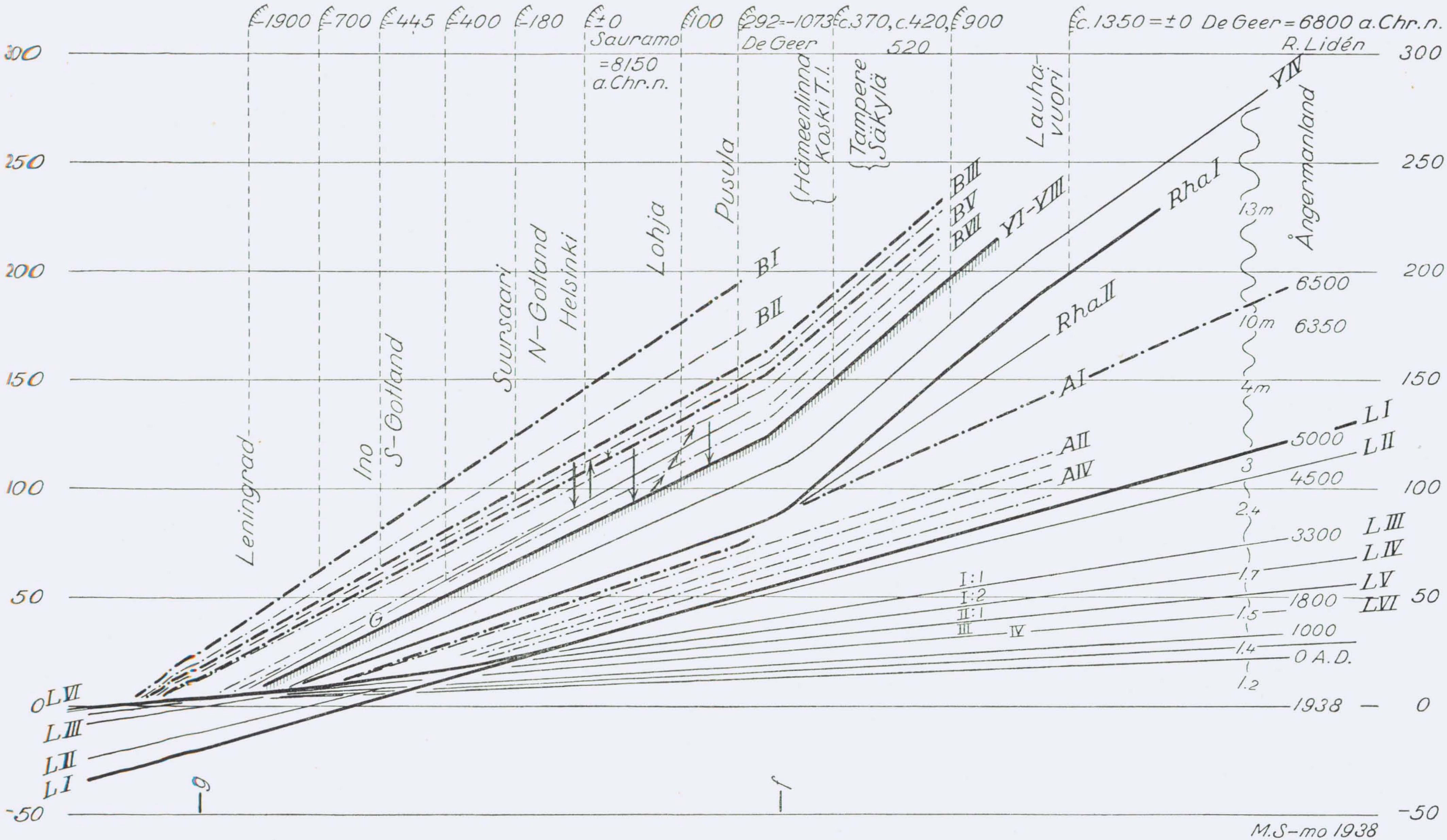

Diagram of the most important shore-lines in the Baltic. The figures in the upper margin give the age of the shore-lines in the Finnish and also in the historical chronology according to G. De Geer and R. Lidén. Fresh water stadia shown by dash and dot. The arrows indicate the successive changes of level during the complicated history of the Baltic ice-dammed lake stages. The undulating line on the right shows with its figures the successive rates of the regression in Ångermanland according to Lidén and Fromm. f = finiglacial hinge-line, g = gotiglacial hinge-line. The situations of the Stone Age dwelling places in relation to the Littorina shore-lines are indicated by numbers, I, II and III being the successive styles of the comb-ceramic culture in Finland according to A. Äyräpää (1930) and IV the cord-ceramic or hammer-axe culture. The lettering of the shore-lines is explained in the text.

4.

THE ROCK-GROUND OF THE COAST OF LABRADOR AND THE CONNECTION BETWEEN THE PRE-CAMBRIAN OF GREENLAND AND NORTH-AMERICA

by E. H. KRANCK.

1 map and 6 figures in the text.

INTRODUCTION.

The Coast of Newfoundland-Labrador from the Strait of Belle Isle to Cape Chidley consists of Pre-Cambrian rocks belonging to the Laurentian shield. The coast-line is highly indented and sheltered

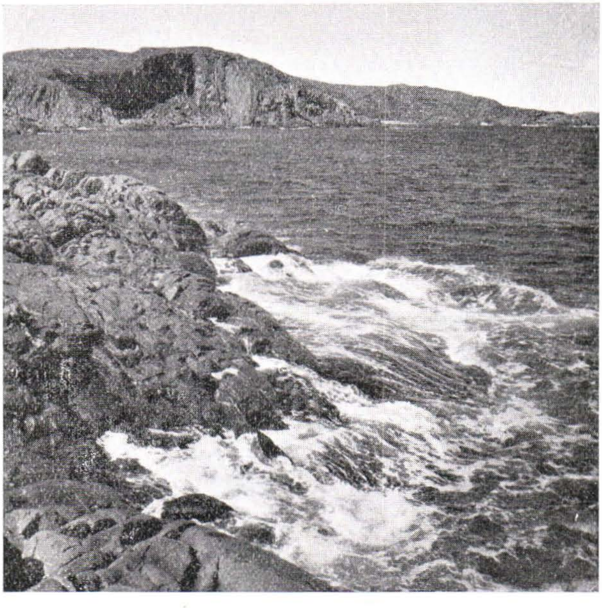

Fig. 1. Gneiss-granite cliffs on the Labrador coast. Fishing Ships Harbor.

by a large fringe of islands. Except for the northernmost section, where the mountains exceed 5 000 feet in height, the coast is comparatively low. If we were to compare it with a coast in Europe, the closest correspondence is shown by the Swedish west-coast and some parts of the coast of southern Norway.

The inner coast is wooded up to about 56° North, but the barren islands and cliffs facing the open sea everywhere offer splendid opportunities to study the rock-formations and their structures (Fig. 1).

The Labrador coast is conveniently accessible in summer by steamer from St. John's. Never-the-less, it is very incompletely known from the geological point of view and the investigations carried out which have dealt with this subject are easily counted. Among earlier explorations the journeys of Packard (13) are worth mentioning. Although not a geologist by profession, Packard has delivered the first accurate data about the rock-ground of the coast in question. In the years 1892—93—94—95 A. P. Low of the Geological Survey of Canada made a number of traverses across the Peninsula. His descriptions of the geology of these waste regions are still the most accurate found in print (11.). In 1902 R. Daly travelled along the Labrador coast with the Harward expedition and visited a number of localities, more particularly in the northern part of the country (5.). In 1912 his investigations were continued by Coleman (4.) who also mainly studied the formations in the Far North. Our knowledge of the geology of the coast of Labrador is above all due to the valuable work of these two geologists.

Later, local investigations have been carried out by *i. a.* Kindle (6.), Odell (12.), Wheeler (17.) a. o.

In the summer of 1937 Prof. Dr. W. Tanner (14.) and I made a journey along the coast from the Belle Isle Strait as far as Hebron. During this journey I had the opportunity to make acquaintance with most of the localities described by the authors mentioned above and to obtain some additional data about the rock-ground geology of Labrador (10.). At these investigations I had in mind the possible connection between the Pre-Cambrian of Greenland and Labrador. The question whether Greenland belongs, or has belonged to the Pre-Cambrian Shield of North America or whether it rather is to be regarded as an independent *bloc* is still a matter of discussion. Further, we do not know when the connection between North America and Greenland was cut off.

In the following it will be shown that Labrador really can deliver some contributions towards an answer to these questions, and therefore also can contribute to the solving of the question regarding the connection between the Pre-Cambrian in Northern Europe and North-America.

THE ROCK-GROUND OF THE LABRADOR COAST.

A. The Basal Gneisses.

The chief part of the rock-ground of the Labrador coast consists of migmatitic gneisses originated by means of a granitization of older

Fig. 2. Aillik-quartzite with ripple-marks. Aillik Point.

rocks, partly of sedimentary, partly of volcanic origin. In general they show the same features as the gneisses of other crystalline areas. The granitic component dominates and occurs in different varieties, both as regards composition and texture.

The microcline-rich varieties dominate. White and gray-coloured rocks are, however, much more common in the shore-cliffs than are the pink coloured ones, this evidently in part depending on the weathering in the cold, humid climate.

The primary character of the supercrustal rocks which have given rise to the gneisses can be seen only on a few localities. The most remarkable of these is the region of Makkovik and Aillik, about midwas between the north- and south-ends of the coast. At Pomiadluk point, west of Aillik, Daly found a series of conglomerates and quartzites older than the surrounding granites. The same sediments were encountered also on Aillik Point in a comparatively less altered state. The quartzites of Aillik are only slightly affected by tectonic deformation and show cross-bedding and ripplemarks. The layers have here an almost horizontal position. At Makkovik the same formation is highly stressed and the original textures are almost lost.

The sediments are here surrounded by a white granite of evengrained structure with microcline as the chief component. The contact between the granite and the quartzite is generally very vague and in many places it is impossible to tell which of the two rocks is at hand. The transformation of quartzite into granite has sometimes resulted in more resistant structures like coarse conglomerates (generally only the mafic pebbles), basic veins a. s. o. beeingleft. The quartzite usually contains lime-rich concretions. These have at the granitization been transformed into lime-silicates, generally garnet or hornblende.

In contrast to this type of gradual transformation of quartz-rich sediments into pure granite, we have in the same locality also normal intrusive contacts between the granite and the sediments. This depends partly on the chemistry of the altered sediments, partly on tectonic conditions. The conditions at Makkovik give a very good idea of the mode of origination of the gneiss-formation and the granites belonging to it.

On other parts of the coast traces of sediments evidently belonging to the same old formation have been encountered, *e. g.* on Huntingdon Island outside Cartwright and at Battle Harbor. On the last named locality lime-rich sandstones and interbedded layers of limestone and sandstone have composed the primary formation.

These localities however only represent scattered ocurrences of limited size not exceeding some miles in diameter. The rest of the oldest sediments have been folded down to the depth of the earth crust where the remelting actions, and generally speaking the mobility of the atoms have caused a rearrangement of the rock-constituents.

Gneisses containing chiefly remnants of Mg-rich supercrustal rocks of igneous origin and pure lime-sediments seem to play a more important rôle in the northern parts of the coast. Here inclusions of soap-stone and »skarn»-rocks are abundant.

A gneiss called »Domino-gneiss» is often mentioned in the litterature dealing with the geology of Labrador. This name was used by Packard (l. c.) to indicate a light gray schistose gneiss, occurring *i. a.* at Domino Harbor. The schist-layers of the rock are often almost horizontal and give, seen at a distance, the impression of a primary bedding. Evidently this bedding caused Packard to describe the gneiss as a sandstone, and owing to Packard's description Low (l. c.) later on classified it as Devonian. The original localities have not

Fig. 3. Domino-gneiss at the »Narrows» of Double Mer.

since been investigated, and the opinions about this gneiss therefore vary considerably in the descriptions given by different authors.

A closer examination of these gneisses on several localities, *i. a.* at Domino Harbor, convinced me that they are highly sheared rocks grading into mylonites, which derive from primary rocks of varying composition. They have a texture in common because of the strong tectonization. The Domino-gneisses evidently have been formed along shear-zones in the rock-ground indicating big thrusts of comparatively recent age (later than the last regional granitization) (Fig. 3).

B. Late Pre-Cambrian and Eo-Cambrian sediments.

Two series of sedimentary rocks separated from the basal-formation contained in the old gneisses by a big unconformity, have been found on Labrador. They have been called The Ramah-Cape Mugford beds and the Double Mer sandstone.

The Ramah-Cape Mugford beds have been found only in the northernmost part of the coast region. At Nachwak

Fig. 4. Double Mer sandstone with current bedding. North shore of Double Mer.

Fjord they consist of a series of quartzites, slates and dolomitic limestone reaching a thickness of about 3 000 feet. The series has been gently folded. At Cape Mugford the series chiefly consists of volcanic and pyroclastic rocks interbedded by ordinary sediments, mostly slates. The folding is here imperceptible.

The Double Mer sandstone is a red arcose sandstone with interbedding conglomerates and clay-stones. It resembles in every respect the red Keeweenawan sandstones of the Lake-Superior country and the Jotnian sandstones of Scandinavia (Fig. 4.).

The rocks have a considerable distribution in the region around Lake Melville and its tributaries, and have also been found over wide areas in the interior parts of Labrador. They occur in the coast-region in »fault-Graben», surrounded by gneissic rocks. No fossils have been found and the age is therefore still a matter of discussion. An Eo-Cambrian age seems. however, to be the most probable.

C. The igneous rocks of the Labrador coast.

In the following only some of the igneous formations of Labrador which are distinctly separated from the gneissic rocks will be dealt with.

The only rock-series which has given Labrador a place in the petrographic text-book literature is that of the anorthosites and labradorites. These rocks occur throughout great areas in different parts of the Peninsula. The best known formations are situated near the south-coast (1.). In the coast-region now in question there are two such areas, the Nain area and the Square Island area. The first-named is the bigger of the two and includes the famous localities of blue Labradorite (Taber Island).

These anorthosite-areas actually consist for the most part of gabbros, as is the case with the areas described by Adams from the province of Quebec (1.). The anorthosites are penetrated by pegmatitic dikes and are older than the last granitization of regional type. They have also in a considerable degree been influenced by tectonic movements, although generally only the marginal parts show a higher grade of deformation. The anorthosite-gabbros have in such sections been transformed into amphibolites and hornblende- schists.

Basic instrusions related to the anorthosites are known more particularly from the south-westernmost parts of the coast between Domino Harbor and Hamilton Inlet. These intrusions have in earlier descriptions all been referred to as »trap»-dikes. This definition however holds good only for a part of them. The main part, *i. a.* the dike-like formations around the Domino Run, actually consists of a coarse-grained gabbro which occurs in dike-like bodies, but which is older than the granitization of the surrounding Domino-gneisses. This granitization has contemporaneously affected both the gabbros and the gneisses which they have penetrated. Later both have been deformed by the tectonic movements which have given rise to the schistosity of the Domino gneisses. Only in the marginal parts have the gabbros been metamorphosed in any considerable degree.

Petrographically the intrusions consist of gabbros and norites. The dark component is augite, hypersthene and hornblende in varying proportions. In the contact with the gneisses the mineral composition has been in some degree altered. The pyroxene has been transformed into actinolitic amphiboles, the plagioclase into epidote, etc. Garnet is often seen as reaction mineral between plagioclase and pyroxene.

These gabbros seem to belong to the same series as the anorthosites, but have possibly intruded a little earlier than the bulk of the first-named.

Younger granites and syenites. Particularly along the coast north of Hamilton Inlet a great number of islands consist of coarse-grained rocks which on cursory study in the field greatly resemble the foregoing rocks. They occur *i. a.* on Ragged Island, Ironbound Island a. s. o. A characteristic feature is the strong weathering, which reminds one of some magnesia-rich diabases and also of »rapakivi»-granites.

The laboratory investigations have shown that these rocks represent a different series, evidently younger than the anorthosites. The composition is for the most part characterized by KNa-felspar and plagioclase with pyroxene, hornblende and some mica. A chemical analysis of the rocks of Ragged Island carried out by Dr. N. Sahlbom (Table 1, No. 1) shows the composition of a typical nordmarkite from the Oslo area. Also the structure and outer aspect recalls that of Norwegian nordmarkites. These KNa-rich rocks seem to grade into pure potash-rocks of partly syenitic, partly granitic composition.

The granites of the series are of rapakivi type. They are megasscopically coarse-grained, bright red or dark-red rocks. Ovoidic felspar has not been found, but the weathering and coarse jointing remind us very much of some rapakivi-varieties. The chief components are very coarse perthitic potash-felspar, bluish quartz, and chloritized mica. A typical feature is the very high content of megascopically visible fluorite and orthite.

Granites of this type have been found at Strawberry Point near Makkovik and along the southern edge of the anorthosite area of Nain. They are unaffected by tectonic movements.

The petrographical investigation of this interesting rock-group is still incomplete.

Dike rocks. True dike-rocks are abundant all along the Labrador coast, even if we exclude from this group all the sheet- and stock-like intrusions mentioned in the foregoing.

They can be divided into two main-groups; 1. normal »trap»-dikes (of diabasic composition) and 2. lamprophyric dikes.

Also dikes of more acidic composition have been found, but the present description will be restricted to the chief types mentioned above.

Diabase-dikes have been described by different authors as a very typical feature of the geology of the Labrador coast. The observations are for the present too incomplete to permit any answer to the question as to the age of these dikes, but evidently there exist several systems of different age. The composition varies considerably. Olivine-bearing and olivine-free diabases are known. Also

Fig. 5. Coarse-grained peridotite, Smoky Island.

coarse porphyric varieties have been observed. In connection with one of the »trap»-series a coarse-grained peridotite occurs in the region of Indian Harbor (Fig. 5.).

Probably a part of the trap-dikes belongs to the same eruptive series as the Cape Mugford volcanics, while another may be as young as the basalts of the coast of Belle Isle Strait (Paläeozoic).

In no part of the coast are these dikes absent.

The lamprophyric dikes seem to be particularly numerous between Hamilton Inlet and the anorthosite area of Nain. Unlike the trap-dikes mentioned above, they generally have a flat, sometimes a horizontal position. Dikes of different systems may cut each other at a small angle, *i. a.* on the locality shown on Fig. 6 p. 74. Generally a great number of dikes occur toge ther; 10—20 dikes often following above each other. The size varies from a thickness of less than an inch to 10—20 feet.

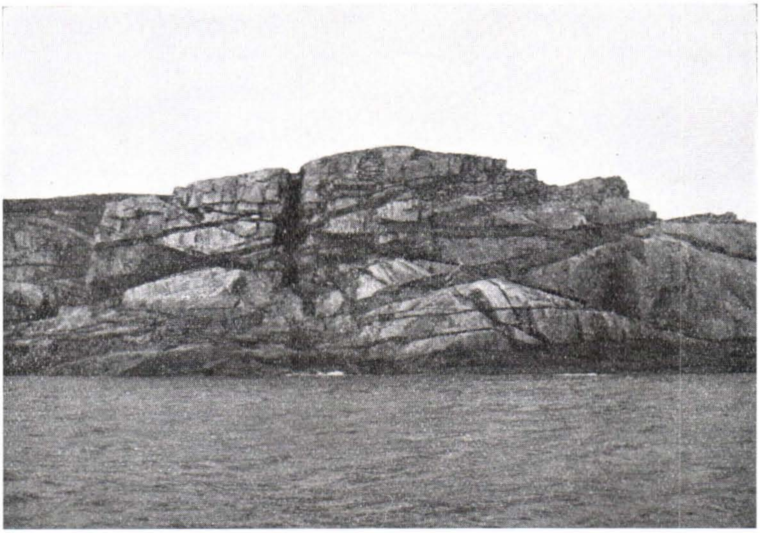

Fig. 6. Lamprophyre dikes, south of Aillik.

The rock-types of which I have made a closer petrographical investigation are megascopically dark-gray even-grained rocks, in more coarse-grained types resembling diorites. The mineralogical composition is : plagioclase, potash-felspar, brownish-green hornblende, the last-named in well individualized crystals. Brown mica is generally present. Quartz occurs only in small quantities.

The composition and structure of these rocks closely correspond to those of the odinites and vogesites of western Germany and seem to belong to some of the granitic or syenitic rock-series of the region. They cut the syenites described in the foregoing and also the young granite cf Point Strawberry. The age-relation to the trap-dikes is not quite clear, but at least a part of the last-named seem to be later than these lamprophyres.

The chemical composition is shown of N:o 2, Table I.

Table I

	1.	2.	3.
SiO_2	60.62	55.10	20.66
TiO_2	1.05	1.28	3.87
Al_2O_3	16.07	18.05	5.35
Fe_2O_3	1.45	3.43	7.51
FeO	5.73	5.60	6.44
MnO	0.22	0.20	0.31
MgO	0.49	3.39	16.96
CaO	2.66	6.88	20.15
Na_2O	6.10	3.23	0.86
K_2O	5.13	2.01	1.93
P_2O_5	0.34	0.30	2.92
CO_2	n. d.	non	10.43
F	n. d.	0.13	0.24
BaO	n. d.	trace	0.15
$H_2O + 105°$	0.36	0.56	2.80
	100.22	100.16	100.39
$H_2O — 105°$	0.20	0.08	0.45

1. Nordmarkite, Makkovik Islands, Labrador. N. Sahlbom, analyst.
2. Odinite, Aillik, Labrador » »
3. Aillikite, Aillik, Labrador » »

The alnöite dikes, which I found in the region of Aillik, form a very interesting series of rocks. They evidently are lamprophyres, deriving from the syenites of Makkovik Islands.

Megascopically they are almost black, soft rocks with a dense ground-mass and abundant phenocrysts of olivine and brown mica. They sometimes contain inclusions of the country-rock, the last-named showing phenomena indicating a considerable, but not very strong heating. Melting could not be stated.

The composition is peculiar on account of the extremely high amount of calcite in the ground-mass, higher than in any other dike rock, except some pure carbonatites. The chemical composition of one of these dikes, shown in Table I, No 3, therefore gives a percentage of CO_2 which clearly distinguishes this rock from normal alnöites. The mineralogical composition is : olivine, biotite, calcite, titaniferous iron ore; in the groundmass there are further apatite, perowskite and often melilite in small crystals. The last-named mineral is generally completely carbonatized. It is therefore evident that at least a great part of the calcite (or dolomite) represents a late-magmatic crystallization from a magma very rich in carbonate solutions. During the first stage of crystallization melilite was formed, but the mineral was later on replaced by carbonate. There is, however, no reason to regard the calcite as a secondary product, although it is hardly probable that there ever has existed a calcite in molten stage.

On account of its rather unique properties I have given this rock a special name, »A i l l i k i t e», after the occurrence first detected. The Aillikite shows some similarities with the alnöites described by Bowen from Isle Cadieux (3), and from the genetical point of view it probably is related to the last-named. It will be dealt with more in detail in a special paper.

Besides these alnöitic dikes, also d i k e s o f p y r o x e n i t i c c h a r a c t e r containing abudance of analcite have been found.

I will limit the description of the igneous rocks of the Labrador Coast to these examples, which of course comprise only some of the more significant types.

A glance at the list of igneous rocks mentioned in the foregoing shows that it contains some rock-associations of special interest. We have first of all the anorthosites, a rock-type which has recently been the subject of theoretical discussions (6). Together with these rocks there are granites of rapakivi-type and diabases of different kinds. The same association is found also in the rapakivi-belt of Fenno-scandia, with the difference that the anorthositic rocks here play a rather unimportant rôle, while the rapakivi-granites on the other kand comprise great areas. Further, this association has been described from South Greenland and Southern Canada (1, 6).

The second association of interest is that of the nordmarkitic rocks and other syenites in combination with alnöites and other lam-prophyric dikes. The nordmarkite type of Labrador corresponds in every respect to the well known nordmarkites of the classic Oslo region in Norway. Further, as regards the composition they offer great similarities with the same types of rocks from the Kangerdluak district of South Greenland (15, 16). These circumstances lead to the conclusion that we may have alkaline rocks also on the Labrador coast in the region of Makkovik-Aillik, though nepheline-bearing varieties have not yet been found. This conclusion is supported by the dike rocks, above all by the alnöitic dikes, which are typical mem-bers of several alkaline provinces, *i. a.* the type locality of Alnö. In addition we have the analcite-bearing, pyroxenitic dikes, pointing in the same direction.

I wish to point out that the existence of the rocks mentioned above gives strong support to the supposition that an alkali-rock province may occur on the Labrador coast, but further finds are requisite before this can be regarded as definitely proved. I hope soon to have the opportunity of continuing my field investigations in order to have this problem solved.

It was shown in the foregoing that the nordmarkites are intimately connected with rapakivi-granites, partly very rich in fluorine-minerals. This also seem to have been the case in South Greenland. We consequently have to take into consideration also a possible relationship between the alkali-rocks on the one hand and the often observed association anorthosite (gabbro) — rapakivi-granite on the other.

I am not prepared to discuss this relationship here, but will return to the question later on. I merely wish to state that the sequence of intrusion or more correctly the sequence of *mise en place* of the rock-families here in question is the following: 1. Gabbro and anorthosites, 2. Nordmarkites and syenites, 3. Potash-rich granites (rapakivi), 4. lamprophyres.

The sequence is the same as in the region mentioned above in South Greenland and in the Oslo region. One difference which, however, may depend on incomplete observations, is the absence of essexite on Labrador.

SOME PARALLELS BETWEEN THE PRE-CAMBRIAN GEOLOGY OF GREENLAND AND LABRADOR.

There exists a certain degree of similarity between every crystalline area of the world, both as to the rock-types themselves and the combination of the rock-formations. These similarities, however, mostly depend on the fact that the geological forces which originate the »crystallines» everywhere are more or less the same and work in the same way. Only in a few cases do petrographical similarities rectify any conclusions regarding the stratigraphical parallelization of Pre-Cambrian formations in different parts of the world. Such may be the case only if the formations in question fit into a greater group of geological events which can be proved to be contemporaneous in both the regions dealt with.

As for Greenland and Labrador, it lies close at hand to look for the corresponding rock-formations on South Greenland and the coast of Newfoundland-Labrador. Both areas are situated close enough to each other to make it probable that the geological development at least at some periods has given rise to identical sediments and eruptives. In that respect the latest Pre-Cambrian or Eo-Cambrian seems to offer the most striking similarities.

Both South Greenland and the coast of Labrador are situated west of the Caledonian folding zone stretching along the eastern coast of Greenland and continuing on Newfoundland. The sedimentation within the folding-zone was of geocynclinal character. It is represented by the Eleonora Bay formation and the Petermann series on Greenland and the Avalonian on Newfoundland. The sedimentation west of the folding zone, which took place during the same facies of sedimentation (probably later than the chief part of the geocynclinal sediments mentioned above) has an epicontinental character. After all, we have to refer the so called Double Mer, sandstone on Labrador and the Igaliko sandstone on South Greenland to this facies of the Eo-Cambrian series. Petrographically both have much in common with the Jotnian sandstones in Scandinavia and the Keeweenawan in Canada.

The geographical distribution of the formations mentioned above seems to indicate that the Pre-Cambrian of Canada and of Greenland acted as a single resistant *bloc* even still during the Caledonian orogeny. As L. Koch has pointed out (8), Greenland no longer belongs to the Pre-Cambrian shield of North America and has shown a positive tendency already during the oldest Palaeozoic time. The definite separation can, however, hardly have taken place earlier than during later Cambrian.

As a starting point for the comparison between Labrador and Greenland I use the systematical division of the geological events during Pre-Cambrian time on South Greenland recently worked out by Wegmann (15.).

He distinguishes two great geological cycles separated by a big disconformity. The older cycle coincides with the formations which have taken part in the »Kettilidian mountain-folding. They are divided into two groups: 1. The Arsuk group, consisting chiefly of old sediments and 2. the Sermilik group, consisting of volcanic rocks. Both have been highly granitized and show the aspect of gneisses.

The events which have given rise to the present character of the rocks which build up the Kettilidian zone have been mainly the same as in every deeply eroded old folding zone of the earth crust. They are schematically expressed as follows:

Supercrustal deposition-folding-granitization-origination of pure granite (Julianehaab granite).

From a genetical point of view and also with regard to the petrography of the rock-types, the Kettilides form a parallel to the old gneisses of Labrador, including the Aillik quartzites. The end stage, the Julianehaab granites, is on Labrador represented by the Makkovik granite.

The Kettilides were completely denudated when the Igaliko sandstone and on Labrador the Double Mer sandstone were deposited. The Igaliko sandstone is cut by, and partly interbedded with numerous volcanic and instrusive rocks. These intrusions started with essexites and gabbros. Thereafter nepheline syenites, composing *i. a.* the classical area of Kangerdluarsuk, described by Ussing (16), were formed. Contemporaneous or still younger are a number of granite-intrusions of rapakivi-type. The plutonic rocks are accompanied by a great number of dike rocks of varying composition.

As Wegmann has shown, the tectonical movements during the *mise en place* of these rocks were restricted to faults and a general widening of the earth crust (16).

A petrographic-tectonic comparison with the Eo-Cambrian formations on Labrador shows some striking similarities. As already pointed out, the Double Mer sandstone offers a good parallel to the Igaliko sandstone, and I have therefore in an earlier paper (9.) provisionally used that rock as the starting point at the parallelisation.

The similarity is however conspicuous also as regards the igneous formations. We have on Greenland the sequence 1. essexite with anorthositic lumps, 2. quartz-porphyries, 3. nordmarkites, 4. nepheline-syenites and rapakivi.

On Labrador we find first anorthosites, which after all are older than the anorthosites of Greenland. However, there exist gabbros which might occupy a similar position in respect of the Double Mer sandstone (Low, l. c.) as the essexites do to the Igaliko sandstone. Then we have typical nordmarkites and syenites resembling corresponding rocks from Greenland. Finally, we have the granites of rapakivi-type and the grand formation of dikes, including several alkaline types. Quartz-porphyries are not known from the coast-region, but boulders of red quartz-porphyries can be found, indicating the existence of such rocks.

In spite of the very convincing petrographical relationship between the latest Pre-Cambrian of South Greenland and Labrador, the argumentation has one weak point: viz., the lack of contacts proving that the plutonic rocks really are younger than the sandstone. As a matter of fact, the field-investigations at first led me to the conclusion that the syenites belonged to the same group as the anorthosites, an opinion which I still believe is to a certain degree correct.

There is, however, nothing which would prevent the referring of the syenites and young granites to a plutonic group younger than the sandstone. This opinion is supported by Low's observations of gabbros and »traps» cutting the Eo-Cambrian sediments in the interior part of the Peninsula. With regard to the lamprophyric rocks which are cutting also the younger granites, I am fairly convinced that they also will be found cutting the sandstones.

The anorthosites on the other hand are decidedly older and are affected by the latest movements before the big late Pre-Cambrian denudation (The folding of the Domino-gneisses). The rapakivi-granites and the syenites are completely unaffected by tectonic movements, which, however, as I already have pointed out (10), might partly depend on the fact that the folding in the gneisses generally is less prominent in the region of the coast where these rocks occur. In any case, the age-difference between these two groups of rocks is obvious. The anorthosite is older than the migmatite granite (the Makkovik-granite) which in regard to the mode of occurrence and petrographic type would correspond to the Julianehaab-granite on Greenland (and the Hangö-type of South Finland).

We are so far entitled to compare the syenites and related rocks of the Labrador coast with nepheline-syenites of Kangerdluarsuk and the Greenland rapakivis with the granite of Strawberry Point and the region around Zoar in the Nain-area.

Strong support for these points of view is furnished by the discovery in the summer 1937 of granitic dikes cutting the red sandstone in the interior of Labrador, according to a private communication by the geologists of the Labrador Mining and Exploring Co. Ltd. to Dr. Tanner. According to the opinion expressed in this paper these dikes ought to belong to the Strawberry granite and related granites of the country.

In other words, there seems to exist a good correspondence as regards geological events during Pre-Cambrian time on both sides of the Labrador Sea. This correspondence can be summed up in the following scheme (Table II), wherein I have given two different alternatives of which No. 1 is in accordance with the points of view brought forward in this paper. It offers the best correspondence with the conditions on Greenland and may therefore be the more probable. No. 2 which is in accordance with a provisional table worked out before the laboratory investigations had been finished (10) holds good provided that the syenites and nordmarkites also as regards age should be found to belong to the same series as the anorthosites. This possibility cannot as yet — before supplementary field evidence for the first supposition has been found — be entirely neglected.

Table II.

Labrador 1.	Greenland	Labrador 2.
Cambrian		Cambrian
Lamprophyric dikes and trap dikes	Dike formation	
Strawberry granite etc.	Rapakivi granites	
Nordmarkites and syenites (Ragged Island etc.).	Nepheline syenites	
Gabbros and diabases	Essexites	Gabbro, diabase etc.
Double Mer sandstone	Igaliko sandstone	Double Mer sandst.
Ramah-Cape Mugford beds	?	Ramah-Cape Mugford beds
Makkovik granite etc. migmatitization	Julianehaab granite migmatitization	Makkovik granite
Anorthosites and gabbros		a. s. o.
Aillik quartzite etc.		
Old supercrustal greenstones. etc. etc.		

This table gives rise to the question about the significance of the disconformity between the Double Mer sandstone and the Ramah-Cape Mugford beds. The main reason for regarding these two series of sediments as different formations is the higher degree of tectonical deformation in the last-named. The Ramah beds are in a considerable degree folded, the Cape Mugford beds only very slightly. Further, according to Low, in the interior of Labrador there exist on different localities conglomerates containing red jasper, a mineral which is found occurring within the Cape Mugford beds. On the other hand, there seems to exist red jasper primarily layered also in beds which Low refers to the Double Mer sediments (according to his nomenclature, Cambrian).

In other words, it is not at all certain that the disconformity between these formations is of any greater inportance. Before these problems can be definitely solved, the Ramah beds have to be followed from the coast to the localities in the interior, where they may occur together with sandstones originated as molasse at the denudation of the mountains formed at the folding which is seen in the Ramah beds.

Another question which has to be discussed a little more in detail, is the relationship between the anorthosites and the younger plutonites. It has already been pointed out that there exists a considerable difference in time between these rocks. On the other hand, more particularly the conditions within the Nain area indicate that the rapakivi-granites and the anorthosites are tied to the same localities. In the same way we find in the Scandinavian countries that the rapakivi-granites are intimately related to the so called labrador-porphyrites, which evidently closely correspond to the anorthosites. Also real anorthosites have been described in this connection (Eckermann l. c.).

Further, we have in the Strawberry Point region the syenites, which are closely connected with the granite and evidently belong to the same intrusion.

In other words, the field observations indicate a relationship between all these rock-types as regards the distribution, but on the other hand it is evident that they have not intruded at nearly the same time. Between the anorthosites there lies an orogenetic phase and, if scheme 1. of Table II holds good, a whole cycle of denudation.

This means that the problems of the relationship between the rocks in question cannot be solved under the supposition of purely a magmatic differentiation, as some authors have tried to do. It seems to me that the occurrence of all these rocks in the same region might depend on the primary composition of the earth crust, which by means of a magmatization has given rise to the plutonites. Here the principles of migmatitization and palingenesis properly used might bring us farther than the principle of magmatic differentiation. The latter, as a matter of fact, covers only a part of the problem.

I am not, however, prepared to enter on the question about the origination of the rapakivi-granites, alkali-rocks and anorthosites before my investigations on Labrador have been finished.

The general conclusions regarding the tectonical development of Labrador arrived at through the preliminary investigations in the year 1937 can be summed up in the following way. Both the Coast of

Labrador and South Greenland were affected by the dislocations of the earth-crust which preceded the Caledonian mountain-folding and which all around the Arctic basin are characterized by intrusions and effusions of tremendous magma-quantities. It was the tectonic phase which L. Koch (8.) has comprehended under the name the Scandian epoch.

The Caledonian folding itself has not affected the rock-formations of Labrador. At Belle Isle Strait the Lower Cambrian sediments of Forteau Bay rest in undisturbed position on the old Eo-Cambrian peneplane. Labrador-Greenland acted during the Caledonian folding as a resistant *bloc*. Only along certain zones was the earth crust broken by faults which later have formed zones of weakness in which movements have taken place up to Tertiary time. As I have pointed out before (10), it is possible that the »Graben» of Sandwich Bay and Lake Melville were originated in zones of this type.

I have in the foregoing tried to point out some of the chief problems of the rock-ground geology of Labrador. Further I have tried to show that these problems generally speaking are the same as on Greenland and in the late Pre-Cambrian geology of Fennoscandia. The progress of the solution of these problems in one of the regions in question is closely dependent on the research work dealing with the corresponding questions in the other regions.

Helsingfors, Dec. 1938.


THE ROCK-GROUND OF THE COAST OF NEWFOUNDLAND-LABRADOR
Cambrian
Eo-Cambrian (Double Mer Sandstone)
Ramah-Cape Mugford beds
Younger Granite (Strawberry G.)
Older Granite (Makkovik G.)
Anorthosite
Basal Gneisses
Domino Gneisse
A.- Aillik quartzites. D.- Diabase
G.- Gabbro
0 20 40 Miles
UNGAVA BAY
CAPE CHIDLEY
ECLIPSE HR
RAMAH
Saglek Bay
HEBRON
CAPE MUGFORD
OKKAK
Norths R.
NAIN
Syenites and Lamprophyres
HOPEDALE
CAPE STRAWBERRY
AILLIK
MAKKOVIK
C HARRISON
INDIAN HR
HAMILTON INLET
George R.
Dyke L.
Michikamau Lake
Naskaupi R.
Lake Melville
Hamilton R.
Sandwich Bay
Eagle River
GRADY I.
DOMINO HR
HAWKE HR
SQUARE I.
BATTLE HR
BELLE ISLE
STRAIT OF BELLE ISLE
NEW-FOUNDLAND
Q U E B E C

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5.

THE PYRITE DEPOSIT OF HEVOSKUMPU IN TUUPOVAARA.

By

ERKKI AUROLA and VEIKKO VÄHÄTALO.

INTRODUCTION.

When the mining company of Outokumpu Oy. executed the prospecting of ores in the vicinity of Kovero (Fig. 1), a village in the parish of Tuupovaara, ore boulders were found at a distance of 3 km. north from the village mentioned, from the environment of a mound called Hevoskumpu. These boulders were of the same type as the pyrite ore of Otravaara. Considering the direction of movement of the glacial ice-sheet, they could not, however, have been derived from the Otravaara region which has been investigated and described before [1]. The frequency of the boulders and their restriction into a small area gave reason to suggest a new and up-to-date unknown ore deposit as their probable source.

Continuing the prospecting in the summer of 1938 the ore was actually discovered in place in the supposed direction, situated west of Hevoskumpu (Fig. 2) as far as 1.5 km. from the place from where the first ore boulders were encountered. The ore deposit has two outcrops from which the boulders had departed, forming a fairly regular fan the bisectrix of which pointed N. 55° W.

THE ROCKS OF THE REGION.

The General Features. The mounds of Hevoskumpu and Niemelänmäki, the latter lying southeast of Hevoskumpu, are underlain by a uniform and coherent amphibolite body, from which an extension projects in a direction southwest of Niemelänmäki. On the western edge of this nearly circular massif there is a lenticular complex of altered rocks, whith which the ore deposit is associated. The amphibolite body is in the east and south adjacent to a fine-grained, grey or somewhat reddish strongly pressed gneissose granite. On the

[1] MARTTI SAXÉN: Über die Petrologie des Otravaaragebietes im östlichen Finnland. Bull. Comm. géol. Finl. N:o 65, 1923.

west it is limited by a coarse-grained, slightly gneissose, darker grey plagioclase-granite which is easily distinguished from the former. On the north side, the solid rock is very little exposed, the few existing

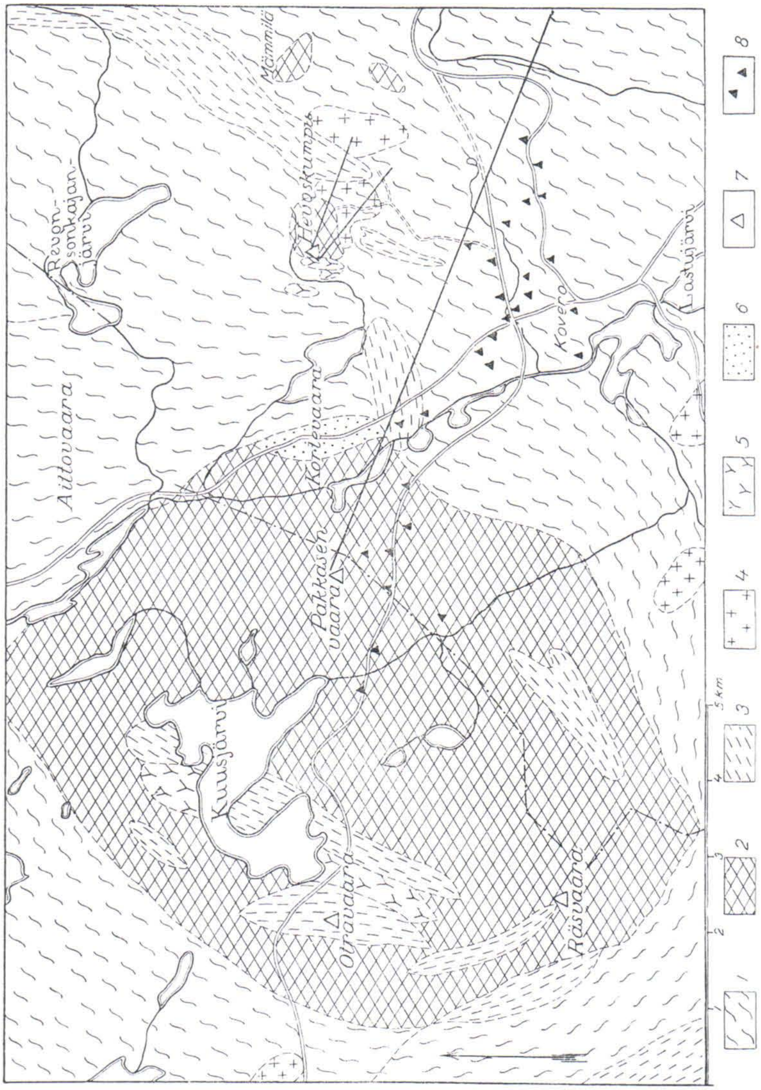

Fig. 1. Geological map of parts of the parishes of Eno and Tuupovaara. According to B. Frosterus and W. W. Wilkman.

Explanations: 1. Gneissose granite. 2. Old amphibolites. 3. Hornblende-schists. 4. Younger granite. 5. Oligoclase-albite-granite. 6. Quartz-diorite. 7. Outcrops of the ore. 8. Ore boulders.

ledges consisting of light grey gneissose granite, similar to the southerly gneissose granite.

A m p h i b o l i t e. The amphibolite of Hevoskumpu is, at a glance, throughout a dense, greenish black hornblende-felspar rock.

This rock type is commonly met with east of the Karelian sedimentary zone, as a component of the great foreland area consisting mainly of old gneissose granites, as well as in the smaller inter-

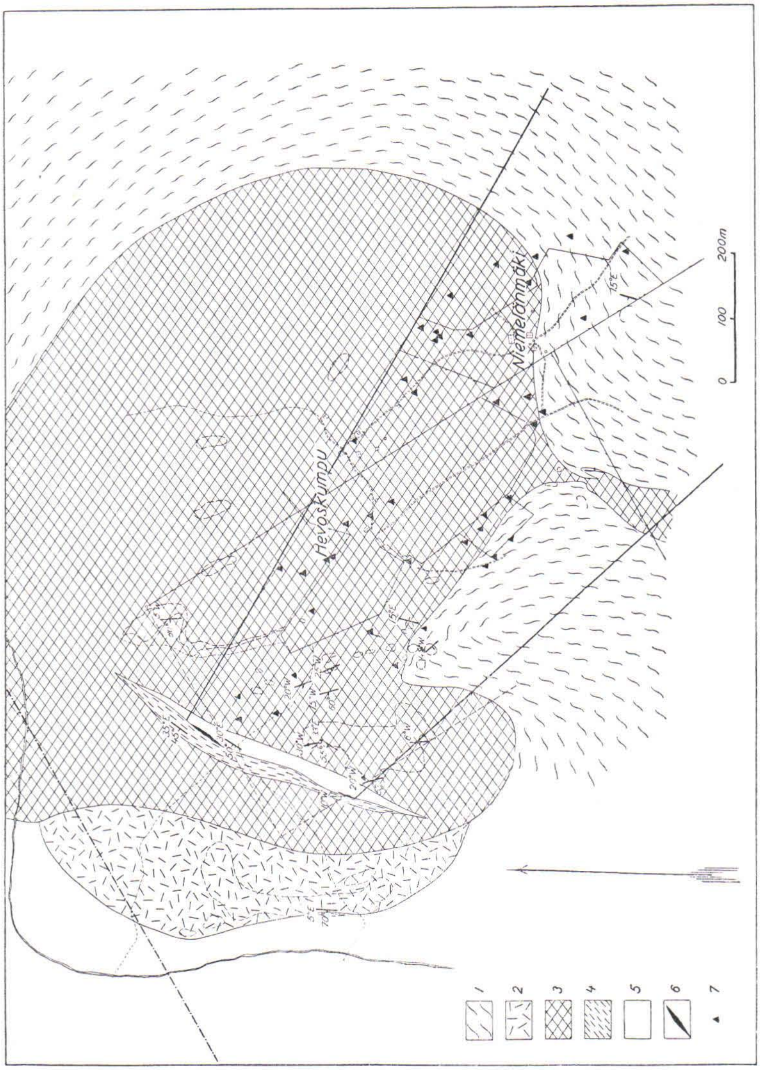

Fig. 2. Geological map of Hevoskumpu and the vicinity.
1. Gneissose granite. 2. Plagioclase-granite. 3. Amphibolite. 4. Epidote-quartzite. 5. Sericite-quartzite. 6. Outcrop of the ore. 7. Ore boulders.

vening massifs of the Karelidic zone proper. The central part of the body is slightly schistose only, the deformation growing stronger towards all the margins, where the influence of the movements, of course, must have been more pronounced. In the center of the massif the strike varies N. 25° W.—N. 15° E., the inclination being rather steep, ranging 55—80° W. Along the strongly schistose margins the strike generally coincides with the direction of the contact.

According to the microscopic examination the mineral composition of the rock is a very common one. The chief constituents are hornblende, plagioclase, and quartz, in addition to which notable quantities of chlorite and biotite occur in the more schistose portions. The minor components were found to be potash-felspar, epidote, apatite, and, in the schistose parts, rutile. The composition of plagioclase is approx. An 23—26 % ($n_\gamma >$ n- Cb, $n_\alpha \geq$ n-Cb, Cb = Canada balsam). The mineral composition reveals that the rock was originally a fairly ordinary gabbro.

Albitic gneissose granite. The gneissose granite bounding the amphibolite massif in the east and south is, when considered more closely, an albitic one. To the naked eye it appears as a strongly sheared rock, the discernible minerals being quartz, felspar, and a little biotite, besides of which well-formed pyrite crystals are detected in places. By the microscopic examination, the rock shows a very fine grain and a typical granoblastic texture. The chief minerals are quartz, plagioclase, light-coloured biotite, and a little muscovite. Accessory constituents are: hornblende, some potash-felspar, apatite, titanite, and pyrite. Immersion determinations show that the plagioclase is albite An 4—6 % ($n_\gamma = 1.539$, $n_\alpha = 1.530$, and maximum extinction angle in the symmetric zone approx. 12—13°). The quartz grains are somewhat stretched in the direction of the schistosity and display a weak undulose extinction. On the edges and in the fissures of the pyrite grains a rim of reddish brown, doubly refracting substance is found, it clearly being an alteration product of pyrite, either hematite or goethite.

Porphyritic albite-granite. The granite situated to the west of Hevoskumpu, named above plagioclase-granite, is really a porphyritic albite-granite. It is rather coarse-grained showing larger euhedral plagioclase individuals, the twinning of which can readily be discerned with the naked eye. Inspected under the microscope, the difference from the gneissose granite is at once apparent.

The large plagioclase phenocrysts have been changed, to some extent, into sericite. Between them there is a matrix consisting of a fine-grained mass of quartz, plagioclase, and biotite. Composition of the plagioclase determined by immersion is: An 5—7 % ($n_\gamma = 1.540$, $n_\alpha = 1.531$, maximum extinction angle in the symmetric zone 12—14°), also nearly the same as in the above gneissose granite. In some of the plagioclase grains the twinning lamellae are bent and quartz has a weak undulose extinction. Biotite is abundant, giving the rock a dark colour. The quantity of quartz is smaller than in the gneissose granite, the rock consequently being evidently less acid than the former. Other minerals present are hornblende which is partly changed to chlorite, epidote as inclusions in plagioclase, titanite, apatite, and zircon.

THE SUCCESSION OF DIFFERENT ROCKS.

The age relation of the granites compared to amphibolites can be easily determined. The contact of the albitic gneissose granite and amphibolite is exposed at the narrowest point of the extension projecting from amphibolite into the granite, situated on the southwest slope of Niemelänmäki. Here granite veins penetrate the amphibolite, containing small angular xenoliths of amphibolite. This shows, beyond doubt, that the granite is younger than amphibolite. West of Hevoskumpu the porphyritic albite-granite likewise encloses large amphibolite fragments, which have been more chloritized at the margins. The granite therefore proves to be younger than amphibolite. The actual contact has not been found. The mutual relations of the granites have not been satisfactorily established, but the slight deformation of the porphyritic granite associated with a more even quality indicate it being the youngest rock of the region, which has not been affected by any stronger movements. It was obviously only intruded after the gneissose granite had assumed its present pronouncedly gneissic habit.

THE ORE DEPOSIT.

The ore complex is situated to the west of Hevoskumpu possessing the form of a long lens-shaped zone. Its rocks can be divided into four different categories (Fig. 3):

1. A pale-coloured amphibolitic schist.
2. The hanging rock of the ore, consisting of a strongly altered light-coloured epidote-quartzite.
3. The ore body.
4. A schistose sericite-quartzite occurring as the base.

1. Farthest in the west of the amphibolite body, separating the ore deposit proper, or zones 2, 3, and 4, from the porphyritic albite-granite, there is a slightly altered amphibolite, which is a little lighter in colour than the chief type of the area. In places it is strongly talcified and chloritized, the resulting rock being much softer than

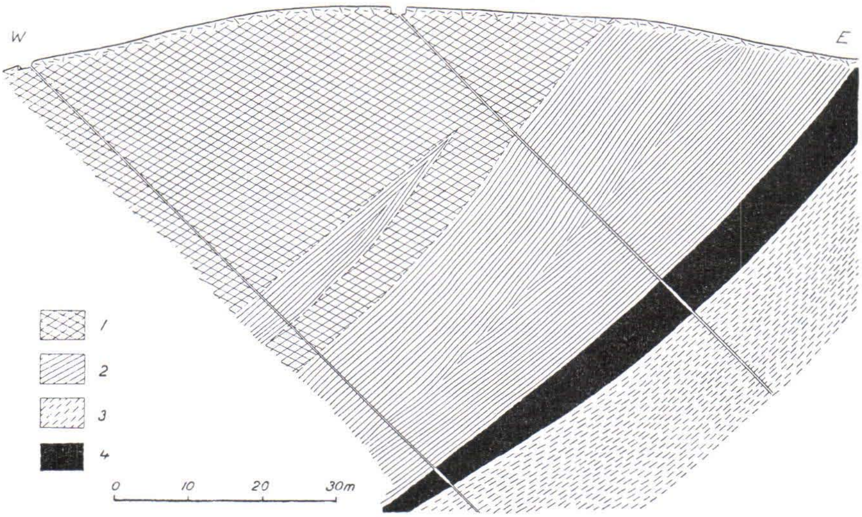

Fig. 3. Section of the larger ore lens of Hevoskumpu, based on diamond drill-holes.
1. Amphibolite. 2. Epidote-quartzite. 3. Sericite-quartzite. 4. Ore.

the usual type. The apperance of talc and chlorite evidently occurred in the connection with the formation of ore, owing to the influence of solutions containing carbon dioxide. This view is supported by narrow carbonate seams in the rock. The alteration is most complete in the proximity of these seams.

2. East of the previous rock, a heavily changed hard light-coloured quartzitic rock follows, which is partly strongly brecciated. The quartzite base looks dull and massive, but scattered dark hornblende needles are discernible to an unaided eye, as well as some intensely green epidote appearing either in the form of granular masses or individual crystals.

Under the microscope one can notice in addition to quartz some sericitized plagioclase, of a composition 10—13 % ($n_\gamma \leq \omega$-qtz, qtz = quartz, maximum extinction angle in symmetric sections is 8—10^0). The hornblende crystals are strongly grown in the direction of the c-axis, the sections perpendicular to it showing base prism (110) and orthopinacoid (100). Clinopinacoid (010) is usually lacking or badly developed. The amphibole sections show rather few cleavage cracks. Pleochroism is strong (γ = blue, β = brown green, α = light green). The conspicously blue colour indicates obviously a fair percentage of alkalies.

The vertical thickness of epidote-quartzite zone varies between 10—30 m., the strike being to the south approximately N. 10° W., and in the northern end N. 30—35° E. The dip is constantly 45—50° W. being in the north end less steep. In the middle part of the zone as well as in the northern end of it there is a narrow and long magnetite-pyrrhotite lens, the length of which is approx. 50 m. and thickness varying between 70—130 cm. Its strike and dip are the same as in the surrounding quartzite. (This lenticle is not shown in the profile). In its southern, thinnest part, the lens consists of pure magnetite, which is bounded against the side-rock by a 10 cm. thick layer, rich in hornblende. In the northerly part the core of the lenticle is pure pyrrhotite, magnetite occurring in the edges of a width of 10—15 cm. only. The transition against the wall-rock is rich in hornblende.

3. Below the epidote-quartzite there is an ore deposit consisting of pyrite and pyrrhotite. It forms rather thin and separate lenses which are schistose in the ends. Two outcrops are found, the one in the southern part of the zone, the other and bigger one in the northern part of the same. The distance between the outcrops is approx. 200 metres. Also, between them, some ore bodies have been found with the aid of drilling, but the investigations concerning this part have not yet been finished. The area of the smaller outcrop is approx. 50—60 m^2. The strike is approx. N. 10°W., the dip 55° W., and the maximum thickness about 4.5 m. The ore is slightly schistose and contains pyrite interspersed in quartz.

The area of the larger outcrop has been ascertained, on the basis of excavations, to be at least 150 m^2., but the extreme point of it has not been considered because it is hidden at too great a depth under a marsh. The length of this outcrop is 55—60 m. and the maximum vertical thickness approx. 6.0 m. The strike goes N. 30—35° E., the dip is 45°W. The pitch of the axis has been determined in the amphibolite south of the ore deposit as being ab. 35° N.N.W. The same was confirmed by the investigation of the diamond drill holes.

According to the sulphide composition the ore body can be divided into three zones:

1. The upper portion of the body is mainly pyrrhotite.
2. In the middle there is approximately as much pyrite and pyrrhotite.
3. The foot portion consists chiefly of pyrite ore.

The transitions from one zone to another are gradual, but the different members are distincly traceable. From the whole mass of sulphides the pyrite makes out the greater part. The ore is covered by till, the thickness of which varies 0.5—1.5 m. The pyrrhotite has been preserved nearly unweathered at the surface, but the pyrite in the lowest part of the mound is weathered and has been leached away to a depth of 1 m. The resulting product is a porous and rusty mass of quartz covered by a 20—30 cm. thick layer of gossan. Estimated by eye, the ore contains ca. 50 % of the original volume of sulphides, the rest being water-grey quartz. Considering the lens of magnetite, inside of the epidote-quartzite, which evidently has a genetic relationship to the other ore bodies, sulphur content increases continually in the same direction, and it may be confidently concluded that during the ore formation the steam pressure of sulphur was higher on the footwall side growing continually less towards higher levels.

4. The schistose sericite-quartzite at the floor resembles the corresponding rock of Otravaara. It was exposed by trenching in the southern end of the ore zone, and in the northern end it was met with in the diamond drill holes. Its chief constituents are quartz, sericite, a strongly sericitized plagioclase, and a little potash-felspar. In addition to these also biotite and occasionally bright green fuchsite occur. Thin strips of sulphides are found as filling the fissures.

SUMMARY.

The pyrite occurrence of Hevoskumpu is thus an obvious counterpart to the larger pyrite deposit of Otravaara, which is situated not far from Hevoskumpu. An essential member in the suite of the altered country rocks is in both cases a sericite-quartz schist. The epidote-quartzite of Hevoskumpu shows much resemblance to the intermediate rock between the above-mentioned rock and the amphibolite which occurs at Otravaara, as described by Saksela [1]. An occurrence of conspicuous hornblende needles is likewise characteristic of this rock, but the epidotization has not proceeded equally far at Otravaara.

The metasomatic changes at Hevoskumpu are, no doubt, simultaneous with the formation of bodies, being most evidently due to an action of solutions rich in carbonates and sulphides. Their origin and occurrence of the metasomatism in detail cannot be explained

[1] Martti Saxén (Saksela): Über die Petrologie des Otravaaragebietes, p. 34.

more fully unless chemical analyses of the rocks concerned were made.

Metasomatic formation of sericite and epidote of a related type has been described by Waldemar Lindgren [1] in the connection with some American epithermal gold ore veins, this alteration having been called »propylitization». The minerals characteristic of the altered zones in this case are pyrite, epidote, sericite, and chlorite.

[1] WALDEMAR LINDGREN: Mineral Deposits, Third Edition. New York, 1928, pp. 530—531.

6.

THE RARE EARTH CONTENT OF WIIKITE

by

TH. G. SAHAMA and VEIKKO VÄHÄTALO

Contents:

INTRODUCTION

In an important paper based on studies of a large number of minerals containing lanthanides, Goldschmidt and Thomassen (1924) have exposed the concentration relations of the rare-earth elements. By the use of X-ray spectrography the rare-earth minerals were divided in respect to their content of lanthanides, into several types, well distinguishable from one another. Since then, further X-ray spectrographic studies on the rare-earth minerals have been carried out by Matveyeff (1932), Bearth (1934), and Björlykke (1934). In order to throw light on the relative abundance of the lanthanides and on the problems of their general geochemistry, also several studies, dealing with the rare-earth content of different rocks, have in recent days been made by Minami (1935), Noddack (1935), Landergren (1936), Goldschmidt (1937), and by Goldschmidt and Bauer, though their results have not yet been published.

The material for the study by Goldschmidt and Thomassen referred to above consists for the most part of minerals found in Norway. As for the rare-earth minerals found in the Archaean rocks of Finland, wiikite, occurring in the pegmatites of Impilahti in Southern Karelia, has given rise to a number of detailed investigations.

Important studies on wiikite have been published by Lokka (1928) and Ant-Wuorinen (1936). In his paper Lokka also gives a complete list of earlier investigations dealing with wiikite.

As shown by the analyses by Lokka and Ant-Wuorinen, wiikite is a titanate-columbate-tantalate containing relatively large amounts of rare earths and showing marked changes in its composition. Owing to the lack of suitable X-ray spectrographic apparatus, these authors have determined only the total amount of the rare earths and the ratio of cerium earths to yttrium earths. Ant-Wuorinen, in addition, presents one determination of scandium.

As the newly established geochemical laboratory of the Mineralogical and Geological Institute of the University of Helsinki gives ample possibilities also for work in X-ray spectrography, the present authors have used this apparatus for determining the concentration ratios of the lanthanides in several types of wiikite.

ACKNOWLEDGMENTS

For the present study, the collections of our Institute were placed at the authors' disposal by Professor Pentti Eskola, who also very generously furnished the authors with some excellent samples of wiikite from his private collections.

The first author wishes to express his most sincere thanks to Professor V. M. Goldschmidt for many helpful hints and suggestions concerning the purchase of the X-ray spectrograph during a visit to Oslo in January, 1938. To Professor Gregori Aminoff, Mineralogical Dept., Riksmuseet, Stockholm, and to his co-workers the first author is greatly indebted for much valuable advice concerning the X-ray spectrograph and its use. The first author is further indebted to Professor Axel E. Lindh, Head of the Institute of Physics, University of Upsala, for his kind help and advice in matters concerning the building of the X-ray vacuum spectrograph, and to Mr. John Amberntsson, Chief Mechanic of the aforesaid Institute, who completed the building of the apparatus to entire satisfaction. Finally, the authors wish to thank Mr. Lars E. Lindfors, M. A., of the Institute of Physics, University of Helsinki, for making the photometric records of the X-ray films.

METHODS

The analyses of wiikites made by Lokka (1928) and Ant-Wuorinen (1936) with few exceptions show appreciable amounts of lanthanides. Therefore, a chemical pre-treatment in order to enrich the rare-earths could usually be omitted. By an enrichment, however, disturbing elements can be removed, and the results obtained by the succeeding X-ray analyses are more easily comparable with each other. All wiikite samples to be analyzed with X-ray spectrograph were therefore submitted to a chemical pre-enrichment the methods given by Lokka (1928, pp. 33—42) being employed.

The wiikite powder (0.5—1 g.) was fused with potassium bisulfate in a platinum crucible. The crucible, placed in a beaker containing very dilute sulfuric acid was left overnight on a steam-bath, covered with a watch-glass. The precipitated earth acids were filtered off. Ammonia water was added to the filtrate, the precipitated hydroxides were filtered off and dissolved in a small amount of dilute hydrochloric acid. This solution was concentrated by evaporating it on a steam-bath, and the rare-earths contained in it were precipitated with an excess of hot concentrated oxalic acid. The filtered and ignited residue was submitted to X-ray analysis.

The apparatus used in X-ray analysis was a vacuum spectrograph. The crystal was one of calcite. When making lanthanide analyses, the crystal was rocked between 14°.5 and 27°.5. For the present study, Ilford Ilfex films were used. The time of exposure usually was two hours.

The procedure for making the analyses was as follows: First, the film was exposed for one hour with about 40 kV and 8—10 mA. The tungsten spiral was then replaced by a new one, fresh material was added to the anode, and the exposure continued for another hour. For every determination a pure plate made of electrolytic copper was inserted into the slit in the head of the anode.

In yttrium and thorium determinations the crystal was rocked between 6° and 9°. The exposure time usually was 20 minutes, the potential and current values being the same as in lanthanide analyses. The values for yttrium and thorium were calculated as described by Minami (1935, pp. 165—169).

The photometric records of the X-ray spectrograms were made at the Institute of Physics, University of Helsinki, by a large Zeiss recording microphotometer.

When calculations of the lanthanide contents based on photometer curves are to be made, the need of allowing for two corrections is evident, one being due to the diversity in absoption for different wavelengths in the spectrograph and in the X-ray tube, and the other arising from the blackening of the film. Attention being paid to both these corrections, the calculations were carried out in the way fully described by Minami (1935) and first presented to him by Goldschmidt. Accordingly the further description of the calculations is here omitted. For use as a standard mixture in the absorption determinations the following components were mixed and homogenized by grinding for two hours in a small agate mortar:

CeO_2	Hilger	Lab.	N:o	10 676	10.74	mg.
Nd_2O_3	»	»	»	6 405	5.34	»
Sm_2O_3	»	»	»	6 407	4.71	»
Gd_2O_3	»	»	»	6 403	5.24	»
Dy_2O_3	»	»	»	6 402	7.44	»
Er_2O_3	»	»	»	10 374	5.33	»
Yb_2O_3	»	»	»	10 375	3.60	»
NiO					8.8	»
Cr_2O_3					13.7	»
Al_2O_3					231.8	»

Known amounts of a standard mixture were added to the lanthanide precipitates separated from the wiikites. The composition of this mixture was:

	per cent.
Cr_2O_3	7.13
NiO	4.80
ZrO_2	27.64
Al_2O_3	60.43

The components having been weighed out on a Bunge micro-balance, the mixtures were homogenized by grinding for two hours in small agate mortars.

For the determination of the lanthanides the X-ray spectrum lines listed below were used. According to the review presented by Noddack (1935) these lines are, in this material, free from coincidences.

La: $L\alpha_1$ and $L\beta_1$
Ce: $L\beta_1$
Pr: $L\alpha_1$ and $L\beta_1$
Nd: $L\beta_1$
Sm: $L\alpha_1$ and $L\beta_1$
Gd: $L\alpha_1$
Tb: $L\alpha_1$
Dy: $L\alpha_1$ and $L\beta_1$
Ho: $L\beta_1$
Er: $L\alpha_1$
Yb: $L\alpha_1$
Lu: $L\alpha_1$

Thulium and europium were determined according to the method presented by Minami (1935).

DISCUSSION OF THE RESULTS

Wiikite.

The results of the analyses are presented in Table I. The percentages presented in Table I are the results obtained from the calculations thus being not free from the errors connected with the X-ray spectrographic methods. As such they do not represent exact values, comparable with the results of chemical analyses. Unfortunately the wiikite specimens, used by Lokka for his study could no longer be identified. The megascopic character of the specimens is presented below:

Wiikite A. K. 3871: Black, lustrous, asphalt-like.
Wiikite 4689: Black, lustrous.
Wiikite 4669: Black, fine-grained. Type e (Borgström 1910).
Wiikite 4670: Black, more coarse-grained than 4669. Type e (Original sample of Borgström).
Wiikite 4437: Deep brownish black, lustrous, asphalt-like.
Wiikite 6037: Wax yellow, lustrous, pitch-like.

Table I

	Wiikite A. K. 3871	Wiikite 4689	Wiikite 4669	Wiikite 4670	Wiikite 4437	Wiikite 6037	Orthite 4704	Monazite 971
ThO_2	0.83	2.16	0.94	0.73	0.74	0.44	1.53	n. d.
Y_2O_3	5.43	9.16	4.91	5.39	5.93	0.91	0.81	n. d.
La_2O_3	—	—	tr.	tr.	—	—	2.23	67
Ce_2O_3	0.16	0.48	0.29	0.14	0.32	0.28	3.58	100
Pr_2O_3	0.04	0.20	0.09	0.05	0.15	0.08	0.72	24
Nd_2O_3	0.25	0.62	0.26	0.14	0.50	0.30	1.90	63
61	—	—	—	—	—	—	—	—
Sm_2O_3	0.29	0.74	0.26	0.13	0.69	0.21	0.57	23
Eu_2O_3	tr.	—	—	—	—	—	—	—
Gd_2O_3	0.33	1.08	0.26	0.14	0.70	0.20	0.50	16
Tb_2O_3	0.11	0.35	0.04	0.04	0.14	0.04	—	—
Dy_2O_3	0.46	1.57	0.36	0.19	0.90	0.29	0.11	4
Ho_2O_3	0.11	0.39	0.10	0.05	0.15	0.04	—	—
Er_2O_3	0.30	1.07	0.23	0.13	0.71	0.09	0.06	2
Tu_2O_3	0.10	0.30	0.07	0.04	0.13	—	—	—
Yb_2O_3	0.64	1.71	0.57	0.30	ca. 1.36	0.12	tr.	tr.
Lu_2O_3	0.19	0.50	0.15	0.06	0.36	0.03	—	—
Sum	9.24	20.33	8.53	7.53	12.78	3.03	12.01	—
Ignited oxalic acid precipitate	14.04	23.45	7.85	6.98	13.54	2.86	13.82	—

Table II presents the totals of yttrium and cerium earths calculated on the basis of X-ray spectrographic analyses, gadolinium being included in the yttrium earths.

Table II

	Ce Earths	Y Earths	Y Earths / Ce Earths
Wiikite A. K. 3871	0.74	7.67	10.4
Wiikite 4689	2.04	16.13	7.9
Wiikite 4669	0.90	6.69	7.4
Wiikite 4670	0.46	6.34	13.8
Wiikite 4437	1.66	10.38	6.3
Wiikite 6037	0.87	1.68	1.9
Orthite 4704	9.00	1.48	0.2

The results of the analyses in regard to the lanthanides are diagrammatically presented in Figs. 1—6, 9, and 10.

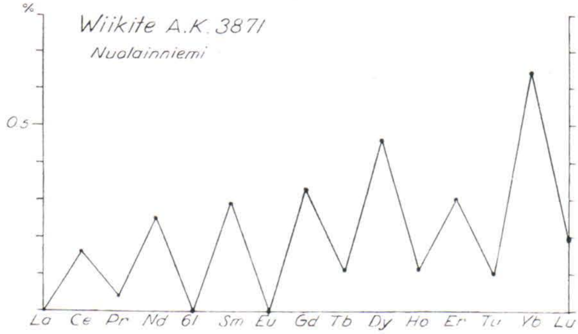

Fig. 1.

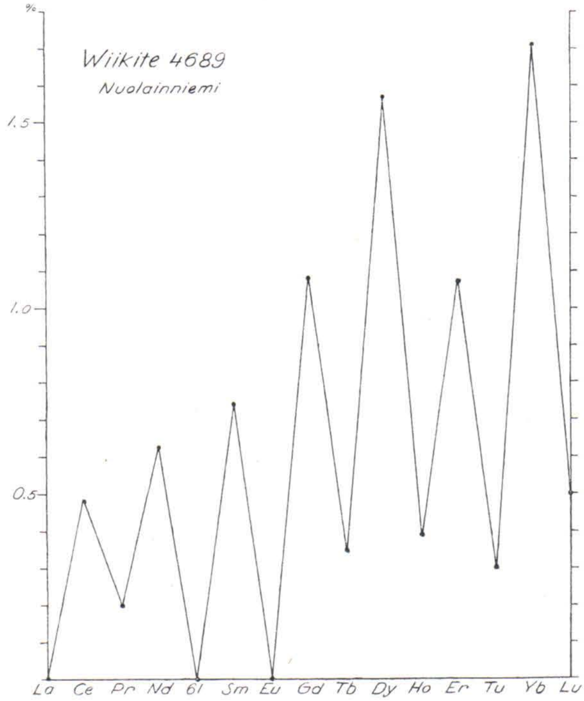

Fig. 2.

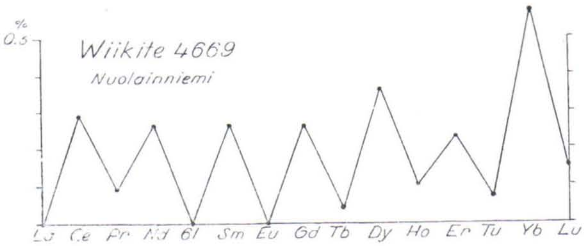

Fig. 3.

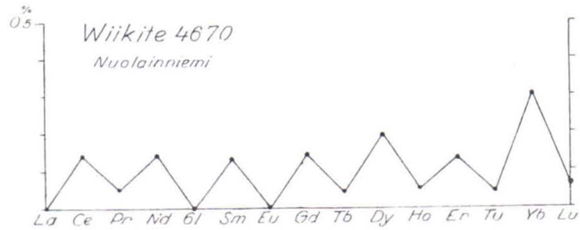

Fig. 4.

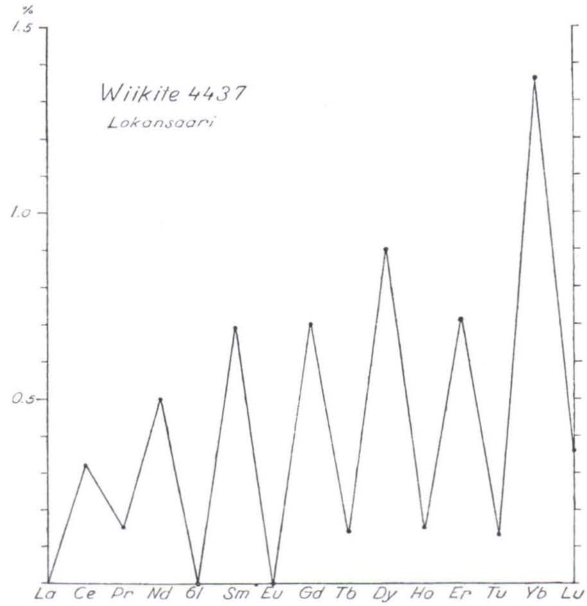

Fig. 5.

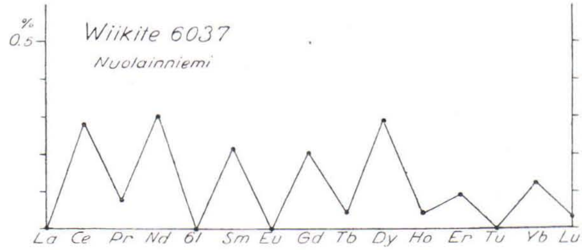

Fig. 6.

Table II provides conclusive evidence that the ratio of yttrium and cerium earths determined by X-ray analyses varies within limits similar to those established by Lokka with the aid of chemical analyses. The amount of the yttrium earths, particularly yttrium, is thus largely in excess over the latter, the only exception being wiikite N:o 6037. In this specimen the preponderance of the yttrium earths is smaller than in the other samples analyzed. However, even this result is fully concordant with those obtained by Lokka. Megascopically judged this wiikite belongs to the type Lf analyzed by Lokka (1928, p. 46). He presents the following percentages for rare earths:

Y_2O_3	1.70
Ce_2O_3	1.12

With the exception of sample N:o 6037, all the samples regularly show very strong ytterbium maxima and well determined dysprosium submaxima when their lanthanide concentration ratios are compared. Lanthanum and europium are present in amounts too small to allow them to be determined with X-ray analysis in the lanthanide precipitates. Their presence has been established here with the aid of optical spectrography. As for europium, this is in accordance with the results arrived at in respect of the geochemistry of this element by Goldschmidt (1937).

With regard to their lanthanide composition, the wiikites — as appears from Figs. 1—5 — show marked differences from the other columbium and tantalum minerals, investigated by Goldschmidt and Thomassen (1924). Though dysprosium predominates in the niobium andtantalum minerals, there is usually no ytterbium maximum present. As pointed out above, such a maximum is highly characteristic of the wiikites, excepting type Lf. To illustrate this, a photometer curve of the film 4689 is presented in Fig. 8. Here, as is shown by Fig. 2, the ytterbium maximum is the least striking one. On examining Fig. 8

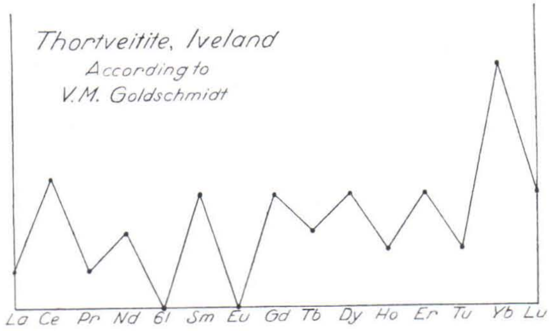

Fig. 7.

one must, in addition, allow for the difference of absorption in the different parts of the spectrum. Owing to this phenomenon, the intensities of the spectrum lines of the long-wave range are relatively smaller than those of the short-wave range.

According to its lanthanide composition wiikite lies near the thortveitite type, presented by Goldschmidt. Fig. 7 shows, according to Goldschmidt, the lanthanide proportions of thortveitite. This mineral, however, shows no well developed dysprosium submaximum, characteristic of the wiikites. Especially the lanthanum and cerium contents of thortveitite are, in addition, relatively higher than those of wiikites. A connecting feature for thortveitite and wiikite lies, however, in their considerable content of ytterbium and lutecium.

A lanthanide composition, fairly similar to that of wiikites, has been presented by Björlykke (1934) in fergusonite from Iveland.

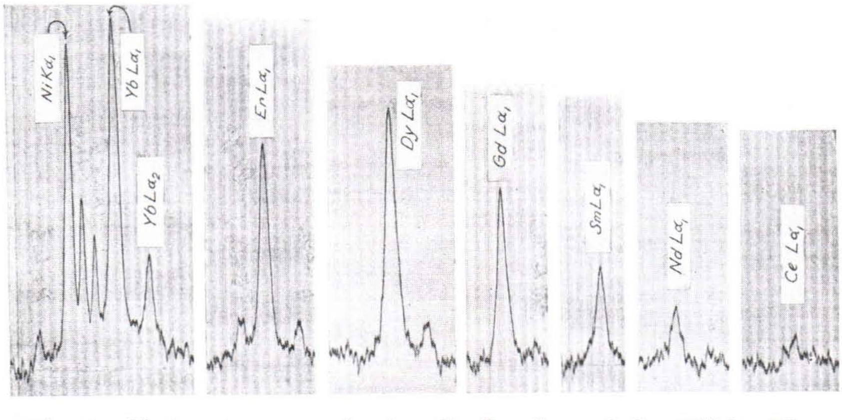

Fig. 8. Photometer curve showing the $L\alpha_1$ lines of the Wiikite Film No. 4689.

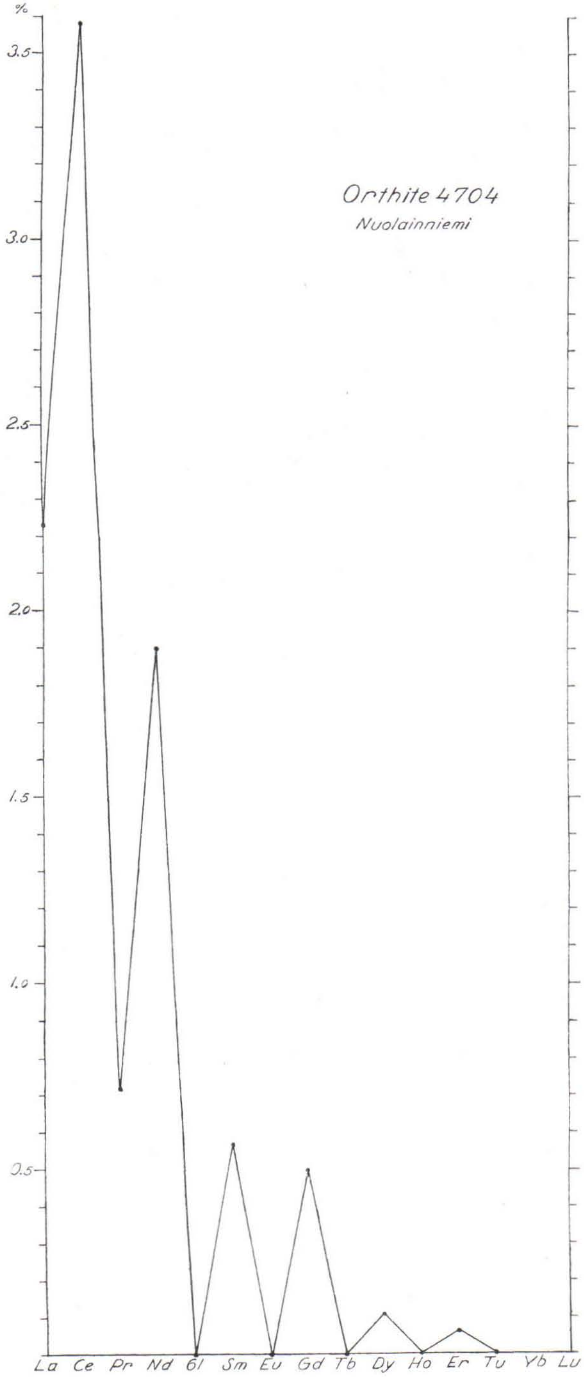
%
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Orthite 4704
Nuolainniemi
La Ce Pr Nd 61 Sm Eu Gd Tb Dy Ho Er Tu Yb Lu

Fig. 9.

The wiikites contain largely variable amounts of scandium, as shown already by Eberhard (1910). Amongst the films which form the basis of the calculations presented in Table I, only N:o 4669 and N:o 6740 show a distinct $ScK\beta_1$ line. With the apparatus used by the authors this line is easily distinguished from the neighbouring $CuK\beta_1II$ line. In addition, in the films 4437 and 6037, a very weak trace of the scandium line could be distinguished. The optical spectra photographed with the Zeiss Three Prism Spectrograph showed, however, well determined scandium lines in all of the samples.

Monazite and orthite.

In the pegmatites of Impilahti, monazite and orthite occur in addition to wiikite. Only one sample of both these minerals was anal-

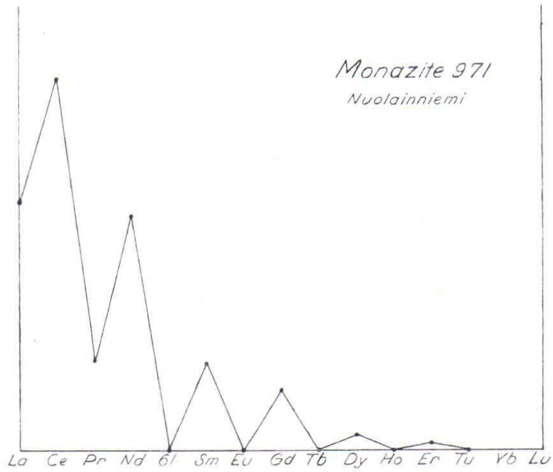

Fig. 10.

yzed. The results are presented in Table I and Figs. 9 and 10. No chemical pre-enrichment of monazite was made, the powdered mineral being used for the X-ray analysis as such without addition of a standard mixture. As shown by Figs. 9 and 10, orthite and monazite are enriched especially in cerium earths.

Geochemical Laboratory, The Mineralogical and Geological Institute of the University, Helsinki, March 1939.

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7.

BEMERKUNGEN ÜBER DR. BRANDERS ENTGEGNUNG AUF MEINE KRITIK ÜBER SEINE ABHANDLUNG »EIN INTERGLAZIALFUND BEI ROUHIALA IN SÜD-OSTFINNLAND».

VON
ESA HYYPPÄ.

In der von der Finnischen Geologischen Gesellschaft herausgegebenen Veröffentlichung Nr. 12 hat Dr. G. Brander eine sehr erbitterte Entgegnung geschrieben auf meine Kritik, welche seine in der Überschrift angeführte Untersuchung betrifft. Dr. Branders Entgegnung, so unsachlich und nichtsbeweisend sie auch ist, gibt mir Anlass, auf einige Punkte dieser Argumentation nochmals einzugehen.

In meiner Kritik habe ich dargestellt, dass Dr. Brander die Auffassungen der russischen Forscher vom Charakter des intramoränen Tons vom Mga-Fluss nicht in hinreichendem Masse berücksichtigt hat. Darauf antwortet Dr. Brander (1938, S. 97): »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, welche letztere ausserdem in bezug auf den interstadialen oder interglazialen Charakter der Bildung keinen e n t s c h e i d e n d e n Beweis beigebracht haben.» Hier also betont Dr. Brander, dass er die betreffenden Untersuchungen unberücksichtigt gelassen hat, da sie klein sind und auch keinen e n t s c h e i d e n d e n Beweis für das Mga-Problem beigebracht haben. Nach diesem Prinzip müsste sich die Benutzung von Literatur bei allen Untersuchungen auf ein sehr geringes beschränken, da sie nicht entscheidend beweisen, ob der betreffende Ton interglazial oder interstadial ist. — Könnte man doch erwarten, dass der Forscher zum mindesten alles in der einschlägigen Literatur vorliegende Material durchginge, namentlich dann, wenn ihm keine eigenen Feldbeobachtungen zur Verfügung stehen. Besonders in diesem Fall ist eine derartige Forderung zu Recht bestehend, da die in Frage stehende Literatur sehr beschränkt ist.

Nachdem Dr. Brander sich so leicht über meine auf die Benutzung des Schrifttums gerichtete Bemerkung hinweggesetzt hat, greift er diejenige Stelle meiner Kritik an, welche die Benutzung der Diatomeen als Zeugnisse für das geologische Alter betrifft. In meiner Kritik wandte ich dieser Frage die grösste Aufmerksamkeit zu, da ich sie für die allerschwächste Seite der Untersuchung hielt. Nachdem ich Dr. Branders Entgegnung gelesen habe, bin ich in dieser meiner Auffassung bestärkt. Insbesondere bin ich verwundert, dass Dr. Brander, der gerade als Diatomeenforscher aufgetreten ist, immer noch nicht zu verstehen scheint, wie durchaus willkürlich er sich zur Bestimmung des geologischen Alters des Diatomeenmaterials bedient hat.

Bevor mittels fossiler Diatomeen das geologische Alter bestimmt werden kann, muss man wissen, in welcher Weise zu diesem Zweck Diatomeen verwandt werden können. Die erste Forderung ist natürlich diejenige, dass das benutzte Diatomeenmaterial gesammelt worden ist aus Sedimenten, die sich an ihrer ursprünglichen Ablagerungsstelle — in situ — befinden. Zweitens ist zu fordern, dass die Diatomeenflora möglichst homogen oder also dem Typ nach so beschaffen sei, dass angenommen werden kann, sie habe an derselben Stelle gelebt und sei nicht grossenteils anderswoher dorthin gekommen. Dies sind die Grundvoraussetzungen.

Angenommen, diesen Forderungen sei befriedigend entsprochen. Es erhebt sich die Frage, wodurch die Gleichaltrigkeit zweier Diatomeenfloren gekennzeichnet ist. Hier sind zwei Bedingungen zu erfüllen: 1. Die Diatomeenfloren müssen in ihrer Artenzusammensetzung in hohem Masse gleichartig sein, wobei natürlich auch der Individuenabundanz der Arten Aufmerksamkeit zuzuwenden ist. 2. Die einander vergleichbaren Diatomeenfloren müssen Arten enthalten, die als entweder ökologisch oder floristisch typisch für eine bestimmte geologische Phase, vielleicht als unmittelbare Leitfossilien, gelten können.

Sind in Dr. Branders Fall diese Bedingungen erfüllt? Leider ist hier in schroff verneinendem Sinne zu antworten. Der Tonklumpen von Rouhiala hat sich nicht an seiner ursprünglichen Ablagerungsstelle gefunden, sondern ist von einer vorläufig unbekannten Stelle dorthin verfrachtet worden. Ebensowenig ist die Artenzusammensetzung der Diatomeenflora von Rouhiala ökologisch so homogen, wie es zu erwarten wäre, zumal in diesem Fall, in dem sie zu Alterskonnektionen weiter Erstreckung benutzt worden ist. Aus der Lagerfolge vom Mga-Fluss verfügt Dr. Brander nur über einige Proben, die er aus den Sammlungen der Universität Helsinki erhalten hat und deren Stelle im Profil nicht genauer bekannt ist. Aus Ablagerungen des Portlandia- und des Eem-Meeres der Ostsee hat er auf Grund der Literatur einige Diatomeenlisten ausgewählt, die ein möglichst wenig homogenes Material vertreten, und z. B. bei der Portlandia-Reihe sind nicht einmal die Frequenzen der Arten angegeben.

Schon aus dem Angeführten ist ersichtlich, dass Dr. Branders Versuch, auf Grund einer derartigen Materials Alterskonnektionen weiter Erstreckung zu unternehmen, durchaus unbegründet ist. Damit könnte denn auch meinerseits die Polemik als abgeschlossen betrachtet werden, da aber Dr. Brander immer noch schroff behauptet, wie überzeugend sein Diatomeenmaterial für das synchronische Auftreten von Rouhiala-Mga und Ostsee-Portlandia spricht, besteht Anlass, auch auf diese Seite des Sachverhalts nochmals einzugehen.

In meiner Kritik stellte ich fest, dass Mga und Rouhiala auf Grund ihres Diatomeengehaltes gleichaltrig sein können, da sie 49 % gemeinsame Arten aufweisen und da sich unter diesen gemeinsamen Arten in ziemlich reichlichen Mengen F o r m e n d e s k a l t e n K l i m a s finden, die dafür zeugen, dass diese Diatomeenfloren unter gleichartigen klimatischen Verhältnissen gelebt haben.

Im Folgenden sei dann die Rouhiala-Mga-Flora mit dem Portlandia der Ostsee verglichen. Es sind nur 25 % gemeinsame Arten vorhanden. Das beweist natürlich keine Gleichaltrigkeit, wenn diese Arten keine grosse quantitative Mehrheit ausmachen und wenn diese Arten keine wirklichen Leitfossilien umfassen. Da kein einziges Leitfossil vertreten ist und da die Frequenzen in den Portlandia-Tabellen der Ostsee fehlen, s o d a s s e i n q u a n t i t a t i v e r V e r g l e i c h ü b e r h a u p t n i c h t a u s g e f ü h r t w e r d e n k a n n, ist es auf Grund von Dr. Branders Diatomeenstatistik unmöglich, die in Frage stehenden Ablagerungen als gleichaltrig zu beweisen.

In meiner Kritik habe ich insbesondere den Sachverhalt betont, dass diejenigen Arten, die Mga-Rouhiala und Portlandia gemeinsam sind, zu den sogenannten Ubiquisten gehören, die in mancherlei klimatischen Verhältnissen zu leben vermögen und also in keiner Weise für eine besondere Zugehörigkeit gerade zum Portlandia-Meer sprechen. Diese Arten bezeugen also in diesem Fall keine Zeit, sondern nur maritime Verhältnisse.

An ähnlichen gemeinsamen Ubiquisten zeigen Rouhiala-Mga und die Eem-Ablagerungen 28 %, so dass deren Nebeneinanderstellung gleicherweise berechtigt, aber natürlich gleicherweise unbegründet wäre. Dass das Eem-Meer Arten enthält, die, abgesehen von einer, Ubiquisten sind und in den Rouhiala-Mga- sowie Portlandia-Verzeichnissen fehlen, beweist nichts für das Alter. In diesem Zusammenhang ist zu bemerken, dass, wenn in der betreffenden Interglazialzeit eine Meeresverbindung von der Ostsee durch Russisch-Karelien nach dem Eismeer bestanden hat, es ganz klar ist, dass der Einfluss des Eismeeres im Rouhiala- und im Mga-Gebiet sowohl zur Zeit des Eem- als auch des Portlandia-Stadiums spürbar gewesen ist und offenbar so gewirkt hat, dass die Flora dieser beiden Meere in der Gegend Rouhiala-Mga in hohem Masse gleichartig und vom Typus eines kalten Meeres gewesen ist.

In seiner Entgegnung schreibt Dr. Brander ausführlich über die Ökologie der Diatomeen betreffende elementare Fragen, die für jeden, der sich auch nur etwas mit Diatomeen befasst hat, bekannte Dinge sind. Diese Darstellung schliesst mit der Behauptung, dass die zur Planktongruppe gehörigen Diatomeen in erster Linie zu berücksichtigen sind, wenn das geologische Alter mittels Diatomeen bestimmt wird. Dr. Brander schreibt S. 101 (G. Brander 1938): »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.»

Auch diese Behauptung ist nur in bestimmtem Sinne haltbar. Wenn wir zwei Floren haben, bei denen dieselben Planktonarten eine grosse quantitative Mehrheit ausmachen, und wenn sich unter diesen Arten ausserdem Formen finden, die der gesamten Flora z. B. einen bestimmten klimatischen Typ verleihen, so ist anzunehmen, dass diese Floren gleich alt sind. Wenn dagegen die Planktonarten Ubiquisten sind, kommt ihnen keine chronologische Beweiskraft zu, soweit zwischen den miteinander zu vergleichenden Floren sonstige bedeutende Typenverschiedenheit besteht. Noch unmöglicher ist es, auf Grund der betreffenden ubiquisten Planktonarten Alterskonnektionen vorzunehmen, wenn sie in einer dritten Flora auftreten, die als ungleichaltrig mit den zwei ersteren betrachtet wird.

Es ist interessant, von diesem Standpunkt aus Dr. Branders Tabellen zu betrachten und zu prüfen, inwieweit die Behauptung zutrifft, die von ihm dargestellten Planktonarten bewiesen durchaus überzeugend, dass Rouhiala-Mga mit dem Portlandia der Ostsee gleichaltrig, aber mit der Eem-Phase der Ostsee ungleichaltrig seien.

Ich habe hier einen Auszug, Tabelle I, aus Branders Diatomeentabelle (G. Brander 1937, Tabelle VII, S. 46) beigegeben; in den Auszug habe ich nur diejenigen Arten aufgenommen, die in diesem Zusammenhang in Frage kommen — also Arten, die den Ablagerungen von Rouhiala-Mga und denen des Portlandia der Ostsee gemeinsam sind. Nach Branders Behauptungen wäre jetzt zu erwarten, dass wenigstens diese Arten (25 % der Gesamtzahl der Arten) Planktonarten wären, da er sie in erster Linie bei der in Frage stehenden Alterskonnektion für beweiskräftig hält. So verhält es sich jedoch nicht, denn nur 10 dieser gemeinsamen Arten (49 Arten) können als Planktonarten gerechnet werden. Ich habe diese 10 Arten gesondert in Tabelle II aufgenommen. Unter ihnen finden sich noch drei Arten (*Actinoptychus undulatus, Melosira sulcata* und *Thalassionema nitzschioides)*, die auch als Epiphyten leben (A. Grunow 1870 und F. Hustedt 1927—37).

Tab. I.

B	U	N	E	B = In Baltikums rezenten oder nacheiszeitlichen Ablagerungen N = In der Nordsee E = In dem Nördlichen Eismeer U = Ubiquist + = Das Vorkommen S = Südliche Form N = Nördliche Form 1—3 = Die Frequenzen	Rouhiala	Mga	Portlandia: Tolkemit	Reimannsfelde	Lenzen	Adlershorst	Hohenhaff	Cadinen
+	+	+	+	*Achnanthes brevipes* Ag. [*A. subsessilis* E.]	1	1	+	+	+		+	
+	+	+	+	*Actinocyclus Ehrenbergi* Ralfs	2	2		+	+	+	+	+
+	+	+	+	v. *Ralfsi* (W. Sm.) Hust. [*A. Ralfsi* Pritch]	1	1	+	+		+		+
+	+	+	+	*Actinoptychus undulatus* (Bail.) Ralfs [? E.]	2	3	+	+	+	+	+	+
+	+	+	+	*Amphora crassa* Greg. incl. v. *punctata* Grun.	1			+		+	+	
+	+	+	+	*Caloneis aemula* (A. S.) Cl.	1	1		+				
+	+	+	+	*formosa* (Greg.) Cl. [*Nav. f.*]	1					+		
+	+	+	+	*Campylodiscus clypeus* E.	1			+	+		+	+
+	+	+	+	*echeneis* E.	1	1		+	+	+	+	
+	+	+	+	*Chaetoceros affinis* Lauder	3	2			+			
+	N	?	+	*mitra* (Bail.) Cl. [*Dicladia m.*]	2	2		+	+	+	+	+
+	+	+	+	*subsecundus* (Grun.) Hust. [*Ch. diadema* (E.) Gran, *Ch. Clevei* Schütt.]	1	2		+	+		+	
+	+	+	+	*Cocconeis quarnerensis* Grun. (incl. fo. *rhomboidale* Schulz)	1	1		+	+		+	
+	+	+	+	*scutellum* E.	2	3		+	+	+	+	+
+	+	+	+	v. *stauroneiformis* W. Sm.	2	3			+		+	+
+	+	+	+	*Coscinodiscus excentricus* E. (incl. v. *minor* E.)	2	3		+	+	+	+	
+	+	+	+	*lineatus* E.	1	1	+	+	+			
	+	+	+	*Dimerogramma minor* (Greg.) Ralfs	1			+				+
+	+	+	+	v. *nana* (Greg.) V. H. [*D. nana* Greg.]	2	1	+	+			+	

B	U	N	E	B = In Baltikums rezenten oder nacheiszeitlichen Ablagerungen N = In der Nordsee E = In dem Nördlichen Eismeer U = Ubiquist + = Das Vorkommen S = Südliche Form N = Nördliche Form 1—3 = Die Frequenzen	Rouhiala	Mga	Portlandia					
							Tolkemit	Reinannsfelde	Lenzen	Adlershorst	Hohenhaff	Cadinen
+	+	+	+	*Diploneis didyma* (E.) Cl. [*Nav. d.*] ..	2	2	+	+	+	+	+	+
+	+	+	+	*interrupta* (Kütz.) Cl. [*Nav. i.*] ...	1		+		+	+	+	
	?	?	?	*lineata* v. *minuta* Schulz		1		+				
+	+	+	+	*Smithi* (Bréb.) Cl. [*Nav. S.*]	3	2	+	+	+	+	+	+
	N		+	*Grammatophora arcuata* E.	2	2		+				
+	+	+	+	*marina* (Lyngb.) Kütz.	+	+	+	+	+			
+	+	+	+	v. *macilenta* W. Sm. [*G. macilenta* W. Sm.]	+	+		+	+	+	+	+
+	+	+	+	*oceanica* E.	3	3	+	+		+		
+	+	+	+	*Hyalodiscus scoticus* (Kütz.) Grun. ..	2	2		+	+	+	+	+
+	+	+	+	*Melosira sulcata* (E.) Kütz.	2	1	+	+	+	+	+	+
+	+	+	+	*Navicula abrupta* Greg.	1	1		+				
+	+	+	+	*granulata* Bail.	1			+				
+	+	+	+	*humerosa* Bréb.	1	1		+		+	+	
+	+	+	?	v. *constricta* Cl.	1				+			
+	+	+	+	*jamaliensis* Cl.		1					+	
+	+	+	+	*latissima* Greg.	1	1		+	+	+	+	
+	+	+	+	*lyra* E.	1			+				
+	+	+	+	*palpebralis* Bréb.	1			+	+		+	
	+	+	?	v. *angulosa* Greg.		1		+		+	+	
+	+	+	+	*Nitzschia marginulata* Grun.	1			+				
+	+	+	+	*navicularis* (Bréb.) Grun. [? *N. naviculacea* Bréb.]	1	1		+	+	+	+	
+	+	+	+	*punctata* (W. Sm.) Grun.	2	2		+	+	+	+	+
	+	+	+	*Plagiogramma staurophorum* (Greg.) Heiberg [*Pl. Gregoryanum* Grev.] ..	1				+			
+	+	+	+	*Rhabdonema arcuatum* (Lyngb.) Kütz.	2	2		+	+	+	+	+
+	+	+	+	*Rhopalodia gibberula* (E.) O. M.	2	1		+			+	+
+	+	+	+	*Surirella striatula* Turp.	1	1		+			+	
+	+	+	+	*Synedra crystallina* (Ag.) Kütz.	2	1		+		+		+
+	+	+	+	*tabulata* (Ag.) Kütz. [*S. affinis* Kütz.]	3	3		+			+	
	+	+	+	*Thalassionema nitzschioides* (Grun.) V. H. [*Synedra n.*]	3	3		+	+			
+	+	+	+	*Trachyneis aspera* (E.) Cl. [*Nav. a.*] ..	2	1		+		+	+	

Tab. II.

B	U	N	E		Rouhiala	Mga	Portlandia: Tolkemit	Portlandia: Reimannsfelde	Portlandia: Lenzen	Portlandia: Adlershorst	Portlandia: Hohenhaff	Portlandia: Cadinen	Eem: Westbalt. Inseln	Eem: Alsen	Eem: Tranderup Klint	Eem: Ristinge Klint	Eem: Stensigmose Klint
+	+	+	+	*Actinocyclus Ehrenbergi* Ralfs	2	2		+	+	+	+	+	2	2			+
+	+	+	+	v. *Ralfsi* (W. Sm.) Hust. [*A. Ralfsi* Pritch]	1	1	+	+		+		+	2	3		3	
+	+	+	+	*Actinoptychus undulatus* (Bail.) Ralfs [? E.] ..	2	3	+	+	+	+	+	+	3	3	2	3	+
+	+	+	+	*Chaetoceros affinis* Lauder	3	2			+								
+	N	?	+	*mitra* (Bail.) Cl. [*Dicladia m.*]	2	2		+	+	+	+	+	2	2			+
+	+	+	+	*subsecundus* (Grun.) Hust. [*Ch. diadema* (E.) Gran, *Ch. Clevei* Schütt.]	1	2		+	+		+						+
+	+	+	+	*Coscinodiscus excentricus* E. (incl. v. *minor* E.)	2	3		+	+	+	+		3	2		2	+
+	+	+	+	*lineatus* E.	1	1	+	+	+				2	2			
+	+	+	+	*Melosira sulcata* (E.) Kütz.	2	1	+	+	+	+	+	+	3	3	3	2	+
	+	+	+	*Thalassionema nitzschioides* (Grun.) V. H. [*Synedra n.*]	3	3		+	+								

Diese 10 Arten (die Gesamtzahl der Arten: Mga-Rouhiala + Portlandia = 198) sind also letzten Endes diejenigen, auf Grund deren, wie Dr. Brander behauptet, Mga-Rouhiala und Portlandia der Ostsee gleichaltrig wären. Den genannten Arten kann als Belegen für das Alter in diesem Fall jedoch keinerlei Bedeutung beigemessen werden, denn diese Arten sind keine Leitfossilien, sondern überall in maritimen Verhältnissen auftretende Arten, die rezent und in ungleichaltrigen geologischen Bildungen anzutreffen sind. Aus Tabelle II ist ausserdem zu ersehen, dass alle diese Arten, ausser *Thalassionema nitzschioides*, auch in den Ablagerungen des Eem-Meeres auftreten, welch letztere sich jedoch auch nach Brander in einem älteren Meere als Portlandia und Mga-Rouhiala abgesetzt haben. Branders Behauptung, er habe auf Grund des Auftretens der in Frage stehenden Planktonarten Rouhiala-Mga als gleichaltrig mit dem Portlandia der Ostsee, aber als ungleich-

altrig mit dem Eem-Meer der Ostsee erwiesen, ist nach dem oben Dargestellten durchaus phantastisch. Dr. Brander scheint nicht einmal sein eigenes Material zu kennen, wenn er derartige Behauptungen immer wieder ernstlich darstellt. Wird ferner in Betracht gezogen, dass die Abundanzstufen der Portlandia-Flora der Ostsee in den ursprünglichen Untersuchungen überhaupt nicht dargestellt sind, so ist ein gegenseitiger quantitativer Vergleich dieser gemeinsamen Planktonarten überhaupt nicht möglich. In seiner Entgegnung behauptet jedoch Dr. Brander, dass ich die Frequenzen der Diatomeen nicht in Betracht gezogen habe. Die Sache wird nicht dadurch besser, dass Rouhiala-Mga Frequenzen aufweist, da sie eben der anderen als Vergleichsgegenstand dienenden Diatomeenflora (den Reihen des Portlandia der Ostsee) völlig fehlen.

Ausserdem ist es interessant festzustellen, dass unter den typischen Planktonarten nach Branders Tabellen mehr Verschiedenheit als Gleichartigkeit zwischen Mga-Rouhiala und dem Portlandia der Ostsee besteht. So sind z. B. von den sieben *Chaetoceros*-Arten nur drei und von den achtzehn *Coscinodiscus*-Arten nur zwei gemeinsam. Die letztere Tatsache ist auch Brander etwas bedenklich erschienen, da er sich bemüht, diesen störenden Faktor zu eliminieren. Dies geschieht in der Weise, dass er erklärt, die Verschiedenheit beruhe auf der ungleichen Diagnose der einzelnen Forscher. Derartiges kann jedoch niemand behaupten, bevor er die betreffenden Präparate geprüft hat, wozu jedoch Brander nicht gekommen ist. Wenn er es übrigens getan hätte, so ist es eben klar, dass ein derartiges Material in diesem Fall keinerlei Gebrauchswert hat. Dr. Brander teilt jedoch zuerst mit, dass in einem wesentlichen Teil seines Materials Verschiedenheit besteht, »was zweifelsohne grösstenteils auf ungleicher Diagnostik beruht» (G. Brander 1937, S. 52), doch zögert er nicht, gleich danach dieses Material für Alterskonnektionen weiter Erstreckung zu benutzen.

Wie bereits aus meiner früheren Kritik hervorgeht, hat sich meine Beurteilung vor allem der methodischen Seite von Branders Untersuchung zugewandt — der Benutzung von Diatomeen bei geologischen Alterskonnektionen. Von meinem Standpunkt aus ist es dagegen fortgesetzt eine offene Frage gewesen, wie alt die Rouhiala- und die Mga-Ablagerungen in Wirklichkeit sind und welchen interglazialen Meeresstadium man sie zuzuzählen hat oder ob es sich bei ihnen überhaupt um interglaziale Bildungen handelt. Solange die ganze Frage der Interglazialzeiten auch in grossen Zügen sowohl in Europa als auch in Amerika in mancher Beziehung noch ein sehr unklares und wirres Problem ist, erscheint es hoffnungslos, auf Grund eines Materials, wie es Dr. Brander zur Verfügung gestanden hat, auf Einzelheiten einzugehen.

Dr. Branders Entgegnung gäbe noch zu mancherlei Bemerkungen Anlass, doch möchte ich auf sie als weniger wichtig verzichten und meinerseits die Kontroverse über diese Frage als abgeschlossen betrachten.

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