GEOLOGINEN TUTKIMUSLAITOS

BULLETIN
DE LA
COMMISSION GÉOLOGIQUE
DE FINLANDE

N:o 142

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

HELSINKI
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Helsinki 1948. Valtioneuvoston kirjapaino.

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SUOMEN GEOLOGINEN SEURA
GEOLOGISKA SÄLLSKAPET I FINLAND

JÄSENLUETTELO 31. 12. 1947 LIST OF MEMBERSHIP

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SUOMEN GEOLOGISEN SEURAN TOIMINTA VUONNA 1946

Geologisella Seuralla on vuonna 1946 ollut 10 kokousta. Puheenjohtajana on kevätkaudella toiminut toht. Paavo Haapala, syyskaudella professori Aarne Laitakari, sihteerinä on kevätkaudella ollut toht. Kalervo Rankama, syyskaudella maist. Kalevi Virkkala.

Seuraan on toimintavuoden aikana valittu seuraavat 14 uutta jäsentä: dipl. ins:t P. Alenius, H. Jalander, M. Ratu, E. Heino, maisterit L. Heinonen, A. Vuorjoki, H. Wiik, E. Peltola, M. Kulonpalo, R. Repo, V. Hyppönen, H. Schröder, A. Toivonen ja metsänhoitaja V. Valovirta. Seuraan kuului v. 1946 yksi kunniajäsen, 9 ulkomaista kirjeenvaihtajajäsentä, 30 vakinaista jäsentä ja 131 vuosijäsentä eli yhteensä 171 jäsentä, joista 46 ulkomaalaista. Seurasta on vuoden aikana eronnut 3 jäsentä.

Vuoden 1946 aikana ilmestyi Seuran julkaisujen numero XIX käsittäen 7 kirjoitusta ja XII + 210 sivua.

ACTIVITIES OF THE GEOLOGICAL SOCIETY OF FINLAND IN 1946

During 1946 10 meetings of the Society were held. Dr. Paavo Haapala and Prof., Dr. Aarne Laitakari acted as President and the duties of Secretary were attended to by Dr. Kalervo Rankama and by Mr. K. Virkkala, M. A.

The following were elected Members of the Society during 1946: Mr. P. Alenius, Civil Engineer; Mr. H. Jalander, Civil Engineer; Mr. M. Ratu, Civil Engineer; Mr. E. Heino, Civil Engineer; Mr. L. Heinonen, M. A.; Mr. A. Vuorjoki, M. A.; Mr. H. Wiik, M. A.; Mr. E. Peltola, M. A.; Mr. M. Kulonpalo, M. A.; Mr. R. Repo, M. A.; Mr. V. Hyppönen, M. A.; Mr. H. Schröder, M. A.; Mr. A. Toivonen, M. A.; and Mr. V. Valovirta, Forester. The List of Members included in 1946 one Honorary Member, 9 Foreign Corresponding Members, 30 Life Members, and 131 other Members, together 171 Members, 46 of whom were Foreign Members.

Of the »Comptes Rendus» of the Society, the 19 th volume containing 7 articles and totalling XII + 120 pages, was published during the year.

Vuoden 1946 lopussa oli Seuran taloudellinen asema seuraava:
At the close of 1946 the financial position of the Society was the following:

Säästö vuodelta 1945 — Brought forward from 1945 .	70 070: 90
Valtionavustukset — Government subsidies	56 500: —
Jäsenmaksuja — Membership fees	19 940: —
Korkoja ja osinkoja — Interest and dividends	1 905: —
Summa — Total mk	148 415: 90
Painatuskulut — Publishing costs	103 527: 40
Toimistokulut — Office costs	10 401: 80
Sihteerin palkkio — Secretary's fee	3 000: —
Edustuskulut — Representation costs	1 006: —
J. J. Sederholm mitali — J. J. Sederholm medaille ..	6 150: —
Säästö vuodelle 1947 — Carried forward to 1947	24 330: 70
Summa — Total mk	148 415: 90

Helsinki 2. 1. 1947.

In fidem:
Kalevi Virkkala

KOKOUKSET — MEETINGS
1946

24. I.

Prof. A. Laitakari, toht. M. Salmi, maisterit M. Kulonpalo, V. Okko, U. Soveri ja *K. Virkkala:* Helsingin ympäristön hyödylliset kaivannaiset. — Useful Rocks in Helsinki Environment.

Esitelmät julkaistu Geologisen tutkimuslaitoksen sarjassa Geoteknillisiä julkaisuja N:o 46. — The lectures are published in the Geotechnical Papers nr 46 of the Geological Survey of Finland.

14. II.

Maist. Ahti Simonen: Hämeenlinnan alueen kallioperästä. — On the Petrology of the Hämeenlinna Area.

Esitelmän sisältö julkaistaan myöhemmin. — The lecture will be published later.

7. III.

Prof. Aarne Laitakari: Selostus Geologista tutkimuslaitosta koskevasta uudesta asetuksesta. — Report on the New Statute Concerning the Geological Survey of Finland.

Prof. V. A. Heiskanen: Uutta amerikkalaista kirjallisuutta geotieteiden alalta. — New American Literature of Geology, Geodesy and Geophysics.

28. III.

Maist. K. Virkkala: Havaintoja pohjois-Satakunnan myöhäisglasiaalisista vaiheista. — Observations on the Late-Glacial Periods in Northern Satakunta.

Esitelmässä selostettiin pohjois-Satakunnan myöhäisglasiaalista kehitystä sekä täällä tavattua jäätikön etenemistä. — The lecturer reported upon the Late-Glacial development in Northern Satakunta and the advance of the Glacier, occurred here.

25. IV.

Maist. Veikko Okko: Oulunlaakson kvartäärigeologiasta. — On the Quaternary Geology in the River Valley of Oulujoki.

Esitelmöitsijä selosti Oulujokilaakson kvartäärisiä vaiheita sekä täällä tavattua sedimenttikivialuetta. — The lecture reported upon the Quaternary Periods in the River Valley of Oulujoki and the sedimentary rocks area, met with here.

9. V.

Prof. H. Väyrynen: Kiteiden symmetrialuokitus ja kiderakenne. — The Symmetry Classes and Structure of Crystals.

H. Väyrynen, On the Didactic Form of the System of Crystal Classes. Bull. Comm. géol. Finlande N:o 140.

26. IX.

Maist. Veikko Pääkkönen: Otanmäen löytö ja tähänastiset tutkimusvaiheet. — The Finding and Investigations hitherto of the Otanmäki Iron Ore Deposit.

22. X.

Seuran 60-vuotisjuhlakokous.

Prof. Leon. H. Borgström: Peridotiternas ombildning till serpentin- och talkmagnesitstenar.

Prof. Aarne Laitakari: Eräitä uutuuksia maamme hyödyllisten kaivannaisten alalta. Esitelmä julkaistu sarjassa Kemian Keskusliiton tiedoituksia N:o 3.

Toht. Esa Hyyppä: Harjujen synty.

Esitelmä julkaistaan sarjassa Bull. Comm. géol. Finlande.

The sixty years celebration of the Foundation of the Society.

Prof. Leon. H. Borgström: The Transformation of Peridotites to Serpentine and Talkmagnesite.

Prof. Aarne Laitakari: Some Newnesses among the useful Rocks of Finland. The lecture is published in the Series Kemian Keskusliiton tiedoituksia N:o 3.

Dr. Esa Hyyppä: The Origin of Eskers.

The lecture will be published in the series Bull. Comm. géol. Finlande.

14. XI.

Toht. Esa Hyyppä esitti prof. R. Flintin laatiman kvartäärigeologisen kartan Pohjois-Amerikasta.

Dr. Esa Hyyppä reported the map of Quaternary Geology of North America drawn up by Dr. R. Flint.

Prof. H. Väyrynen: Valon eteneminen anistrooppisessa aineessa. — The Advance of Light in Anisotropic Substance.

5. XII.

Toh. Martti Salmi: Ancylustransgressio Sippolassa. — The Ancylus Transgression in the parish Sippola.

Martti Salmi, Ancylustransgression in dem Moore Hangassuo im Süd- Finnland. Bull. Comm. géol. Finlande N:o 142.

Maist. Aimo Mikkola: Havaintoja Pohjois-Ruotsin kallioperäkartoituksesta. — Observations on the Mapping of the Pre-Quaternary Rocks in Northern Sweden.

Valittiin seuran toimihenkilöiksi vuodeksi 1947 seuraavat: puheenjohtajaksi prof. Aarne Laitakari, varapuheenjohtajaksi toht. Erkki Aurola, sihteeriksi ja rahastonhoitajaksi maist. K. Virkkala, tilintarkastajiksi dipl. ins. Matti Häyrynen ja maist. Eetu Savolainen.

The Ballot for the Officials was taken and the following functionaries were declared elected for the year 1947: President Prof., Dr. Aarne Laitakari; Vice President Dr. Erkki Aurola; Secretary and Treasurer Mr. K. Virkkala, M. A.; Auditors Messrs. Matti Häyrynen, Civil Engineer, and Eetu Savolainen, M. A.

SUOMEN GEOLOGISEN SEURAN TOIMINTA VUONNA 1947

Geologisella Seuralla on vuonna 1947 ollut 11 kokousta. Puheenjohtajana on toiminut professori Aarne Laitakari ja sihteerinä maisteri K. Virkkala.

Seuraan on toimintavuoden aikana valittu seuraavat 15 uutta jäsentä: kirjeenvaihtajajäseneksi tohtori Ernst Cloos; vuosijäseneksi professorit K. Järvinen ja R. Jurva, tohtorit L. H. Ahrens, Erik Fromm, L. M. J. U. van Straaten ja A. F. Frederickson, dipl. insinöörit A. Arvela, T. Siikarla ja M. von Timroth, maisteri N. Edelman sekä ylioppilaat A. Huhma, O. Oksanen, H. Paarma ja M. Vanninen.

Seuraan kuului v. 1947 yksi kunniajäsen, 10 kirjeenvaihtajajäsentä, 32 vakinaista jäsentä ja 142 vuosijäsentä eli yhteensä 185 jäsentä, joista 50 ulkomaalaista.

Vuoden 1947 aikana ilmestyi Seuran julkaisujen numero XX käsittäen 24 kirjoitusta ja XVIII + 302 sivua.

ACTIVITIES OF THE GEOLOGICAL SOCIETY OF FINLAND IN 1947

During 1947 11 meetings of the Society were held. Dr. Aarne Laitakari acted as President and the duties of Secretary were attended to by Mr. K. Virkkala, M. A.

The following were elected Members of the Society during 1947: Dr. Ernst Cloos (as Corresponding Member), Dr. R. Jurva, Dr. L. H. Ahrens, Dr. A. F. Frederickson, Dr. Erik Fromm, Dr. L. M. J. U. van Straaten, Mr. K. Järvinen, Mining Engineer; Mr. A. Arvela, Mining Engineer; Mr. T. Siikarla, Mining Engineer; Mr. M. von Timroth, Mining Engineer; Mr. N. Edelman, M. A.; Mr. A. Huhma, Mr. O. Oksanen, Mr. H. Paarma, and Mr. M. Vanninen, all Students of Geology.

The List of Members included in 1947 one Honorary Member, 10 Foreign Corresponding Members, 32 Life Members, and 142 other Members, together 185 Members, 50 of whom were Foreign Members.

Of the »Comptes Rendus» of the Society, the 20 th volume containing 24 articles and totalling XVIII + 302 pages was published during the year.

Vuoden 1947 lopussa Seuran taloudellinen asema oli seuraava:
At the close of 1947 the financial position of the Society was the following:

Säästö vuodelta 1946 — Brought forward from 1946 .	24 330: 70
Valtionavustukset — Government subsidies	164 500: —
Yksityiset avustukset juhlajulkaisuun — Private subsidies to the festival publication	161 413: —
Jäsenmaksuja — Membership fees	19 849: 50
Mitaleista — From medailles	70 436: 50
Korkoja ja osinkoja — Interest et dividends	4 776: —
Summa — Total mk	445 305: 70

Painatuskulut — Publishing costs	322 796: —
Ulkomaiset esitelmöitsijät — Foreign lecturers	6 891: —
Toimistokulut — Office costs	17 084: 50
Sihteerin palkkio — Secretary's fee	3 000: —
Edustuskulut — Representation costs	400: —
Mitalikulut — Medaille costs	68 821: —
Säästö vuodelle 1948 — Carried forward to 1948	26 313: 20
Summa — Total mk	445 305: 70

Helsinki 2. 1. 1948.

In fidem:
K. Virkkala

KOKOUKSET — MEETINGS
1947

23. I.

Prof. Pentti Eskola: Amerikan matka. — The Excursion to America.

Esitelmöitsijä selosti Amerikan matkaansa, erikoisesti niitä havaintoja, jotka koskivat graniittien syntyä. — The lecturer reported upon his excursion to America, specially observations concerning origin of granites.

20. II.

Toht. A. Metzger: Pihlajan kaoliinista. — The Kaoline Occurrence of Pihlajavaara in Puolanka.

Esitelmässä selostettiin täällä suoritettuja tutkimuksia. Paikalle on perustettu kaoliinin liettämislaitos. — The lecturer reported investigations performed here. A sorting apparatus of kaoline has been built in this locality.

Maist. Veikko Okko: Pihlajan kaoliinin subfossiileista. — On the Subfossiles of the Kaoline Occurrence of Pihlajavaara.

Kaoliinista tavatut subfossiilit viittaavat esitelmänpitäjän mukaan sen sekundääriseen sedimentääriseen syntyyn. — The subfossiles met with in kaoline suggest according to the lecturer, that there has occurred secondary formation of kaoline with sedimentation.

13. III.

Toht. Martti Salmi: Turpeiden tuhkapitoisuudesta ja lämpöarvoista. — The Heat Value and Percentage of Ash in Peat.

Esitelmän sisältö julkaistaan myöhemmin. — The lecture will be published later.

Maist. N. Edelman: Om reaktionen kvartsglas — kristobalit. — On the Reaction Quartz Glass — Cristobalite.

N. Edelman, On the Reaction Quartz Glass — Highcristobalite from the Thermodynamical Point of View. Bull. Comm. géol. Finlande N:o 140.

27. III.

Maist. Veikko Pääkkönen: Otanmäen malmin ja sen ympäristön geologisesta rakenteesta. — On the Geological Structure of Otanmäki Iron Ore and its Environment.

Esitelmän sisältö tulee julkaistavaksi myöhemmin. — The lecture will be published later.

Maist. Veikko Okko esitti tiedonannon Alavieskan rikkikiisulohkareen alkuperästä ja kulkusuunnasta. — *Mr. Veikko Okko. M. A.* made a communication on the origin of the pyrite boulder of Alavieska.

Veikko Okko, On the Origin of the Alavieska Pyrite Boulder. Bull. Comm. géol. Finlande N:o 142.

17. IV.

Maist. Ahti Simonen: Geologisen tutkimuslaitoksen kallioperäkartoituksista kesällä 1946. — On the Mapping of the Pre-Quaternary Rocks by the Geological Survey of Finland during the Summer 1946.

Kallioperäkartoituksia suoritettiin Oulun ja Turun karttalehtien alueilla sekä Tampereen liuskealueella. — Mappings of Pre-Quaternary rocks were performed on the areas of the map sheets of Oulu and Turku and on the schist area of Tampere.

Maist. M. Kulonpalo esitti tiedonannon rapakivessä tavatusta lyijyhohdejuoenesta Inkeroisista. — *Mr. M. Kulonpalo, M. A.* made a communication on a galenite vein met with in rapakivi at Inkeroinen.

Toht. Martti Salmi esitti tiedonannon Heklan tuhkasateesta maassamme. — *Dr. Martti Salmi* made a communication concerning Hekla ashfall in Finland.

Martti Salmi, The Hekla Ashfalls in Finland A. D. 1947. Bull. Comm. géol. Finlande N:o 142.

8. V.

Toht. Esa Hyyppä: Maalajitutkimuksen uudelleenjärjestely Geologisessa tutkimuslaitoksessa. — The Reorganization of the Investigation of Superficial Deposits in the Geological Survey of Finland.

Päähuomio maalajitutkimuksessa on maalajikartoituksella. Varsinkin materiaalitutkimuksiin sekä teknillisesti käyttökelpoisiin maalajeihin on kiinnitetty huomiota. Viimemainituista ovat polttoturve- ja tiilisavitutkimukset olleet ajankohtaisimmat. Myös pohjavesitutkimukset on otettu ohjelmaan. — The most important object is the mapping of superficial deposits. Especially the material of superficial deposits and the technical usefulness are taken into consideration. Among the last mentioned peat researches and brick-clay investigations are actual. Also ground water investigations have been taken into consideration.

Toht. Martti Saksela: Piirteitä malmimuodostuksesta Tampereen liuskealueella. — On the Formation of Ore on the Schist Area of Tampere.

Martti Saksela, Über eine Antimonr iche Paragenese in Ylöjärvi, SW-Finnland. Bull. Comm. géol. Finlande N:o 140.

2. X.

Toht. L. M. J. U. van Straaten: Subaquatische Abrutschungserscheinungen. — Subaquatic Disturbance of Deposits.

Esitelmä tulee julkaistavaksi myöhemmin. — The lecture will be published later.

20. X.

Toht. S. Thorarinsson: Hekla utbrottet 1947. — Hekla Eruption 1947.

Esitelmöitsijä selosti yksityiskohtaisesti Heklan purkauksen ja näytti tapahtumasta ainutlaatuisen värielokuvan. — The lecture reported detailedly upon the eruption and exhibited an unique coloured film about the event.

23. X.

Toht. Martti Saksela: Outokummun löydöstä. — On Discovery of Outokumpu Copper Ore.

Martti Saksela, Outokummun kuparimalmin löytö. — English Summary: The Discovery of Outokumpu Ore Field. Geologinen tutkimuslaitos. Geotekn. julk. N:o 47.

Toht. Martti Salmi: Turpeiden bitumipitoisuudesta. — On the Percentage of Bitum in Peat.

Esitelmä tulee julkaistavaksi myöhemmin. — The lecture will be published later.

20. XI.

Prof. Harry von Eckermann: Från Alnö området. — On the Rocks of the Area of Alnö.

H. von Eckermann, Alnö alkalina intrusionstektonik och genesis i belysning av dess gångbergarter. Geol. Fören. i Stockholm Förh., Bd. 68.

11. XII.

Selostuksia pohjoismaisesta geologikongressista Norjassa kesällä 1947. — Reports on the northern geologist congress in Norway during the summer 1947.

Maist. Heikki Tuominen: Bergenin alueen geologiasta. — On the Geology of the Area of Bergen.

Toht. Th. Brenner: Qvartärgeologisk exkursion till Jostedalsbrä. — A Quaternary Geological Excursion to the Glacier of Jostedalsbrä.

Esitelmöitsijä kuvasi jäätikön toimintaa, joka tarjoaa erinomaista havaintoaineistoa geologille. — The lecturer dealt with the activity of the glacier, which offers excellent material of observation to geologists.

Prof. Aarne Laitakari: Sulitjelman alueen geologiasta. — On the Geology of the Area of Sulitjelma.

Esitelmässä kuvattiin malmin geologiaa, kaivoksen toimintaa sekä niitä vaikeuksia, joita jylhä tunturimaasto kaivostoiminnalle täällä asettaa. — The geology of the ore, the action of the mine and the difficulties, caused to mining industry by the rugged fjeld terrain were dealt with in the lecture.

Valittiin seuran toimihenkilöiksi vuodeksi 1948 seuraavat: puheenjohtajaksi toht. Erkki Aurola, varapuheenjohtajaksi maist. Ahti Simonen, sihteeriksi ja rahastonhoitajaksi maist. K. Virkkala, tilintarkastajiksi dipl. ins. Matti Häyrynen ja maist. Eetu Savolainen ja varatilintarkastajiksi maisterit Reino Repo ja Kalle Neuvonen.

The Ballot for the Officials was taken and the following functionaries were declared elected for the year 1948: President Dr. Erkki Aurola; Vice President Mr. Ahti Simonen, M. A.; Secretary and Treasurer Mr. K. Virkkala, M. A.; Auditors, Messrs. Matti Häyrynen, Civil Engineer, and Eetu Savolainen, M. A., reelected; Vice Auditors Messrs. Reino Repo, M. A., and Kalle Neuvonen, M. A.

HEIKKI VÄYRYNEN

60 YEARS OLD

Professor Heikki Väyrynen, active member and former President of the Geological Society of Finland, occupying the chair of mineralogy and geology at the Technical University in Helsinki, attains the age of sixty years on May 18, 1948.

Professor Väyrynen was born in Pielisjärvi parish, Karelia. After having been at school in Nurmes and after studying at Helsinki University he obtained the degree of Mag. Phil. in 1915 and of D. Sc. in 1921. Professor Väyrynen was attached to the Geological Survey as an ore geologist in 1919 and since 1936 has been a State Geologist until he entered upon his present post at the Technical University. He was appointed a docent at Helsinki University in 1929 and has acted as President of the Geological Society of Finland in 1928, 1939 and 1940.

Professor Väyrynen has undertaken foreign exploring expeditions to Central Sibiria, Sweden, Norway, Central European countries and Russia. His scientific research work comprises in especial petrography, tectonic and ore geology. His dissertation dealt with South-Ostrobothnian granodioritic rocks and his later papers treat especially the petrology and tectonics in the Karelian schist-zone. The Petsamo and Outokumpu ore fields may be mentioned among his ore geological researches.

In congratulating Professor Heikki Väyrynen on his festival day the Geological Society of Finland expresses the hope that his active work both in the field of scientific research and of teaching may long be continued.

1.

DIE ANCYLUSTRANSGRESSION IN DEM MOORE HANGASSUO IM SÜD-FINNLAND

VON

MARTTI SALMI

INHALT

VORWORT

Als ich in die Aufzeichnungen von Stud. Erkki Veijalainen, der im Sommer 1946 an den Torfuntersuchungen der Geologischen Forschungsanstalt als Sommergehilfe teilgenommen hatte, einen Einblick nahm, wandte sich meine Aufmerksamkeit den über das Moor Hangassuo in Sippola gemachten Eintragungen zu, nach denen dort an zwei Bohrstellen eine Torflage zwischen Tonschichten angetroffen worden war. Da ich annahm, dass es sich um eine beachtenswerte Beobachtung handeln könne, und da wir uns in der Nähe des besagten Moores aufhielten, suchten wir es gemeinsam auf. Nach einigen Bohrungen stiessen wir auf die gesuchte Schicht, wobei sich zugleich ebenfalls herausstellte, dass sie sich auf bestimmte Stellen im Moore beschränkte. Diesmal führte ich an der Stelle nur eine orientierende Untersuchung aus. Doch entnahm ich dem Moore eine Probenserie für die Pollen- und Diatomeenuntersuchung sowie Proben für die Bestimmung der Makrofossilien.

6968/47

Bei den Laboratoriumsuntersuchungen zeigte es sich, dass es sich um einen sehr wichtigen Transgressionsvorgang handelte, der eine eingehende Untersuchung verdiente; infolgedessen begab ich mich noch im Herbst nach dem Moore Hangassuo in Begleitung Mag. phil. A. V. P. Toivonen, der eine Nivellierung des Untersuchungsgebietes vornahm, sowie von Oberförster V. E. Valovirta, beide von der Geologischen Forschungsanstalt.

Es sei angeführt, dass das Moor Hangassuo kurz zuvor in regelmässige, ein Hektar umfassende Torfstreuflächen eingeteilt worden war. Das so entstandene Netz gereichte der Kartierung des Untersuchungsgebietes zum Nutzen. Desgleichen von Vorteil waren die Nivellierungen der Topographen des Landsvermessungsamtes, Arbeiten, die gerade in der Umgebung des Moores vor sich gingen.

Die mit der Untersuchung verbundenen Pollenbestimmungen hat Mag. phil. Ester Uussaari, zum Teil Mag. phil. Kyllikki Salminen ausgeführt und die Diatomeenbestimmungen Dr. phil. K. Mölder. Die makroskopischen Pflanzen- und Samenbestimmungen sind von Oberförster V. E. Valovirta. Die Übertragung der Untersuchung ins Deutsche hat Dr. phil. Marta Römer besorgt. Allen obengenannten möchte ich meinen besten Dank zum Ausdruck bringen.

DAS MOOR UND SEINE LAGE

Das Moor Hangassuo liegt in dem Tal des Flusses Kymijoki in dem Kirchspiel Sippola, etwa 7 km von der Station Myllykoski nach ESE. Die Mooroberfläche mit ihren ausgedehnten Buchten umfasst etwa 210 ha (Abb. 1). Es ist Hochmoor, dessen Hochmoorteil mit seinen mehr oder weniger deutlich ausgeprägten *Calluna*-Reisermoor-Strängen sich auf ein verhältnismässig kleines Gebiet in der Mitte des Moores beschränkt. Von den Pflanzen dieses Teiles seien folgende genannt: *Sphagnum fuscum*, *S. cuspidatum coll.*, *Eriophorum vaginatum*, *Scheuchzeria palustris*, *Betula nana*, *Calluna vulgaris*, *Ledum palustre*, *Empetrum nigrum*, *Rubus chamaemorus* und *Pinus*. Die Höhe des Hochmoorteiles beträgt 52—53 m ü. M.

Der übrige Teil des Moores ist verschiedenes Weissmoor. Im Norden findet sich als vorherrschender Moortyp kurzhalmiges Weissmoor, aber im Westen und vor allem im Süden liegt auf weiten Flächen schwappendes Rimpi-Weissmoor. Höchst typische Pflanzen der Weissmoore sind *Sphagnum balticum*, *S. papillosum*, *S. magellanicum*, *Eriophorum vaginatum*, *Scheuchzeria palustris*, *Rhynchospora alba* und *Carex limosa* (Abb. 2).

Das Moor hat die natürlichen Gefällsverhältnisse nach Süden und Südosten gerichteten Moorbuchten, wo die Höhe ca 48 m ü. M. ist. Die von den Buchten ausgehenden Bäche sind klein, nur 2—3 m breit. Sie verlaufen jedoch meistens auf dem Grunde von dekameterbreiten Rinnen, was darauf hinweist, dass sie einst Wanderstrassen grösserer Wassermassen gewesen sind. Ein Teil der Moorgewässer fliesst gegenwärtig auch nach Nordwesten und Osten ab.

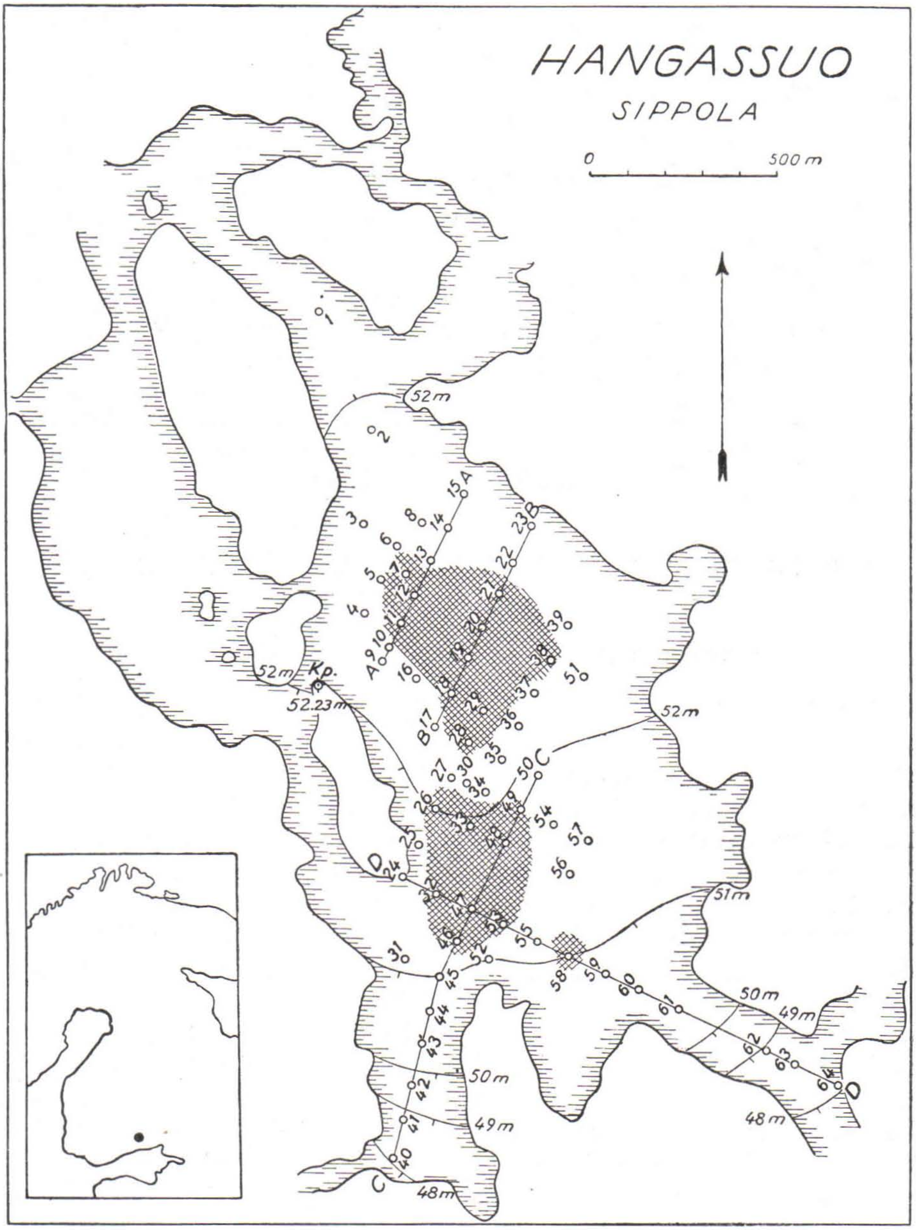

Abb. 1. Karte vom Hangassuo. In die Karte sind Höhenkurven mit 1 m Höhenunterschied eingetragen. Die kleinen Kreise mit Ziffern bedeuten die Bohrstellen und die Geraden nebst Buchstaben die Zeichnungsstellen der Querprofile (Abb. 3). Die Kreuzliniierung bezeichnet die Verbreitung des eingebetteten Torfes. Aus der Skizze in der linken Ecke unten ist die Lage des Moores Hangassuo zu ersehen.

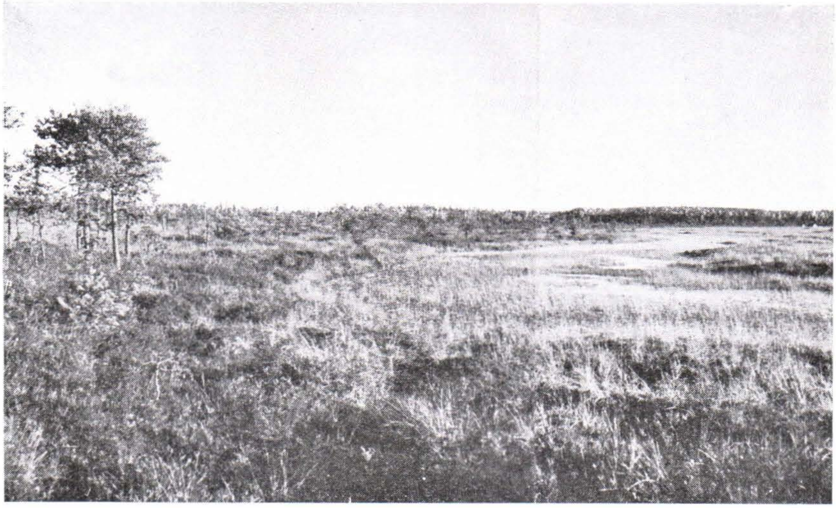

Abb. 2. Anblick des Hangassuo an der Grenze zwischen Hochmoor (links) und Rimpi-Weissmoor (rechts).

DIE SCHICHTEN DES MOORES UND IHRE GEGENSEITIGEN VERHÄLTNISSE

DIE VON DER TRANSGRESSION BEDECKTE TORFSCHICHT

Bei der Kartierung der von der Transgression überspülten Torfschicht wurden an 64 verschiedenen Stellen Bohrungen ausgeführt (Abb. 1). Dabei stellte es sich heraus, dass eingebetteter Torf im Hangassuo in drei getrennten Gebieten vorkommt. Das nördlichste und zugleich umfangreichste Gebiet liegt in der Mitte des Moores und umfasst etwa 16 Hektar. Davon getrennt durch einen schmalen Sund liegt direkt nach Süden das zweite, ca. 11 Hektar grosse und von diesem nach Südosten das dritte, ca. 1 Hektar ausmachende Gebiet. Von der Transgression eingebetteter Torf findet sich also im Hangassuo in einer Fläche von insgesamt etwa 28 Hektar.

Die in Frage stehende Torfschicht ist durchweg verhältnismässig dünn. Die stärkste Dicke ist angetroffen worden an der Bohrstelle 11, wo die Schicht 20 cm mächtig ist. Den deutlichsten Begriff von der Dicke der eingebetteten Torfschicht und des transgressiven Sediments vermittelt Tabelle 1. Aus den Profilzeichnungen (Abb. 3), die in verschiedenen Richtungen für die von der Transgression überfluteten Torfvorkommen ausgearbeitet worden sind, sind die gegenseitigen Verhältnisse der verschiedenen Schichten zu ersehen.

Die von der Transgression eingebettete Torfschicht ist allgemein am dicksten in der Mitte der verschiedenen Gebiete und wird dünner nach den Rändern zu, wo sie stellenweise nur 2 cm stark ist. Da, wo die Schicht

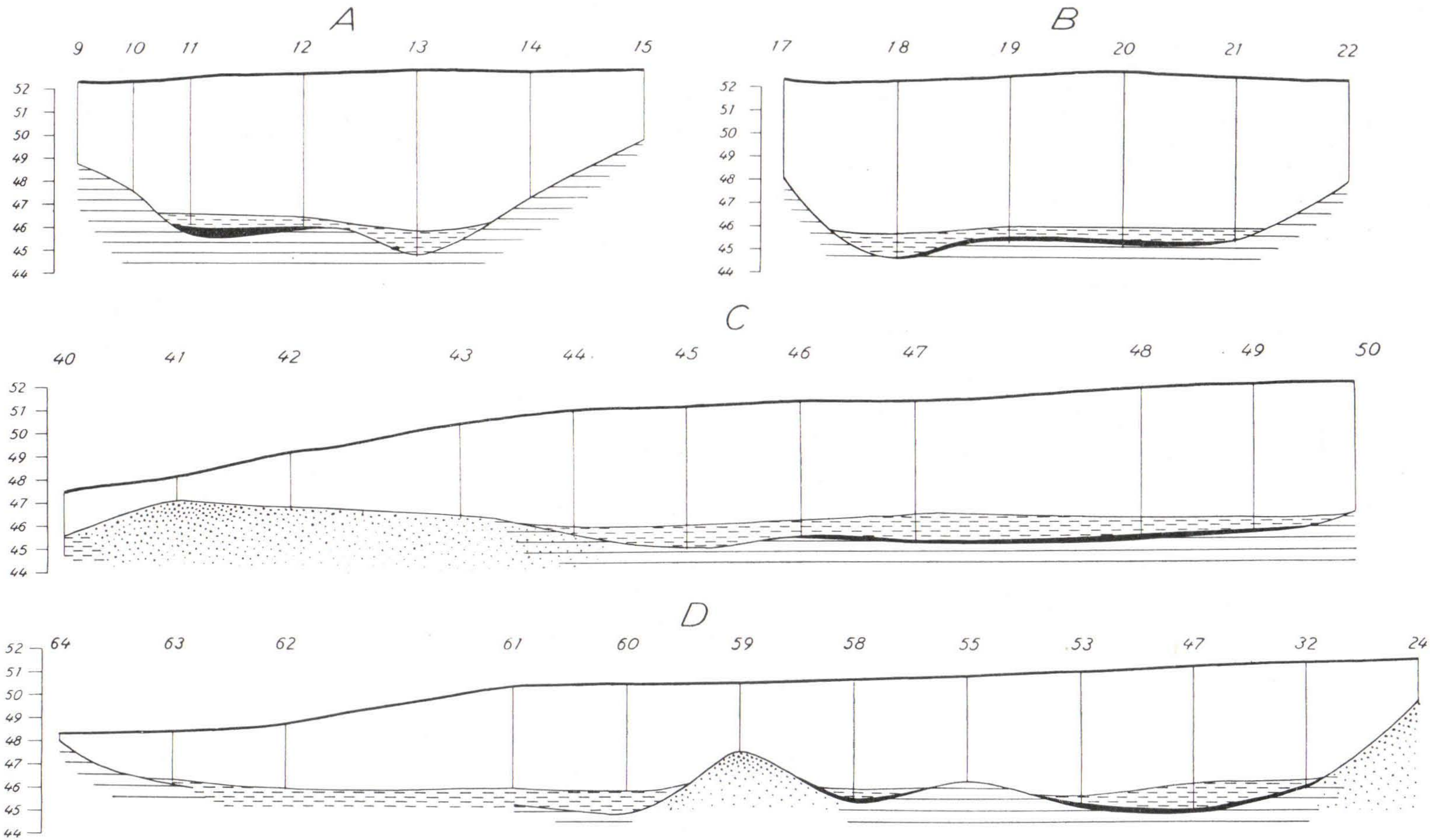

Abb. 3. Profilzeichnungen vom Hangassuo (Abb. 1). Weiss = regelmässig gewachsener Torf, gestrichelt = transgressives Sediment, schwarz = eingebetteter Torf, waagerecht schraffiert = warviger Ton, punktiert = Feinsand.

Tabelle I

Bohrstelle	Eingebettete Schicht, cm	Transgressive Schicht, cm	Bohrstelle	Eingebettete Schicht, cm	Transgressive Schicht, cm
7	15	55	26	10	12
11	20	50	32	5	20
12	8	37	33	15	35
13	—	100	46	5	65
18	2	105	47	2	116
19	15	40	48	2	20
20	9	58	49	2	10 Detr.
21	10	40	53	15	30
28	5	5 Detr.			
29	15	30	58	6	55

dünn ist, besteht sie aus dunklem, telmatischem *Carex-Equisetum*-Torf. Ähnlicher Torf findet sich auch in dem unteren Teil der dickeren Torfschichten, der erst in terrestrischen *Sphagnum-Carex-* und zuoberst in *Sphagnum-Carex-Musci*-Torf übergeht.

DIE ÜBRIGEN SCHICHTEN DES MOORES

Unter dem eingebetteten Torf liegt dichter warviger Ton, der sich nur sehr mühsam mit einem gewöhnlichen Moorbohrer durchdringen liess. Daher ist seine stärkste Mächtigkeit nicht bekannt. Dagegen besteht das transgressive Sediment aus weniger dichtem Ton, der in frischem Zustande etwas körnig ist. Die Dicke dieser Schicht schwankt an den verschiedenen Stellen zwischen 5 und 116 cm. Ihr unterer Teil ist Feindetritusgyttja, die in den Randteilen der Vorkommen ausschliesslich auf der Torfschicht 5—10 cm stark anzutreffen ist, während der Ton völlig fehlt. In seinem oberen Teil geht der transgressive Ton durch Vermittlung von Grobdetritusgyttja erst in Torf mit überwiegender *Carex* und dieser dann in *Sphagnum*-Torf über (Abb. 4). An Bohrstelle 13 liegt auf dichtem, warvigem Ton eine 1.16 m dicke Schicht von Sedimenten, die in ihren Eigenschaften dem transgressiven Ton ähnlich sind und auf Grund des Pollens und der Diatomeen denn auch als mit diesem identisch erkannt worden sind. Zwischen diesen Tonen fehlt jedoch die Torfschicht. Ähnliche Sedimentablagerungen hat man im Hangassuo auch an anderen Stellen gefunden. Die oberste Torfschicht des Moores ist bei den von der Transgression überdeckten Schichten 4—7 Meter mächtig.

Die Huminosität (H) der Torfablagerung ist durchweg verhältnismässig niedrig. Aus Abb. 4 sind ihre Schwankungen an Bohrstelle 11 zu ersehen. Aus ihr entnehmen wir, dass sie von 3.5 m an aufwärts, postlitorinazeitlichen *Sphagnum*-Torf umfassend, unter H 5, meistens H 2—3 ausmacht. In den älteren Schichten schwankt sie zwischen 4 und 7.

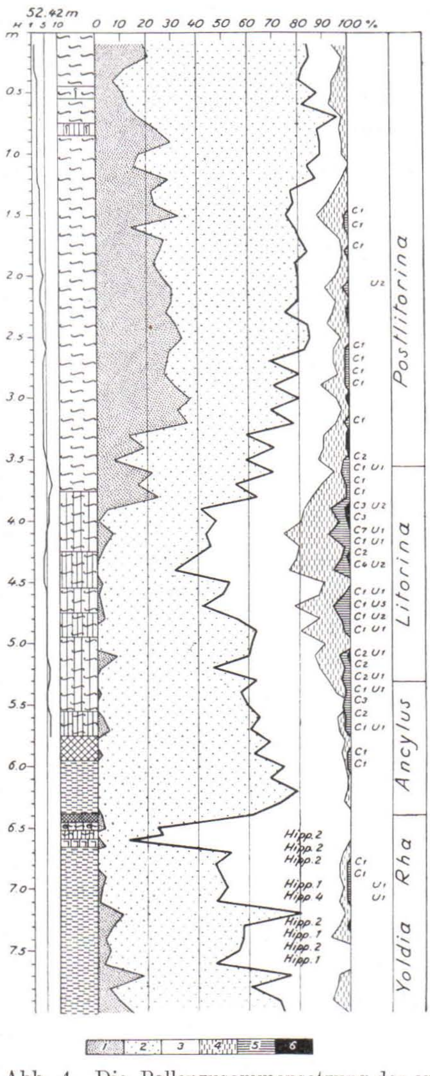

Abb. 4. Die Pollenzusammensetzung der an Bohrstelle 11 entnommenen Probenserie. Links Kurve, die die Humifizierung der Torf angibt. 1 = *Picea*, 2 = *Pinus*, 3 = *Betula*, 4 = *Alnus*, 5 = edle Laubbäume ausser *Tilia*, 6 = *Tilia*, C_1 = *Corylus* 1 %, U = *Ulmus*, Q = *Quercus*, Hipp. = *Hippophaë*. Erläuterungen zu den Bodenarten S. Abb. 5.

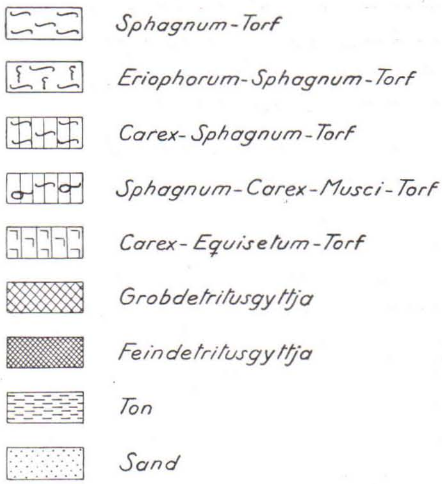

Abb. 5. Erklärungen der Zeichen für die Bodenarten.

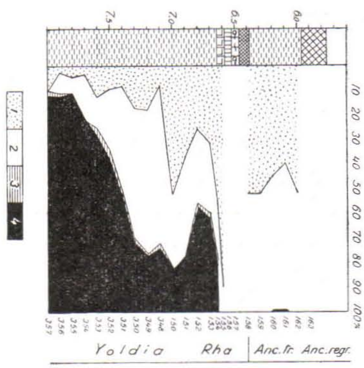

Abb. 6. Die Diatomeen aus den Wassersedimenten vom unteren Teil des auf Abb. 4 dargestellten Profils ach K. Mölder (1943) in ökologische Gruppen eingeteilt. 1 = Süsswasserdiatomeen, 2 = Süss- und Brackwasserdiat., 3 = Brackwasserdiat. und 4 = Salzwasserdiat.

DIE ZEITLICHE UNTERBRINGUNG DER TRANSGRESSION

Zur Datierung der Transgression ist an Bohrstelle 11 für die Pollen- und Diatomeenuntersuchung eine Probenserie entnommen worden, und zwar an einer Stelle, deren Höhe 52.4 m ü. M. beträgt. Sie reicht bis in eine Tiefe von 8 Metern. Es sei angeführt, dass weiter abwärts ein 2 m mächtiges, so wässeriges Sediment lag, dass ihm keine Proben entnommen werden konnten. Auch liessen sich wegen der Kürze des Bohrers tiefer als 10 Meter gelegene Schichten nicht erreichen.

Das Pollendiagramm (Abb. 4) ist übersichtlich, und seine Datierung wird im folgenden in erster Linie nach Hyyppä (1937) und Sauramo (1940) vor sich gehen. Sein unterster Teil bis 6.4 m vertritt nach der heutigen Auffassung das Yoldia, Hyyppäs (1944) Bottniameer. Hier sehen wir die für jene Zeit kennzeichnende Fichte verhältnismässig reichlich. Auch seien *Tilia*, *Ulmus* und *Corylus* angeführt. *Hippophaë* tritt in diesen Sedimenten recht allgemein auf. Am meisten Aufmerksamkeit verdient jedoch das in dem oberen Teil dieses Zeitfeldes gelegene *Betula*-Maximum, Sauramos (1945) Rha-Zeit, in die das von der Transgression überflutete Torflager in seiner Gesamtheit fällt.

Den folgenden Anhaltspunkt bei der Datierung des Pollendiagrammes finden wir bei 5.3 m, welche Stelle nach dem Pollen die Grenze zwischen Ancylus und Litorina bedeutet. Hier endet das für das Ancylus bezeichnende *Pinus*-Maximum, und an dieser Stelle beginnt die litorinazeitliche Erstarkung von *Alnus*. Zugleich werden dann auch die edlen Laubbäume allgemein.

Setzen wir ferner den Ausklang des Litorina bei 3.6 m an, so interessiert uns diesmal der obere Teil des Diagrammes nicht mehr, da wir sehen, dass die transgressive Tonschicht im Bereich des Zeitfeldes des Ancylus bleibt, in seinem unteren Teil, bei dem stärksten *Pinus*-Maximum, das im allgemeinen als Zeitpunkt der Ancylustransgression im Pollendiagramm gilt.

Doch ist es auf Grund des Obigen noch nicht ausgemacht, ob die in dem Moor Hangassuo angetroffene Transgression durch den Ancylussee verursacht worden ist oder ob es sich vielleicht um ein anderes zu gleicher Zeit hier eingetretenes örtliches Transgressionsgeschehen handelt.

Zur Beantwortung dieser Frage betrachten wir die Ergebnisse der über die Wassersedimente angestellten Diatomeenanalysen. Die Diatomeen sind nach Mölder (1943) eingeteilt in vier Gruppen, deren gegenseitige Verhältnisse in Form eines Diagrammes dargestellt werden (Abb. 6). Wir stellen zunächst fest, dass beiderseits 6.5 m die von der Transgression bedeckte Torfschicht liegt, wodurch das Diagramm an dieser Stelle eine Lücke aufweist. Der liegende Ton enthält in reichlichen Masse Salzwasserdiatomeen. In den untersten Proben sind es deren 88—89 %, aber aufwärts nimmt ihre Menge schnell ab, so dass sie bei 7 m nur noch 17 % ausmacht. Sie steigt noch einmal vorübergehend, aber in Probe 154 hören sie ganz auf, und die nächsthöhere Probe enthält ausschliesslich nur in seichtem und süssem Wasser gedeihende Diatomeen, hauptsächlich *Eunotia*-Arten, die erweisen, dass die Stelle damals dem Einflussbereich salzigen Wassers entrückt gewesen ist.

Unter den Salzwasserdiatomeen am häufigsten ist *Nitzschia navicularis*, deren z. B. in Probe 356 ganze 77 % vorkommen. Auch *Diploneis Smithii* ist verhältnismässig allgemein, aber sonstige Salzwasserarten sind spärlicher anzutreffen. Von ihnen seien *Nitzschia granulata*, *Amphora giganthea* und *Campylodiscus echineis* genannt. Auf Grund der Diatomeen ist der Ton ein Sediment des Yoldiameeres, in dessen Bereich es auch seinem Pollen nach gehört. Dass die am reichlichsten anzutreffenden Arten *Nitzschia navicularis* und *Diploneis Smithii* beide Diatomeen von Küstengewässern sind, weist darauf hin, dass diese Yoldiatone in flacherem Wasser entstanden sind.

Aus dem Diagramm geht des weiteren hervor, dass das die eingebettete Torfschicht überlagernde Tonsediment unverkennbar eine Diatomeenflora süssen Wassers enthält. Salzwasserformen finden sich nur in zwei Proben, je 0.5 %, in der einen nur eine *Nitzschia scalaris* und in der anderen desgleichen ein *Campylodiscus echeneis*. In dem unteren Abschnitt dieses Sediments (Probe 158) finden sich sogleich Süsswasserformen wie *Melosira arenaria* (10.5 %), *Epithemia Hyndmanni* (5 %), *Campylodiscus noricus v. hibernica* (1.5 %) und *Stephanodiscus astraea* (0.5 %), und die Flora setzt sich gleichermassen auch in den anderen Proben fort. Die angeführten Diatomeen erweisen, dass es sich wirklich um eine von der Ancylustransgression überflutete Torfschicht handelt. Nach den Diatomeen hat sich auch dieser Ton in flachem Wasser abgesetzt. Tiefstes Wasser vertritt das Sediment der Proben 160 und 161, in denen am meisten Planktonformen anzutreffen sind. Liegt doch im Pollendiagramm an derselben Stelle das stärkste ancyluszeitliche *Pinus*-Auftreten, das nach der allgemeinen Auffassung, wie oben bereits angeführt, einen Zeitpunkt bedeutet, wo die Ancylustransgression in ihrem Maximum stand.

DAS MAXIMUM DER ANCYLUSTRANSGRESSION

Bei dem Versuch, den höchsten Wasserstand der Ancylustransgression im Bereich des Hangassuo aufzuklären, werden wir noch die auf Abb. 3 wiedergegebenen Profilzeichnungen eingehender kennen lernen. Aus ihnen ist zu ersehen, dass in dem warvigen Ton des Hangassuo-Beckens Senken auftreten an den Stellen, wo er von dem eingebetteten Torf überlagert ist. Ausserdem erkennen wir, dass die Höhe der oberen Grenze des Ancylustons an einigen Stellen etwa 46.5 m, meistens aber etwa 46 m ü. M. beträgt. Der rha-zeitliche Torf beschränkt sich ausnahmslos auf eine Höhe von 45—46 Metern. In Senken, wie z. B. bei Bohrstelle 13 (Abb. 3, Profil A), wo das Ancylussediment unterhalb 45 Meter einsetzt, ist er nicht von Torf unterlagert, sondern grenzt unmittelbar an den älteren warvigen Ton.

Um die Schwellenhöhe des Hangassuo herauszustellen, sind in seinen nach Süden und Südosten ausgreifenden Buchten Bohrungen und Nivellierungen sowie in den ihnen entspringenden Bachbetten Barometermessungen ausgeführt worden. In dem Profil C (Abb. 3) sehen wir bei den Punkten 41, 42 und 43 eine Feinsanderhebung, die sich quer durch die Moorbucht erstreckt und deren breiter, ebener Scheitel etwa 47 m ü. M. liegt. In Profil D (Abb. 3), in der Längsrichtung einer nach Südosten auslandenden Bucht gezeichnet, liegt bei Punkt 59 ebenfalls eine Feinsanderhebung, deren Höhe ca. 47.5 m ü. M. beträgt. Sie erstreckt sich jedoch nicht quer durch die Bucht, aber östlich von ihr beläuft sich die Höhe des aus warvigem Ton bestehenden Moorgrundes auf etwa 48 m ü. M. Im Südteil dieser wie auch der vorhergehenden Bucht liegt der warvige Ton 45—46 m. ü. M. und verläuft die Sohle des Bachbettes eine Strecke weiter südlich in gleicher Höhe, um sich später zu senken. Aus diesen Zahlen können wir schliessen, dass die Höhe der Schwelle des Moorbeckens um die Wende Yoldia-Ancylus ca. 47 m ü. M. betragen hat. Die obengenannten in den Moorbuchten anzutreffenden Feinsanderhebungen können ehemalige Uferwälle sein.

Dass sich im Becken des Hangassuo in der Rha-Zeit in 45 m Höhe Torf abgelagert hat, erweist, dass der Wasserspiegel nach der gegen Ende des Yoldia eingetretenen Regression hier unter 45 m gelegen hat, da sonst im Becken des Hangassuo in der genannten Höhe kein Torf hätte entstehen können. Aber in welcher Höhe der Wasserspiegel Halt gemacht hat, bleibt auf Grund des Materials dieser Studie unaufgeklärt. Doch ist es recht gut möglich, dass eine Höhe von 45 m dem betreffenden Niveau nahekommt, da unterhalb desselben ausschliesslich Wassersedimente auftreten.

Zu Beginn des Ancylus stieg der Wasserspiegel über die Schwelle des Moores, und das Becken des Hangassuo geriet in den Bereich des Ancylussees. Da begann auch der gegen Ende des Yoldia, zur Zeit des Birkenmaximums entstandene Torf von Wassersedimenten überlagert zu werden. Die Frage aber, wie hoch das Wasser hier während der Ancylustransgression stieg, bedarf noch der Klärung. Zu diesem Zweck sind einige Probeserien in verschiedenen Höhen beiderseits des Kontaktes zwischen Torf und Ton entnommen worden an Stellen, wo wenigstens nicht auf Grund von Feldbeobachtungen eine transgressive Schicht hat angetroffen werden können.

Wir betrachten zunächst die Pollenflora, die durch die an Bohrstelle 3 (Abb. 1 und 7) entnommenen Proben vertreten ist. Die Höhe der oberen Grenze des Tons beträgt an der Stelle 47.6 m ü. M. oder ein Meter mehr, als die obere Grenze des transgressiven Tons beim eingebetteten Torf gelegen hat. Aus dem Pollendiagramm ist festzustellen, dass der Torfteil in dessen oberen Abschnitt in das ausgehende Litorina gehört, aber beim Ton die Datierung unsicher ist. Doch sei angeführt, dass die unterhalb 5 Meter entnommenen Proben wenig Pollen enthalten, die unterste nur einige Pollenkörner. Dagegen sind in ihnen *Lycopodium*- und *Polypodiaceae*-Sporen verhältnismässig allgemein angetroffen worden, desgleichen *Ca-*

ryophyllaceae- und *Chenopodiaceae*-Pollen. Diese alle weisen auf ein altes Sediment hin (vgl. Abb. 10).

Auf Grund der Diatomeen ist die Datierung des unteren Diagrammteils besser möglich. Die unterste Probe ist diatomeenleer, aber die drei obersten Proben enthalten unverkennbar eine Salzwasserflora, an der die Salzwasserdiatomeen mit 36—96 % beteiligt sind. Ihre Menge vermindert sich von unten nach oben. Von den Arten als am häufigsten seien genannt *Nitzschia*

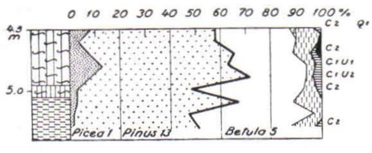

Abb. 7. Bohrstelle 3.

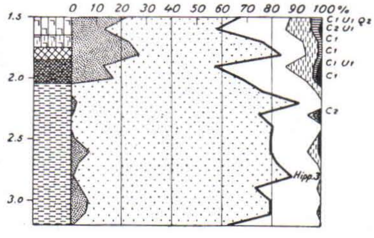

Abb. 8. Bohrstelle 1.

navicularis, Diploneis Smithii und *Campylodiscus echeneis* oder dieselben Arten, denen wir in den Yoldiasedimenten begegnet sind. Ein Litorinasediment kann hier nicht in Frage kommen, da die Grenze des Litorinameeres auf diese Ancylusisobasen einem etwa zwanzig Meter tiefer gelegenen Niveau entspricht (Hyyppä 1937). Es muss sich also um ein Yoldiasediment handeln, auf das auch die Pollenzusammensetzung hindeutet. Wir stellen also fest, dass an der Stelle die Ancylusablagerungen völlig fehlen. Sie sind also entweder abgetragen worden, oder sie haben sich aus dem einen oder anderen Grunde hier nicht absetzen können. Auch ist das Yoldiasediment dünn, denn die unterste Probe des Profils, die sehr spärlich Pollen enthält und in der überhaupt keine Diatomeen angetroffen worden sind, mag entweder in das beginnende Yoldia oder vielleicht zu voryoldiazeitlichen Sedimenten gehören. Dasselbe Resultat haben auch die Proben von Bohrstelle 10 und der etwas südlicher gelegenen Bohrstelle 2 (Abb. 1) gegeben. An ersterer Stelle liegt die obere Grenze des Tons 47.4 m und an letzterer 47.9 m ü. M.

An Bohrstelle 1, wo die nördlichste Probenserie entnommen worden ist, liegt die obere Grenze des Tons 49 m ü. M. Der obere Abschnitt des Pollendiagrammes (Abb. 8) gehört von der unteren Grenze des Feindetritus an aufwärtz zum Litorina und jüngeren Schichten, aber der Ton ist zweifellos älter als das Litorina.

Bei der chronologischen Einreihung des Tonsediments ist man wieder auf die Diatomeen angewiesen. Die Diatomeenbestimmungen sind für drei Proben, nämlich aus 2.2, 2.4 und 3.0 m Tiefe, ausgeführt worden. Alle Proben enthalten deutlich eine Süsswasserflora, denn nur in der mittleren Probe sind 2 % Salzwasserdiatomeen *(Campylodiscus echeneis)* angetroffen worden. In den obersten Proben ist *Pinnularia nobilis* sehr allgemein, was auf ganz seichtes Wasser hinweist. Aber in einer Tiefe von 3 Metern macht *Melosira arenaria* 24 % und *Epithemia Hyndmanni* 20 % der Diatomeen aus, und bei 2.2 m sind sie entsprechend mit 32 % und 18 % oder zur Hälfte an der gesamten Flora beteiligt. Auf Grund der Diatomeen ist der Ton also offenbar ein Ancylussediment. Im Bereich des Hangassuo hat sich die Ancylustransgression somit in eine Höhe von 49 Metern und auch noch höher erstreckt, da das Sediment Ton ist.

Hyyppä (1937) hat festgestellt, dass die Ancylustransgression auf dem Haukkasuo, etwa 2 km vom Hangassuo nach Norden, nicht 51 Meter erreicht hat, da dort in dieser Höhe terrestrischer Torf anzutreffen ist, der sich seit Beginn der Ancyluszeit abgesetzt hatte. Auf Grund dessen und des Obigen lässt sich denn auch schon mit hinreichender Genauigkeit schliessen, dass der Wasserspiegel des Maximums der Ancylustransgression im Bereich des Hangassuo einer Höhe von etwa 50 Metern entspricht. Zugleich ist festzustellen, dass zur Zeit der Ancylustransgression der Wasserspiegel hier um wenigstens 5 m (50—45) gestiegen ist.

Die Wasserbedeckung im Becken des Hangassuo war in der Ancyluszeit recht flach, ungefähr 4—5 m, worauf im übrigen auch der Diatomeenbestand hinweist. Über der Moorschwelle stand das Wasser damals höchstens 3 m. Das Becken des Hangassuo ist also eine verhältnismässig ruhige, durch schmale Sunde mit dem Ancylussee verbundene Bucht gewesen. Daher ist es auch zu verstehen, dass sich dort über ein Meter dicke Ancylusschichten, hauptsächlich Ton, abgesetzt haben. An der südfinnischen Küste sind nach Sauramo (1942) in allgemeinen keine Ancylussedimente anzutreffen, sondern sie sind aus diesem oder jenem Grunde weggeschwemmt worden, weswegen die Angaben über sie in Finnland recht dürftig sind. In Süd-Ostrobottnien habe ich jedoch in dem Becken des Moores Lammasneva in Teuva etwa vier Meter Ancyluston festgestellt.

Wie wir erinnern, gibt es in dem Becken des Hangassuo in 47—48 Meter Höhe Stellen, an denen die Ancylussedimente fehlen und in gleicher Höhe auch die älteren Tone deutlich abgetragen sind. Auf der anderen Seite erinnern wir und daran, dass die Schwellenhöhe des Moores 47 m beträgt. Demgemäss scheint es, dass unmittelbar über der Schwellenhöhe im Bereich des Moores zur Zeit der Ancylustransgression eine Sedimentabtragung vor sich gegangen ist. Dagegen ist etwas weiter aufwärts, nahe dem höchsten Wasserstand, wie an Bohrstelle 1 festgestellt, vor allem aber auf dem Moorgrunde unterhalb des Schwellenscheitels Sedimentation eingetreten. Es ist klar, dass der während der Ancylustransgression am Grund des Hangassuo-Beckens abgesetzte Ton, der den rha-zeitlichen Torf eine gebettet hat, in erster Linie im Bereich des Moores weggespülter yoldiazeitlicher oder älterer Ton ist. Hier hat sich also hauptsächlich allochthone Sedimentation des Tonmaterials vollzogen. Auf Grund der Untersuchungen ist zur Veranschaulichung des Obigen eine schematische Darstellung ausgearbeitet worden (Abb. 9). Ein derartiges stellenweises Fehlen gleichzeitiger Sedimente ist auf mehrere verschiedene Bedingungen zurückzuführen, von denen vor allem Wasserströmungen, Windverhältnisse und Beckenform genannt seien. Diese Zusammenhänge hat Lundqvist (1927) eingehend untersucht. Als sich zur Zeit der Ancylustransgression die Sedimente im Hangassuo-Becken verteilten, ist gewiss dessen Schwelle von entscheidender Bedeutung gewesen.

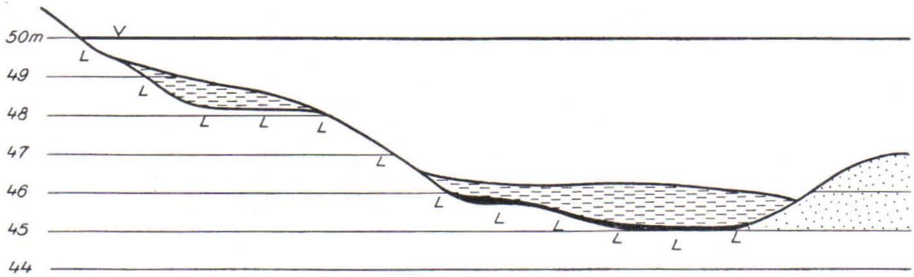

Abb. 9. Schematische Darstellung von Auftreten des Ancylustransgressionssediments (gestrichelt) im Hangassuo-Becken.

In diesem Zusammenhang wendet sich die Aufmerksamkeit der Mikroflora des aus der Zeit der Ancylustransgression herrührenden Sediments an Bohrstelle 11 zu (Abb. 4). Obgleich es also offenbar ist, dass das betreffende Sediment hauptsächlich durch sekundäre Sedimentation aus Yoldiaablagerungen sich gebildet hat, sind kaum überhaupt Anzeichen der Mikroflora jener Zeit festzustellen. Das Yoldiasediment enthält ziemlich viel Fichtenpollen und reichlich Salzwasserdiatomeen (Abb. 6). Nur in den untersten Proben des Ancylustons findet sich spärlich Fichte und in zweien seiner Proben sehr wenig Salzwasserdiatomeen. Dagegen ist an Bohrstelle 1 (Abb. 8), wo sich das Ancylussediment in ganz flachem Wasser abgesetzt hat, die Pollenzusammensetzung nicht kennzeichnend, vielmehr lässt sich hier der Einfluss der yoldiazeitlichen Pollenflora deutlich erkennen. Im Diatomeenbestand lässt sich jedoch keine Vermischung feststellen. Diese Beobachtungen weisen darauf hin, dass die Mikroflora des sekundär abgelagerten Sediments zum mindesten nicht erheblicher das Bild stört, das uns durch die in jeder Periode primär sedimentierte Pollen- und Diatomeenflora dann vermittelt wird, wenn die Ablagerung in tiefem Wasser vor sich geht; soweit sie aber in der seichten Uferzone stattfindet, vermengt sich die Pollenflora stark unter dem Einfluss des älteren Sediments, wogegen im Diatomeenbestand so gut wie keine Vermengung wahrzunehmen ist.

SONSTIGE FÄLLE VON ANCYLUSTRANSGRESSION

Unverkennbare Ancylustransgressionen sind in Finnland bisher nur sehr wenig angetroffen worden. Aus dem Bereich der Ostsee ist, soweit bekannt, die einzige der von Hyyppä (1937) dargestellte Fall aus dem Moor

Suursuo von Virojoki. Hier ist Feindetritusgyttja, zur Zeit des *Betula*-Maximums im ausgehenden Yoldia entstanden, von Tongyttja aus der Zeit der Ancylustransgression überlagert. Die Schwellenhöhe des Moores liegt dort 35 m und das Maximum der Ancylustransgression 36—37 m ü. M.

Aus dem Bereich des Ladoga und der Karelischen Landenge hat Hyyppä (1942) zwei Fälle veröffentlicht, den einen von Mantsinsaari und den anderen aus Pölläkkälä. An der ersteren Stelle liegt das Maximum der Ancylustransgression 17—20 und an letzterer 23—25 m ü. M.

In der Umgebung von Leningrad haben Markow und Poretzky (1935) mehrere Ancylustransgressions-Fälle angetroffen. Nach dem von Hyyppä (1937) dargestellten Relationsdiagramm liegt das von den Forschern in Lachta, in der Nähe der Küste des Finnischen Meerbusens angetroffene Maximum der Ancylustransgression etwa 5 m ü. M.

Aus Schweden sind mehrere Ancylustransgressions-Fälle verschiedener Stellen bekannt (Munthe 1940). Im südlichen Schweden liegen, wie in Dänemark, die Zeugen der Transgression unter dem gegenwärtigen Meeresspiegel. Nach der Auffassung Munthes (1940) geht die betreffende Transgression ungefähr auf der 95 m-Isobase des Ancylus in eine Regression über.

Der Fall Hangassuo in Sippola erweist, dass der Ancylussee in Finnland im Bereich der Ostsee wenigstens bis zu der 50 m-Isobase transgressiv gewesen ist. Vermutlich haben sich von der im Rede stehenden Transgression in verschiedenen Teilen Südfinnlands unter günstigen Verhältnissen Anzeichen erhalten, die der Zufall ans Tageslicht bringen wird. Des weiteren ist es möglich, dass derartige Anzeichen auch auf höheren Isobasen anzutreffen wären, wie in Schweden. Nach Sauramo (1934) ist der Ancylussee von Tampere bis Leningrad transgressiv gewesen.

DIE VORZEITLICHE VEGETATION DER GEGEND

Was sich oben im Zusammenhang mit der Datierung der Pollendiagramme über die frühere Vegetation der Gegend ergeben hat, sei des weiteren ergänzt durch das Material, das der Nichtbaumpollen und die Sporen sowie die von einigen Ausspülungsproben gegebenen makroskopischen Subfossilien bieten.

Eine Zusammenstellung des Nichtbaumpollens und der Sporen aus den an Bohrstelle 11 entnommenen Proben sehen wir in Abb. 10, wo ihre Menge ihre Anzahl je 100 Baumpollenkörner bedeutet. Zu beachten ist nur das Resultat, das die unter 5.0 m entnommenen Proben gegeben haben und das also die vorlitorinazeitlichen Sedimente betrifft. So ist in erster Linie der Raumersparnis halber und auch darum verfahren worden, weil die oberen Proben in sehr reichlichen Mengen *Sphagnum*-Sporen und spärlich Nichtbaumpollen enthalten, unter denen *Ericaceae* am häufigsten vorkommt. Aus der Zusammenstellung ist zu entnehmen, dass sich in den Yoldiasedimenten hauptsächlich Pollen und Sporen folgender Pflanzen gehäuft hat: *Caryophyllaceae*, *Chenopodiaceae*, *Hippophaë*, *Lycopodiaceae* und *Salix*. Im Birkenmaximum des ausgehenden Yoldia erreichen

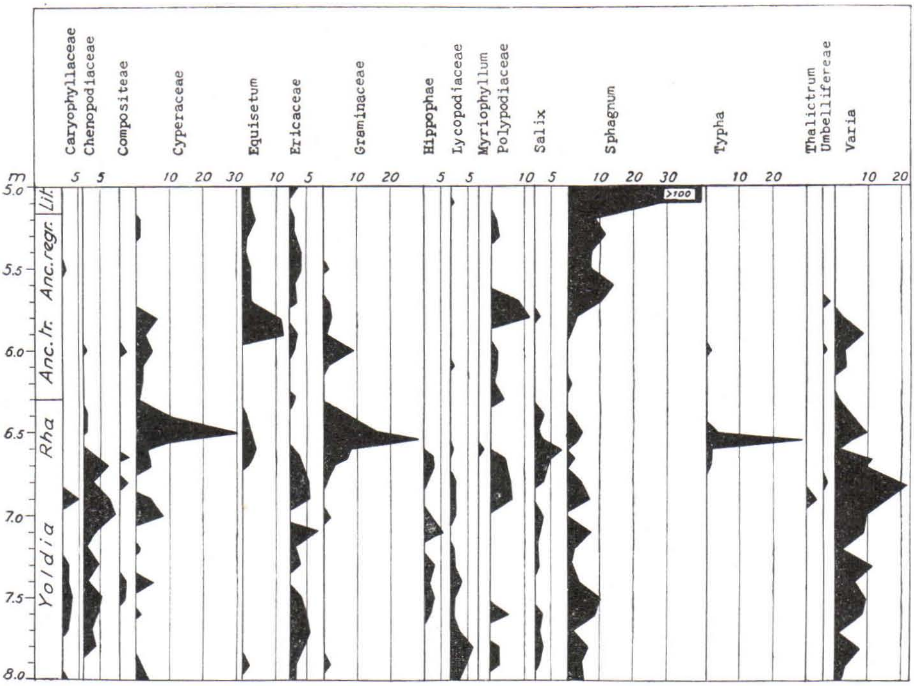

Abb. 10. Die Menge des Nichtbaumpollens und der Sporen je 100 Baumpollenkörner. Darstellung der Proben aus dem unteren Teil des an Bohrstelle 11 aufgenommenen Profils (vgl. Abb. 4).

die *Cyperaceae*, *Graminaceae* und *Typha* ihr steiles Maximum. An derselben Stelle ist auch ein *Ceratophyllum*-Stachel gefunden worden. Zu gleicher Zeit tritt auch *Equisetum* ziemlich reichlich auf, obgleich sein Maximum erst etwas später, im Beginn der Ancylusregression liegt. Der Schwerpunkt des *Ericaceae*-Pollens liegt ebenfalls in den Yoldiasedimenten, doch ist er auch, wie weiter oben angeführt, ununterbrochen bis zur Gegenwart anzutreffen. *Polypodiaceae*-Sporen kommen die ganze Zeit mit Unterbrechungen vor, aber das Feld der *Sphagnum*-Sporen ist bedeutend einheitlicher. Sie sind in den unteren Sedimenten verhältnismässig spärlich vertreten, fehlen völlig bei der Ancylustransgression, werden aber gleich danach allgemein und erreichen im beginnenden Litorina eine ungewöhnliche Frequenz, die sich bis in die Gegenwart fortsetzt.

Demselben Profil sind zwei Ausspülungsproben entnommen worden, die eine dem eingebetteten Rha-Torf, 6.45—6.65 m Tiefe, die andere dem Grobdetritus zwischen Ancylustransgression und -regression, 5.75—5.95

m Tiefe. Makrofossilien rha-zeitlichen Torfes sind in Finnland meines Wissens zuvor nicht dargestellt worden. Aus der untenstehenden Zusammenstellung sind die in diesen Proben angetroffenen Makrofossilien zu entnehmen.

Rha-Torf

Andromeda Samen		4	*Cicuta virosa* Teilfrucht		14
Betula	»	10	*Comarum palustre* Samen		14
Carex lasiocarpa Schlauch		1	*Juniperus communis*	»	1
C. limosa	»	15	*Menyanthes trifoliata*	»	42
C. rostrata	»	62	*Potamogeton natans* Steinkern		12
C. vesicaria	»	1	*P. sp.*	»	2

Ausserdem hat die Probe Stengelstücke von *Equisetum* und *Musci* (reichlich) sowie Halmknoten von *Phragmites* enthalten.

Ancylussediment

Betula Samen		2	*Cicuta virosa* Teilfrucht		11
Carex canescens Schlauch		1	*Comarum palustre* Samen		27
C. lasiocarpa	»	52	*Menyanthes trifoliata*	»	51
C. limosa	»	7	*Ranunculus sp.*	»	3
C. rostrata	»	48	*Scirpus lacuster* Früchtchen		2
C. vesicaria	»	47	*Sc. paluster*	»	3

Ferner sind *Betula*-Rinde und Holzstückchen, *Carex*-Wurzeln sowie *Equisetum*-Stengel angetroffen worden.

Auf Grund dessen, dass im rha-zeitlichen Torf in reichlicher Menge Früchte von Grossseggen, *Typha*-Pollen sowie *Cicuta virosa*-Samen aufgefunden worden sind, was für eine reiche Vegetation spricht, kann geschlossen werden, dass im Gebiet des Hangassuo in jener Zeit üppige Sumpfmoore geherrscht haben.

Viele Mikro- und Makrofossilien des Hangassuo sind Reste von Pflanzen oder Pflanzengruppen, auf Grund deren die vorzeitlichen Verhältnisse nicht erhellt werden können. Bei ihnen hat man sich zufrieden zu geben mit der Festgestellung, dass die Pflanzen einst in der Gegend gelebt haben. Doch sind auch Subfossilien vertreten, mittels deren sich auf Grund der Kenntnis ihrer rezenten Verbreitung Schlüsse über die Vorzeit der Gegend ziehen lassen. Solche Pflanzen sind in erster Linie *Ceratophyllum*, *Cicuta virosa*, *Hippophaë*, *Phragmites*, *Scirpus lacuster*, *Sc. paluster* sowie *Typha*. Angaben über ihre gegenwärtige Verbreitung werden kurz nach Lagerberg-Linkola-Väänänen (1939) dargestellt.

Ceratophyllum wächst vorwiegend in Südfinnland, wird aber auch in einigen binnenfinnischen Seen angetroffen. Sein nördlichster isolierter Standort ist bis aus der Gegend von Kemi bekannt. *Cicuta virosa*, die zu den artenreichsten Pflanzengesellschaften gehört, ist in Südfinnland gemein, aber in Südlappland ziemlich selten. Doch kennt man aus den Gegenden von Kemi und Enontekiö ihre niedrigwüchsige Form, die als durch ungünstige Verhältnisse verursacht gilt. *Hippophaë* tritt auf den Inseln und am Ufer des Bottnischen Meerbusens von Åland bis Kemi auf. In Norwegen liegt sein nördlichster Standort an der Küste des Atlantiks 67°56′ nördl. Br., die klimatisch annähernd der Breite von Kemi entspricht. *Phragmites* ist gemein bis Lappland, überschreitet aber nicht die Nordgrenze des Nadelwaldes. *Scirpus lacuster* und *Sc. paluster* sind gemein in Süd- und Mittelfinnland, aber selten in den nördlichen Teilen des Nadelwaldgebietes. Letzterer überschreitet die Grenze der Nadelwaldzone in Norwegen. *Typha* ist hier und da in Südfinnland und an der Küste des Bottnischen Meerbusens auch weiter nördlich anzutreffen. Ihre nördlichsten Standorte liegen in Turtola und Rovaniemi.

Die betreffenden Pflanzen sind gegenwärtig eher süd- *(Ceratophyllum)* und mittelfinnische Arten als weiter nördliche, und gegen diesen Hintergrund ist auch ihr vorzeitliches Auftreten zu betrachten. *Hippophaë*-Pollen ist verhältnismässig reichlich in den Yoldiasedimenten anzutreffen, und auf Grund dessen ist zu schliessen, dass damals in Südfinnland Verhältnisse geherrscht haben, die dem Klima des heutigen Nord-Ostrobottnien, vielleicht Mittelfinnlands entsprechen. Diese Auffassung wird des weiteren durch den in demselben Sediment angetroffenen *Corylus-*, *Tilia-* und *Ulmus*-Pollen gestützt. Die Birke hat in der Gegend ihr Maximum erreicht in jener Zeit, als die eingebettete Torfschicht sich abgelagert hat. Der in dem Torf angetroffene *Ceratophyllum*-Stachel, *Typha*-Pollen und *Cicuta virosa*-Samen weisen hin auf ein günstigeres Klima als das vorherige und war beinahe dasselbe, wie das gegenwärtige Klima von Süd- oder Mittelfinnland, obgleich nach dem Pollenbestand die *Betula*-Wälder schon vorherrschend sind. Das Überwiegen der Birke als Waldbaum kann hier zum Teil auf der zu jener Zeit eingetretenen Regression beruhen. Das Ergebnis über das Klima der Rha-Zeit ist dasselbe, zu dem O. V. Lumiala (1940) in Nord-Savo und E. Hyyppä (1941) in Nordfinnland gekommen ist, stützt aber nicht L. Aarios (1940) Auffassung, nach der in Finnland in der Rha-Zeit allgemein subarktische Birkenwälder oder Mischwälder mit vorherrschender Birke gewachsen wären.

Gleich zu Beginn der Ancyluszeit gewannen die *Pinus*-Wälder die Oberhand, was bedeuten mag, dass die Wälder erstarkten und das Klima kontinentaler wurde. Der Unterschied im jährlichen Temperaturmittel im Vergleich zur Rha-Zeit dürfte nicht gross gewesen sein, denn die Makrofossilien aus den um die Mitte jener Zeit entstandenen Sedimenten bezeugen keine beträchtlichere klimatische Wandlung. Von den Neuankömmlingen seien die beiden *Scirpus*-Arten und *Ranunculus* angeführt.

Das Auftreten von *Hippophaë* in den Yoldiasedimenten ist insofern interessant, als diese Pflanze heutzutage nicht mehr an der südfinnischen

Küste anzutreffen ist. Aus ihrer heutigen Verbreitung ist festzustellen, dass die solche Meeresküsten bewohnt, deren Landhebung am stärksten gewesen ist. Ausserdem weiss man, dass der Strauch nicht mit grosswüchsigeren Pflanzen, etwa mit den Bäumen, zu wetteifern vermag, da er viel Licht erfordert. In Anbetracht dieser Umstände ist zu schliessen, dass *Hippophaë* in der Yoldiazeit an der südfinnischen Küste in erster Linie darum gediehen ist, weil die Landhebung damals dort grösser als heute gewesen ist. In jener Zeit tauchte aus dem Schosse des Meeres fortgesetzt Neuland empor, auf das *Hippophaë* sich zurückziehen konnte, während andere Arten seine Standorte bezogen. Später haben die Verlangsamung der Landhebung sowie die wiederholten Transgressionen das Schwinden der Pflanze aus Südfinnland verursacht. Möglich ist, dass *Hippophaë* schon durch den Einfluss der Ancylustransgression aus dem Bereich des Hangassuo sich zurückgezogen hätte, denn in den damals abgesetzten Sedimenten ist Pollen von dieser Pflanze nicht anzutreffen.

Palmgren (1912) hat festgestellt, dass sich die rezente Verbreitung von *Hippophaë* konzentriert auf Meeresküsten, wo kein Wettbewerb mit anderen Pflanzen besteht. Zu demselben Ergebnis gelangt auch Valovirtas (1937) Untersuchung, die die Vegetation des Schärenhofes von Vaasa behandelt. Auf niedrigen (1.5—2.0) Inseln, die meistens baumlos sind, kommt *Hippophaë* gut fort, doch ist der Strauch dort auch noch 12 m ü. M. anzutreffen, soweit die Vegetation offen ist. Aario (1940), auf mitteleuropäische Forscher gestützt, führt an, das Auftreten von *Hippophaë* im Pollengehalt weise auf lichten Wald hin. Nach Hyyppäs (1932) Auffassung ist *Hippophaë* von der südfinnischen Küste verschwunden, weil das Wasser dort transgressiv geworden ist. Die Ergebnisse aller angeführten Forscher stützen für ihren Teil meine oben dargestellte Auffassung von dem vorzeitlichen Auftreten von *Hippophaës* in Südfinnland und von seinem Schwinden aus diesen Gegenden. Das Ergebnis stimmt auch überein mit der Kenntnis, die man zuvor in Schweden erlangt hat. Dort hat in letzter Zeit vor allen R. Sandegren dem spätquartären Auftreten von *Hippophaë* Aufmerksamkeit zugewandt und darüber eine auf umfassendes Material gegründete Untersuchung veröffentlicht, in der auch die Auffassungen früherer Forscher über diesen Sachverhalt dargestellt werden (Sandegren 1943). Nach seiner Ansicht hat sich *Hippophaë* als Vorkämpfer des Waldes in engem Anschluss an den zurückweichenden Eisrand, von Süden her vordringend, nach Schweden ausgebreitet. Den Transgressionen zufolge hat sich der Strauch schon gegen Ende des Anculys und während des Litorina aus Südschweden zurückgezogen, weil die Fluten seine Standorte an der Küste überspült haben und er nicht imstande gewesen ist, in den Wald einzudringen. Denselben Gedanken hat Halle (1915) schon früher dargestellt.

In den ältesten Sedimenten des Moores Hangassuo ist der Artenreichtum des Nichtbaumpollens und der Sporen am grössten. Desgleichen ist in diesen Ablagerungen die Anzahl derselben gegenüber dem Baumpollen am höchsten (Abb. 10). Das dürfte in erster Linie darauf hinweisen, dass auf dem das gegenwärtige Hangassuo-Becken umgebenden Boden, der Schärenhof gewesen ist, lichterer Wald gestanden hat, wofür auch das Auftreten von *Hippophaë* spricht. Diese Auffassung wird auch dadurch gestützt, dass die Proben bei 6.7—8.0 Meter so spärlich Baumpollen enthalten, dass für die Auszählung von 100 Pollenkörnern im allgemeinen mehrere, in einigen Fällen sogar 6 Präparate erforderlich gewesen sind, während bei den oberen Proben zur Erlangung der genannten Pollenmenge oft nicht einmal ein ganzes Präparat für die Zählung notwendig gewesen ist.

Oben sind wir zu dem Ergebnis gekommen, dass die eben genannten und nur wenig Baumpollen enthaltenden Sedimente, in denen *Hippophaë* verhältnismässig reichlich auftritt, entstanden sind unter Verhältnissen, die ungefähr dem Klima des gegenwärtigen Mittelfinnland entsprechen. Danach zu schliessen, braucht die absolute Spärlichkeit des Baumpollens nicht immer zu erweisen, dass für einen Waldwuchs keine Voraussetzungen bestanden hätten, wie Aario (1940) darstellt, vielmehr kann sie auch darauf beruhen, dass die Gegend in der betreffenden Zeit Schärenhof gewesen ist, vor kurzen aus dem Schosse des Meeres aufgetauchter Boden, wo der Wald noch nicht festen Fuss gefasst und auch nicht die Oberhand gewonnen hat über die Nichtbaumpflanzen, deren Pollen und Sporen daher in den Prozentverhältnissen in den Vordergrund treten. Ein entsprechendes Verhältnis zwischen den Baum- und Nichtbaumpflanzen herrscht auch heute auf den flacheren Inseln wenigstens in Gegenden, in denen die Landhebung noch stark ist, wie z. B. im Schärenhof von Vaasa, was aus der Untersuchung von Valovirta (1937) hervorgeht. Nach Hyyppä (1936) sind Nichtbaumpollen und Sporen nur von örtlicher Bedeutung, denn sie sind in solchen, auch alten, Tiefwassersedimenten spärlich anzutreffen, die weit von der Küste entfernt entstanden sind, dagegen treten sie in den in Küstennähe und flachem Wasser entstandenen Sedimenten reichlich auf. Das an Hand Hangassuo gewonnene Ergebnis stützt diese Auffassung von der Beweiskraft und dem Auftreten der genannten Subfossilien.

Des weiteren sei im Auftreten der *Sphagnum*-Sporen Zweierlei beachtet, nämlich ihre schnelle Zunahme gleich zu Beginn des Litorina und ihr Fehlen in den Ancylustransgressionssedimenten. Das plötzliche Ausbleiben der Sporen dürfte darauf beruhen, dass die Transgression den *Sphagnum*-Wuchs an der Stelle erstickt hat. Die gleiche Auffassung hat Aario (1933) früher über das plötzliche Schwinden der *Sphagna* geäussert.

Zum Schluss sei angeführt, dass man in Schweden vor kurzem (Erdtman 1946) zu dem Ergebnisse gekommen ist, dass dort der in den alten Sedimenten angetroffene und zuvor als *Salix*-angesehene Pollen *Artemisia* gewesen ist. Im Zusammenhang mit dieser Untersuchung ist auch diese Frage geklärt worden. Doch haben die Kontrolluntersuchungen das Resultat gegeben, dass in dieser Untersuchung die genannten Pollen nicht miteinander verwechselt worden sind. Dagegen ist es nicht ausgeschlossen, dass sich unter dem unbekannten Pollen, der recht reichlich ist, einige wenige *Artemisia*-Pollenkörner finden können. Dem Auftreten von *Artemisia* ist in Finnland fortgesetzt Aufmerksamkeit zuzuwenden, da es weiteren Aufschluss über die vorzeitlichen klimatischen Verhältnisse geben könnte.

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2.

ON THE ORIGIN OF THE ALAVIESKA PYRITE BOULDER

BY

VEIKKO OKKO

The Alavieska pyrite boulder was found by the farmer Visuri when digging a ditch in his field in Somero village (Alavieska parish). The boulder lay at the depth of ½—1 meters.

The boulder, which has been in the possession of the Geological Survey since the year 1935, is round in form and about 30 cm. in diameter. Its surface is corroded, so that the crystals of pyrite are sunk. The chief components are coarse-grained pyrite and feldspar. The additional elements are quartz and here and there molybdene glance as small grains. On the ground of its texture the Alavieska boulder belongs to the pegmatites.

In the year 1936 attempts were made to trace the source of the boulder. In the vicinity of the place of discovery new pyrite boulders were not found nor pyrite occurrences met with. The search was also carried on in the direction from which the glacier had moved (Sauramo 1924). This direction was ascertained 300° (N 60° W) on the ground of local striae and boulder observations, but the results remained insignificant. Dr. Sampo Kilpi, the leader of the search, could only state that the boulder might be separate and of distant derivation or come from a small occurrence with but few boulders. Further, he thought it possible that the pyrite boulder might have been brought by a block of ice drifted to Somero during the Late-Glacial time, when this region was covered by sea. The negative result led to the cessation of investigations and the origin of the boulder remained unexplained (Laitakari 1937).

In August 1946 the place of discovery was visited again. The surface there resembled moraine with few stones. The deposit was, however, not moraine, but assorted fine sand containing some boulders. This layer was over one meter thick, so that the boulder had been situated in this layer.

In the laboratory of the Geological Survey it was ascertained that the deposit contains about 4 % sand, 75.3 % fine sand, 16 % silt, and 3.5 % clay. Further there is an abundance of recent pollen, as was to be expected in a relatively porous layer so near the surface. The flora contains 66 % pine, 4 % spruce, 25 % birch, and 5 % alder pollen. In addition to the pollen, there was plenty of diatom, the greatest part of which is composed of salt water species. The commonest are *Hyalodiscus scoticus* (22 %), *Rhabdonema arcuatum* (20 %), *Grammatophora oceanica* (19 %), *Epithemia turgida* (18 %) and *Grammatophora marina* (10 %). As a whole, the diatom flora represents the species characteristic of the Post-Glacial Littorina Sea sediments (e. g. Hyyppä 1937). Among these species the share of *Campylodiscus clypeus* and *Nitzschia scalaris* is only 2 % in total. As a rarity it may be mentioned that in the flora was one specimen of *Melosira sulcata*, which has hitherto been found only once in the Littorina Sea sediments in Finland (Hyyppä 1936). The scarcity of littoral diatoms indicates that the sediment has been deposited in fairly deep water, so that the Alavieska pyrite boulder lay in the bottom sediment of the Littorina Sea. According to the earlier investigations at the beginning of the Littorina-stage the level of this sea reached in this region the height of about 95 m. (Backman 1937).

At that time the place of discovery, whose altitude is about 70 meters above sea level, was covered with the 25 m. deep Littorina Sea. Its shore-line went winding 30 km. east of Somero (fig. 1) and was formed in the valleys of the rivers Pyhäjoki, Kalajoki, and Lestijoki long bays, at the upper ends of which these rivers discharged themselves. The Kalajoki was then bigger than now, because it was the outlet of the great lake in Central Finland (Tolvanen 1923). Also in the other rivers there was then more water than now, as the Littorina Sea stage occurred during the humid climate period.

From its uppermost Littorina-position the shore-line gradually descended under the influence of the land upheaval to the level of the present shore-line. The Visuri area was laid bare while the shore receded from the level of 70 m. After that no marine sediments could be formed at the place. In these circumstances the fine sand must have been deposited during the incipient stages of the Littorina Sea, when the sea level was between 95—70 m. and nearer to the former altitude, as can be seen from the quality of the sediment and from the diatom flora.

The fact that the boulder occurs in such a sediment can hardly be explained otherwise than by supposing the boulder to have been transported from the Littorina coast by drift-ice to the open sea and to have dropped off during the thawing of the floating ice. The point, from which the boulder set off on its last voyage, has thus been situated somewhere between 95—70 meters. This trip was apparently not very long, for the then prevailing optimum of the climate hastened the melting of the drift-ice. It therefore seems probable that the departure of the boulder took place from the Littorina coast of Finland. This is supported by the fact that the current of the rivers was directed outward from the coast, hampering the movement in the opposite direction. On the other hand, it is known that in the open sea the water is driven northward under the influence of the force of Coriolis on the eastern coast of the Gulf of Bothnia (Hela 1946), so that the boulder most likely has had its point of departure south-east or south of Somero.

Attention is next drawn to the valley of the river Kalajoki, whence a strong current was directed toward the place of discovery. Even at present

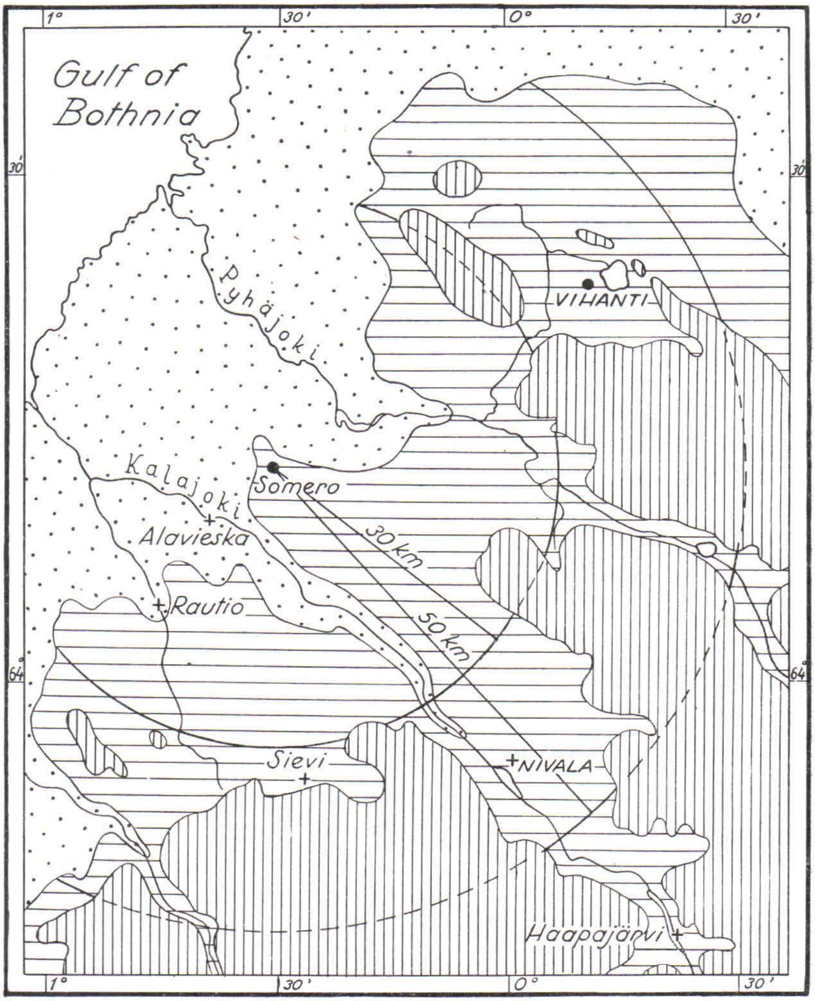

Fig. 1. Place of discovery of the Alavieska boulder and its neighbourhood. At the beginning of the Littorina-stage the area indicated with vertical striation was already dry land. The horizontal striation shows that altitude (65—95 m. above sea level), from which the boulder could have been transported by the ice of the Littorina Sea. Over the zone with black points the shore-line retreated only after the Somero district was laid bare.

the river Kalajoki rapidly breaks up the ice in spring, when it is in strong flood. The ice of the river then carries with it stones etc. as far as the open sea, where these fall down when the ice floats are melting. This was probably the case also during the Littorina period, when the ice of the river could bring separate stones all the way from the lake district of Central Finland. The chief part of the drift may have stuck to the ice from the stony bottom of the Kalajoki in the parishes of Nivala and Haapajärvi or from the moraine ground bordering the valley of the river in these districts. Also the region south of the Kalajoki, in the parishes of Sievi and Rautio, belongs to the altitude from which the boulder may come. If the ice of the sea has taken it from there, then, owing to the ice pressure in winter, the boulder must have stuck so fast to the ice that, after the ice had become detached from the shore, the boulder could be carried out to the open sea. This possibility is naturally worthy of consideration, though not so probable as the above-mentioned facts referring to the Kalajoki valley. On the other hand, the pyrite occurrences of Vihanti cannot be thought of as a source of the Alavieska boulder. They are situated north-east of Somero, besides which the ice carrying the boulder must have drifted first to the open sea or else have forced its way through a fairly narrow sound toward the south-west.

In such circumstances it is most likely that south-east or south of Somero, — preferably in the Kalajoki valley — at the altitude of 95—70 m. more pyrite boulders of the same type or actually the source of the Alavieska boulder can be found.

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3.

ZWEI SUBFOSSILE TIERKNOCHENFUNDE AUS POHJANMAA

VON

MARTTI SALMI

In dem Aufsatz wird die geologische Altersbestimmung zweier Tierknochenfunde vorgenommen. Der eine von ihnen, der eine Menge Hasenknochen umfasst, ist in Mittel-Pohjanmaa in Kirchspiel Kannus und der andere, der als Überreste der Ringelrobbe erkannt worden ist, in Süd-Pohjanmaa im Kirchspiel Vähäkyrö gemacht worden. Die in den Funden enthaltenen Knochen werden im Zoologischen Museum der Universität Helsinki verwahrt.

Die mit dem Aufsatz verbundenen Pollenanalysen hat Mag. Ester Uussaari und die Diatomeenbestimmungen Dr. phil. Karl Mölder ausgeführt, nach dem auch die ökologische Gruppierung der Diatomeen vorgenommen worden ist (Mölder 1943). Die Übertragung ins Deutsche hat Dr. phil. Marta Römer besorgt. Allen Genannten wie auch denen, die die Funde gemacht haben, möchte ich den wohlverdienten Dank zum Ausdruck bringen.

DER HASENFUND VON KANNUS

Im März 1946 fand der Bauer Onni Keski-Petäjä im Kirchspiel Kannus im Dorfe Välikannus (Abb. 1) 2.2 m unter Gelände Knochen, die er dem Nationalmuseum zusandte. Von dort wurden sie weiter in das Zoologische Museum der Universität Helsinki geschickt, wo Dozent Olavi Kalela sie als Überreste eines Hasen, von *Lepus timidus* L., festgestellt hat. Der Fund, von dem die meisten grossen Knochen defekt sind, umfasst folgende Knochen:

Die mit Zähnen versehenen Vorderteile beider Unterkieferhälften.

Hinterer und mittlerer Teil (mit 2 Backenzähnen) des rechten Oberkiefers sowie der sich anschliessende vordere Teil der Schädelbasis und die Ansätze des Jochbogens.

Beide Oberarmknochen, beide Ellen und Speichen.

Beide Hüftbeine, beide Oberschenkelknochen, beide Schien- und Wadenbeine.

Beide Fersenbeine sowie einige Mittelfuss- und Zehenknochen.

Fragmente von Wirbeln und Rippen.

Mit der geologischen Altersbestimmung des Fundes wurde Verfasser dieses betraut. In diesem Sinne betrachtete ich die Hasenüberreste. Sie waren noch umgeben von blaugrauen Ton, so dass sich auch eine Pollen- und eine Diatomeenanalyse ausführen liess. Zugleich stellte ich fest, dass der die Knochen umgebende Ton Vivianit enthielt. Besonders deutlich fand er sich an den Enden der gebrochenen Schienbeine, was auf seinen organischen Ursprung hinweist.

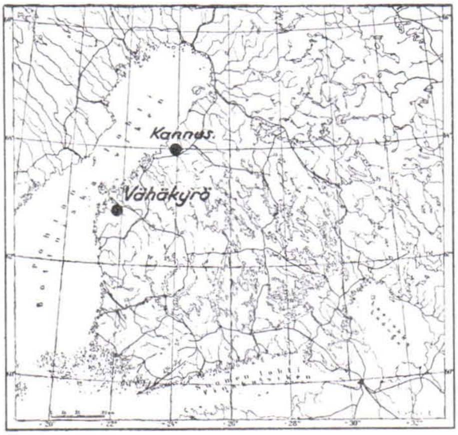

Abb. 1. Die Fundstätten des Hasen und des Seehundes.

Im Sommer 1946 fand ich Gelegenheit, Kannus aufzusuchen, als ich unter der Führung des Finders die Fundstätte des Hasen kennenlernte. Dabei wurde 2—3 m von der Knochenfundstätte zwischen dieser und einem einige Meter davon entfernt gelegenen flachen Moränenrücken eine Bodenprobenserie entnommen. Ausserdem wurde ein Nivellement angestellt, nach dem sich als Höhe der Stätte 31.47 m ü. M. ergab.

Auf Abb. 2 links ist die Lagerfolge der Bodenarten an der Fundstätte zu sehen. Zuunterst liegt auf Moräne Ton, der in 1.4 m Tiefe in Schluff übergeht, während dieser bei 0.5 m durch Feinsand abgelöst wird. Auf derselben Abbildung rechts findet sich ein Pollendiagram, aus dem die waldgeschichtliche Entwicklung der Gegend in jener Zeit, als sich die angeführte Sedimentfolge abgesetzt hat, hervorgeht.

Nach den Grundsätzen, gemäss denen in Finnland gegenwärtig Pollendiagramme datiert werden (Sauramo 1940), schloss das Litorina in 0.9 m Tiefe. Der für das Litorina bezeichnende Pollengehalt edler Laubbäume ist spärlich, aber ausgeprägt. Der untere Teil des Diagrammes vertritt zweifellos die Flora der Yoldiazeit, aber die Unterbringung von Anfang und Ende des Ancylus erfordert eine Musterung der in den Sedimenten auftretenden Diatomeen.

Die unterste Probe enthält zu 8 % Salzwasserdiatomeen, wie *Grammatophora oceanica*, *Rhabdonema arcuatum*, *Thalassionema nitzschioides* sowie *Coscinodiscus sp.* und *Stephanopyxis sp.* Die Brackwasserdiatomeen *Coscinodiscus lacustris v. septentrionalis* und *Achnanthes hauckiana* machen 16.5 % der in der Probe enthaltenen Diatomeen aus, so dass auf die Süsswasserdiatomeen 75.5 % entfallen. Unter letzteren sind die *Melosira*-Arten am häufigsten. Die Diatomeenflora setzt sich gleichartig, wenn auch spärlich, eine gewisse Strecke aufwärts fort und stützt somit die auf Grund des Pollens gewonnene Auffassung, dass die Sedimente im unteren Teil des Diagrammes zum Stadium des Yoldiameeres gehören. Der Diatomeenbestand verändert sich bei 2.0 m, wo Grossseeformen erst spärlich aufzutreten beginnen; später aber nimmt ihre Menge zu. Als Beispiel sei angeführt, dass bei 1.7 m die Süsswasserdiatomeen 84 % betragen. Unter ihnen machen die Grossseediatomeen *Epithemia Hyndmanni*, *Eunotia Clevei*, *Melosira arenaria* und *Stephanodiscus astraea* einen beträchtlichen Teil aus, sich auf 39 % vom gesamten Diatomeenbestand belaufend. Die Probe enthält 2 % Salzwasserdiatomeen, 5 % Brackwasserdiatomeen sowie 9 % Süss- und Brackwasserformen. Es handelt sich also deutlich um die Diatomeenformen des Ancylussees, die sich bis in 1.5 m Tiefe fortsetzt. Da wandelt sich abermals ihre Zusammensetzung, indem der Anteil der Süsswasserformen entscheidend abnimmt und erst besonders Brackwasser-, später auch Salzwasserdiatomeen zunehmen. Die genannte Stelle kann als Grenze zwischen Ancylus und Litorina gelten. Es sei angeführt, dass in 1.4 m Tiefe 7 % Süsswasser-, 26 % Süss- und Brackwasser, 60 % Brackwasser- sowie 7 % Salzwasserdiatomeen auftreten.

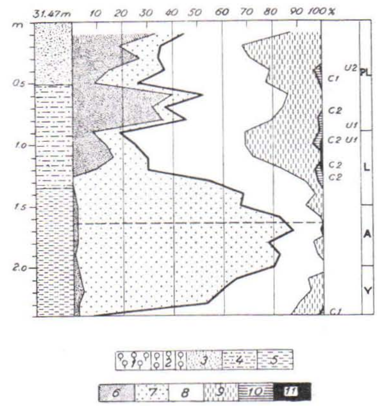

Abb. 2. Profil und Pollendiagramm für die Fundstelle des Hasen von Kannus. Die gestrichelte Linie bezeichnet die Fundtiefe des Hasen. Zeichenerklärungen: 1 = Laubholz-Torf, 2 = Laubholz-*Carex*-Torf, 3 = Sand, 4 = Schluff, 5 = Ton, 6 = *Picea*, 7 = *Pinus*, 8 = *Betula*, 9 = *Alnus*, 10 = edle Laubbäume (ohne *Tilia*), Ca 1 = *Carpinus* 1 %, C = *Corylus*, Q = *Quercus*, U = *Ulmus*, 11 = *Tilia*, Y = Yoldia, A = Ancylus, L = Litorina, Pl = Postlitorina.

Auf grund des Diatomeenbestandes lässt sich das Ancylus im Diagramm zwischen 1.5—2.0 m unterbringen. An derselben Stelle befindet sich in der Pollenflora *Pinus* in seinem Maximum und beginnt das ununterbrochene Auftreten der Erle, beides für das Ancylus typische Züge im Pollendiagramm.

Über die um die Hasenknochen entnommen Tonproben sind vier Pollenanalysen ausgeführt worden. Ihre Ergebnisse sind aus der folgenden Zusammenstellung zu ersehen:

	I	II	III	IV
Alnus	2	—	—	—
Betula	14	10	12	16
Picea	—	1	1	2
Pinus	84	89	87	81
Tilia	—	—	—	1

Die Analysenergebnisse sind einander sehr ähnlich. Die Aufmerksamkeit wendet sich bei ihnen in erster Linie der zwischen 81 und 89 % schwankenden Abundanz von *Pinus* zu. Einzig schon auf Grund dessen gehört die von den Proben vertretene Flora in das Ancylus, und *Alnus* wie auch *Tilia* in den Proben I und IV verlegt diese in dem eben genannten Diagramm am ehesten in 1.6—1.7 m Tiefe, also gleich nach dem Ende des *Pinus*-Maximum der Ancylustransgression.

Die Diatomeenflora derselben Proben ist ebenfalls unverkennbar ancyluszeitlich. Doch finden sich in den Proben II und IV spärlich Salzwasserdiatomeen, von denen nur *Grammatophora oceanica* angeführt sei.

Wie oben angeführt, sind die Knochen der Mitteilung gemäss in 2.2 m Tiefe in Ton gefunden worden, und in dem Profil auf Abb. 2 liegt die Fundstelle bei 1.6—1.7 m. Der Tiefenunterschied ist jedoch zu verstehen, denn die Probenfolge ist neben der Fundstelle und ganz nahe einem Moränenrücken, in welcher Richtung der Boden sanft ansteigt und die Schichten sich verjüngen, entnommen worden. Infolgedessen verändert sich auch das Verhältnis der gleichaltrigen Absätze zur Bodenoberfläche.

Auf Grund der obigen Betrachtung stellt es sich als Endergebnis heraus, dass die in Kannus aufgefundenen Überreste eines Hasen bald nach der Ancylustransgression in Sedimente des Ancylussees eingebettet worden sind.

Es dürfte im allgemeinen selten sein, dass Hasenüberreste ins Wasser geraten und von Wassersedimenten überlagert werden, aber als ein um so grösserer Zufall hat das zu gelten, dass die vor 7 500—8 000 Jahren in ein grosses und tiefes Gewässer gelangten Hasenüberreste aufgefunden und einer Untersuchung unterzogen worden sind. Der Hasenfund von Kannus ist, soviel man weiss, unter den in Finnland angetroffenen einzig in seiner Art. Das Interessante des Fundes vird durch sein grosses Alter gesteigert, und er ist daher auch für die faunengeschichtliche Forschung in Finnland von Bedeutung.

DER SEEHUNDFUND VON VÄHÄKYRÖ

Als ich im Sommer 1946 auf dem Gelände der Ziegeleien von Vedenoja Tonuntersuchungen anstellte, erzählten die mit Tonausheben beschäftigten Arbeiter, dass sie am Vortage am Grunde einer Tongrube Knochen gesehen hatten. Als ich, von Arbeitern geführt, an die Fundstelle, die in Rekilänkylä im Kirchspiel Vähäkyrö in der Nähe des Moränenhügels Hietamäki etwa 1.5 km von der Eisenbahnhaltestelle Vedenoja nach Nordosten gelegen ist (Abb. 1), anlangten, schaufelte man gerade von der daneben gelegenen Tonentnahmestelle den oberflächlichen Boden in die Grube. Die Knochen waren dann schon teilweise bedeckt. Ich legte sie wieder frei und nahm sie so vollzählig in Verwahr, wie es eben noch möglich war.

Doch ist es klar, dass ein Teil der Knochen schon verlorengegangen war, wie auch meine Führer meinten.

Immerhin lag ein 70—80 cm langer Teil des Skelettes an seiner ursprünglichen Stelle. Auf Grund der von mir angetroffenen Knochen schloss ich sogleich an der Fundstätte, dass es sich um eine Seehundeart handelte. Später hat Dozent Olavi Kalela auch diese Knochen bestimmt und festgestellt, dass es die Überreste einer Ringelrobbe, *Phoca hispida* Schäffer, sind.

Der Fund umfasst folgende Knochen:

Rechter Unterkiefer mit 1 Backen und 1 Eckzahn.

Vorderer Teil des rechten Oberkiefers.

Beide Schulterblätter, linker Oberarmknochen, beide Ellen sowie linke Speiche.

Beide Hüftbeine (defekt), linker Oberschenkelknochen und linkes Wadenbein. 15 teilweise sehr defekte Wirbel (davon 2 Hals-, 5 Brust- und 3 Lendenwirbel), einige Rippen und Mittelfussknochen.

An der Fundstelle, etwa 15 m ü. d. M. gelegen, wurde, um den Zeitpunkt der Einbettung des Seehundes zu bestimmen, eine Bodenprobenreihe entnommen. Die Lagerfolge sehen wir auf Abb. 3 rechts. Zuoberst liegt 0.3 m Laubholz-*Carex*-Torf und darunter blosser Laubholz-Torf, der durch Vermittlung einer dünnen Feinsandschicht in Ton übergeht. Dieser setzt sich aus 0.5 m Tiefe bis auf den Moränengrund fort und ist bei 0.7 m jedoch unverkennbar feinsanddurchsetzt. Der Ton ist bei 0.5—1.2 m grau, geht aber weiter unten in dunklen Sulfidton über. Die Seehundsknochen lagen in der Tonablagerung 1.2 m unter Gelände.

Die Ergebnisse der über die Bodenproben angestellten Pollenanalysen sind auf Abb. 3 zu sehen. Auf Grund des vorhergehenden Diagrammes (Abb. 2) und meiner vorigen Untersuchungen in Vähäkyrö (Salmi 1944) ist die Einteilung dieses Diagrammes in die Zeitfelder der Ostsee-Entwicklung verhältnismässig leicht durchzuführen. Der Ausgang des Litorina liegt nach dem Pollen der Fichte und der edlen Laubbäume bei 0.7 m. Wie oben erwähnt, ist der Ton an dieser Stelle feinsandhaltig, was wohl die Zeit der letzten Litorinatransgression an der Stelle bedeutet. Der Beginn des Litorina wiederum ist auf Grund des Allgemeinwerdens der Erle und der edlen Laubbäume in 1.9 m Tiefe zu verlegen. Demgemäss liegt also im unteren Teil des Profils eine dünne Schicht ancyluszeitlichen Sediments. Über den Pollen der litorinazeitlichen edlen Laubbäume sei bemerkt, dass *Ulmus* fast in allen Proben vorkommt und erreicht ihr Maximum um die Mitte jener Zeit, als auch *Quercus* auftritt. Dagegen ist *Tilia* in der ersten Hälfte des Zeitfeldes am häufigsten, und *Corylus* verdichtet sich an seinem Ende.

Der Diatomeengehalt stützt die Verlegung der Grenze zwischen Ancylus und Litorina an die eben genannte Stelle. Die drei untersten Proben lassen deutlich einen Gross- und Süssgewässer-Diatomeengehalt erkennen, von dessen einzelnen Arten *Epithemia Hyndmanni*, *Melosira arenaria* sowie die reichlich auftretende Art *Stephanodiscus astraea* genannt seien. Dagegen findet sich in 1.8 m Tiefe eine bereits ausgeprägte Salzwasser-Diatomeenflora, zu deren Nachweis das ziemlich reichliche Auftreten folgender Arten genügt: *Campylodiscus echeneis*, *Diploneis interrupta*, *D. Smithii*, *Navicula peregrina*, *Epithemia turgida v. Westermanni*, *Mastogloia Smithii*, *Nitzschia tryblionella v. debilis* und *Thalassiosira baltica*. Doch lässt sich der Ausgang des Litorina auf Grund der Diatomeen nicht festlegen, da sich dieselben Salzwasserarten noch in den Postlitorinasedimenten fortsetzen und teilweise auch heute noch im Ostseebereich leben.

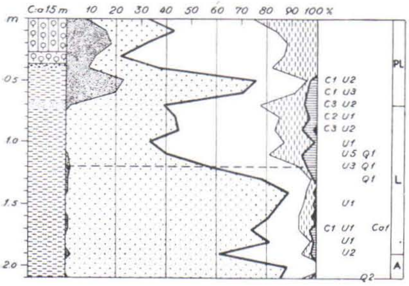

Abb. 3. Profil und Pollendiagramm für die Fundstelle des Seehundes von Vähäkyrö. Die gestrichelte Linie bezeichnet die Fundtiefe des Seehundes. Die Zeichenerklärungen S. Abb. 2.

Aus dem Obigen ist bereits hervorgegangen, dass der Seehund, dessen Fundstelle bei 1.2 m liegt, in Sedimente des Litorinameeres eingebettet worden ist. Um jenen Zeitpunkt genauer festlegen zu können, betrachten wir ferner ausführlicher den Pollengehalt der Litorinazeit. Zum Vergleich eignen sich dann das von Sauramo (1937) dargestellte Diagramm, auf Grund dessen er das geologische Alter der unweit der Stadt Oulu ebenfalls in der Lehmgrube einer Ziegelei aufgefundenen Überreste eines Seehundes bestimmt hat, sowie Fromms (1938) Gesamtdiagramm zu den Sedimenten am Ångermanjoki. Sie gleichen einander in hohem Masse, und auch das Diagramm von Vähäkyrö ist ihnen ähnlich. In allen drei Diagrammen ist in der ersten Hälfte des Litorina *Pinus* sehr stark, und an der Stelle, wo ihre Menge gleich nach dem reichlichsten Auftreten von *Tilia* stark abfällt, beginnt neben *Betula* auch *Alnus* beträchtlich zuzunehmen. Diese Stelle im Diagramm ist denn auch am interessantesten, da der Seehund von Vähäkyrö gerade damals eingebettet worden ist. Es ist zu beachten, dass die Überreste des Seehundes von Oulu an entsprechender Stelle aufgefunden worden sind, so dass die Seehundfunde ungefähr gleichaltrig sind. Nach Sauramo ist die Einbettung des Seehundes von Oulu etwa 2 000 v. Chr. vor sich gegangen. Diese Datierung ist mit einem Vorbehalt von zwei Jahrhunderten in dieser oder jener Richtung vor sich gegangen. Nach Fromms Diagramm ist der Seehund von Vähäkyrö jedoch schon etwas früher oder etwa 2 400 v. Chr. eingebettet worden. Fromms Diagramm gründet sich auf die Jahreswarven der Wassersedimente, so dass die nach ihm gegebene Datierung etwas genauer als die von Sauramo ausgeführte sein dürfte. An und für sich aber sind ihre Ergebnisse annähernd gleich, zumal in Anbetracht des von Sauramo dargestellten Vorbehalts von zwei Jahrhunderten.

Als Ergebnis des obigen Vergleichs erhalten wir, dass der Seehund von Vähäkyrö nach der Mitte des Litorina, etwas 2400 v. Chr. oder vor etwa 4400 Jahren, am Grunde des Litorinameeres eingebettet worden ist.

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4.

ON THE DEVELOPMENT OF THE HEPOSUO BOG NEAR THE TOWN OF KUOPIO

BY

VEIKKO OKKO

In the year 1945 the farmer Yrjö Pitkänen (Kuopio, Kurkiharju) informed Professor M. J. Kotilainen Ph. D. that he had found clay between peat layers in the Heposuo bog. This exceptional stratigraphy interested Prof. Kotilainen, who gave me a sample of this clay. The sample appeared to be coarse detritus ooze stratified into fresh and shallow water in the Littorina period [1]. According to earlier investigations (Hellaakoski 1922, Sauramo 1940) the Kuopio area, where the Heposuo bog is situated, belonged at that time to the Ancient Saimaa lake-phase. The water level of that stage lies here at the height of 100 m. above sea level (Hellaakoski 1922), or 18 meters higher than the present water level of Lake Kallavesi. It could therefore be supposed that the detritus ooze layer in question signified some greater transgression.

As. fig. 1 shows, the Heposuo bog is situated at a distance of 10 km. from the town of Kuopio ENE, Kurkiharju, Riihilahti (62°55′ north. lat. and 2°58′ to the east of Helsinki). The bog is partly cultivated, partly covered with grass and herb forest. On the walls of the pit dug between both parts it could be seen that the peat layer was horizontally divided into two parts separated from each other by a detritus ooze layer about 0.5 m. thick. Ooze had been driven to nearby fields where it appeared to forward growth. Mr. Pitkänen stated that on digging up ooze he had found some subfossils there, which, judging from his description, were nuts of *Trapa natans* grown in Finland in the Littorina period. The most northerly place where nuts have hitherto been found is the Mikansuo bog in Siilinjärvi, at a distance of 30 km. NWN from Heposuo (Backman und Cleve-Euler 1922, Lumiala 1940). I myself, however, did not find any nuts in the pit of Heposuo.

[1] The terms Post-Littorina, Littorina and Ancylus are used for the Post-Glacial phases in the development of the Baltic. Every phase is also characterized by a certain pollen flora. For that reason the same terms can be used also in paleobotanic cense (e. g. Hyyppä 1937 pp. 215—220).

The boring made on the edge of the pit (95 metres above sea level) shows the stratigraphy of the bog to be as follows (fig. 2, the left vertical column): Uppermost there is a 30 cm. thick layer of decayed peat containing remains of deciduous trees, *Cyperaceae*, and *Sphagnum*. The thickness of this layer varies in the walls of the pit. Under this layer is the abovementioned ooze-layer. Under the ooze is again peat, the chief part of which now consists of *Cyperaceae-*, *Sphagnum-*, and *Equisetum*-remains. From the lower limit of peat downwards there are only limnistic sediments. Their uppermost part consists of a 20 cm. thick layer of detritus ooze. Under this layer comes clay ooze and clay, which at the depth of 300 cm. gradually turns into silt clay. In its lower part silt clay begins to contain fine sand, the quantity of which increases to such a degree that the lowest part of the sediment consists almost entirely of sand. Under the sediment layers there are moraine deposits.

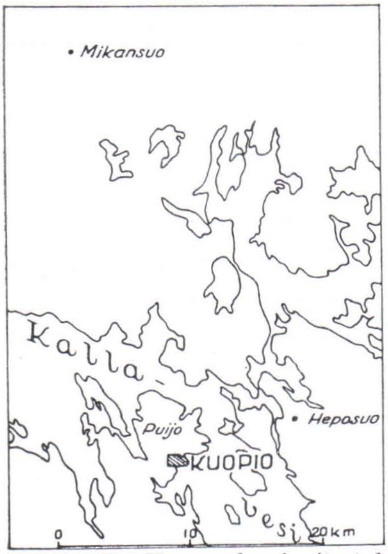

Fig. 1. The Heposuo bog is situated at a distance of 10 km. from the town of Kuopio ENE in Central Finland.

Judging from the stratigraphy, Heposuo bog had come under water after having been released from the ice sheet. Into this water there were deposited first fine sand, then silt clay, clay, clay ooze and finally detritus ooze as a sign of the water becoming shallower. After the land became dry the development of the bog began, but was interrupted by transgression, which put terrestric peat layers under water. After the sinking down of the water paludification continued until cultivation put a limit to it.

For the dating of these phases a series of samples was taken as far as the bottom of the bog, of which samples the pollen and diatom analyses are made in the Quaternary Department of the Geological Survey of Finland.

The results of pollen analyses are presented in a diagram drawn beside the previous profile (fig. 2). The analytical diagram construction recommended especially by American scientists is used here for which reason the diagram differs from those hitherto customarily used in Finland. The diagram is divided into 5 separate columns. In these *Picea excelsa, Pinus silvestris, Betula* coll., *Alnus* coll. and rare deciduous trees *(Corylus avellana, Quercus robur, Tilia cordata* and *Ulmus* coll.) form vertical columns of their own. In the place for rare deciduous trees *Tilia* is in addition separated from the others. In this way an attempt has been made to get the real changes of frequency of each group easily recognizable. The same method has been earlier used especially in diatom investigations.

The form of separate pollen lobes in the diagram is fairly distinct. Pollen of spruce appears most in the upper peat layer, from which its lobe stretches as a narrow projecting part down to ooze and breaks off there. In the limnistic bottom strata spruce forms again a narrow pollen lobe, which becomes stronger downwards.

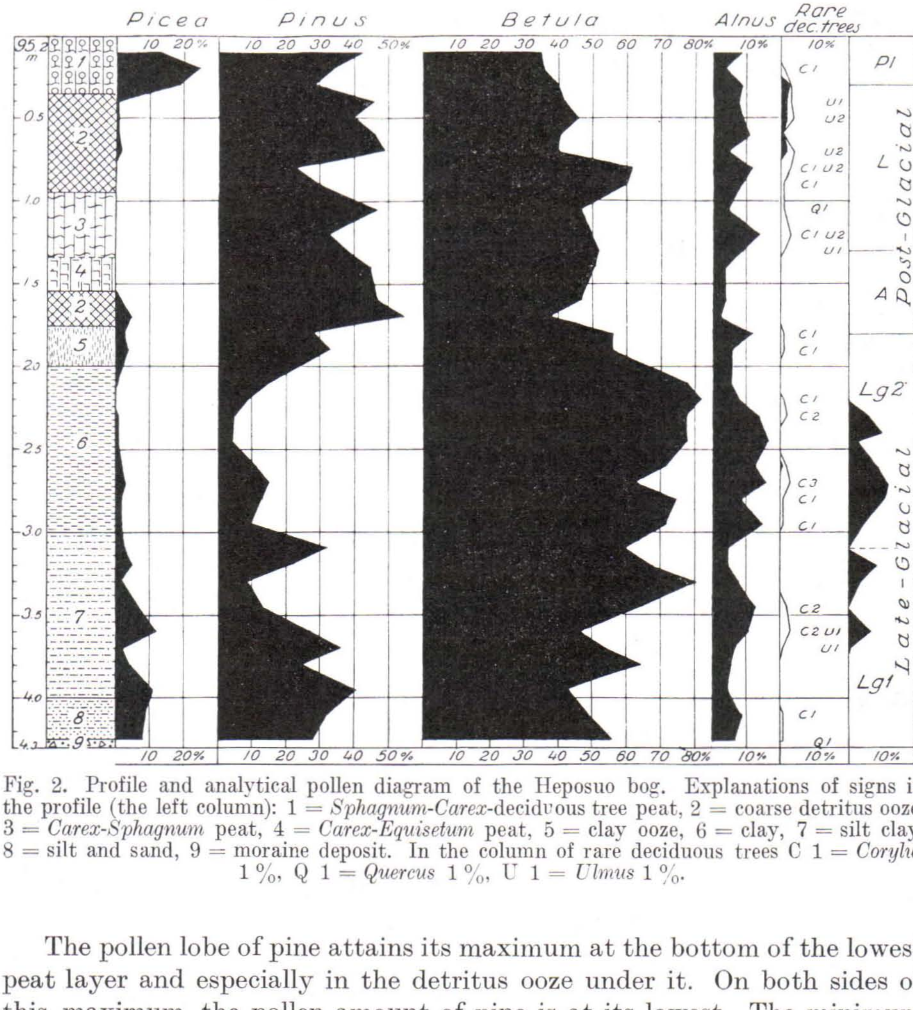

Fig. 2. Profile and analytical pollen diagram of the Heposuo bog. Explanations of signs in the profile (the left column): 1 = *Sphagnum-Carex*-deciduous tree peat, 2 = coarse detritus ooze, 3 = *Carex-Sphagnum* peat, 4 = *Carex-Equisetum* peat, 5 = clay ooze, 6 = clay, 7 = silt clay, 8 = silt and sand, 9 = moraine deposit. In the column of rare deciduous trees C 1 = *Corylus* 1 %, Q 1 = *Quercus* 1 %, U 1 = *Ulmus* 1 %.

The pollen lobe of pine attains its maximum at the bottom of the lowest peat layer and especially in the detritus ooze under it. On both sides of this maximum the pollen amount of pine is at its lowest. The minimum lies in silt clay at the depth of 245 cm. Under it the pollen amount of pine varies, forming four tops altogether. Corresponding to these, the pollen amount of spruce, too, increases. This part of the pine lobe resembles that of the spruce also therein that the former, too, becomes stronger, when approaching the bottom.

The pollen lobe of birch is almost a reflection of that of pine, as its maxima place themselves just as do the minima of pine. The uppermost of these maxima lies in detritus ooze between peat and the lowest in silt clay at the depth of 210—350 cm.

In the pollen lobe of alder, the maxima and minima place themselves just at the same points as on the lobe of birch. Alder pollen is found least at the depth of 170 cm. or in the maximum of pine.

The most abundant occurrence of pollen of rare deciduous trees concentrates itself on the upper part of the profile at the depth of 20—130 cm. or on the horizon corresponding to the occurrence of spruce and the uppermost maximum of birch. The coherent lobe breaks off already on the upper part of the maximum of pine, but beneath this the lobe continues with some breaks as far as the bottom of the bog. *Corylus* pollen is the commonest at this part, whereas the uppermost coherent part of the lobe is especially characterized by the relative abundance of *Tilia*.

On the basis of the above analysis the diagram can be divided in a vertical direction into some pollen horizons. They are: 1. the upper, 30 cm. thick part nereast to the present time. It is characterized by the abundant pollen of spruce, pine and birch as well as lesser occurrence of alder. Rare deciduous trees are lacking; 2. the horizon at the depth of 30—130 cm. *Tilia* and other noble foliaceous trees reach their maximum, deciduous trees are predominant. The uppermost lobe of spruce begins; 3. the maximum of pine at the depth of 130—180 cm. At the same time alder becomes rarer and noble deciduous trees are lacking; 4. the strong birch period at the depth of 180—310 cm. The lobe of pine reaches its minimum. Some pollen of spruce and rare deciduous trees appear; 5. the horizon at the depth of 310—425 cm. where birch still dominates, though conifer pollen is more common than in the former period. Pollen of rare deciduous trees becomes rarer.

The dating might be carried out in a more detailed way, but it is not necessary for the connecting of the diagram. The above-mentioned general features are sufficient to indicate that the diagram of the Heposuo bog can easily be dated to the pollen chronology of the Post-Glacial time. Thus its regularities are also characteristic of the Siilinjärvi diagrams, which Lumiala dated according to general chronology (Lumiala 1940). The same features can also be ascertained both on the pollen diagram of South Finland (Hyyppä 1937) and on those of Kainuu (Kilpi 1937), as well as on those of West Finland (Sauramo 1940). The result of the dating is shown in the right column of fig. 2. The uppermost peat layer is formed after the Post-Glacial optimum of the climate or in the Post-Littorina period (Pl), the following zone shows the schists of the Littorina period (L), to which, in addition to the transgressive ooze layer, there belongs also peat on both sides of this layer. The pine period (A) before the Littorina is similar to the typical Ancylus and it forms another easily recognizable zone in the diagram. According to general chronology the beginning of the pine period is placed on that horizon in which pollen of rare deciduous trees again begins to appear and pine loses its predominance for the benefit of birch (cf. e. g. Sauramo 1940 p. 149). The maximum of pine indicating the date of the Ancylus transgression places itself in this profile into detritus ooze under peat that forms the oldest Post-Glacial layer in Heposuo.

The chief part of the limnistic bottom strata of Heposuo is deposited during the Late-Glacial epoch (Lg). The dating of these old layers is more uncertain on account of several disturbing influences and their interpretation is still a matter of opinion. In spite of this, the above-mentioned pollen horizons can be observed in many pollen diagrams published both in Finland (e. g. Hyyppä 1937 p. 15 and 1941 p. 603, Kilpi 1937 pp. 82 and 97, Lumiala 1940 p. 4) and in Sweden (Thomasson 1927 p. 57 and Sten Florin 1944 pp. 561 and 564). In Sauramo's latest general pollen diagram, too, based on the material collected in West-Finland (Sauramo 1945), the quantity of conifers is increasing beneath the first Late-Glacial birch period, whereas their abundance is varying. Under these circumstances it seems obvious that the variation of the pollen percentage in the Late-Glacial sediments, too, is a regional conformity. This opinion is confirmed especially by the fact that at least in one case (Hyyppä 1941) these pollen horizons are found in terrestric peat. As these Late-Glacial pollen horizons have not yet established names, they have been marked in the diagram with neutral terms Lg 1 and Lg 2. The uppermost of these (Lg 2) indicates also the birch period at the end of the Late-Glacial epoch, whereas the lower part (Lg 1) contains the layers deposited before the birch period. According to the earlier standpoint Lg 2 corresponds to the two phases, viz. the Rha- and Rho (= Y IV)-periode, which mark the end of the Late-Glacial time (Sauramo 1934, 1940 and 1941). Their limit falls on the maximum of birch or in the Heposuo profile at the depth of 230 cm. This interpretation Sauramo has later on revised and refers the whole birch period to the Rha-phase (Sauramo 1945 and 1947), the beginning of which is marked by the first (uppermost) Late-Glacial maximum of pine or here at the depth of 310 cm. The lowest part of the profile belongs thus to the earlier period of the Late-Glacial epoch or to the collective Yoldia-phase. Sauramo divides this phase further into two pollen horizons: the upper, which is characterized by the occurrence of conifers (Y IV), and the lower Late-Glacial birch period (Y I—III) (Sauramo 1947). Of these phases only the younger one can be observed in the Heposuo bog.

According to the dating carried out above, the Heposuo area was released from the ice-sheet during the Late-Glacial time between the two strong birch periods or, according to Sauramo's chronology, at the Yoldia IV-phase and came directly under water. The Heposuo turned into dry land in the time of the Ancylus-regression, but got under transgression in the Littorina period. Before its end the water was again sinking and since that time the Heposuo has been dry land.

The diatom analyses made of limnistic sediments indicate that the bottom part of the profile was deposited as far as the depth of 370 cm. in fresh water. The flora is first at its sparsest, but soon becomes richer and consists of such species, as are typical of the oldest Late-Glacial sediments everywhere in Finland (e. g. *Campylodiscus noricus v. hibernica, Cymbella naviculiformis, Eunotia sibirica, Melosira arenaria, Melosira granulata, Melosira islandica ssp. helvetica* and *Surirella robusta).*

At the depth of 370 cm. there appear salt water diatoms in this flora. The cold water species *Grammatophora arcuata* is the first of them. Gradually salinity increases, for already at the depth of 360 cm. there is a total of 7 % of salt and brackish water diatoms (*Grammatophora oceanica, Synedra tabulata* and a fragment of marine *Coscinodiscus*-species). Later on there appear in the diatom flora more salt water diatoms such as *Diploneis Smithii, Melosira sulcata* (at the depth of 300 and 230 cm.), *Navicula peregrina f. minor, Pyxidicula sp., Rhabdonema arcuatum, Rhabdonema minutum* and *Stephanopyxis sp.*, Salinity rises to its maximum (12 %) at the depth of 270 cm., from where it gradually sinks. The uppermost horizon containing salt water diatoms lies at the depth of 230 cm. The percentage of salt water species appears from the abundance curve drawn in the right column of fig. 2, which curve starts from the middle part of the oldest horizon (Lg 1), reaches its maximum at the first half of the birch period and comes to an end about the maximum of birch.

From the depth of 220 cm. onward the diatom flora passes into fresh water flora where *Melosira islandica spp. helvetica* is predominant. Among other species may be mentioned *Cymbella aspera, C. cistula, C. prostrata, Cymatopleura elliptica, Diploneis elliptica, Epithemia turgida, Gomphonema acuminatum v. coronata, Melosira distans, M. granulata,* many species of *Pinnularia, Synedra ulna, Stephanodiscus astraea* and *Surirella* fragments. The amount of *Pinnularia* increases especially in the detritus ooze under peat.

Detritus ooze between peat contains a very abundant diatom flora too, to which there belong solely fresh water species. Among them one finds almost all ecological diatom groups, from epiphytes to plankton species. The appearance of the latter in such a strata proves that ooze was deposited in the littoral zone of a great open water. The investigation concerning the walls of the pit led already in the field to the same conclusion.

The seemingly homogeneous quality of the ooze did not allow of any conclusions being drawn about what point of the layer had descended into the deepest water or during the culmination of transgression. Therefore one had to resort to the analyses of diatom flora. At my request Mr. Karl Mölder Ph. D. separated three ecological groups of diatoms in the ooze. The first of them comprises the epiphytes, the second the diatoms of the proper littoral zone and the third plankton species. The abundance relation of these groups will be seen in fig. 3. The changes are smallest in the group of the epiphyts (I), the abundance of which is at its greatest (30 %) at the depth of 60 cm. The species of group II are most numerous in the lowest and highest parts of the ooze, whereas the maximum of group III falls between them at the depth of 50 cm. This indicates that at the time when this layer was deposited the plankton species have had the easiest access to the basin of Heposuo. As at the same

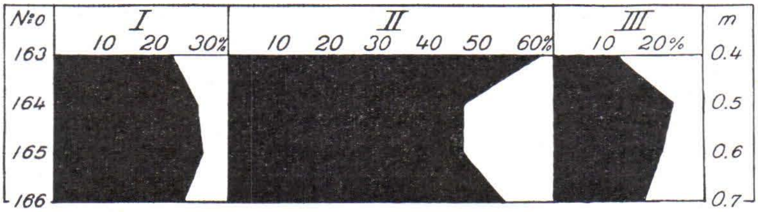

Fig. 3. Ecological diatom groups in the uppermost detritus ooze layer of the Heposuo bog. I = epiphytes, II = littoral diatoms, III = plankton diatoms.

time the proper species of the littoral zone are at their minimum, it seems that the ooze strata at the depth of 50 cm. should represent the deposit descended during the culmination of transgression. Above this horizon the littoral species (II) become more common than before. According to this the water level slowly rose during most part of the time which was taken for the sedimentation of ooze, reached its maximum when about $3/4$ of the ooze was deposited, and sank, faster than it had risen, lower down the surface of the Heposuo bog.

The abundance of some plankton diatoms at the lowest strata of the profile indicates that this sediment was not formed at the bottom of a small lake. On the contrary there must already have been a vast and rather deep water, in which the salt water diatoms appear later on. Their occurrence being limited to the sediment in the middle part of the strata excludes the possibility of the secondary origin of these diatoms. Therefore it is obvious that the Yoldia sea then extended as far as the Kuopio region. The influence of the sea was at its strongest during the first half of the Lg 2. In the middle part of the same period connection with the sea was cut off again, as the water became fresh.

In the Kuopio district is found some more evidence confirming this opinion. The Late-Glacial diatom horizons of the Heposuo correspond to the profile of the Törönniitty bog in Siilinjärvi (Lumiala 1940). Furthermore, according to the pollen diagrams, both of them seem to be of the same age. In the Late-Glacial epoch each bog has obviously undergone analogous phases. The salinity in the Heposuo bog has been stronger than that in the Törönniitty bog, indicating that in the Kuopio region the sea connection was better than in Siilinjärvi.

On the other hand, there are in the Kuopio district many ancient shorelines (Ramsay 1896 and 1931, Hackman 1899, Hellaakoski 1922) above

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the surface of the Heposuo peat bog. Among these two strong shore-lines can be mentioned at the height of 140 and 100 m. above sea level. According to Sauramo they belong to the shore-lines of the Y IV and Rha I phases of the Baltic (Sauramo 1940). Above the Y IV shore-line some more shore-lines are found on the Puijo hill, which according to Ramsay (1931) marks the local ice-lake stage. These observations, as well as several ice-lake phases ascertained by Hellaakoski in the southern part of the same water-course (Hellaakoski 1934), support the theory of the ice-lake phase. This phase should then have stretched as far as Siilinjärvi. Both the bottom layers may also represent successive stages. In such case the freshwater zone should have followed the retreating ice-sheet and been caused by the meltwater. In both cases the sandiness of the sediment refers to the proximity of the ice-sheet.

The Y IV shore-line at the height of 140 m. may thus be contemporaneous either with the bottom layer or with the first salinity in the Heposuo profile. The Rha I shore-line at the height of 100 m. lies only 5 m. above the surface of the Heposuo. Therefore it is difficult to understand that the whole layer of silt clay and clay ooze over 1 m. thick, which was deposited in the birch period, could have been sedimented in such shallow water. It seems rather that the 100 m. shore-line was formed during the maximum of birch. At the beginning of the birch period the water level should have reached higher than this level.

As salinity was stronger in the Heposuo basin than in Siilinjärvi during the Yoldia stage, the sounds connecting the Central Finland lake complex with the sea were at first situated farther to the south than in Kiuruvesi or Pielavesi (Sauramo 1940). While the edge of the glacier receded gradually still farther to the northwest new outlets began to appear. They remained in existence even after the oldest sounds had already shrunk under the influence of the regression. Thus the last sea connection can be found in Kiuruvesi or in Pielavesi. After these thresholds had risen above the sea level, the great lakes in Central Finland were separated from the sea and began their own development.

When regression passed by the threshold separating the Heposuo basin, this was isolated from the receding sea. As the sediment from the horizon at the depth of 220 cm. upwards contains no more salt water diatoms, this horizon has been influenced by isolation. In other words the shore-line has passed by the altitude of about 95 m. at the latter part of the Lg 2 period. One cannot follow the course of regression in the strata of the Heposuo bog any farther. It is therefore uncertain, how low the isolation shore-line of Ancient Lake Saimaa may lie in the Kuopio district.

After its isolation the Heposuo basin began to fill up. This took place first at the bottom. At the time of the maximum of pine, detritus ooze was already deposited at the boring place and a little later there was telmatic *Carex*-swamp, where peat began to be formed. The development of peat bog continued during the end of the Ancylus period and the first part of the Littorina period, till during the latter the Heposuo bog was covered by a transgression. Detritus ooze was then deposited over peat. Compared to the pollen diagram the culmination of transgression occurred about the middle part of the Littorina period, for the pollen lobe of rare deciduous trees is then relatively strong and there appears i. a. pollen of *Tilia*. At the same time the first pollen of spruce occurs in ooze in the Littorina period. Transgression has consequently taken place in the Post-Glacial optimum of climate, so that the occurrence of *Trapa natans* nuts in ooze would seem quite natural, the more so, as nuts in the Siilinjärvi discovery point are situated in the corresponding horizon.

As during the transgression in the Heposuo bog only coarse detritus ooze was deposited, it is certain that during the culmination of transgression the water level could be situated only a few metres above the surface at the Heposuo. When levelling the height of the boring-place by the road leading to the head of the near Riihilahti bay there was found, too, a fairly distinct ancient shore, composed of an abrasion cliff with boulder rim. At the base of this cliff I got the height of 98 m. or 3 m. above the surface of the Heposuo bog. The sandy littoral accumulations spreading around near the farm Pitkänen seemed also to be placed at the same height. The open exposition of these shore-lines toward Lake Kallavesi gives one sufficient motive for concluding that transgression brought about the rising of the water level in the whole basin of Lake Kallavesi.

This opinion was confirmed by another fact, too. Prof. Kotilainen remembered to have seen in the »Society of Friends of Nature in Kuopio» a sample of peat, which was taken from a layer covered with sand. The place of discovery was situated in the town of Kuopio, in the street Puistokatu, near the corner of the street Minna Canthinkatu. According to the information obtained from the geodesist in Kuopio, the height of the street at the mentioned place is 97.9 m. above sea level. Thus it is obvious that peat has been covered by beach sand, while the water level was situated almost exactly at the height of the above-mentioned ancient shores.

As to their height, these ancient shores are fairly closely applicable to the shore level of the lake phase »Suur-Saimaa», whose isobase of 100 m. passes by the Heposuo bog (Hellaakoski 1922). Lake Saimaa was consequently transgressive previous to Hellaakoski's S—S phase also in the Kuopio district. The transgression on such a high isobase confirms Sauramo's opinion (1940), according to which the first outlet of Lake Saimaa was situated in the north-western part of the watercourse or about the same places where isolation had earlier occurred. On the south-eastern side of the inclination axis that passes through the threshold of the outlet the transgression occurred in the circle of the whole basin. This transgression could only continue until the water level rose above the lowest points of the watershed surrounding the basin of the then existing Saimaa. According to Hellaakoski, these new outlets were situated in Suonteenselkä and in Kuolimojärvi (Hellaakoski 1922), or on lower isobases than the Kuopio district. For that reason the transgression then turned into regression, the access of plankton diatoms to the Heposuo basin became difficult and the previous shores remained dry. After the retreat of the shore level to the height of 95 m. the Heposuo bog was isolated from Lake Saimaa.

Under these circumstances the culmination point of transgression, which was determined by means of the diatoms of the detritus layer in the Heposuo bog, indicates the phase in which the first Saimaa outlet situated on higher isobases than Kuopio district ceased to exist. The turning of transgression into regression is also a sign of the forming of a new outlet that was situated on lower isobases than the Heposuo bog. According to the pollen diagram the culmination of transgression is placed in the middle part of the Littorina period. So it grows older in age than the transgressions ascertained more to the south in the Saimaa district (Hellaakoski 1936, Sauramo 1940) and than the delta formed at the outbreak of the River Vuoksi (Hellaakoski 1938). These latter are namely connected with the youngest phases of the Saimaa development, previous to which the regression had already passed by the surface of the Heposuo bog. That the transgressions are of different age in the northern and southern part is perhaps reflected in the course of the Suur-Saimaa isobases drawn by Hellaakoski, because in the NW-part of the district their gradient is greater than in the SE-part (Hellaakoski 1922 and 1936).

As a summary the following conclusions might be presented:

1. The Heposuo bog was released from the inland ice during the Yoldia period in the Late-Glacial epoch and came at once under cold, fresh and rather deep water.

2. In the Yoldia period this water turned brackish. Gradually salinity increased and reached its maximum in the first part of the birch period (Lg 2). Then the water became shallower and again turned into fresh at the maximum of birch, because Heposuo became isolated from the retreating sea.

3. After its isolation the Heposuo basin was filled up and turned into swamp. The formation of peat continued from the latter end of the Ancylus period to the first part of the Littorina period.

4. After the great Lake Saimaa had been isolated from the retreating sea, transgression began in the lake basin, under the influence of which transgression the water level rose to the height of 98 m. in Kuopio and Heposuo. At that time the peat layer of Heposuo came under 3—4 m. deep water and was covered by detritus ooze.

5. The transgression reached its maximum in the middle part of the Littorina period. The turning of transgression into regression indicates that the outlet of the ancient Lake Saimaa had changed its place. The new threshold had to be situated on lower isobases than Heposuo. After

this the development of Lake Saimaa may have continued in the way described earlier, till the outlet took its present bed at the outbreak of the River Vuoksi.

6. When the Saimaa shore-line had retreated after the transgression from the height of the Heposuo surface, paludification could continue there. Judging by the thinness of the peat layer it was, however, insignificant in the Post-Littorina period.

In conclusion I beg to thank Prof. M. J. Kotilainen Ph. D. at whose suggestion this study was started, and Doc. Esa Hyyppä Ph. D. for their valuable advice. Mr. K. Mölder Ph. D. and Miss Kyllikki Salminen M. A. have made the diatom and pollen analyses. I wish to express to them my special thanks.

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5.

DIE VERBREITUNG DER DACITBLÖCKE IN DER MORÄNE IN DER UMGEBUNG DES SEES LAPPAJÄRVI

VON

KARL MÖLDER

EINLEITUNG

Schon Jahrhunderte haben sich die Geologen und Erzlagerstättensucher auf ständiger Suche nach neuen Erzlagerstätten befunden. Und wie es der Fachmann sehr gut weiss und wie es auch aus der Fachliteratur hervorgeht, verlangen die Feststellungen der Lagerstätte jahrzehntelange, mit bedeutenden Schwierigkeiten verbundene Untersuchungen an Ort und Stelle. Häufig sind die Erze nur durch Findlingsblöcke angedeutet, während von den Lagerstätten selbst nicht die Ahnung besteht, da sie mitsamt dem umgebenden Felsen gewöhnlich unter den losen Erdarten verdeckt liegen.

In solchen Teilen der Erde, wie z. B. in Nordeuropa, wo das Landeis weite Flächen bedeckt hat und wo seine Bewegungen nach den hinterlassenen Spuren auch noch heute feststellbar sind, kann man zu einem Ergebnis gelangen, wenn man alle Erzfindlinge auf der Erdoberfläche aufsucht und die Fundstellen auf Karten einträgt. So erhält man einen Fächer, dessen Spitze nach der Richtung zeigt, aus welcher die Erzfindlinge herstammen. Häufig sind letztere durch das Eis weite Strecken von ihrem Entstehungsherd in eine völlig fremde Umgebung transportiert worden, deren Gesteinsarten nicht das geringste mit der betreffenden Erzlagerstätte zu tun haben. Es gilt bei diesen Erzsuchungen daher die Bewegungen des ehemaligen Landeises am fraglichen Ort genau zu kennen, eine Aufgabe, die allerdings nicht immer zu den leichtesten gehört. Besonders schwierig gestaltet sich die Feststellung der Bewegungsrichtung des Landeises in Gegenden, wo der nackte Felsgrund fehlt und man sich also bei den Untersuchungen nicht an die vom Eis in der Felsoberfläche hinterlassenen Schrammen halten kann.

K. Richter (1937) hat in Deutschland, wo nackte Felsen nicht vorkommen, die Bewegungen des Landeises mit Hilfe von Richtungsanalysen festgestellt und ist dabei zu recht guten Resultaten gekommen. In den Vereinigten Staaten hat Ch. Holmes (1941) diese Richtungsanalysen methodisch weiterentwickelt und festgestellt, dass gewisse Steine in der Moräne die Bewegungsrichtung des Landeises angeben, während sich andere quer gegen dieselbe eingestellt haben. In Finnland hat E. K. Kivekäs (1946) Richtungsanalysen im sommer 1940 ausgeführt und er konnte feststellen, dass die Längsachsen der Steine mit den Bewegungsrichtungen des Inlandeises zum grössten Teil gleichgerichtet sind. Im Jahre 1945 hielte E· Hyyppä (1948) in dem Geologischen Gesellschaft Finnlands einen Vortrag, wo er auf Grund diesbezüglicher Untersuchunzen im Sommer 1943 im Vihanti feststellen konnte, dass sich in der Moräne vorkommende Steine orientiert sind und dass man die Ankunftsrichtungen des Moränenmaterials ermitteln kann. Auch Virkkala (1948) hat im Kainuu festgestellt, dass die Steine in der Moräne orientiert sind.

Um weiteres Licht auf die Frage zu werfen, hat Verfasser es unternommen, den auf der im See Lappajärvi in Süd-Pohjanmaa gelegenen Insel Kärnäsaari verbreiteten Dacit in dieser Hinsicht einer Untersuchung zu unterziehen. Dieses Eruptivgestein wurde deshalb gewählt, weil es von den übrigen Gesteinsarten dieser Gegend gut unterscheidbar ist und Fehler bei den Steinzählungen daher nicht zu befürchten sind. Auch begegnet man ihm eben nur auf der genannten Insel Kärnäsaari, es ist also der Ursprung der vorhandenen Findlingsblöcke bekannt und die Bewegungsrichtung des Landeises mit ihrer Hilfe ohne weiteres feststellbar.

Schon i. J. 1914 wurden der Kärnäsaari-Dacit und die Verbreitung der Findlingsblöcke in der umgebenden Gegend von A. Laitakari untersucht. Es erwies sich, dass Dacitfindlinge ausschliesslich südlich von der genannten Insel vorkamen, während sie in sämtlichen anderen Richtungen fehlten. Denselben Gegenstand hat auch M. Sauramo (1924) in einer Untersuchung behandelt. Nach M. Sakselas neueren, noch unveröffentlichen Untersuchungen begegnet man Dacitfindlingen sogar südlich der Stadt Jyväskylä, sie sind also vom Landeis über beträchtliche Strecken transportiert worden.

Alle obengenannten Untersuchungen befassen sich ausschliesslich mit den auf der Erdoberfläche vorkommenden Dacitfindlingen, während jegliche Untersuchungen über die Moräneneinschlüsse in dieser Hinsicht fehlen. Wir wissen noch gar nicht, ob die Findlinge in der Moräne weitere oder kürzere Strecken gewandert sind, als auf der Erdoberfläche. Um diese Frage zu beleuchten, hat Verfasser während der Sommer 1944—46 Findlingszählungen aus der Moräne in der Umgebung des Sees Lappajärvi durchgeführt. Ausserdem wurden Richtungsanalysen unternommen, weil in weiten Gebieten hier die nackten Felsen fehlen, aus deren Oberflächenschrammen ja gewöhnlich die Bewegungsrichtung des ehemaligen Landeises zu erlesen ist. Häufig sind aber auch diese Felsen so stark verwittert, dass jegliche Spuren der Schrammen von ihrer Oberfläche verschwunden sind. Schöne Schrammen konnte man an solchen Stellen finden, wo die Erde in Verbindung mit Wegebau- und anderen Arbeiten bis zum unterliegenden Fels abgetragen worden war.

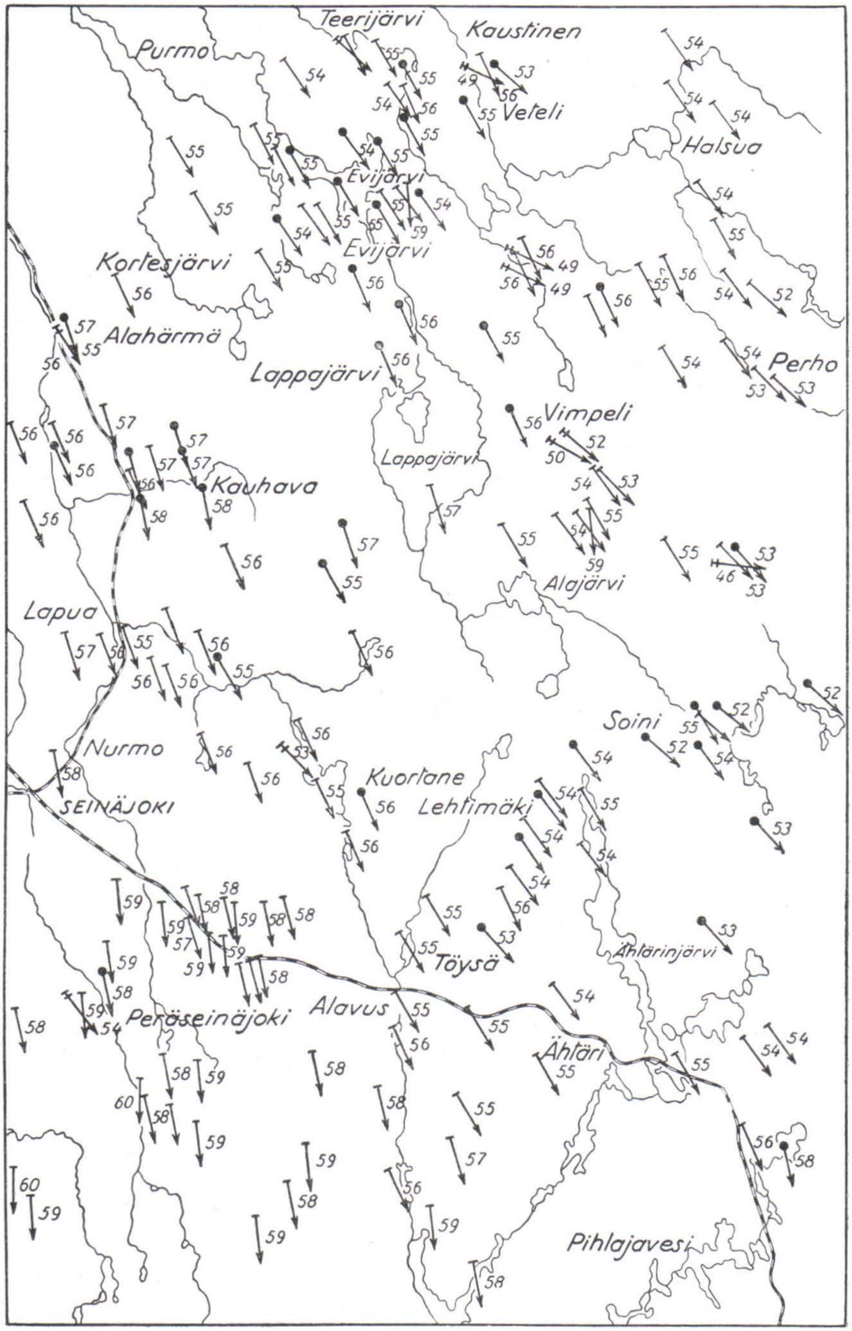
DIE BEWEGUNGSRICHTUNGEN DES LANDEISES IN DER UMGEBUNG DES SEES LAPPAJÄRVI

In der Literatur (Sauramo 1929, 1940) wird als hauptsächliche Bewegungsrichtung des Landeises NNW—SSE angegeben; einige Schrammen liegen aber auch sogar in der Richtung N—S. Aus diesen Untersuchungen ist zu ersehen, dass die letzte Bewegung des Landeises eine sehr einheitliche gewesen ist. Auf Karte 1 sind mit Pfeilen alle in der Gegend bisher festgestellten Schrammenrichtungen angegeben; die Pfeile mit einem Querstrich beziehen sich dabei auf die letzte oder jüngere Landeisbewegung, die mit zwei Querstrichen auf die ältere. Die den Pfeilen beigegebenen Nummern sind aus dem finnischen Kompass, wo der Kreis in 60 Einheiten geteilt ist, wobei 1 Einheit, 6 früher verwendeten Graden entspricht. Die Nummern stehen auf dem Kompass so, dass 0 im Norden, 15 im Westen, 30 im Süden und 45 im Osten ist. Zum Beispiel 55 im finnischen Kompass bedeutet nach den anderen Kompassen also N 30°W, 5 wiederum entsprechend N 30°E.

Betrachten Wir nun die angegebenen Schrammenrichtungen näher, so können wir feststellen, dass sie in der Umgebung des Lappajärvi zwischen den Richtungen 55 und 57 liegen. In der Gegend von Kaustinen, Halsua und Perho ist das Eis mehr von W gekommen und wir finden hier die Richtungen 52 bis 54 vorherrschend. Bei Seinäjoki und Peräseinäjoki wiederum liegen die Richtungen mehr nördlich, die Schrammen verlaufen hier in den Richtungen 58 bis 60, d. h., das Landeis ist hier direkt von Norden gekommen. Selbstverständlich kommen kleinere Abweichungen vor, bedingt durch die lokale Konfiguration der Felsen.

Ausser den obigen Schrammenrichtungen gibt es auch andere, die mehr in der Richtung von W nach E liegen. Diese Kreuzschrammen sind gewöhnlich schwächer entwickelt und durch die letzte Landeisbewegung oft schon weitgehend ausgewischt. Besonders sind die westlichen Schrammenseiten niedriger, und an den tiefsten Stellen der Schramme sieht man sehr schwache striche, die nach derselben Richtung gehen, wie die letzten oder jüngsten Schrammen. Diese älteren Schrammen haben grösstenteils die Richtung 46—49, es gibt aber auch Schrammen, die in den Richtungen 53 und 54 liegen. Dass jene älteren Schrammen hier so spärlich vorkommen, erklärt sich dadurch, dass sie sich nur an den geschütztesten Stellen besser erhalten haben.

Es ist nun interessant näher zu betrachten, wie sich die Resultate der Richtungsanalysen zu den oben dargestellten Schrammenrichtungen verhalten. Auf Karte 1 sind durch Kugelpfeile diejenigen Richtungen angegeben, in welchen bei den betreffenden Analysen die meisten Längsachsen gelegen haben. Selbstverständlich sind bei den Analysen auch zahlreiche andere Richtungen vertreten gewesen, diese sind aber hier nicht berück-



Karte 1. Die Bewegungsrichtungen des Landeises.

sichtigt. Je länger und schmäler die Findlinge sind, desto mehr weichen ihre Längsachsen von der vorherrschenden Richtung ab.

Wie man sieht, besteht eine recht gute Übereinstimmung zwischen den Schrammenrichtungen und den Ergebnissen der Richtungsanalysen. Wohl sind kleinere Abweichungen zu verzeichnen, allein diese leiten sich von örtlichen Abweichungen in der Landeisbewegung her.

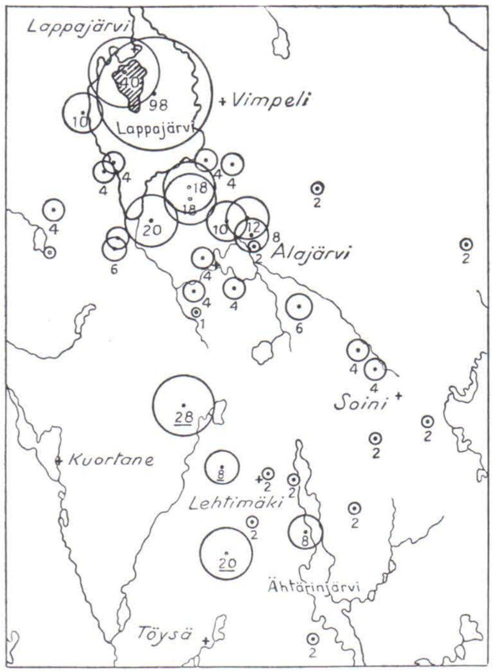
Wie verteilen sich nun die Längsachsen der Findlinge in einer Analyse? Zur Beleuchtung dieser Umstände möge eine Richtungsanalyse aus Kauhava als Beispiel gewählt werden. Ihre Resultate sind in der beigefügten Abbildung 1 graphisch dargestellt. Man ersieht, dass auf die Richtung 57 (also N 18°W) 36 % von allen gefundenen Richtungen entfallen. Als nächstgrösste Richtung ergibt sich 56, wohin 20 % von den Längsachsen zeigen. Alle übrigen Richtungen sind durch bedeutend kleinere Anteile vertreten. Die Analyse bestätigt also vorzüglich, dass das Landeis an dieser Stelle von Nordnordwest gekommen ist. Interessanterweise sieht man, dass einige Findlinge in der Moräne so liegen, dass ihre Längsachsen quer zu der Richtung der Landeisbewegung eingestellt sind. Bei der Analyse konnte festgestellt werden, dass diese Findlinge durchgehend recht lang und auch sonst schmal geformt waren. So verhielten sich gewöhnlich die Phyllite, während die rhombischen oder nur etwas länglichen Vertreter der anderen Gesteinsarten in der Moräne so lagen, dass ihre Längsachsen die Landeisbewegung angaben. Zusammenfassend kann gesagt werden, dass die Richtungsanalysen aus der Moräne uns wohl ein recht gutes Bild von den Bewegungsrichtungen des Landeises zu vermitteln vermögen und daher recht gut verwendbar sind in Gegenden, wo geschrammte nackte Felsen fehlen.

Abb. 1. Richtungsanalyse aus Kauhava.

DIE VERBREITUNG DER DACITFINDLINGE IN DER MORÄNE

Zur Feststellung der Dacitfindlinge in der Moräne in der Umgebung des Sees Lappajärvi wurden in den Sommern 1945 und 1946 Steinzählungen vorgenommen. Diese erfolgten so, dass aus der Moräne an jeder untersuchten Stelle aus 40—60 cm Tiefe wahllos 100 Steine von den Massen 3 bis 10 cm (alle grösseren wurden unberücksichtigt gelassen) genommen und daraus dann in Prozenten die verschiedenen Gesteinsarten festgestellt. Die Resultate dieser Steinzählungen sind an dem Teil des Dacits graphisch in Karte 2 wiedergegeben. Die Darstellungsweise ist dieselbe, der sich früher schon Lundqvist (1930) und andere bedient haben.

Auf der Insel Kärnäsaari, wo sich der Dacit-Mutterfels befindet, belief sich der Anteil der Dacitfindlinge in der Moräne auf 40 %. Auf der nebenan gelegenen Insel Lokkisaari, wo es keine Moräne gibt, bestanden nicht minder als 98 % der Ufersteine aus Dacit. Dieser Umstand mag wohl durch die Nähe des Mutterfelses zu erklären sein, indem die Findlinge leicht durch die Eisschubwirkung und auch von den Wellen an das Ufer getrieben werden.



Karte 2. Die Verbreitung der Dacitfindlinge.

Bedeutenden Dacitprozenten begegnet man noch am Südende des Lappajärvi, wo an einer Stelle 20 % und an zwei Stellen 18 % verzeichnet wurden. Je weiter nach Süden man kommt, desto kleiner werden die Prozentwerte; ebenso sind, wie aus der Karte 2 zu ersehen ist, an den beiden Seitenflanken des Fächers durchgehende niedrige Werte zu verzeichnen.

Eine interessante und bei diesbezüglichen Untersuchungen nicht ausserachtzulassende Ausnahme bilden die Dacitfindlinge in den Osen. Aus unserer Karte 2, in der die aus Osmaterial berechneten Dacitprozente durch einen Strich unter der Prozentzahl kenntlich gemacht sind, ersehen wir, dass im Bereich des Kirchspiels Lehtimäki plötzlich Werte von 28, 20 und 8 % auftauchen. Der fragliche Os, aus welchem diese Zählungen stammen, kommt von der Südspitze des Sees Lappajärvi und bestätigt also seinerseits, dass das Material in den Osen viel weiter transportiert wird, als in der Moräne. Es ist folglich von grosser Wichtigkeit genau zu beachten, aus welchem Material die Steinzählungen durchgeführt werden.

Einer Ausnahme begegnen wir auch am Ufer des Ähtärinjärvi, wo auf den Dacit 8 % von allen Findlingen entfielen.

Steinzählungen wurden auch noch in der weiteren Umgebung vorgenommen, Dacitflindlinge wurden aber nicht mehr angetroffen. Diese sind also offenbar auf das in Karte 2 angedeutete Gebiet begrenzt. Es ist interessant festzustellen, dass der Dacit in der Moräne nur 60 km weit vom Mutterfels transportiert worden ist, ebensowie dass die seitliche Ausdehnung des Fächers eine recht geringe ist. Nach Sakselas noch unveröffentlichten Untersuchungen, auf die eingangs bereits hingewiesen wurde, begegnet man Dacitfindlingen auf der Erdoberfläche noch bedeutend weiter im Süden, sogar südlich der Stadt Jyväskylä. Daraus ist zu schliessen, dass die Findlinge auf der Erdoberfläche mit dem Landeis viel weiter vom Mutterfels gelangen, als in der Moräne. Deshalb müssen bei künftigen Erzsuchungen auch die Moräneneinschlüsse gehörig berücksichtigt werden. Wenn in der Moräne keine Erzfindlinge zu finden sind, ist der Mutterfels noch weit entfernt, und man muss weite Strecken in der Ankunftsrichtung des Landeises wandern, ehe man zu ihm gelangt.

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6.

ON THE WATER CONTENT OF ROCKS

BY

NILS EDELMAN

The water content of rocks is scarcely investigated, although its importance in magmatic differentiation and metamorphism is often emphasized. V. M. Goldschmidt does not give any value for the frequence of hydrogen in the igneous rocks, because in his opinion a calculation of the water content is very difficult and does not give a right value of the primary water content of the magmas (10, p. 16). Th. G. Sahama refers to Goldschmidt in his textbook in geochemistry (20, p. 247). F. W. Clarke and H. S. Washington give the average 1.15 % H_2O for all igneous rocks (4, p. 32) and R. A. Daly gives averages for many types of magmatic rocks (5, pp. 9—28). The present paper is an attempt at solving the question whether the water content of rocks follows any rules.

The present investigation deals in the first place with the calc-alkalic igneous rocks and some metamorphic rocks; granites and liparites rich in potassium are also included. The diagrams are arranged with the percentage of H_2O as a function of the percentage of SiO_2. Where nothing to the contrary is stated in the diagrams, dots mean H_2O+ in such analyses where both H_2O+ and H_2O- are determined, and circles total H_2O content. Analyses with total H_2O determination are used only when the number of available analyses is small. The following collections of analyses are used H. S. Washington (21), Walter Larsson (15), Lauri Lokka (16) and Sole Munck- Arne Noe-Nygaard (17). The unpublished analyses of pyroxene gneisses and of the hornblendite-gneissose granite suite of S Pargas SW Finland have been made at the laboratory of the Geological Survey of Finland. The analyses of the granulites of Lapland are taken from a table by Pentti Eskola (8) and of the granulites of Sachsen from Harald Johansson, who refers to some analyses published by Scheerer (14, p. 402).

The results of the investigation require scarcely any detailed explanation. In regard to the extrusive rocks the water content seems to be connected with the crystallinity, so that the completely crystallized lavas such as leptites (fig. 2) and amphibolites (fig. 3) are poorer in water than the young lavas, which partly are glassy (fig. 1). Among the intrusive rocks the maximal water content seems to be a function of the content of silica or rather of iron or magnesia (fig. 4) depending on the fact, that among the magmatical minerals principally amphiboles and biotite contain water. Of the minerals free from Fe and Mg, quartz and feldspars are free from water and muscovite plays an unimportant role in unaltered magmatical rocks. Because olivine and pyroxenes are free from water in fresh condition, there are also basic rocks poor in water. In the altered

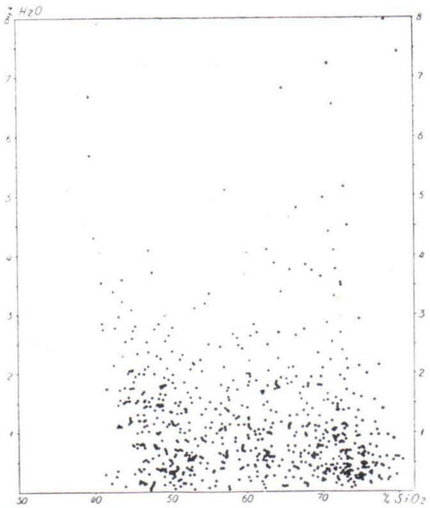

Fig. 1. Water content of volcanic rocks belonging to the calcalkalic suite and of liparites rich in potassium.

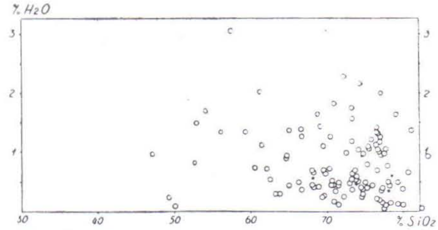

Fig. 2. Water content of leptites of Sweden and Finland.

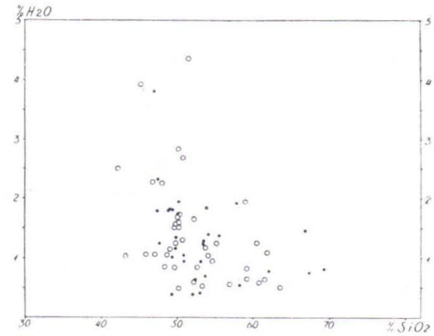

Fig. 3. Water content of amphibolites, porphyrites, metabasites and other volcanic rock of Sweden and Finland.

igneous rocks (fig. 5) the maximal water content increases with sinking SiO_2-percentage and compared with the fresh rocks it is much higher, showing that the water content has increased during the alteration (chloritization, serpentinization, uralitization, sericitization *i. a.)*. The formation of granulites and pyroxene gneisses is obviously connected with a decrease in water (fig. 6; 6, p. 168), as the pyroxene-gneisses seem to be metamorphic leptites (18, p. 506) and the granulites metamorphic, both sediments and igneous rocks (1, p. 362). In all these cases a decrease in water content has apparently taken place. An instance of decrease in water content by contact metamorphism is described by Goldschmidt (11 p. 109).

The PT-conditions of formation of the hydrous minerals are still practically unknown. Therefore it is impossible to discuss quantitatively the water problems of rocks. T. C. Phemister has tried to explain the role of the water in basaltic magma, using the results of G. W. Morey and C. N. Fenner, who have investigated the system H_2O — K_2SiO_3 — SiO_2 (19). N. L. Bowen has pointed out the increase in water content in the reaction series olivine — pyroxene — amphibole — biotite (3 p. 61). I would qualitatively discuss the water problems from the view-point of the pressure of the saturated vapour over the molten or moleculardispersement phase and the crystalline phases. We get further a gas phase, as the sum of all the partial pressures or the total gas pressure exceeds the external pressure. Depending on the water content of the magma and on the external pressure the gas phase can arise at different points of the differentiation diagram, which explains pegmatites belonging to gabbros and granites.

The pressure of the saturated vapour over hydrous crystalline phases increases with the temperature (fig. 9), or, in other words, an increase of the temperature displaces the equilibrium rightwards in the reaction

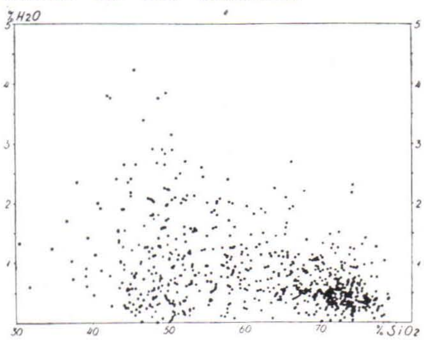

Fig. 4. Water content of intrusive calc-alkalic rocks and microclinegranites.

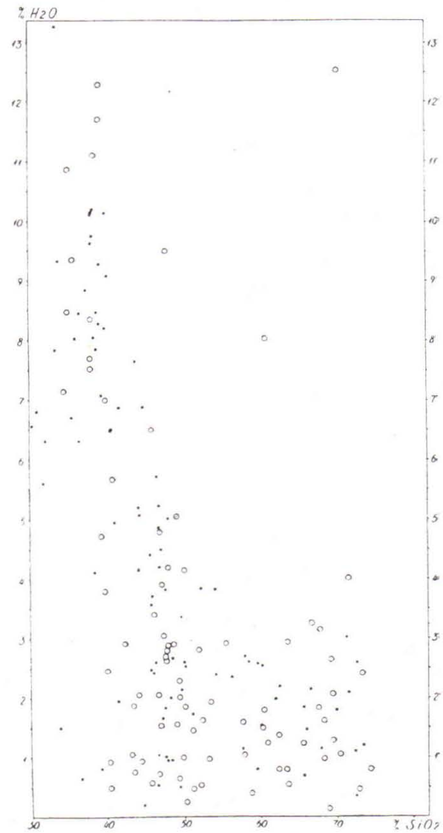

Fig. 5. Water content of altered intrusive calc-alkalic rocks (21).

$$\text{hydrous mineral} \rightleftarrows \text{anhydrous mineral} + H_2O.$$

An increase of the pressure displaces the equilibrium towards the side, where the volume is smaller. According to field experience of the occurrence of pyroxenes and amphiboles, the hydrous phase seems to be stable at higher pressure than the anhydrous one. An increase of pressure displaces the equilibrium leftwards (2; 7, p. 107). The vapour curve of the hydrous mineral represents in the PT-diagram the limit between the hydrous and anhydrous minerals, if the pressure P means the partial pressure of the water vapour.

If we discuss Goldschmidt's differentiation diagrams (12) from this point of view, we notice that the mica diorite suite occurs in the central zones of mountain chains, *i. e.* in areas where the external pressure has been high enough to prevent the vapour from diffusion (fig. 7). The mangerite suite again occurs in old granites and gneisses, where the water vapour has been able to leave the magma along fissures in the brittle rockground (fig. 8). The normal diagram represents the evolution of magmas at

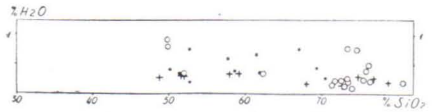

Fig. 6. Water content of granulites, crosses — H_2O +, circles — total H_2O and pyroxenegneisses — dots.

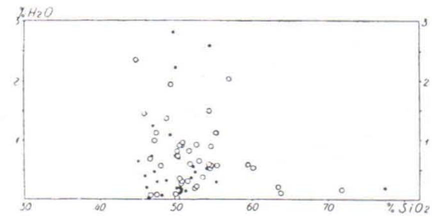

Fig. 8. Water content of hyperstenebearing calc-alkalic rocks, norite — charnockite — suite.

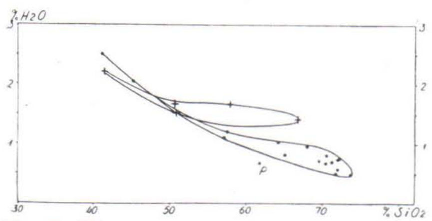

Fig. 7. Water content of rocks of the trondhjemite suite of Kalanti-region, dots (13 pp. 42—45) and of the hornblendite-gneissose granite suite of S Pargas, crosses (p = trondhjemitepegmatite).

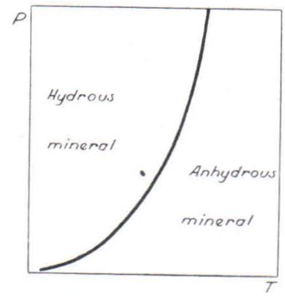

Fig. 9. The curve of the vapour pressure of a hydrous phase as the limit between the stability fields of the hydrous and the anhydrous phase.

pressures between the two above-mentioned ones. It is, however, possible that the magmas of the micadiorite suite have also originally been richer in water than the mother magmas of the other suites.

In the metamorphic rocks the conditions are more complicated, depending partly on the material, which varies from igneous rocks poor in water to clays rich in water, partly on the metamorphism itself, which can either increase on decrease the water content. It is possible that similar materials with different water content can under different conditions during the metamorphism give similar mineral parageneses and in similar conditions give different parageneses. Therefore the mineral paragenesis alone does not give an unmistakable image of the metamorphism and it is possible that we must draw different ACF-diagrams for water-rich and water-poor rocks in the same mineral facies, just as we have different diagram for rocks with K_2O in excess and rocks with Al_2O_3 in excess in the amphibolite facies (1 p. 352). Eskola has himself expressed similar opinions: »— es wurde nicht danach gestrebt, ähnliche Analysen zu finden was jedoch von der Prozentzahl des Wassers abgesehen, möglich gewesen wäre.» (1 p. 345) and »— es können zwei Kombinationen PT und P_1T_1 zum gleichen Mineralbestand führen, obwohl weder P gleich P_1 noch T gleich$_1$ ist.» (1 p. 341). On the vapour curve of a hydrous mineral the same equilibrium occurs at different points.

There still remain many questions which perhaps are connected with changes in the water content, for instance the formation of garnets, the differentiation of alkaline rocks, and others and I hope that this little paper in spite of its shortness may have given some contribution to our knowledge of the geochemistry of hydrogen and of the influence of water on the mineral parageneses.

I wish here to express my sincere thanks to Professor Walter Wahl for his kindly criticism.

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7.

LATE-GLACIAL DEVELOPMENT OF SHORE-LINES IN SOUTHERN KAINUU AND NORTHERN KARELIA

BY

K. VIRKKALA

CONTENTS

FOREWORD

The material of this paper has been collected during the carrying out of revision investigations for an explanation book to the map of superficial deposits of Nurmes. A more exact report of the late-glacial development of the area proved necessary because in the explanation only a short summary can be presented.

The field works were begun in the summer of 1939 under the direction of Dr. S. Kilpi, and the author took part in the mapping work as his assistant. Dr. Kilpi met the death of a hero during the battles of East-Karelia in the summer of 1941, and thas the continuation of the work was left to the author. During the summer 1946 I carried out the field investigations necessary for the explanation of the map.

Besides the author, who has performed the greatest part of the field works for the investigation J. Mattila, M. A., who already in the summer of 1938 made investigations in the N part of Kuhmo parish, and R. Kanerva, M. A., who during the summers 1945 and 1946 carried out investigations on the watercourse of Hyrynsalmi have taken part in these revision investigations. Dr. S. Kilpi and V. Okko, M. A. took part in the revision investigations in the summer of 1939.

The State Geologist of the Geological Survey, Dr. E. Hyyppä, has directed and instructed my work, Dr. K. Mölder has checked some of my diatom analyses. Ester Uussaari, M. A. has performed the pollen analyses needed in the investigation.

This paper has been translated into English by Mrs. Helvi Vasara, M. A., and the drawings have been prepared by Mrs. Lyyli Orasmaa, Miss Thyra Åberg, and Miss Karin Dahl.

To all persons mentioned above I owe my most profound thanks.

INTRODUCTION

I pass over here the earlier investigations relating to the area of the map of Nurmes and refer to a publication by Kilpi (1937), in which there is a detailed account of the N part of the area. The changes of level in the S part have been treated by Sauramo (1928).

In the summer of 1928 when carrying out investigations with Dr. Kilpi in the neighboorhood of the Kuhmo watercourse, we observed that the opinion put forth by Kilpi 1937 as to the changes of level in the region requires controlling, because on the area are to be observed marks of water-levels, which are on a remarkably higher niveau than was supposed by Kilpi in 1937. We now paid attention especially to the levelled esker plains, which in places were 30—40 m. higher than the highest shores of Kilpi. Dr. Kilpi intended to revise this earlier opinion, but this was prevented by his death. When I now put forth the changes of level in the region in the light of the newest investigations, I do this in the first place as a duty towards the unfinished work of Dr. Kilpi.

The elevation measurements of shore-marks is performed mainly with the aid of the barometer of Paulin. I have here been contented with a less exact manner of performing elevation analyses, than generally used in investigations of this kind, because I had to gain time and to adapt myself to scarcity of labour, but chiefly, because in connection with the mappings during the war years plenty of new elevation fixed points were defined in the region. Besides, I have used only observations, the beginning and end points of which I have been able to check by fixed point. The observations by Kilpi show further, that owing to shore-features the elevations of the ancient sea-levels are so difficult to define exactly even by levelling, that these changes of elevations are contained within in the error limits of the barometer measurements.

Seeing that very numerous water-level marks of various kinds have been determined in the region, is in the following presented only the most important observations, paying at the same time attention in the first place to the highest shore-features. The numbers indicate Figs. 1 and 2, of which the geographical location, elevation, observer, nature of the shore-feature, and the manner of measuring of elevation of the observation at the same time be put forth.

SHORE-MARKS

THE NEIGHBOURHOOD OF LAKE PIELISJÄRVI

2) On the N slope of *Laklavaara* wooded hill there is an indistinct abrasion cliff, and a shore-plain beneath it 192 m. above sea-level. In fine sand is met a scarce flora of diatoms, in which, besides the predominant *Pinnularia-*, *Melosira-*, *Navicula*-flora, some specimens of marine *Coscinodiscus* and *Pyxidicula mediterranea* diatoms are met with. As lower shore-features near to Laklavaara farm a shore-plain at 182 m. and at the W side of the wooded hill a washing-limit at 180—182 m. above sea-level are to be seen.

3) The till of the *Kivivaara* wooded hill, 256 m. high, seems to be washed up to the top, the stones seem to be washed pure and loose from the ground. On the NE edge there is shore-cliff corroded into the rock at 248—249 m. and shore-plain at 248 m. The beach-sand is a typical sorted and washed deposit, which at places on the slope of the wooded hill comes forth concreted to form hard ortstein.

21) In the valley of River *Viekinjoki* unbroken shore-plains continue from an elevation of about 185 m. up to level of Lake Pielisjärvi at 94 m. above sea-level. The largest shore-plains are located at the following elevations: 135, 157, 162, 168, 170, 183, and 185—186 m. At many places shore-plains are situated on the top of drumlins, because of which fact they have by mistake been marked as eskers on the map of deposits.

26) The top of *Siltavaara* wooded hill, situated at 245.5 m., is covered by indistinct and weakly sorted shore-deposits. Lower on the slope of wooded hill, at elevation of 224 m., there runs a distinct shore-cliff; on the shore-plain extending before same a wooded hill settlement typical for Karelia is located.

79) At *Heinävaara* wooded hill is met water-level marks at the following elevations: washed rock 246 m., shore-cliffs and -plains: at 219—220 m., 226—227 m., and 233 m.

86) At *Pertunvaara* wooded hill the washing-limit according to Sauramo (1928) is at 149 m. From the same wooded hill is determined a higher, very distinct washing-limit, accentuated by boulder rim stones at about 172 m., but this wooded hill is clearly washed up to the top (about 192—194 m.).

THE WATERSHED OF SUOMENSELKÄ

121) *Naulavaara.* On the sides of the path leading from Lammasmäki farm to Peltoaho field shore-deposit reach at least up to the elevation of 270 m. A very distinct shore-cliff, the shore-plain of which has in part part become boggy, is situated along the same path at 264 m. above sea-level. About 20 m. below this cliff is in some places met with partly distinctly varved clay and silt in a layer 60 cm. thick, the pollen analyses performed on which gave the following results: *Alnus* 66 per cent, *Betula* 26 per cent, *Pinus* 8 per cent. In the sediment is found following diatoms:

	Depth 20 cm.	40 cm.	60 cm.
Coscinodiscus spp.	—	1	3
Eunotia spp.	10	—	1
Grammatophora arcuatum	—	—	2
» *marina*	—	2	3
» *oceanica*	—	4	4
Hantzschia amphioxys	5	—	1
Melosira distans	—	—	2
» *islandica ssp. helvetica*	—	2	10
Pinnularia spp.	10	5	2

On the side of the path leading from the highway to Ahola farm there is a very distinct shore-cliff at 256 m. Below the cliff there extends a shoıe-plain many hundreds meters in extent.

Even above these shore-features there indistinct marks of activity of water-level are possibly still to be met with. As the very highest of the last-mentioned a couple of indistinct abrasion cliffs nearly on top of the wooded hill at 339 and 335 m. may be mentioned.

116) *Heitonvaara.* At Heitto farm there is a shore-plain about 100 m. broad at 268 m. above sea-level. Higher on the slope of the wooded hill at 289 m., under a layer of peat, is a thin layer of beach-sand.

52) The esker running in a northerly direction from *Lake Petäisjärvi* at many places into vast flat sand-stone plains at elevations: 226, 230, and 236—241 meters above sea-level. The heights of the plains vary irregulary in different parts of the esker, and so they cannot possibly have been formed on the level of the highest water-level.

41) On the esker running between *Lake Petäisjärvi* and *Lake Pusulanjärvi* there is an unbroken series of levelled sandy or stony plains at a height of between 185 and 200 meters. On the *Kapionvaara* wooded hill, situated in the neighbourhood of the esker, shore-deposits in a layer over 1 m. thick have been met with at the elevation of 226 m.

35) The esker running to SE of *Lake Mujejärvi* levels itself into vast sand-moors, which can continue for several kilometers. Plains is here

determined at the following elevations: 219—220, 226—227, 229—230, 235, 237, and 240 m. above sea-level. The plain at 230 m. is the most vast and most distinct. At the elevation of 220 m. a very distinct abrasion cliff is to be met with, too, and at the foot of it spreads a vast and flat shore-plain, which in places forms the top of the esker. The plains in question thus evidently do not represent actual melt-water deltas formed on the highest water-level, but are parts of the esker levelled at different elevations by shore agencie.

18) From the W slope of *Losovaara* wooded hill is determined a distinct washing-limit at about 244 m. above sea-level.

13) The esker running from *Lakes Kiekinjärvi* past *Katajavaara* wooded hill spreads itself on the S side of the hill into vast, quite level sand-moors at elevations of 244 and 237 m. The last-mentioned sand-moor is connected with the former one by means of a beautiful shore-cliff, 7 m. high, and the lower plateau appears to be its shore-plain. On the N side of the wooded hill there are indistinct plains at elevations of 222, 235, 246, and 255 m. The highest summit of the esker reach 260 m. above sea-level. On the slopes of Katajavaara wooded hill a very-developed washing-limit runs at the elevation of 260—265 m., and from the lower part of this the esker derives its origin. Because the till on the top of the wooded hill seems to be wholly unwashed, the thought is near at hand, that the washing-limit mentioned above represents one of the highest, if not the very highest, marks of water-level in the neighbourhood.

THE WATERCOURSE OF SOTKAMO

47) At *Kokkolanvaara* wooded hill I have taken the level of a distinct washing-limit at the elevation of 208.8 m. although, because of the forms of the bedrock, it can only be followed for a short distance, while on the N slope of the wooded hill is found a rather distinct abrasion cliff, and below it a shore-plain corroded into the till at 253 m. The 270 m. high *Louhirinne* with its gentle slopes is very strongly washed up to the top.

27) Kilpi (1937, p. 42) has taken the level of a washing-limit on *Polvelanvaara* wooded hill, to be about 199—200 m. On the 211 m. high top of the hill the wooded hill settlement is situated on a shore-deposit, which in a highway section forms a shore-bar at 210—211 m. above sea-level.

25) On the slope of *Venäjänvaara* wooded hill there is a weak abrasion cliff at the elevation of 261 m. On the S side of the same wooded hill a beautiful shore-cliff is situated, with a shore-plain extending below it at 247 m.

33) Esker chain *Kälkkäjärvi—Lammasjärvi*. The highest point of the esker is on the S shore of Lake Kälkkäjärvi, where it forms a slight plain at the elevation of 213 m, and below it are a couple of indistinct shore-

cliffs at 194 and 204 m. When going northwards the esker descends little by little, until on the N shore of Lake Lutjanjärvi it rises again into a slight plain at the elevation of 193 m. About 1 km. more to N from there vast, quite flat plains begin, and those continue unbroken for 4—5 km., at first at a height of 203—204, then 193—194, and at last indistinctly at 185 m. As the plains situated at different elevations also in this esker chain show, there cannot be any question of glacio-fluvial deltas formed at the highest water-level, but they must be esker tops levelled by shore powers during the regression of the water-level.

63) On the SW slope of *Kuohuvaara* wooded hill Mattila (datebook in the Geological Survey) has taken the level of a distinct shore stone heap at 240—243 m.

50) Beside the path leading to *Hotakanvaara* wooded hill there are slight abrasion cliffs at 237 and 240 m above sea-level.

44) *Jyrkänvaara* wooded hill, 258 m. high, is distinctly washed up to the top. On the gently sloping SE side the exposed rocks of vast extent end somewhat abruptly at the elevation of 256 m. On the steeper SW slope they attain a height of about 248 m.

77) On *Vepsänharju* the slight esker plains or equally high running esker ridges continue for several kilometers with relatively small height differences. The activity of the water-level has been felt most distinctly at the following elevations: 239—240, 243, and 231 m. On *Alanteenvaara* wooded hill there is a strongly developed washing-limit at 220 m.

130) The highest washing-limit of *Pöllyvaara* wooded hill, *Vuokatti*, has been determined by Kilpi (1937, p. 27) at about 198 m. Alongside the path, rising from the side of Sapsojärvi, up the hill there is a distinct boulder rim at 211 m. The highest shore-marks are at the elevation of about 265—266 m., and here extends a slight shore-plain, the material of which is weakly sorted fine sand. From this elevation upwards exposed steep rocks begin, and the top of the wooded hill itself shows an entire lack of any cover of loose deposits.

In the list above is in first place paid attention to the highest water-level marks met with in the region, because they above all throw new light on the changes of level in Kainuu and the neighbouring Karelia. At the same time I have restricted myself to the most distinct and convincing cases.

As a summary of the shore-marks in the map of Nurmes may be mentioned, that they are here met with everywhere and at every elevation, except possibly on some highest summits of wooded hills. Mostly the marks of water-level, however, are rather weak: partly sorting and washing of till, and as a consequence of this, exposure of the biggest stones on the surface of the soil. Because of this they have been neglected by earlier investigators. There are, however, also so many convincing marks of water-level, as is evident from the about, that there can be no misgivings with regard to the extension of the activity of shore agencies over the whole region.

The wooded hill settlement previously explained as supra-aquatic thus receives an other significance. The wooded hill settlement by no means manifests any lacking of water-level, but rather the reverse. The till characteristic of the wooded hills is more often weakly sorted, or it has turned into a shore-deposit. Even the abundant appearance of stones on top of the wooded hills gives evidence, on the contrary, for the activity of the water-level, and not for any lack of it. Water has partly washed the till material away from between the stones, and it appears on lower niveaux as distinctly sorted shore-deposits. Only the biggest stones and boulders, most difficult to move, have been left over, and thus these are so to say washed clear of finer material (Kivinen 1941).

SHORE-DIAGRAM

In order to illustrate the shore-marks mentioned above and determined elsewhere I have in Fig. 1 represented my material graphically as a diagram, whence at the same time the elevation and the nature of the shore-marks are to be seen. The numbers in the shore-diagram indicate the map of the region investigated, Fig. 2, from which also the geographical location, the observer, and the way of performing the measurement are apparent.

In drawing up the shore-diagram is followed the practice used by Kilpi (1937). For an index-level I have taken the shore-level of Kilpi Y I, which according to the observations of Kilpi and myself is the most distinct one and in many cases is the most strongly developed mark of water-level, at least in the middle and the northern parts of the region. The isobases of this shore-level have been drawn on the map Fig. 2. In the diagram I have in addition drawn some watershed thresholds from the eastern boundary regions. 1 thus means the threshold between Lake Hämejärvi and Lake Kivijärvi, 2 = the threshold on the N side of Lake Viiksimojärvi, 3 = the threshold of Lake Kaitakiekki, and 4 = the threshold of Lake Hukkajärvi and Lake Kuusijärvi in SE Kuhmo.

As is apparent from the diagram, shore observations have been made and convincing water-level marks met up to a hundred meters higher than shown in the earlier investigations. The shore-marks explained by Kilpi as highest shores are thus actually lower, although very strongly developed water-level marks.

Contrary to the relation diagram by Kilpi, the shore observations here are by far not so beautifully situated on the same lines. This is not due solely to more inaccurately performed elevation measurements, but rather to the greater amount of observation material. The lower observations

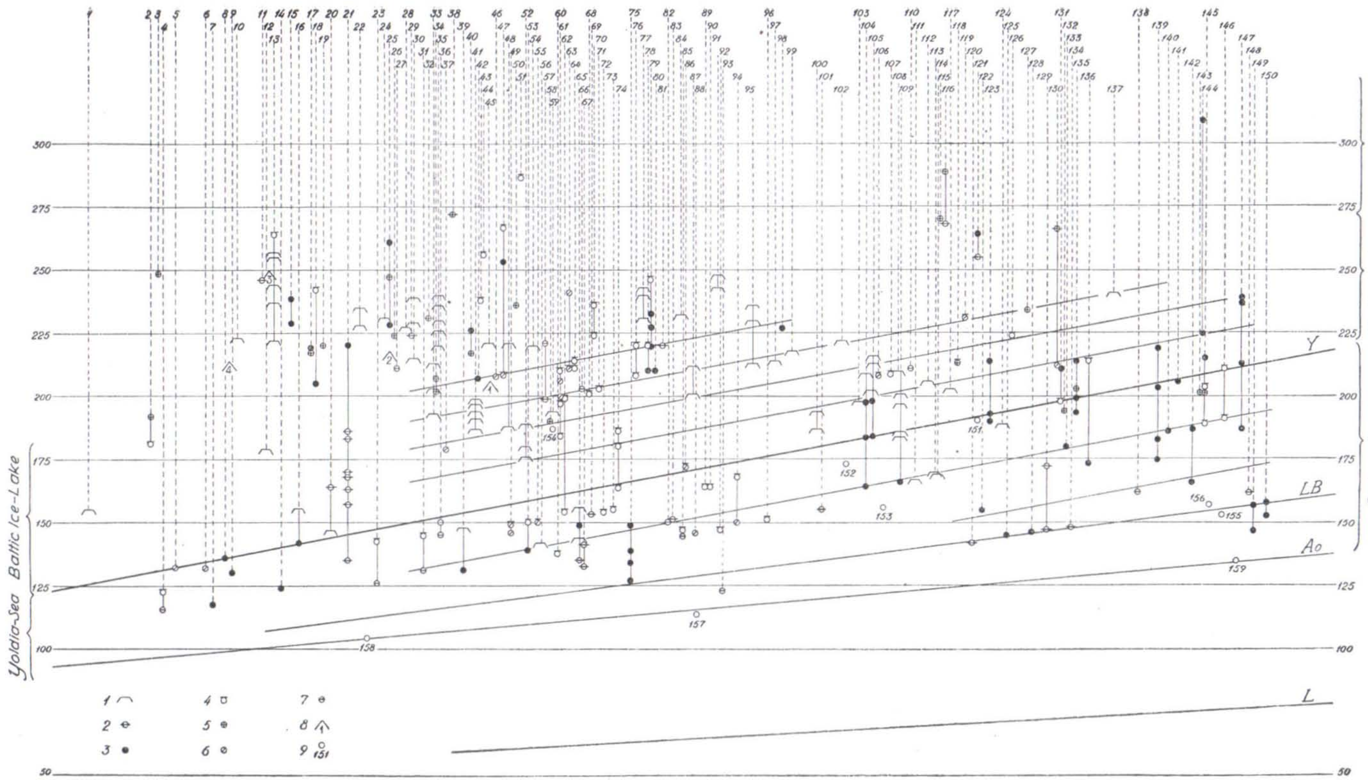

Fig. 1. Shore-diagram and shore observations in the region. 1. Esker plain, 2. Other shore-plains, 3. Shore-bank, 4. Washing-limit, 5. Shore-deposits, 6. Shore-rim, 7. Shore-wall, 8. Watershed threshold, 9. Peat bog profile.

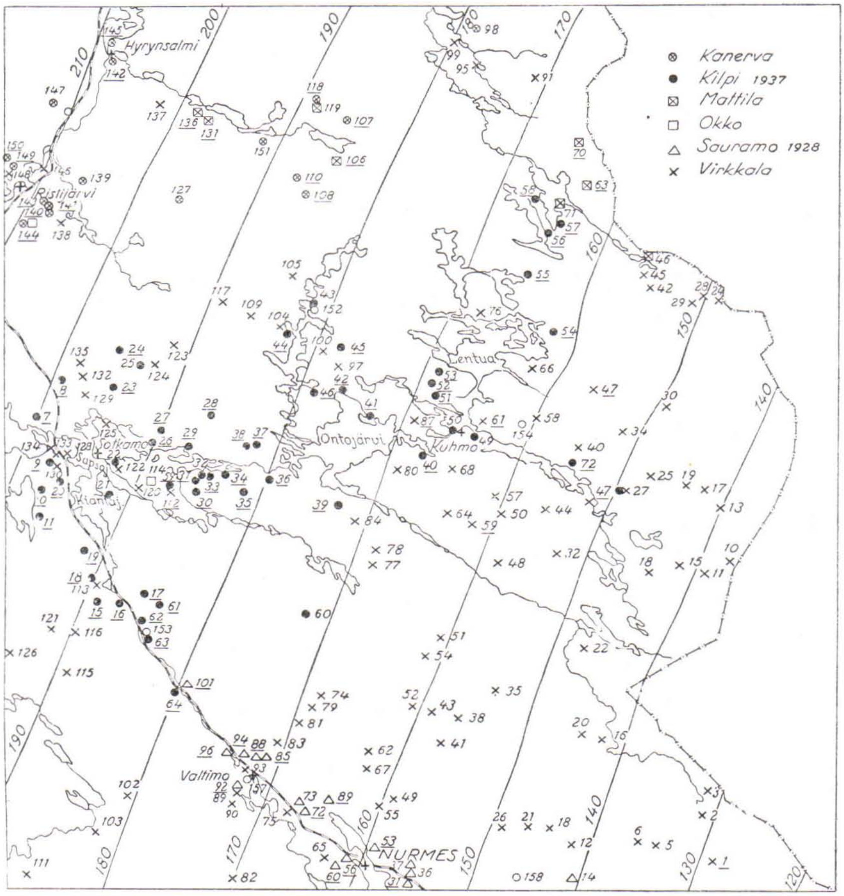

Fig. 2. Shore observation points and the isobases of the index-level. Observations of various investigators represented by different marks. The numbers of observations by Kilpi refer to Kilpi 1937, p. 46; others to Fig. 1. The underlined observations are levelled from fixed points, the others are barometer observations. White circles, investigated profiles of peat bogs.

seem generally to be situated more on the same straight lines than are the upper ones. This may be at least partly caused by the fact, that they in generally are better and sharper developed, and that it has been possible to make their elevation measurements with greater accuracy. Among the higher shore-marks, on the other hand concentration to given niveaux is not easy to observe, if this can be done at all. Vertically the activity of the water-level seems to have been approximately similar for several tens meters. This can be explained only by the assumption, that the land upheavel during formation of the oldest shore-marks met with on the region has occured under regular regression. Not until later, during the latter half of the Late-Glacial, did such uplift take place in more distinct jerks. Now delay or stopping may have occured in the regression, and then more and more distinct marks of water-level, have been formed on given niveaux, than on the vertical zones between them. Inclination in land upheavel is not to be observed until during the very last stage of the Late-Glacial in the region.

Water-level marks called esker plains are very abundant at all elevations, and they do not appear to have been formed at the level of the highest water-level. Evidently they are to be understood as shore-plains spread by surges of sea, which, when situated in favourable exposition and in a deposit easy to corrode, can attain very remarkable proportions. From the above is evident, too, that their levelled tops cannot be explained as fluvio-glacial deltas formed in front of the glacier.

When comparing some watershed elevations on the shore-diagram with shore-marks observed at the same places, one can easily ascertain, that the shore-surfaces corresponding to the highest water-level marks extend over the watershed into the watercourse flowing to the White Sea. Already the highest shore-level by Kilpi has also extended somewhat over the watershed between Lake Hämejärvi and Lake Kivijärvi. Also above the higher situated watershed thresholds, for instance the threshold of Kaitakiekki at about 250 m., shore-levels corresponding to the highest shore observations extend for at least some 10—15 m. On the Suomenselkä watershed, situated in the region investigated, only some tops of wooded hills attain the elevation curve of 300 m; this means, that there has been in fact no dry land in the whole watershed area during the early stage of the Late-Glacial, while the White Sea has as an extensive and vast sea reached to the Sotkamo watercourse. This, however, that the elevation relation extend on both sides of the watershed approximately alike. During the earliest period broken ice sheet and floating icebergs disturbed this connection. A similar late-glacial connection between the Baltic basin and the White Sea has been verified by Hyyppä (1943) and Mölder (1944) in the southern part of East-Karelia (Karelian Ice Sea of Hyyppä), and Cleve-Euler (1942), too, is convinced of the existence of such a sea-contact.

On the left and right edge of the shore-diagram is drawn the height zones by Sauramo (1947) and Hyyppä (1943). The connection of my shore-diagram to the greater relation diagram covering stages of the Baltic has been performed by making use of the nearest Littorina shore observation in the valley of River Oulujoki. According to Okko (1946) the Littorina shore is in Utajärvi 93—94 m. By extrapolating from here at right angles against the isobases and taking for the inclination of the shore-level 20 cm./km., we get for the value of L I in Sotkamo church village 71 m. and in Kuhmo 62 m. above sea-level.

PEAT BOG INVESTIGATIONS

For the chronological division of the shore-diagram put forth above I have investigated several peat bog profiles in the region, some of which profiles have been presented in Figs. 3—7. For the sake of completeness is in addition taken a couple of profiles, Figs. 8 and 9 from the publication of Kilpi (1937). In the explanation of the marks used I refer to the publication by Kilpi mentioned above, page 63; in the same way the diatom tables of the bogs investigated by him are found in the publication of Kilpi. My own diatom investigation is combined with a number series in the pollen diagram. In connection herewith the explanations of the letters are as follows: Sz = marine diatoms, S = fresh water diatoms, E = epiphytes, Pl = plancton, Kl = small lake forms. The percentage of each ecological group has been counted to the whole of the diatom flora. By presenting the diatom investigations in this manner I have been able to put them forth in clearer form than as long tables difficult to read.

Because the elevation relations of the region make it evident, that the youngest stages of the Baltic have no longer reached into the region, only the lower parts of the diagrams are interesting in this connection, and it is easy to connect same with the general course of the pollen diagram. The Ancylus period is in all diagrams indisputably clear. It is in the first place characterized by the distinct maximum of the pine, and a corresponding cut, or at least reduction in the fields of alder and noble leaf trees. That part of the Late-Glacial, which comes next to the Ancylus and is earlier than that, is typically a time of leaf trees, in the first place of birch. In many diagrams, however, a culmination of pine comes forth more or less clearly in the upper part of this field of birch (Figs. 4, 5, 7, and 9), and this is everywhere so alike, that it evidently is of the same age in all parts of the region. To this late-glacial maximum of pine corresponds also a remarkable rise in the curve of spruce, the late-glacial appearance of which is limited to downwards from the younger late-glacial maximum of birch between the Ancylus and the Late-Glacial. This happens independent of whether peat has been formed during the last stages of Late-Glacial, as in Fig. 4, or if accumulation of the clayey sediment has been going on also during Post-Glacial. In this connection the main question in fact is not, that whether the late-glacial appearance of spruce on the region is of secondary or of primary nature; in all cases it seems to be certain, that its appearance in the pollen diagrams has throughout the whole region come to an end at the same time.

From Figs. 6 and 7, and from the diatom table annexed to Fig. 8 (Kilpi 1937, pp. 93—96) it is evident, that nearly all the peat bogs in question have been isolated from the late-glacial sea at the same time. The isolating shows itself, besides as a limit of sediments, in the first place as the ending of the marine forms in the diatom flora and also in a strong rise of the small lake forms. In pollen diagrams this place corresponds to the time, which falls fairly exactly between the Late-Glacial and the Ancylus. By the threshold elevations of the bog basins in question is drawn the next to lowest shore-level of the shore-diagram Ao (Fig. 1) to represent the elevation of the water-level of the Baltic basin corresponding to the beginning of the Ancylus in the region.

In the diagrams Figs. 6 and 7 is shown, how the share of the marine diatoms broadly speaking diminishes evenly from the bottom upwards. This is especially clear in the diagram Fig. 6 throwing at the same time light on the diminishing influence of the sea towards the end of the Late-Glacial. This evidently means, that the sounds, through which the area was connected with the Baltic, little became ever narrower and more strait. This fact is to be observed also in the sediments of the profiles of Egyptinkorpi and Haapakylä. At the bottom in both places there is fairly homogeneous or only very indistinctly varved clay, which upwards, gradually becomes more clearly varved, until there is an abrupt limit to the homogeneous clay around the isolating contact.

The diagrams of Egyptinkorpi and Haapakylä show further that during the time corresponding to the younger late-glacial maximum of birch the sea-level has been higher than the thresholds of the peat bogs in question; how much, it is difficult to say, because in the southern part of the region no bogs from this elevation have been investigated. From the Alasenjärvi diagram of Kilpi (Fig. 9) it is evident, that the marine influence during this time has remained lower than about 156 m., the elevation of the index-level being about 185 m. (Kilpi 1937, pp. 74—79). In the same way the bog situated on the boundary between Ristijärvi and Hyrynsalmi parishes (Fig. 3) shows, that the sea during the time corresponding to the younger late-glacial maximum of birch has reached up at least to the elevation of 153 m., the elevation of the index-level being at the bog about 210 m. According to Kanerva (oral information) the time corresponding to the same maximum of birch can be ascertained in Hyrynsalmi, in isolated small lake ooze at the elevation of about 156 m., which means that the position of the sea-level of that time was between 153 and 156 m. On the ground of observations above is drawn in the shore-diagram the shore-level LB to correspond to the younger late-glacial maximum of birch.

When passing over to the higher isohypses, the determination of zones from the pollen diagrams corresponding to different shore-levels becomes more uncertain. The regression of the sea-level has in addition apparently been so rapid, that the typical features in pollen diagrams do not always come into light in pollen analyses performed at vertical intervals of 10 cm. The profile of Kokkosuo peat bog taken somewhat from below the elevation of the index-level (Fig. 4), however, throws some light on this. The forest-historical zones corresponding to the different stages of the Baltic are remarkably clear in the Kokkosuo bog. The younger late-glacial maximum of birch exist in peat and coarse detritus ooze, according to which the position of the sea-level corresponding to this time remains below the threshold of the bog, 190 m. In the lower part of the clay forming the

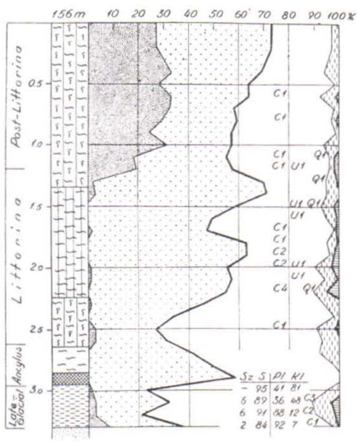

Fig. 3. Profile, pollen diagram, and results of diatom investigations of a peat bog situated on the border line between Ristijärvi and Hyrynsalmi parishes. In Figs. 1 and 2 number 155.

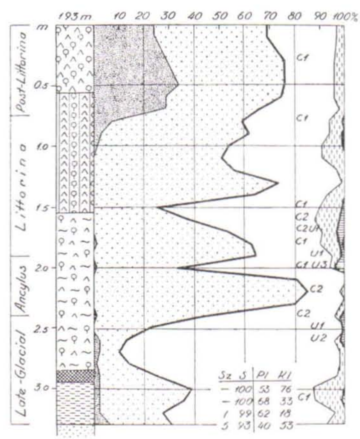

Fig. 4. Profile, pollen diagram and results of diatom investigations of Kokkosuo peat bog. In Figs. 1 and 2 number 151.

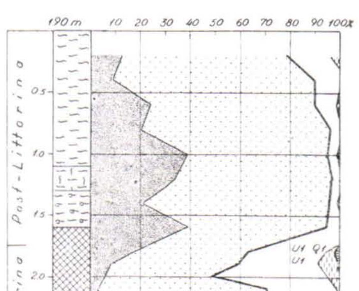

Fig. 5. Profile and pollen diagram of Sammakkolampi peat bog. In Figs. 1 and 2 number 154.

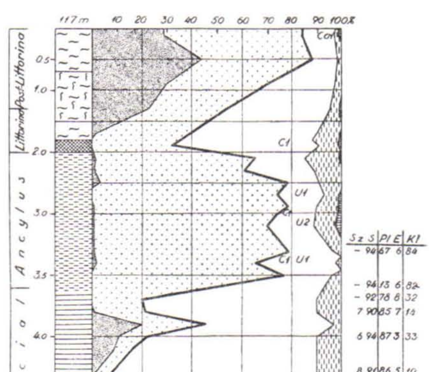

Fig. 6. Profile, pollen diagram and results of diatom investigations of Haapakylänsuo peat bog. In Figs. 1 and 2 number 157.

bottom of the bog, the marine influence in the diatom flora is rather distinctly felt, but this is not the case in the upper part of the clay. As at the same time the field of pine attains its maximum apparently corresponding to the late-glacial culmination of pine, it seems to be likely, that the lower part of clay is roughly speaking of the same age as the formation of the index-level. Fig. 9 further supports this opinion, because in it the same maximum of pine is situated in a sediment, which, according to the diatoms, is under marine influence (Kilpi 1937, pp. 74—79) while the position of the sea-level corresponding to it is higher than the threshold of the bog 156 m. Further, the profile of Sammakkolampi (Fig. 5) confirms the opinion mentioned above, though this profile cannot be determined as to age as distinctly and indisputably as the earlier ones. The age of this profile may, however, mainly on the ground of the occurrence of lateglacial spruce, be such as represented in the figure. The late-glacial maximum of pine is in the Sammakkolampi profile located in clearly isolated ooze. The corresponding sea-level, too, has been lower than the threshold of the bog situated about 25—30 m. above index-level.

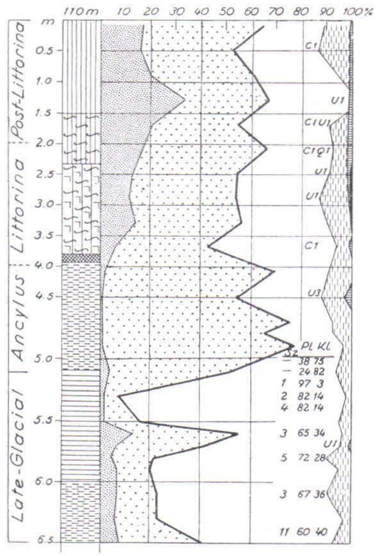

Fig. 7. Profile, pollen diagram and results of diatom investigations of Peiponsuo peat bog, Egyptinkorpi. In Figs. 1 and 2 number 158.

When passing over to higher niveaux it is no longer possible to determine even with this accuracy any ages of different elevation zones and shorelevels. The lack of peat and sediments of this period makes it still more difficult. Numerous peat bog profiles not published here show, that peatformation in the region has in general not begun earlier than during the last stage of Late-Glacial, independent of the elevation at which the bogs are situated nowadays. As in addition sediments as a rule are absent from their bottom parts, it is difficult to get a reliable picture of the oldest late-glacial stages. The instance of the marine clay occurence situated on the slope of Naulavaara wooded hill, mentioned above p. 62, shows, however, that also from the oldest late-glacial stages deposits exist, although they are very scarce. In the pollen analysis performed on the Naulavaara clay, attention is in the first place drawn to its high content of alder, which cannot be of recent origin, as alder in the region nowadays appears very rarely. This gives proof, I think, of an alder vegetation having been in the neighbourhood of the late-glacial shore-line.

The shore-diagram shows, that the highest shore-marks, at least those located upwards from the Hämejärvi watershed threshold, *i. e.* situated more than 50 m. above the index-level marked Y I, have been formed as results of an activity of the shore-powers of the sea. The marine deposits of Naulavaara and Laklavaara, which are situated just above this niveau, and the continuing of the shore-levels over the watershed thresholds when going towards the White Sea provide indisputable proof thereof. The bog profiles show, too, that the marks of shore-level below the index-level are marine up to the shore-level Ao, until which time also the places situated on lower isohypses were already isolated from contact with the water-level of the Baltic basin. On the other hand, there is a height zone about 50 m. broad above the index-level, concerning which it is not so easy to get direct knowledge. The peat bog profiles from this area are younger, than what they might be in view of their elevation, and thus they do not contain any sediments illustrating this case. Thus there arises a question, as to the nature of the water covering this area that time, when the lowest known eastern watershed thresholds by Hämejärvi had been left dry because of the land upheavel. Was there still at that time some sea contact to the area via some other place, or was the hydrography of the region connected with the Baltic Ice Lake, the existance of which

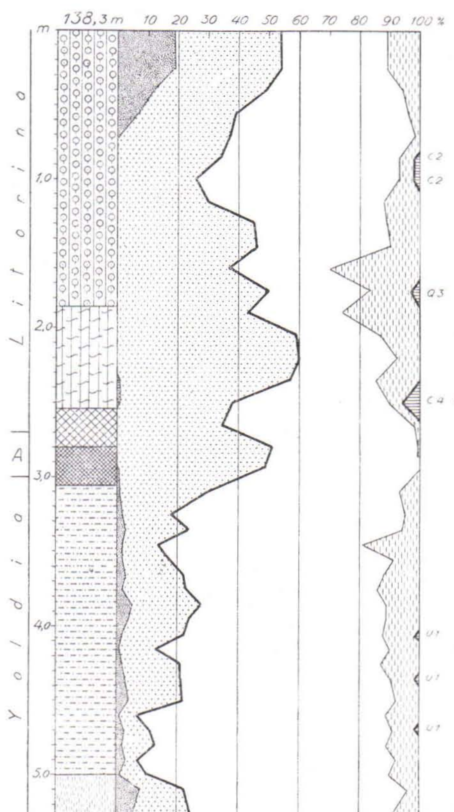

Fig. 8. Profile and pollen diagram of Takkasuo peat bog (Kilpi 1937). In Fig. 1 number 159.

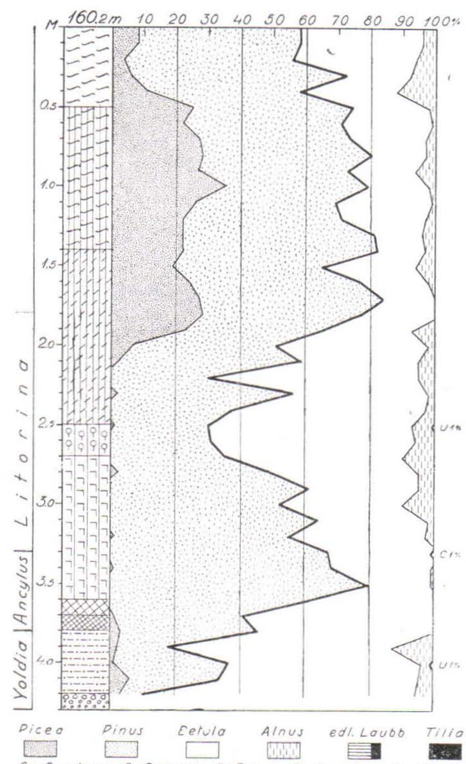

Fig. 9. Profile and pollen diagram of Alasenjärvensuo peat bog. (Kilpi 1937). In Figs. 1 and 2 number 153.

in the Baltic basin during the early lateglacial time has been explained by many investigators (*f. i.* Sauramo 1937, Munthe 1940)? In the first place there is a possibility, that there could have been sea contact eastwards through some other threshold than that of Hämejärvi, which is nowadays known to be the lowest one. In Northern Karelia the finding of such a threshold is very improbable, because the values of the isobases fall rather steeply when going this direction, while the actual elevation of the land grows. In Northern Kainuu, on the other hand, threshold situated at lower elevations might exist, the heights of which, howerer, have not been investigated more in detail. Only in NW and in SW through the watercourses of Sotkamo and Pielisjärvi the region has thus at that time been connected with a larger water-cover.

Up to the present day it has not been possible to ascertain with any certainty the nature of this water-cover of the Baltic basin in the region. In the numerous peat bogs situated at this elevation and investigated by Kilpi and the author, no trace of marine diatoms has been observed. It is therefore evident, that the water of the Baltic basin has been in Kainuu fresh during the time corresponding to the zone 50 m. above the shore-level Y I. Above and below this zone, on the other hand, marine diatoms have been met with.

THE DIATOM FLORA OF ESKERS AND OF TILL

Besides in clays and silts of fine texture the influence of the late-glacial sea is felt also in the fluvio-glacial accumulations of the region. In connection with several esker chains there exist fine sandy sediments, which can in places contain a fairly strong marine diatom flora. Such is found *i. a.* in esker chains running through Sotkamo and Kuhmo church villages, in many eskers in the neighbourhood of Nurmes, and in the fluvio-glacial series in the environs of Nurmijärvi and Pielisjärvi. In all places mentioned here the deposits containing marine diatoms have evidently belonged to the primary esker itself, and have not been secondary shore-deposits formed around the eskers. This is shown by their relation to the remaining fluvio-glacial material, the stratigraphy of the formation, where there usually is a topmost layer ½—1 m. thick of beach-sand, and the depth of the place of discovery below the surface of the soil.

As an example of an occurrence of this kind a large sand-pit situated 2 km. E of Sotkamo church, about 150—160 m. above sea-level, may be mentioned, in which the material is rather homogeneous fine sand, but in which, at intervals of about 1 m., thinnish layers richer in silt are found. The stratification order resembles greatly a varved sediment, in which, however, the thickness of the varves is remarkably greater than normal. The sand-pit is situated on the slope of the high fluvio-glacial Pöllyvaara.

A diatom analysis performed on one of these parts richer in silt, about 3—4 m. in depth, has given the following results:

Coscinodiscus sp.	5	per cent
Diploneis Smithi	2	» »
Eunotia sp.	2	» »
Grammatophora marina	12	» »
Grammatophora oceanica	4	» »
Hyalodiscus scoticus	1	» »
Melosira arenaria	1	» »
» *islandica ssp. helvetica*	48	» »
» *sulcata*	7	» »
Pinnularia sp.	6	» »
Rhabdonema arcuatum	7	» »
Stephanodiscus astraea	1	» »
Stephanopyxis turris	4	» »

As is appearent from the list, the marine influence in the diatom flora is rather strong, and apparently corresponds to those earlier sea-stages, when the ocean extended directly from the White Sea into the area of the Sotkamo watercourse. This esker chain cannot have been formed during the Yoldia period, because the ice had already melted away, as shown by the numerous shore observations. As the activity of melt waters at the formation time of eskers was very lively, this means, that there was plenty of ice present in the region. Through numerous crevasses water from the White Sea could, however, flow up at least to the surroundings of Sotkamo.

Also in till one often meets slight fine-textured lenses and layers, which evidently have been formed in cracks and crevasses of the ice, rich in till material, from the material brought along by melt waters. In the parish of Nurmes is at a couple of places found — in such sorted till material — besides a scarce *Melosira-Pinnularia*-flora also the following marine diatoms: *Thalassiosira gravida*, *Rhabdonema arcuatum*, *Grammatophora arcuatum*, and *Gr. marina*. These show that at least in some cases the marine influence has been felt in the region already during formation of the till.

SUMMARY

The shore observations performed show that marks of shore-level are met with throughout the whole region and at all elevations. On higher niveaux they usually are more weakly developed, and do not form distinct shore-surfaces, which fact is an evidence of an evenly continuing regression of the land upheavel in this region. At lower elevations the shore-marks,

on the other hand, are more strongly developed and located on more distinctly shown shore-levels, which may be caused by the jerky nature of the land upheavel (Sauramo 1937). As the parallel shore-levels of the Late-Glacial show, no land inclination had yet occurred at that time. During the very last stage of the Late-Glacial this is, however, already clearly to be seen.

The highest shore-marks and the shore-levels corresponding to them reach much higher than the threshold of the eastern watershed area, and thus show that from there a direct sea-contact to the White Sea has been in existence. During the earlier stages plenty of dead ice has, however, been present in the region to impede this connection. When the lowest threshold, that of Hämejärvi, dried up, this connection was however broken off, and at the same time the Karelian Ice Sea stage (Hyyppä 1943) in the history of the Baltic came to its end.

The stage of fresh water — the Baltic Ice Lake — was the next to follow in this region and during same the land rose about 50 m. After this the region become connected with the Yoldia Sea (Kilpi 1937), but this salt water connection was achieved from the Baltic basin, and not via the White Sea.

COMPARISON WITH THE RELATION DIAGRAMS OF SAURAMO AND HYYPPÄ

The connection with the latest relation diagram of Sauramo on this basis (Sauramo 1947) shows, that the shore-level Rha I of Sauramo with an accuracy of some meters corresponds to my lowest late-glacial shore-level LB. From the pollen analyses of Sauramo it is evident, that in the evolutionary history of the forests Rha I corresponds to the falling upper part of the late-glacial culmination of pine. On the other hand in Kainuu and Northern Karelia it seems to locate itself a little younger, and to be of the same age as the upper late-glacial maximum of birch.

There is a somewhat greater difference between the shore-level Ao — between the Late-Glacial and the Post-Glacial — put forth by me, and that of Rha regression, evidently representing the same age. On higher isobases this difference is neareby some ten meters, on lower ones 4—5 m.

The shore L I extrapolated by me to the region from the valley of River Oulujoki, on the other hand, is in my diagram related to YI with an accuracy of a couple meters as in the relation diagram of Sauramo.

The designation Baltic Ice Sea (Hyyppä 1943) has later been changed by Hyyppä (oral information) to Baltic Ice Lake, which corresponds better also to the conditions met with on the area of Kainuu as verified above.

I have been compelled to lower somewhat the lowest shore-level of the Karelian Ice Sea presented by Hyyppä (1943), because thresholds lower than in Eastern Karelia here have been met with and because, according to Hyyppä (1943), the lowest threshold has determined the extension of the Karelian Ice Sea.

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8.

SOME OBSERVATIONS ON THE TECTONICS IN THE TAMPERE SCHIST AREA

BY

K. J. NEUVONEN AND A. S. I. MATISTO

During the winter 1946—1947 the present authors had to work up in the Geological Survey the field material gathered in the schist area of Tampere. In this work they call attention to the fact that the directions of the lineations have no regularity and that they are inconsistent with the local direction of the Svecofennidic mountain chain. These lineations are seen in map 1 and in the stereographic projection in Fig. 1.

The schist belt of Tampere forms a supercrustal rock zone over 100 km in lenght running from NW Tampere east to Lake Päijänne. In conformity with the general strike of the Svecofennidic rocks in S- and SW-Finland the foliation trends also in this belt east-west. Northwest of the town Tampere the general strike makes a bend to NW and one is able to follow schist formations in this direction about 160 km northwest of Tampere. Farther north, in South-Ostrobotnia, schist belts trending north-south have been met with. This general variation in the direction of the strike, which also appears in long axes of the schist belts, indicates the change of the longitudinal direction of the Svecofennidic mountain chain in this part of Finland. N of Tampere, where the material under consideration has been gathered, the direction of the mountain chain is generally east-west, in the NW part northwest-southeast. Thus one would naturally expect, that this general direction could be seen also in lineations, if the linear structure in the area, according to the common principle, has developed in the direction of the tectonic b-axis. However, in many cases it is here impossible to see any such tendency. On the contrary, the horizontal projections of het measured lineations run in the most varying directions throughout in het region and the pitch is also changing, but generally very steep. This sheer position of the lineations, which is common also at many other places in South Finland, must be contradictory to the longitudinal direction of the mountain chain. We wonder how it can be thought that the longitudinal direction of the Svecofennidic mountain chain could have a pitch of 60—90 degrees from the horizontal position and how the schist belt with a length of a hundred kilometers could be a cut of the mountain chain standing in a steep position.

The character of the rock crust in the Tampere area shows also, that there could not be any question of a disturbed region having many depressions and culminations indicated by the different positions of lineations. The maps published by Sederholm (7) and especially the results of the new

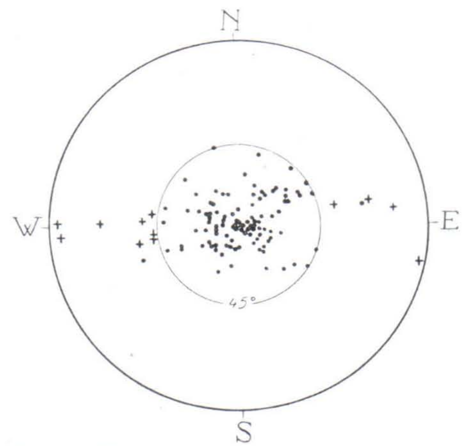


Fig. 1. The axes of the major folds (+) and lineations (•) in stereographic projection.

geological mapping (8), unpublished for the most part, show a great change of the different schist beds across the formation in the north-south direction, and on the other hand, along the strike narrow beds running continuously for scores of kilometers. In a formation like this there naturally cannot occur the sharp variation in the axes, which is met with in the directions of the linear structures.

FOLDING

In the Tampere schist area the folds appear most clearly in the phyllite formation, in which by means of the well developed varved texture the change of the bottom directions of the strata and the existence of the folds is easily observed. The excellent outcrops on the western shore of Lake Näsijärvi show that folding is very common and there the axial directions of the folds can be measured. The axial planes are almost without exception vertical in the direction E-W and only in the minor folds are there axial pitches steeper than 45 degrees. In place of this, in the major folds with dimensions of several tens of meters, the pitch of the axes is regularly between 0 and 40 degrees and generally to the east. Cleavage in the folds parallels the stratification and it does not occur in the direction of the axial plane. The folding evidently thus represents the flexure or true folding according to Billings (1) (Echte Faltung, Cloos). The isoclinal and chevron folds are the most common geometrical forms occurring.

Major folds do not occur in the N part of the region. The abundance of the stratified rocks and the general structure of the area, however, indicate, that also there folding has taken place, mostly in accordance with the same principle as in the phyllites. However, the cleavage, parallel to the axial plane in the minor folds shows, that in this part of the area a folding has occurred also as shear folding (Scherfaltung, Cloos). Foliation and bedding are, however, mostly parallel also in this part of the area.

LINEATION IN THE PHYLLITES

The gentle axes of the major folds in the phyllite formation, referred to above, conform to the local longitudinal direction of the mountain chain. During the summer 1947 the writers made some observations about the relation of lineation to these fold axes. The linear structure is seen in the phyllite on the boundary plane of the different varves quite clearly as a parallel striation which looks like the »Rillung» of Sander on the slickensides. This kind of linear structure was observed to be always at right angles to the direction of the axis of the fold.

This striation had been observed to occur only in the rocks where there is a well developed S-plan parallel to the stratification. There is in question obviously a mechanical trace, made by the lamellar movements connected with the flexure folding. The type of this lineation is similar to the »slippage on bedding» according to H. Cloos and Martin (4), who term this lineation striae.

The directions of the elongated concretions are in conformity with those of the slippage and perpendicular to the folding axes. This fact shows clearly that lamellar differential movements have taken place in the phyllites. The geometrics of the folds show also that the proportional movement of the strata has been great.

LINEATION IN THE VOLCANIC ROCKS

As mentioned above, Fig. 1, the steep position of the linear structure is typical of the whole schist formation and is not limited solely to the phyllites of the S-part of the area. The lineation does not occur, however, in the volcanic rocks as a mechanical trace of the movements as in phyllites, but appears mostly as an elongated direction of the minerals. When in the northern part of the area any major folds have been observed, it is impossible to determine the relation of lineation to a true folding axis. In the basic intercalated beds of phyllites in the southern part, however, the longitudinal directions of the hornblende grains are parallel to the striae measured in the phyllite. In these cases the hornblende is orientated in the direction of the lamellar differential movement and the authors have thought that a similar explanation is feasible also as regards the steep stretching directions in the volcanic rocks of the northern part of the area.

The projections of the lineations must now situate in the stereographic projection in Fig. 1 in a field in the middle of the net, because the lineations are generally at right angles to the measured gentle folding axes and the dip of the stratification is mostly very steep.

Earlier several authors (2, 3, 5, 6, 9) have described stretching parallel to the tectonical movements. Although the stretching of minerals in the Tampere area has developed in the direction of differential movements of the folds, there is, however, a certain similarity with the results of the earlier investigations referred above.

APPLICATION

The lineation in the area is, according to its genesis, in general perpendicular to the b-axes on the planes of bedding. It is, therefore, of great importance. If the strike and dip of the bedding are known it is possible by means of the lineation to construct the direction of b-axes. When the detailed observation material from the Tampere area was at the disposal of the authors they determined, as an experiment, the corresponding axial directions from the measured linear directions. This translation is made by the Wulff net and the result is seen in map 2. The directions of the axes are in this map nearly parallel and they agree with the direction of the schist belt.

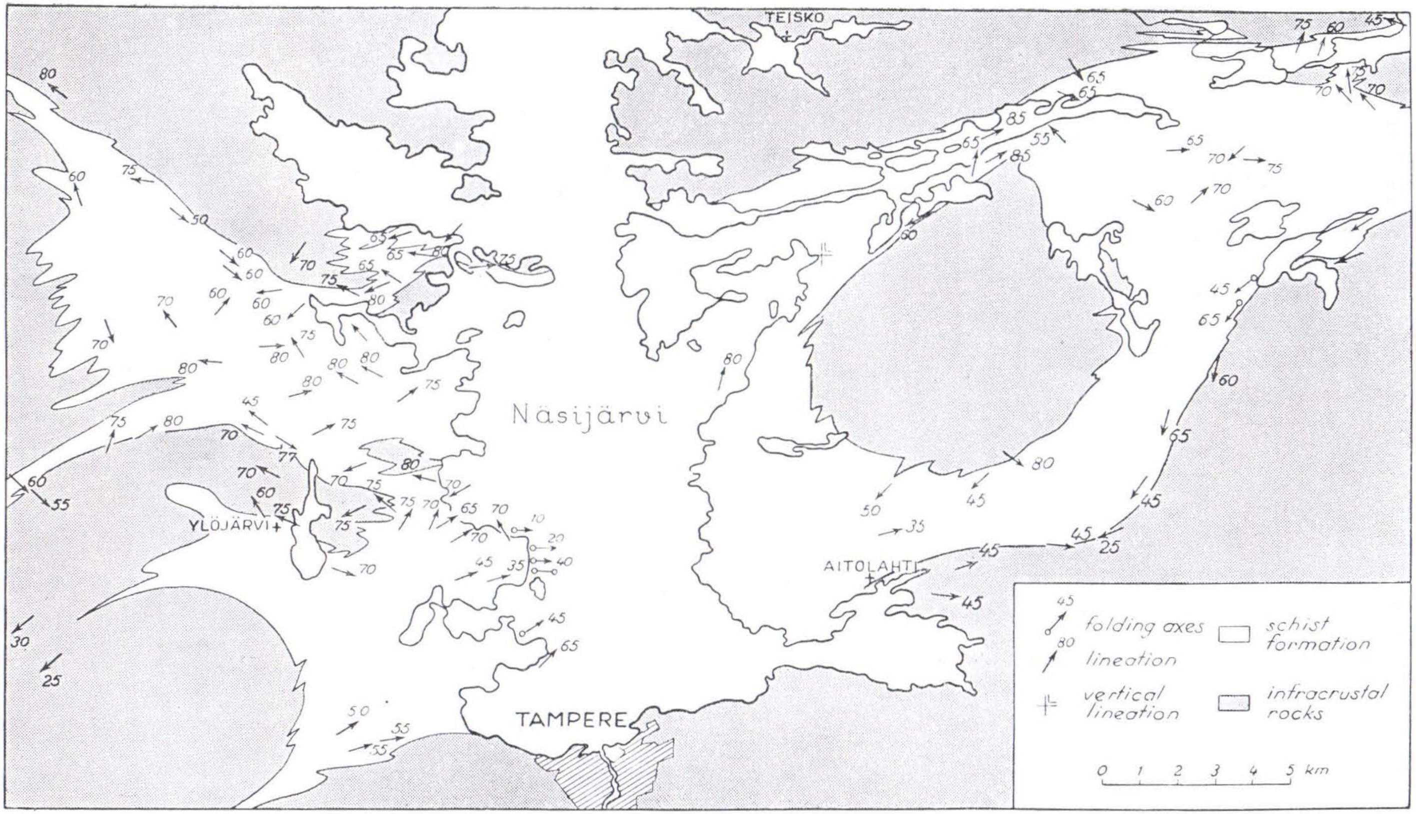
The authors want to point out that there can be some errors in the map because in the field work the possibility of there being different kinds of lineations has not been noticed and, therefore they have perhaps turned directions, which could have been left unturned and vice-versa. However, the reconstructed directions in map 2 give a better insight into the variations of the b-axis than does map 1, as is attested especially by the fact, that the depressions and culminations indicated by the pitches of the axial directions are now situated in places, in which they are to be expected also on the ground of the rock crust. The new directions are in harmony with the local longitude of the mountain chain and the pitches are now intelligibly gentle.

The disagreements of the regularity in these reconstructed directions of the axes are easy to understand. Part of them can be caused by a small undulation in the direction of the b-axis. The occurrence of zones with opposite pitch directions, on the other hand, is in agreement with the true axial observations made in the field and such phenomena are known also in younger formations.

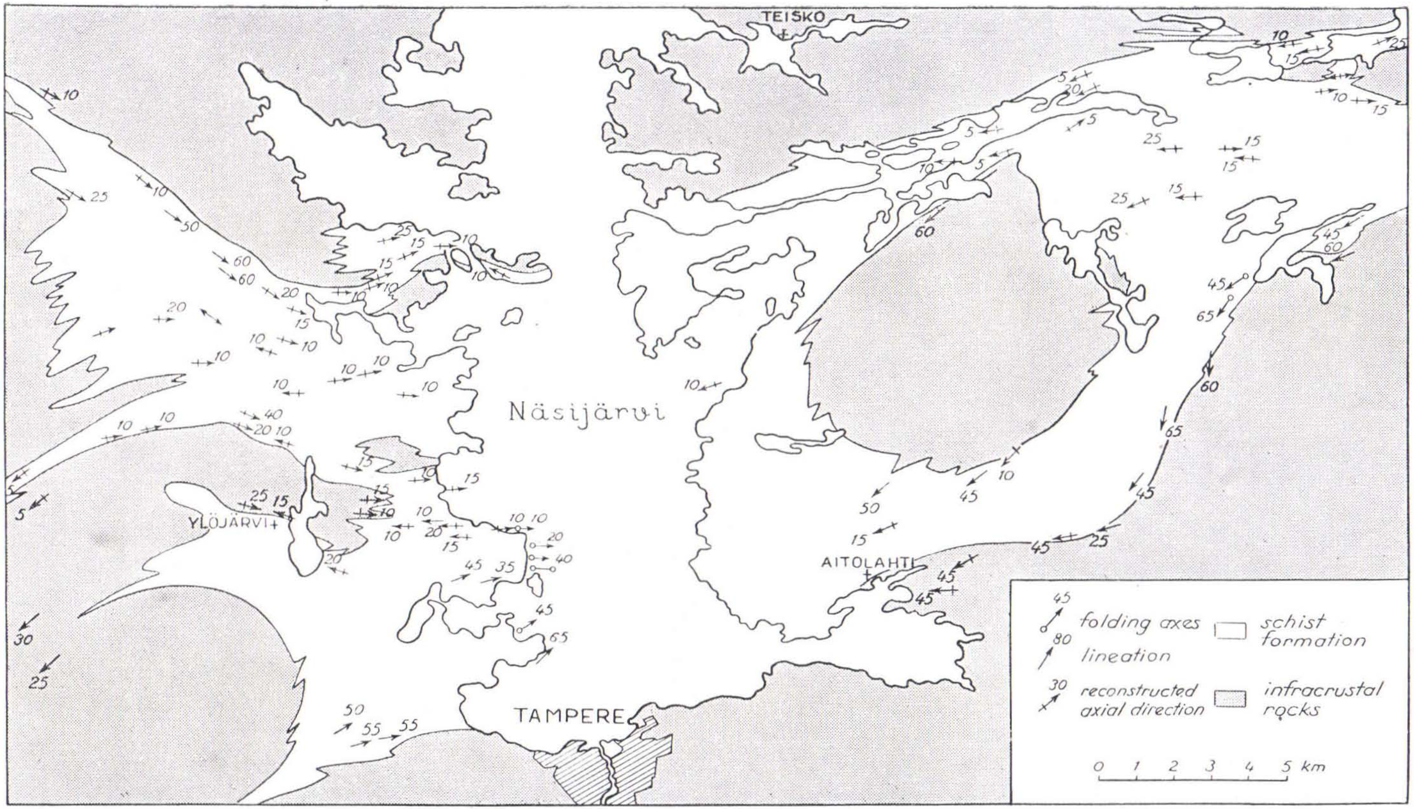
The inconsistency between lineations and directions of the folding axes is not limited only to the Tampere area. The present authors have for instance observed in several places in Finland together both gentle and steep pitching linear structures. One of them cannot be parallel to the primary tectonic axis.

E. Cloos has recently in his critical review (2) noticed, that there are as much as 15 different kinds of lineation. Therefore it is most important in all different cases to make clear the development of lineation and above all its relation to the directions of tectonical movements.

GEOLOGICAL SURVEY OF FINLAND, FEBRUARY ,1948.



Map 1. Lineations in the schist formation N of Tampere.



Map 2. Axial directions reconstructed according to the principle described in the text.

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9.

THE HEKLA ASHFALLS IN FINLAND A. D. 1947

BY

MARTTI SALMI

According to reports an eruption took place at 9.40 a. m. (Finnish time) on the 29th of March of this year in the main craters of the volcano Hekla, in the southern part of Iceland. The last eruption in the main crater took place in 1845. The present eruption, which was preceded by a slight earthquake, was explosive. Stones detached from the walls of the craters were ejected into the air together with a great quantity of pumice and volcanic ash. Fine, dustlike ash rose to a height of about 27 kilometres to be carried there by the higher atmospheric strata. Heavier material, such as stones, pumice, and coarser ash, fell down in the vicinity of the volcano, covering fields and meadows with a layer dozens of centimetres thick and doing a great deal of damage. Simultaneously there was an outflow of lava. This flowed in several lobes to a distance of some up to 9 kilometres from the volcano and of course devastated everything in its way. The eruption was thus a combined ash and lava eruption, as so many previous Hekla eruptions have been.

In the nearest future, we shall certainly have detailed accounts and scientific descriptions of the eruption and phenomena connected with it, written by the investigators who had an opportunity of travelling to the place immediately after the eruption to study the action of the volcano. This paper is restricted to an account of those circumstances which refer to our country in connection with the Hekla eruption.

When the newspapers reported that Hekla ash was found i. a. in Denmark and Sweden, it was to be expected that it could be carried as far as Finland. At the writer's suggestion, the Geological Survey appealed to the public through the radio and newspapers, requesting them to make observations of possible ashfalls, to notify some and to send in samples.

ASH IS FOUND IN FINLAND

The first report of an ashfall in Finland came from Helsinki. A woman had noticed that during a shower of rain peculiar, dustlike stuff had stuck to her window, situated towards the south, which she had cleaned ten minutes earlier. She suspected it to be the Hekla ash and made a report, on the ground of which the writer visited the place. He was able to gather a little sample and by means of the microscope ascertained same to be volcanic ash that plausibly had come from Hekla. The observation was made 31. 3. at 1 p. m. or some 51 hours after the Hekla eruption had begun. Thus an accurate date was obtained concerning the arrival of the ash at Helsinki. On the following days, reports began to come in also from the country with information of ashfalls, and containing bigger samples, so that the first observations thus received confirmation.

Some fifty reports concerning ashfalls came in; about twenty of them containing samples. To these belong also the reports and samples which were sent to the Meteorological Survey and which Prof. J. Keränen Ph. D. kindly let me investigate. Only two of the reports were such as apparently had nothing to do with the ashfalls. This indicates that the public makes accurate observations. Public interest in this occurrence rare in our country, was very great and people often showed praiseworthy resourcefulness in regard to the safe-keeping of ash samples.

The spread of the Hekla ash in our country is shown on the map (Fig. 1 p.) to which referrence is made later.

THE OCCURRENCE OF THE ASH

The ash was mostly found on the surface of the snow, on which it descended during a snow- or rainfall. Especially in the tracks of a hare or a dog, in the trails of skis or in other small »depressions» did the ash attract attention. Further, the ash was found on roofs, window-sills, windows, spectacles, on a ship's deck, on polished surfaces of motor cars etc., in short, in very different places.

Most of the observations indicate that the ash did not fall down as a coherent layer over extensive areas, but that its occurrence was mostly sporadic. The fine ash, reddish brown in colour, was absorbed, in some cases, into the snow even to a depth of 2—3 cm. and caused some erraneous conclusions when determining the thickness of the layer. Most likely, the ash layers here were generally thinner than 1 mm., in so far as one can speak of a coherent layer. Owing to this, the samples are mostly small in quantity. The gathering of a somewhat bigger sample made special measures necessary. In some cases, snow dyed by the ash was gathered from an area of one or two square metres. Then the snow was melted, and either by evaporating the water, or by filtering it through blotting-paper it was possible to separate the ash for investigation. In Dragsfjärd, 60 litres of rain water were gathered which had flowed from a roof. 8 gr. of ash were separated from this amount. This was the biggest sample and the only one of which a chemical analysis could be made, after visible organic impurities had been removed through a shift. The other samples weighed only ½ gr. or still less.

THE CHARACTER OF THE ASH

PHYSICAL QUALITIES

The ash is a reddish brown, dustlike, fine, and light powder. Under the microscope it has been ascertained that the ash consists of isotropic, volcanic glass, where exclusions are small anisotropic mineral grains.

There are two main types of the glass. One of them, which is fairly rare, is of light yellow colour, fluid and vesicular. The particles are longitudinal plates. The index of refraction is

1.525 — 1.535

As to colour and index of refraction it corresponds to the ash which has erupted in Iceland in prehistoric times (Thorarinsson 1944, p. 89, Table IV, sample 19).

The second type is formed of reddish brown volcanic glass which is of more frequent occurrence than the former glass. Its texture is compact and the separate particles are plates, undefined in shape and of broken outline. The index of refraction is

1.560 — 1.570

According to Thorarinsson's above-mentioned Table (samples 27—34) the indices of refraction of volcanic glass vary from 1.546 to 1.575 in the Hekla eruptions in 1693, 1766, and 1845, so that the index of the glass found in Finland corresponds to these. Prior to the above-mentioned eruptions ash has been thrown up from the volcano, with a considerably lower index of refraction. This indicates that the oldest ejectments of Hekla are more acid than the younger ones. The fact is that such a relation exists between the index of refraction of the volcanic glass and the SiO_2 content, that when the index of refraction increases, the SiO_2-content decreases (Stark 1904, Salmi 1941, Thorarinsson 1944). According to these investigators, the refractory indices 1.560—1.570 correspond to 55—56 % of SiO_2.

According to measurements, the size of the ash grains is 0.003—0.015 mm. The chief part of the ash distinctly belongs to the finer grain size of the above-mentioned limits.

Jurek (1932) and Larsson (1936) have made measurements of the ash ejected from the Quizapu volcano in 1932. This ash has been gathered at Olguita and Buenos Aires, the former being at a distance of 780 km., the latter of 1 120 km. east of the volcano. The results will be seen in Table I. They indicate that especially the Olguita ash is mostly of the same fineness as the Hekla material transported to Finland.

TABLE I

Diameter of ash grains mm.	% 1 Buenos Aires	% 2 Olguita
0.137	0.34	—
0.11	1.12	—
0.0825	2.36	—
0.0686	4.06	—
0.055	7.00	0.3
0.041	9.36	1.5
0.0275	12.06	11.8
0.0137	15.56	32.2
0.0055	19.39	36.2
0.0027	28.75	18.0
	100.00	100.00

Determinations have been made concerning the weight of volume of the ash, the results of which are presented in Table II. Before measuring the ash is dried at a temperature of 105° C.

TABLE II

Treatment of sample	Weight of volume
1. Glass measure filled lightly with ash	0.48
2. » » shaken gently	0.67
3. Ash influenced by a weight of 2 kg	0.88

In this connection it is interesting to known that the weight of volume of the ash increases in the course of its journey, as Larsson (1936) has shown. This only holds good in the event that the ash has been transported so far from the point of eruption that heavy mineral grains or small pieces of pumice, containing these grains in greater quantity, have fallen from the ash cloud nearer to the volcano. At a greater distance from the volcano the ash particles become small. Simultaneously the amount of air bubbles, which are characteristic of pumice volcanic ash, decreases in comparison with the ash material; from this follows an increase in the weight of volume. In this respect the ash fallen in Finland may afford interesting material for comparison with the weights of volume of the Hekla ash determined elsewhere. So far as we know volcanic ash carried so far away from the eruptive volcano has not previously been an object of investigation in this sense.

CHEMICAL QUALITIES

The chemical composition of the ash transported to Finland is shown in Table III, which presents the analysis of the Dragsfjärd sample (5). The analysis was made by Mr. H. B. Wiik M. A. in the laboratory of the Geological Survey. The sample contains plenty of organic substances as impurities, as the ash was gathered from the rain-water flowing from a roof. The ash contains a little CO_2, which is a common substance in volcanic eruptions. In the sample there are organic matters, CO_2 and water to such amount that these hinder the comparing of this analysis with the others previously made. Therefore they have been eliminated and the remaining oxides have been calculated at a hundred.

TABLE III

Anal. by H. B. Wiik

	Weight %	Modified %	Hekla in 1693 (Thorarinsson 1944)
SiO_2	45.84	56.38	55.23
TiO_2	1.00	1.23	1.64
Al_2O_3	15.58	19.16	15.31
Fe_2O_3	4.44	5.46	3.38
FeO	1.84	2.26	7.58
MnO	0.07	0.09	0.40
MgO	3.26	4.01	2.59
CaO	5.41	6.66	5.66
Na_2O	0.52	0.64	2.97
K_2O	2.87	3.53	2.19
P_2O_5	0.47	0.58	0.80
H_2O	6.60	—	H_2O+ 2.36
CO_2	4.91	—	—
Org.	6.77	—	—
	99.58	100.00	100.11

For the sake of comparison, in Table III there is presented also the analysis made of the Hekla ash ejected in 1693. Its SiO_2 content is approximately the same as that of our analysis (Thorarinsson 1944, p. 81, anal. V).

Before we compare the analyses with each other it may be mentioned that in earlier investigations (Lacroix 1904, Larsson 1936, Salmi 1941) it has been ascertained that the ash becomes assorted when transported far away from the volcano and this also has en effect upon the chemical composition of the eruptive material. The most distinct changes are discernible in the SiO_2 content, which rises with increasing distance. In many cases also the alkalis, at least K_2O, increase, whereas the Al_2O_3 and MgO content decreases. There are, however, cases (Salmi 1941) where with the increase of the distance also Al_2O_3 increases.

In the ash gathered in Finland the aluminium content in considerably greater than that of the above-mentioned analysis, as well as that of the other eruptive materials previously gathered in Iceland (Thorarinsson 1944). This may be due to impurities, but may, with good reason be attributed also to the assortment caused by the air or to the different composition of the magma. Attention is also attracted by the weak Na_2O content of our analysis. To draw any conclusions of greater importance about the changes of the composition of the ash, on the ground of these differences is, however, premature, since it is a question of the materials of different eruptions. Before we are acquainted with the complete study dealing with the Hekla eruption, it will be interesting to see the degree in which the chemical composition of the Icelandic ash and that of the Hekla ash gathered in Finland, at a distance of 2 500 km. from the volcano, differ from each other. The Dragsfjärd sample may, however, contain impurities to such an extent that the original composition of the ash becomes disturbed and renders the comparison difficult. The composition of the Hekla ash transported to Finland is next dioritic, but considering the assortment made by the air and the changes resulting from it, the original material may be basaltic.

THE TRANSPORTATION OF THE ASH INTO FINLAND

The places where the Hekla ash was found in Finland, about fifty, are shown on a map (Fig. 1.). The black dots 1—47 each represent one observation, excluding the dot on Helsinki (17) which includes several.

When we had begun to place observations on the map immediately after their arrival, it soon became clear that they were concentrated to the southern part of the country, in a fairly narrow zone running in the SW-direction. Much later than the others, a report came from the parish of Perho, Central Ostrobothnia, stating that also there had been found a matter suspected to be Hekla ash. No sample was enclosed and the date of the observation was a fortnight later than that of the others, so that it cannot originate from the same ashfall. It is not impossible, however, that the ash might have been transported into our country later and as several clouds, as successive explosive eruptions occurred in Hekla. As the Perho observation could not be verified, it has to be considered as an uncertain case and therefore an interrogationmark indicating this place of discovery is shown on the map.

To save space, no individual places of discovery are given, nor are the names of private persons, mentioned though they would well deserve it. On the ground of our map we content ourselves with investigating the material to the extent which is needed to elucidate the spread of the Hekla ash.

The ash fell first in SW-Finland. In Maarianhamina (on the map the observation point No 1) ash had fallen on the deck of s/s Tursas at night

30—31/3. The time of the ashfall could not be given more accurately. The thickness of the layer was rated at 0,25 mm. At Dragsfjärd (5) the ash descended in connection with rain on the same night 30—31/3 and continued to come down in the daytime, but in Viksvidja, Perniö (7), the ash still fell between 13—18.30 on April lst.

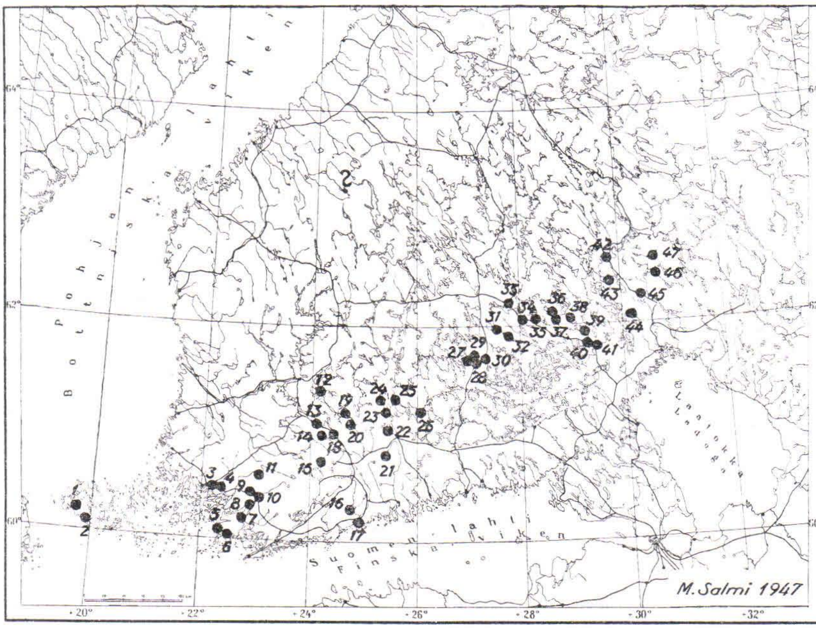

Fig. 1. Observation points indicating the Hekla ashfalls in Finland.

In Helsinki (17) the ash was ascertained 31/3 at 13 o'clock as already mentioned, but in the capital some further observations were made. At Hauho (9) the ashfall occurred on the same day at 17 o'clock and at Kangasala (12) at 16.30—17. 30 o'clock but from Padasjoki (24) it was reported that the ash descended so late as 17.40 o'clock on 2/4.

At the Mikkeli Aerodrome (28) an accurate observation was made of the ashfall. There it was noticed that on 1/4 after a heavy snowfall at 8.45 the surface of the snow was dyed red by the Hekla ash. Also in the town of Mikkeli (30), a chauffeur stated that on the same day he had found the Hekla ash on his motor-car. The ash had come down during the snowfall between 12—16. The observations made at Otava (27) and Vuolinko (28) indicate that the ash had fallen there during the night 1—2/4.

At Rantasalmi (33) the ashfall was ascertained already 1/4 at 5.30 o'clock and at Sääminki (36 and 37) during the night 31/3—1/4, at which time the ash had fallen also on the easternmost observation points at Tohmajärvi (45) and at Rekivaara, Tuupovaara (46) in connection with a combined snow- and rainfall. It may be mentioned that the latest ashfalls to occur in our country were ascertained at Punkaharju (40 and 41) 2/4 at 14—15 and at Padasjoki (24) at 17.40 o'clock.

Judging from the foregoing, the ash had been transported into our country from the southwest, advancing in about twentyfour hours from Maarianhamina as far as Tuupovaara. Unfortunately, accurate dates as to the ashfalls could not be given in either locality. It can, however, be roughly calculated that the ash had been carried this journey of 600—700 km. at a velocity of 25—50 km. per hour, these figures then indicating the smallest and apparently also the greatest possible velocity of the ash. It has also been ascertained that the ash fell in our country between 30/3 —2/4.

The direction of the ash cloud from SW to NE seems strange, seeing that Iceland is situated west of Finland. It is, however, easy to understand on the ground of the information that Mr. J. Ylinen. M. A., of the Meteorological Survey, gave to the writer about the directions of the air currents in Europe and especially in the Atlantic as also in Fennoscandia during the eruption and on the following days. These currents are presented on the map, Fig. 2.

The map shows that at the beginning of the Hekla eruption, in Iceland air currents prevailed which had different directions at different altitudes. In the lower atmospheric strata the direction of the wind was NE, but when ascending it changed via N to NW. Thus the direction of the wind was at the altitude of 5 km. straight from N. Its direction changed later, being at 8 o'clock on 30/3 from NW west of Iceland, on the western coast of the Iberian Peninsula at 8 on 31/3. from W and at 8 on 2/4 on the Black Sea from SW. At this altitude the velocity of an air current was about 63 km. per hour.

It is more interesting to follow air currents at an altitude of 9 km. and the transportation of the possible ash cloud. When the eruption occurred, the direction of the wind was from NW in Iceland, but north of Scotland it changed, blowing at 5 o'clock on 30/3 from SSW and in Norway at 5 o'clock on 31/3 from SW. The ash cloud would have advanced with it before 5 o'clock on 1/4. as far as the White Sea. The velocity of this air current was about 45 km. per hour, or considerably less than that of the air current at an altitude of 5 km.

On the basis of the above it is clear that the Hekla ash was transported into our country at an approximate height of 6—8 km. Its course was presumably as follows: Hekla — the North of Scotland — the North of Denmark — the South of Sweden — Finland. The velocity of the ash cloud is rated at about 56 km. per hour on the basis of the Helsinki observation. This is greater than the velocity of the wind at an altitude of 9 km. This must have been the case, for of advancing at a height of 9 km. the ash would have been at 5 o'clock on 31.3 only in Norway, whereas it is with certainly known to have fallen in Ahvenanmaa and elsewhere in SW

— Finland already during the night 30—31/3 and at 13 o'clock on 31/3 in Helsinki. In addition, we recall that at an altitude of 5 km. the velocity of the wind was still greater. Thus the velocity of the wind diminishes with increasing height.

On the days following the eruption, the southern coast of our country belonged to the centre of the low pressure (Fig. 2). A limit surface of air

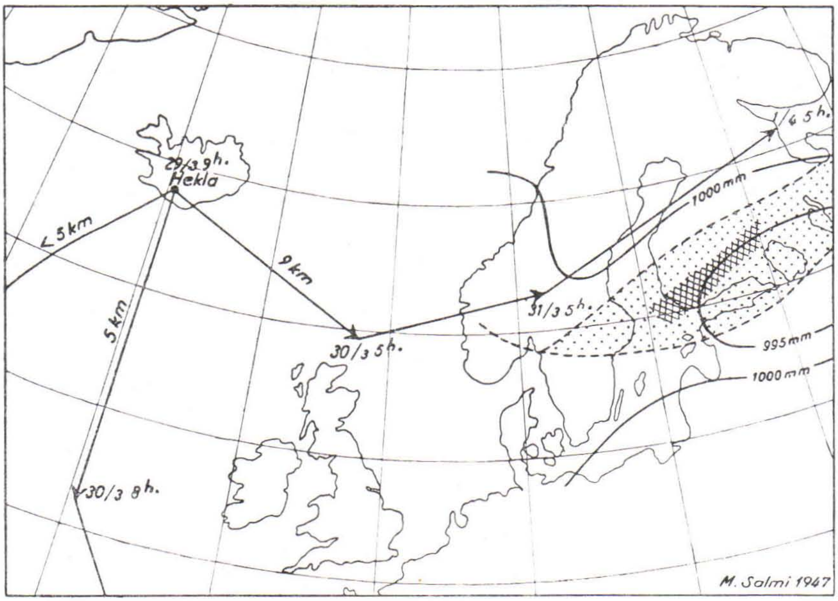

Fig. 2. The schematic meteorological map of the North of Europe at the beginning of the Hekla eruption and on the following days. The arrows show the direction and the advance of air currents a different altitudes. The rain district is marked with dots and the ashfall zone ascertained in Finland with cross striation.

masses, a front, was formed there, at which time cold air was moving from NE in the lower atmospheric strata while in the higher strata warmer and damper air which contained ash advanced from SW. When meeting each other, they caused snowfalls and rain, with which the ash came down. According to the observations, the ashfalls did not occur in the whole rain district, only over a comparatively narrow zone, on both sides of the line Maarianhamina—Joensuu. This may be explained so that over the mentioned zone the ash cloud advancing from SW met the rain cloud at the same height, whereas it elsewhere passed over rain clouds. It is namely very possible that the ash came into our country on a broader front than ascertained on the ground of observations. The Perho observation may then be correct. The continuance of the ashfalls in the same localities on several successive days may be due to the fact that the front remained nearly the same for several days.

As far as is known observations of ashfalls have not been made previously in our country though in all probability they have occurred here. In the year 1875 March 28—30, the Askja volcano on Iceland erupted and its ash was found in the vicinity of Stockholm, Sweden, and north of that city. It is fairly certain that the ash was transported to Finland, but observations were not recorded, if any such were made. The mean velocity of the ash was then ascertained to be 85—90 km per hour between Iceland and Norway, but on its passage from the western coast of Norway to Stockholm the velocity was about 50 km. per hour (Thorarinsson 1944). In 1912 Katmai in Alaska erupted very violently and its ash was found to have spread throughout the whole northern hemisphere; also our country belonged to the circle of its influence. The ashfalls caused by volcanic eruptions are here very rare, so that they are consequently, well worth investigating, whenever they occur in our country.

After my paper had been translated into English, a report came in from Oulu, stating that even there »red snow» had fallen. The date could no longer be ascertained, but according to my estimate this observation was made approximately at the same time that the ashfalls in South-Finland were observed. The Perho observation, which was presented above as an uncertain case, is thus given support. The ashfalls in Ostrobothnia may have occurred scattered in different places, possibly also elsewhere in the country. My opinion that ash was carried into our country on a broader front, than could be ascertained on the basis of the observations made in South-Finland, is thus proved correct.

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10

TRACING THE SOURCE OF THE PYRITE STONES FROM VIHANTI ON THE BASIS OF GLACIAL GEOLOGY [1]

BY

ESA HYYPPÄ

CONTENTS

THE STAGES OF PROSPECTING

The Geological Survey of Finland made in the summer of 1936 ore prospectings at Vihanti under the direction of S. Kilpi. Prospectings were undertaken because samples of quartzite containing pyrite, found in the northern section of the Alpua village in Vihanti, had been sent to the G. S. by the farmers J. and A. Lumiaho, and J. Salo. Mr. Jaakko Salo claimed to have discovered the outcrop of the ore, which is located at about 300—400 metres from the Mätäsaho farmstead to the northwest, in a place called Vuorisaari. Geologists ascertained the outcrop to be pyrite-bearing quartzite. Whether the »rock», which was of the same type as the cobbles found, was true bedrock or a great erratic boulder remained unsolved. In no case was there question of a discovery of a true ore deposit.

The expedition under Kilpi continued prospectings throughout the whole of the Vihanti district, registering with the greatest possible

[1] Lecture given before the Geological Society of Finland, 1945.

exactitude all stones and boulders containing pyrite and maping the bedrock of the region. The distribution of pyrite quartzite stones, was thus clarified in detail. The results of the prospectings did not hold out great hopes of the discovery of valuable ores. However, Vihanti again drew the attention of geologists when farmer Edward Kesälä sent to the Institute of Geological Survey a stone found by him in the summer of 1939 containing rather large amounts of zinc sulphide and in addition, pyrite and pyrrhotite. According to Kesälä's information the stone was found at Törmänperä on the south-east border of the Vihanti district, about 400 metres to S 60° W from Kesälä's house (fig. 2).

At the same time another and still more promising discovery of cobbles of ore was made in Vihanti. In cleaning his well of basal sediment, farmer Aate Lumiaho found cobble stones containing rich pyrite ore. The stones were incorporated in silty till about 40 cm. from the surface of the granite bedrock. The till is here 3—4 metres thick. This find was the incentive for prospecting in the summer of 1941, presently to be cut short by the begining of the war.

K. Mölder, V. Okko and the present writer continued prospectings in Vihanti in the summer of 1943. The purpose was to determine on the basis of glacial geology the direction of transit of the pyrite stones found in the well of the Rantala farm, and if possible to find traces of the outcrop itself.

PLEISTOCENE FEATURES OF THE REGION

The terrain in Vihanti is very level, as is the Ostrobothnian flatland in general: it is a boggy, ancient seabottom about 80—100 metres above sealevel, and therefore belongs to the zone of the maximum limit of the Littorina Sea. The gently sloping swells of ground moraine rising above the network of bogs are low, and offer very little variety to the monotonous landscape of the region. There are few exposed hills of bedrock. The chief feature bringing variety to the landscape is the esker running from northwest to southeast through Vihanti; it is part of one of Finland's longest esker chaines. It takes its rise on the northwest of Jaamankangas in North-Carelia and ends, after having branched in two directions at the border of the Oulu-Kuopio provinces, at the Gulf of Bothnia. In the district of Vihanti this esker is at its most typical in the village of Alpua, where it is a true ridge, as for example at Lumijärvenmäki (Fig. 1). The ridge on which the Vihanti churchvillage is situated is a sand heath gently rising and falling for several kilometres, showing only here and there typical ridges. The esker in the northwest part of the district splits into a double low-backed ridge.

The erosional and depositional wave action of the Littorina Sea has deeply influenced the present morphology of the esker. Its gentle slopes,

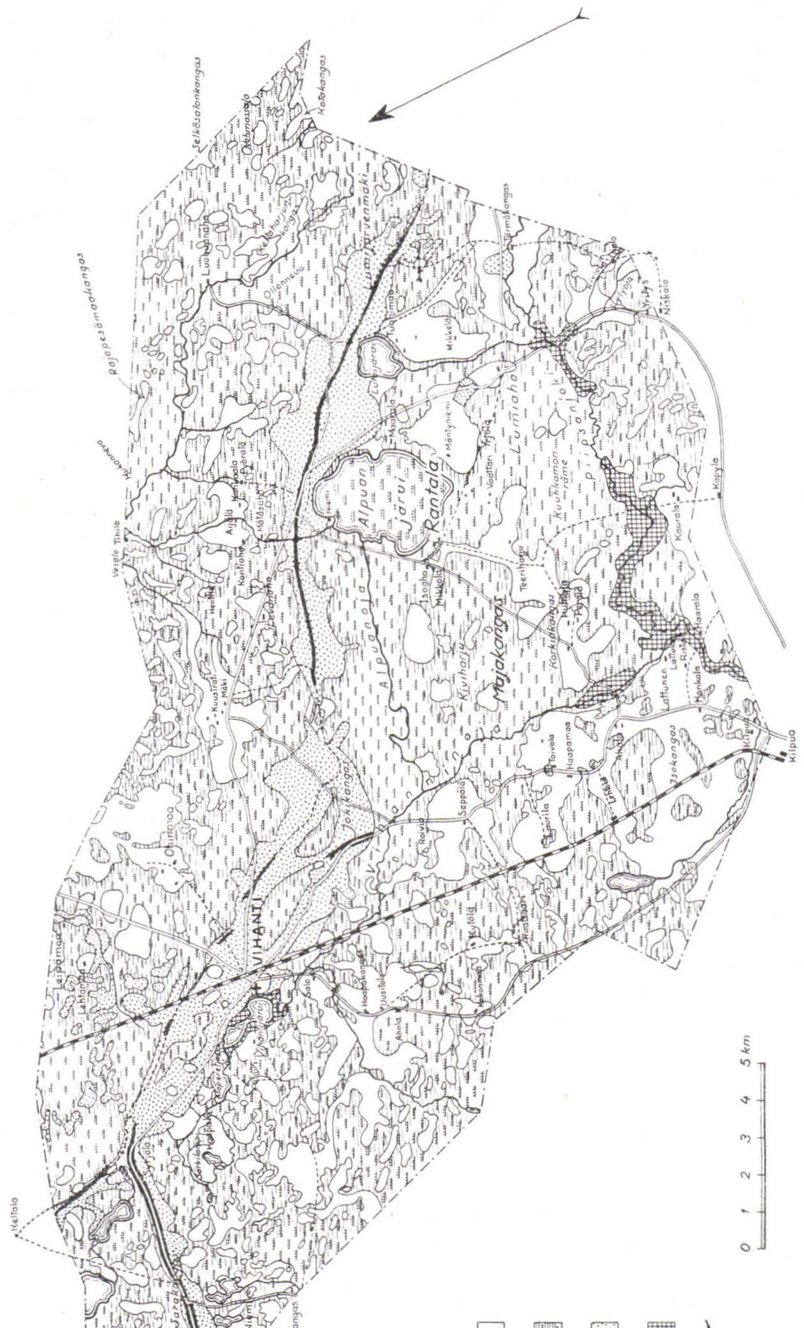

Fig. 1. Map of surficial deposits of the Vihanti District. 1. Moraines. 2. Peat, ooze and mud. 3. Sand and gravel. 4. Silt and clay. 5. Esker ridge.

which at their lowest spread out into level fields are proof of this secondary deformation. The maximum limit of the Littorina Sea has reached the elevation of the esker. Only its highest ridge-like parts have projected above the limits of the Littorina. About three kilometres to the northwest of the village of Alpua on the SW-slope of the esker was a distinct, stony wave-cut cliff, indicating the maximum limit of the Littorina Sea in this region. Hitherto it has been supposed that there had not been developed any shore features at the time of the Littorina Sea in the central area of uplift, because the shore-line was retreating. On the bases of the fixed point of the precision levelling (90.1 m) at the Vihanti station, Okko has by barometric measure established the height of the ancient shore to be 93 m. above sea level. The crown of the ridge at the corresponding point is 5 m. higher.

No remarkable surficial deposits appear in Vihanti in addition to the till, peat and stratified drift. Clay is not met with exposed, but under deposits of peat and litoral sand accumulations. Sand also appears in greater quantities than shown on the map, for under very thin layers of peat there were wide sand plaines built up by the Littorina Sea.

As is seen from the accompanying map of surfical deposits, the Pleistocene forms of the region do not any clear orientation as is otherwise usual in the Finnish lanscape. A primary reason for this may be the levelness of the underlying bedrock, over which glacier ice moved without causing clearly orientated erosional and depositional forms.

BEDROCK

The Kilpi expedition examined stones and bedrock throughout the Vihanti region. On the basis of the results of that survey, I have prepared a map of bedrock, in which the boundaries between rock bodies are rather summary, owing to the scantiness of outcrops. Fig. 2, presents the above-mentioned map of bedrock in Vihanti, in which it can be seen that the main part of the district is of granites and gneisses.

The main observations of the Kilpi expedition were focused on the northern region of the Alpua village, where stones of sulphide quartzite were found. All the pyrite stones of ore type which Kilpi found he plotted on his map, on which he also plotted the frequency curves showing the relative amounts of quartzite stones. (fig. 2). The latter prove that quartzite and sulphidebearing quartzite stones are numerous within the same limited are where the previously mentioned quartzite outcrop, Vuorisaari, is located. The result of the stone count made by Kilpi, 25 % quartzite (diagr. No. 15 on the map) points also to the existence of quartzite bedrock. It is, therefore, highly probable that in this region there is quartzite in the bedrock from which derive the stones containing

Fig. 2. Map of rocks of the Vihanti district, and certain graphic statistics on the activity of glacial erosion and transportation. 1. Granites. 2. Gneisses. 3. Quartzites. 4. Sandstones. 5. Basic rocks. 6. Mica schists. 7. Leptites. 8. Porphyries. 9. Other stones collectively. 10. Diagram of stone count and orientation of till stones. 11. Striation. The degree given beside the arrow indicates the azimuth of the upstream direction of glacial flow. 12. Pyrite stones. 13. Stones containing zinc sulphide and other sulphide minerals. 14. Quartzite stones rich in pyrite. 15. Percentage of quartzites. 16. The general limits of distribution of the Rantala-type till.

sulphide. Kilpi has sketched the presence of this quartzite on his map as two oval-shaped fields.

THE RANTALA TILL

Investigations were at first confined to the Rantala till. Two more pieces of the same compact pyrite ore were found in the till taken from the Rantala well, of which Lumiaho had found several cobbles while cleaning his well. The till itself is relatively rich in clay and silt and poor in stones, except at the surface. Mechanical composition of the Rantala till, particles > 2 mm. excluded, is as follows:

2,0 —0,5	mm =	8,5 %
0,5 —0,25	» =	6,56 »
0,25—0,05	» =	54,54 »
0,05—0,02	» =	9,0 »
0,02—0,002	» =	15,6 »
>—0,002	» =	5,8 »

Despite thorough search among surface stones, in ditche cuts and gravel pits, no trace of pyrite stones was found. In the lithologic composition of the surficial deposits there were, however, to be noted sandstone and agglomerate cobbles, and in addition the rarer special type, feldspar-porphyry stone, not earlier found in Finland.

Okko after having examined these deposits, wrote in his notes as follows: »The Lumiaho house (Rantala) is located on a low moraine ridge whose surface is comparatively rich in boulders of granites, gneisses, and gabbro. A collection of the small stones is heterogenous as in additions to granite stones, there are agglomerates, coarse-grained sandstones, arkose, red schistose quartzites, and dense quartzites. The whole collection seems to be from the boundaries of pre-Cambrian rock and a slightly metamorphic sedimentary zone. At the boundary the bedrock is reddish, at least here and there of pegmatitic granite which has split and weathered at the surface. The sedimentary series containes sandstones, quartzites, and mica schists.»

The prospecting was now planned to follow the supposed direction from which the pyrite stones came. It was of course of special importance to examine the composition of the till as near as possible to the place of discovery of the ore cobbles. With that purpose in view a pit was dug about 26 m. NWW of the Rantala well.

The total thickness of the till mantel in the cut of the pit was 2.7 m. Throughout it was typical ground moraine till, but relatively rich in silty clay. The larger stones were rather well rounded, just as were the pyrite stones of the Rantala well. The change of the color at a depth of 2.2 m.

from brown to blue-grey indicates the reaching of the ground water table, the weathering of which in a downward direction was largely slowed up, and which took place under other conditions.

For the stone counts there were used 3—10 cm. cobbles (cf. G. Lundqvist 1935), averaging 100 stones per analysis. The first count was made at the surface of the moraine, the second at a depth of one metre, the third at 2 m., and the fourth at 2.2—2.5 m.

These four consecutive counts proved that the lithologic composition of the till is the same from the surface to the bottom with granites and gneisses in the majority. The biggest part of the granite cobbles is of a reddish brown, coarse-grained biotite granite, appearing as large erratic boulders in the terrain to the NWW and the W of Alpua, especially on the surface of the esker running through the district and in the bedrock at Korvenkylä to the W of Alpua. Furthermore, in the till there are middle-grained reddish and greyish granites, likewise several types of gneisses, such as mica hornblende and dense, darkish gneisses.

In addition to the granitic stones the sandstones and porphyries are especially to be remarked. Among the porphyries there are both quartz and feldspar porphyries. Of the latter there are two cobbles about 20 cm. in diameter. Dark leptites appear rarely. The sandstones are partly arkose and of various grain sizes, the coarser ones resembling conglomerates. The sector (pie) diagram of the stone collections of the strata (on the map, fig. 2, diagram No. 1) is the average of the above-mentioned four consecutive stone counts.

In the granite bedrock laid bare at the bottom of the section there were no indications of sulphide ores, but Okko found in the till strata at the depth of two metres a pyrite-impregnated sandstone 6 cm in diameter. According to the microscopic examination made by V. Pääkkönen, the stone is a conglomerate approaching sandstone, cemented by pyrite, in which the materials are quartz, quartzite, microcline, mica schist, plagioclase and amphibolite in order of quantity. The stone is unmetamorphic, and raises the question as to whether it perhaps is country rock of ore representing Rantala pyrite stones. Farmer A. Marjomaa found (1939) similar sandstone containing pyrite at Lumimetsä to the south of Rantala.

In order to find more pyrite stones another pit was dug to the WNW at about 30 m. from the first one. During the digging, the stones of the till were examined in detail, but we did not succeed in finding a single pyrite cobble. The materials of the till were precisely the same type as that in the former pit, though perhaps a little richer in boulders. The prospecting did not reach bedrock, as already at the depth of 2.5 m. there was ground water in abundance. The auger did not reach bedrock even at 3.3 m.

THE LITHOLOGIC COMPOSITION OF THE TILL

To the north of Alpuanoja there is a small moraine hill, Pirttisaari, on which a house was being built; a stone count was made of the till when the foundations for the house were being dug (Diag. 13). Till material was noticeably poorer in clay than at Rantala, but richer in silt. The lithologic composition proved to be simpler than in the Rantala till, and differed from it by its large content of quartzite (35 %). The quartzite cobbles were mainly dark and in part pyrite-containing, being thus representative of the quartzite described from the nothern side of the Alpua village. It is to be remarked that in the Pirttisaari moraine not a single sample of agglomerate, sandstone, or porphyry was found.

A stone count (Diag. 14) made for the till of the drainage canal of the Alpuanjärvi Lake, gave the same results as did the former count.

The result of the stone count shown in Diagram 12 (Mölder) differs to some extent from the two preceding ones. There are more granites than gneisses. Quartzite is very scarse, but on the other hand there is 5 % of sandstone, which was totally lacking in the former count. There were no porphyries in this stone count, either.

Prospectings made in a north-easterly direction from Rantala proved that at 2 kms distance (Diag. 13) from Rantala, the ground moraine material contained less clay, but was more silty than at Rantala. Furthermore there was a change in the lithologic composition: granite stones increased in number and also quartzite, to some extent. The feldspar-porphyries so characteristic of the Rantala till were completely lacking.

To the SW of Rantala the moraines were examined in the direction of the road between Alpua and Korvenkylä. The first stone count was made at 5.8 kms from Alpua at the juncture of the road leading to the Maja-kangas farm with the main road. Here is a moraine heath the surface of which is sandy shore deposite. Diagram 7 gives the stone count (made by Okko) of the surface of the moraine, which proves it to be wholly the same type as that of Rantala. Percentages of the different kinds of stones are almost the same as those for Rantala. Among the cobbles there are even porphyries and coarsegrained sandstones, although the latter, owing to their scarcity are not shown on the diagram.

The following stone count, Diagram 9, was made from a ditch cut by the main road at 3.6 kms from Korvenkylä toward Alpua. Only the surface of the moraine was examined here, and was found to be sandier than at Rantala. The stone count also gave a different result here than at Rantala. In addition to granites and gneisses there was a small per cent of quartzite and leptite. One per cent of reddish sandstone was discovered, but feldspar-porphyry was altogether lacking.

An analysis (Diag. 10) of a collection of till stones gathered from the fields near the Perälä farm at about 1.5 km SW from the former place led to a similar result. Among these stones there was found one quartz-porphyry stone, but the feldspar-porphyry typical of the Rantala till were lacking. The most southwesterly point at which it was found in the direction of the Korvenkylä road proved to be 2.5 km from Rantala, between Diagrams 7 and 9. From among the stones of the main road ditch were found two sandstone cobbles and one cobble of feldspar-porphyry of the Rantala type. The point in question may thus on the line prospected and until further examination, be held as the western boundary of the Rantala till type. In the lower parts of Korvenkylä area and especially deep down, the till is as rich in clay as at Rantala.

The next step was to prospect the spreading of the Rantala-type till in the course of flow of the glacial ice. There follow two stone counts from the SE side of the Alpua-Korvenkylä road. Diagram 8 represents a stone count made of a Littorina Sea shore deposit in the Teeriharju gravel pit lying about 2 kms south of Rantala. Under the shore deposit there comes to light in a number of places a greyisch red, medium-grained granite in which there are gneiss-like parts resembling agglomerate. The lithologic composition no longer corresponds to an unwashed till composition. The granite stones, especially, seem to have increased there. This is partly explicable from the fact that the deposite is itself located in a granite region, so that the local mass rocks, especially when the sediment stratum is thin, come very noticeably to view. Thus in the stone count granite increased to 61 %. Gneisses and quartzite were found in about the same proportions as in the Rantala till, but the basic stones, mica-schists, phyllites, sandstones and porphyries are not marked on the diagram although they were found now and then in the region of the gravel pit.

About 4 kms from the above-mentioned, is a place called Lamminaho where the mantle rock is a fine silty till as at Rantala. A stone count was taken at a depth of 0.5—1.0 m. (Diag. 11). The lithologic composition is in general similar to that of Rantala, but the porphyries and the leptites are totally lacking. On the other hand the unusually large percentage (12 %) of sandstone is remarkable. Furthermore, the basic stones are found in greater quanity than the granite bedrock would presuppose. The map of the bedrock is, however as was remarked in the beginning, rather general owing to lack of outcrops. Nevertheless, it would seem that the Lamminaho till is not one of the Rantala type as to its lithologic composition. The sout-east boundary of the Rantala till would run somewhere between Teeriharju (Diagram 8) and Lamminaho. Even this result must be held to be only hypothetical, owing to the few points of observations.

In the following we shall examine the spreading of the Rantala till toward the general direction of advance of the glacial ice.

Diagram 2 represents a stone count made by Okko of the moraine hill just under 2 kms NW of Rantala. The stones are for the most part granite, and the Rantala sandstones and porphyries are totally lacking. A final decision as to the type of the till cannot be made with complete surety because the stone count was made only for the surficial part of the deposite, from which the absence of sandstone and porphyry may be a matter of chance. This applies also to other points where the prospecting was only superficial.

At one km NW from the place of the last-mentioned count, Okko made another stone count (Diag. 3) under exactly the same conditions. The result is by and large the same, the stones special to Rantala being lacking. To judge by the foregoing, it would seem that the Rantala-type till at Alpuanoja ends here, also.

We shifted our stone counting a little to the SW, to the Majakangas and Kiviharju terrain, (Diag. 4, 5 and 6). Here stone piles collected from the fields during plowing were first examined. A few sandstones, agglomerates and porphyries were found, as had been found from the stone piles of the Rantala region fields to whose lithologic composition the surficial stones of the Majakangas moraine corresponded.

The Majakangas moraine was examined also in a vertical direction, a pit (No. 3) at a point about 50 m. from the highest point of the ridge to the WNW. The material was throughout the silty-rich Rantala-type till of ground moraine, stonier at the surface than farther down. The pit was dug to a depth of 3.5 m., at which point ground water hindered excavation. The moraine sheet is at least 4.2 m. deep, possibly deeper. In the well of the Aho farm, bedrock was said to be met at a depth of 3 m. Stones blasted from it are dense, dark granite or leptite. Kilpi has on his map of bedrock marked this region as a gneiss resembling leptite and evidently in this region there are both dense gneisses and leptites. I have marked the region as leptite in anticipation of a more exact mapping of the bedrock. To the NE of Majakangas there is an outcrop of bedrock called Kiviharju, whose rock may in part, at least, be designated as dense gneiss.

Diagram 5 represents the stone count made by Okko at a depth of 0.5—1.0 m. in the Majakangas pit. The lithologic group clearly shows the influence of the local bedrock: gneisses over 50 %, basic rocks and leptites are also to be remarked. Sandstones and porphyries were not found here, nor from deeper strata, but as they regularly appeared among the surficial stones this lithologic composition can rightly be considered as belonging to the Rantala type, the more so as the till material taken as a whole is in both cases very much alike. Pyrite cobbles of the Rantala type were not found in the Majakangas pit, but there were signs of sulphide quartzites which are to be found at various localities in Vihanti.

Diagram 4 gives the lithologic composition of the sandy surface of the small moraine hill at depths of 0.0—0.5 m. It is much the same type as the one just mentioned. The most remarkable difference between the two last-mentioned stone counts is a larger amount of gneisses in Diagram 5.

This may be due to the fact that the Majakangas stone count (Diag. 5) was made of dense ground moraine, while Diagram 4 represents the surficial stones. The local bedrock is of gneisses and leptites. These kinds of stones, derived of the bedrock immediately upstream, have increased in number especially in the ground moraine (Diag. 5), whereas the granites, come from farther off, are rather to be seen among the surficial stones of the till (Diag. 4).

Diagram 6, Okko's stone count for Suksikangas, resembles the Majakangas diagram (No. 5). The material is about 0.5 m. deep from the moraine-born shore gravel. Rantala porphyry was not found in this pit, either, but there was found a little sandstone, which however, does not show on the diagram.

The above reported prospectings show that the Rantala-type till extends to the NW and the WNW, or toward the direction of approach of the glacial ice, at least as far as Majankangas. To continue the prospectings in these directions from Majankangas would have been difficult, as the terrain going toward Vihanninoja brook is boggy throughout (see map of superficial deposites, p. 99). Instead, prospectings in the above-mentioned directions were continued from the Vihanti church village along the road to Korvenkylä.

Diagram 19 (Mölder) records the stones of a till pit at a depth of 1 m. Granites and gneisses make up only a fourth part of the stones, whereas in the Rantala-type till they account for one third or over. The leptites have disappeared altogether, but on the other hand, quartzites and mica schists form 50 % of the whole. The percentage of basic rock has risen also, as was to be expected. The Rantala sandstones porphyries, and agglomerates are altogether lacking. The till material in its entirety is dense and rich in silt as in the Rantala region, and is 3 metres thick.

Diagrams 20, 21, and 22 are also based on Mölder's stone counts which were made from stone piles at the side of the road. The results are in accord with the bedrock map. The proportion of basic rock was still on the increase, which is understandable since the corresponding bedrock is very near on the upstream side. Mölder also found to the west of Haapakangas basic bedrock the area of which to the south is larger than the map shows. To judge by the outcroppings of bedrock and the increase in granite stones, granite must be in the majority here, however. This can be seen especially from Diagram 22.

Diagram 18 represents a stone count made N of the basic bedrock. Here there is an esker gravel pit in which the types of stones are for the most part granites, gneisses and quartzites. Gneisses and granites are representative as well of local as of distant bedrock, but the quartzites may clearly be considered as transported from a distance, especially since they appear as far away as Korvenkylä in comparative abundance, and also as numerous boulders on the surface. They are evidently derived from some farther distant quartzite bedrock. There was no sign here of Rantala porphyries and pyrite stones more than there was at Korvenkylä. Sulphide quartzites are to be found here and there, but they do not belong to the Rantala ore stones types. No agglomerate was found, and only in Diagram 21 are there any signs of sandstones.

It would seem that the Rantala-type till taken on the basis of lithologic composition does not continue up to the Vihanti-Korvenkylä road. To confirm the result, stone counts (Mölder) were made farther to the south, at the branching of the Vihanti-Kilpua road. On the map we have the corresponding diagrams, No's 24, 25, 26, 27, 28. The till in this region is very stony and rich in cobbles, differing thus from the silt-rich till of Rantala. The lithologic composition of the till does not differ on the whole, from the Rantala-type. This is comprehensible, for both regions are located in corresponding positions in relation to their granite- and gneiss-bedrock. The lack of leptites is to be remarked here, just as at the side of the Vihanti-Korvenkylä road. In Diagrams No. 24, 25, and 26 there is in addition so great an abundance of basis rocks that one may think the corresponding bedrock to reach farther to the WSW than is shown on Kilpi's map. There were found no signs in this region, either, of the Rantala pyrite ore nor of porphyries. Sandstone appears only in Diagram No. 28. These stone counts confirm the results of the prospectings made at the branching of the Vihanti-Korvenkylä road.

There follow a number of stone counts from the region of the Vihanti church village, and thence northward (Mölder). — The till in the region in question is generally sandy, very stoney, and here and there are to be seen erratic boulders, for instance in the direction of Ohinmaa. The results of these stone counts are in their broad outlines in accord with Kilpi's map of bedrock. In detail the attention is drawn to diagrams 17 and 19. The former represents the lithologic composition of an esker material, the latter the stones of the till. In both there is a relative abundance of sandstone which is also typical for the Rantala till. Since sandstone seems to appear here and there in the district, it is impossible to localize it to date as belonging to some particular till type. Sandstone is not, however, the less interesting for us, as it would seem, on the basis of a pyrite cobble found in pit No. 1 that it is one of the country rocks of the pyrite ore (see p. 103). It is also to be remarked that the maximal appearance of sandstone is limited according to the afore-presented stone counts, to the direction 310°—320°.

A short summary of the foregoing will recall to mind results:

Despite diligent search compact iron pyrites cobbles found in the Rantala well have not to date been found elsewhere. In the pit dug near the Rantala well (No. 1) there was found, however, a sandstone impregnated with iron pyrite, which may perhaps represent a country rock of the ore. The till material of the ground moraine of the Rantala area is of the silty rich type, the lithological composition of which from the surface to the bottom is rather homogeneous. The stones of the till are for the most part granites and gneisses, as is the local bedrock. Among the quartzites, basic rocks, and other rarer stones in the lot, the sandstones and feldspar-porphyries and agglomerates attract special attention.

The regional distribution of the above-described till type (the Rantala-type) would seem on the basis of prospectings made to date to be limited to a relatively small area of boggy basin to the WNW of Rantala. The low points of the landscape regularly take possession of the local material of the ground moraine. On the basis of this even the pyrite stones found in the Rantala till may be of local origin. On the map (Fig. 2) the broken line indicates the probable distribution of the Rantala till.

TILL FABRIC

The arrangement of the rock fragments in till have been studied especially by the German, K. Richter (1932, 1933, 1936 a, b) and the American, C. D. Holmes (1938, 1941). Richter has explained this question in detail for end moraines of present-day mountain glaciers and for melt-water streams. He has established the fact that the longest dimension of glacier-carried stones lies parallel with the direction of flow of the lacier. This held true for the end moraines near the edge of the glacier n which the meltwater streams had not washed away the finest material. The material of the older end moraines, which usually were washed by meltwater and were coarser, had moved by rolling after having become anew subject to the pushing of the ice whereby the long axis of the stones become transverse to the directions of push. Stones over 50 cm. in length had always moved by rolling through the pushing of the ice.

In meltwater-streams and brooks Richter remarked the same regularity. Fist-sized and smaller stones lay with their long axes (dimensions) more or less exactly parallel to the flow of the stream whereas the head-sized and larger boulders had always rolled, their long axis transverse to the flow of the stream.

The American, S. D. Holmes (1938, 1941) adapted Richter's analyses of arrangement to the drumlin-rich ground moraine region south of Syracuse, New York. Here on the basis of the glacial morphology of the region, the direction of flow of the ice taking place when the moraine came into being was known exactly. Holmes's investigations show that the long axes of the moraine stones were for the most part arranged either in the direction of the flow of ice or at right angles to it. The former arrangement was more frequent. Holmes could show, furthermore, that the form and roundedness of the stones as well as the axial ratio played a part in the arrangement chosen. According to Holmes, the decisive factor in this choice was the action of the glacier itself in the area under consideration: »but the relative frequency in these two positions appears to be governed more by the behavior of the glacier in the particular environment of deposition than by any qualities inherent in the stones themselves» (C. D. Holmes, 1938).

E. Kivekäs (1946) is the first to have analyzed the arrangement of moraine materials in Finland (see also Mölder 1948 and Virkkala 1948). He has shown that for several south-Finland moraines the long axis of the stones is parallel with the local striation.

The arrangement of moraine stones has not remained unremarked in Sweden. It appears from the explanation to the map of Filipstad (pp. 81—83) by N. H. Magnusson and E. Granlund (1928) that in general there is no arrangement in the till stones of a granite area, but that there is to some degree in a corresponding formation of schist areas.

Since the determination of the direction from which the till was transported is of special importance in the search for the mother lode of ore, several fabric analyses were made of the till in Vihanti.

The first fabric analysis was made of the Rantala pit No. 1. The long axis of the stones was determined on the average of 100 stones per analysis. Messurements were taken from the surface of the till to the bottom. The direction is expressed by azimuths, the eastern azimuth being 90°, the southern 180°, western 270°, and northern 360°. The measurements have been made with the compass to the accuracy of 5°, which is entirely sufficient for the purpose in hand. The declination being $< 5°$, it was not taken into consideration in measurement.

The work of the very first day showed that the foregoing method could be used at Vihanti with excellent results. It seems certain that a typical, ground moraine till rich in the finest materials lends itself to fabric analysis, independent of the kinds of rocks, although schistose stones offer for this purpose the best materials of all.

The result of the fabric analysis made of the No. 1 pit at Rantala is represented graphically in connection with a stone count diagram by an arrow drawn through the center of a circle which showe the direction of a stone's long axis, while the length of the arrow shows the percentage of the stones in that direction. The result of the fabric analysis gives the average upstream direction of flow of the ice as 280°—290°, that is, in a rather westerly direction. A full 14 % of the stones point straight west, and the stones turned most to the northwest (305°) make only 4 % of the total. As is to be expected, part of the stones (rotated stones) are at right angles to the direction of transport of the material, but they form only 2 % of the whole.

In order to check on this result, Okko made a fabric analysis of the Majakangas pit (No. 3) also, as per Diagram 5. It is amazing to what similar results both analyses lead. The arrangement of the Majakangas stones showed a still clearer maximal direction than the former.

The two former fabric analyses confirm that made by Mölder at the roadside of the village of Liminka. The main direction from which the till stones have been transported was 280°, that is, exactly the same as in the two former fabric analyses.

On the basis of the foregoing stone counts and fabric analyses it can be stated with surety that the material of the ground moraine of the Vihanti area has come from the WNW, the azimuth of which is 280°—290°. The pyrite stones found in the Rantala well have therefore, also come from this direction, and not in any case from the pyrite-quartzite locality to the north of the Alpua village, the direction from which to Rantala is at right angles to the direction of transit according to the fabric analyses, as can be clearly seen from the map.

STRIATIONS

The advance of glacial ice can be established through a third means, by the observation of striations which flowing ice has by means of stones and rock fragments carved in the bedrock. It is to be remembered that the striations in the same locality may have been made at different times and in different directions. On the other hand striations running in different directions may have come into being during the same phase of movement (Flint 1947).

Owing to the lack of outcrops, there are relatively few observations to be made at Vihanti. Most often there is recorded the observation of striations made 7 kms from the church village of Vihanti toward Korvenkylä on the west side of the road, where in an outcrop of diabase Kilpi has measured the main direction of striation to be 300° (the azimuth of the upstream direction or departure of flow). Okko describes this place in his diary as follows: »The rock ledge is glacially polished, containing striations in the directions 280°—310°. The general abrasion surface and the numerous small striations indicate a direction of departure of 280°—290°, whereas the northermost striations lying in the direction 300°—310° are rare although long and well preserved.»

The above-mentioned rock exposure seems then to have striations of two different ages, of which the 280°—290° one probably is the result of the older and stronger movement, the striation of which the flow from the direction 300°—310° was not able completely to efface. The force of the westernmost glaciation is shown by the stream line form of the glaciated ledge, which follows the direction of striation.

Striations in the direction 280°—290° correspond completely with the arrangement of the till stones. Several other observations of striations made at Vihanti show a slightly more northwesterly direction of departure as is indicated on the map (p. 101).

Striations and stone counts lead to the following conclusion: The oldest glacial movement in the Vihanti region occurred from the WNW (280°—290°), after which the direction of departure has degree by degree shifted to NW.

Although many observations have been made in Finland on striations, there is little reliable information as to the relative age of the striations lying in different directions and in different regions. Thus in connection with the transport of the Vihanti pyrite cobbles there arises the question whether the WNW (280°— 290°) direction of departure encountered at Vihanti is to be met with elsewhere in Central Ostrobothnia.

According to V. Rantala's observation's (field notes 1936) the WNW direction of striation appears also at the side the Oulainen—Pyhäjoki road. He has messured about 13 kms from Oulainen in road cut striae 280° and 320° (up stream direction), of which the former corresponds to the oldest striations of Vihanti or from WNW, and the latter from the NW. In a road cut 26 kms from Oulainen toward Pyhäjoki Rantala measured two more striations, one of which lay directly west (270°) and the other (290°) in the direction of departure of the older Vihanti glacial ice.

On the map of striations of Kajaani region (sheet C 4, Sauramo 1926) there is marked only one observation from Vihanti. This is in the north-west of the district, and lies 265°. In Sauramo's opinion the direction is exceptional and came into being as the result of local movement at the edge of the ice when the glacier ice was withdrawing.

Sauramo's map shows, on the average, that glacial ice came from the north west. A part of the striations show a more westerly departure, 290°—295°, or more nearly that of the direction of departure of the Vihanti cobbles. Sauramo does not go into the question of possible age differences, but presents the general remark that the striations have come about with the movement of the withdrawing glacial ice.

Helaakoski (1943) has thoroughly examined the striations of the Ostrobothnia coastal region. The study is worth special examination not only because of its exact observations but also because the author attempts to differentiate the ages of the systems of striations which would show that the glacial ice had in its initial stages moved from the west and little by little changed its direction of departure to the north. It is especially to be noted that Helaakoski assigns different ages to different directions of movement. According to him, the observation may be more than a hypothesis »that the westerly movement of the glacial ice is older than the others, so old that signs of it have been preserved for the most part only in the general form of the rocks especially in the directions of the grooves, the finest striae being only exceptionally to the leeward of the other movements. The westerly direction at least must be older than the Late Glacial Age.» (Helaakoski 1943, p. 26). Helaakoski has got proofs from the depositional forms of the coastal region as well as from the marks of erosion. Thus the conclusion that the oldest glacial movement has come from west seems sure. According to Helaakoski this direction fans out between 250°—275° in Central Ostrobothnia. Its northwesterly limit 275°, approaches the direction of the Vihanti till stones.

The second direction of departure of the ice established by Helaakoski in Central Ostrobothnia is 290°—295°, which Helaakoski also thinks is a very old direction. It appears also in the Vihanti striations and approaches that of the Vihanti till stones (280°—290°), so that practically I should consider these directions as being of the same age.

The third direction of departure of glacial ice given by Helaakoski is 325° — a little north of northwest. The fourth direction 344°—348° is close to north, and Helaakoski consideris it to be the freshest of all, drawn under the edge of the retreating ice, though he does not have absolutely sure proofs of the age. In Ostrobothnia the direction of departure of the glacial ice would seem to have shifted degree by degree from west to north. The conclusion is in accord with the Vihanti till fabric and with the striations.

According to investigations made by Heinonen (field notes 1945, 1946, and 1947) the orientation of the till stones from Vihanti to Pyhäjoki (map, fig. 3) is 280°—290°, thus exactly the same as at Vihanti. The general direction of striations in the same region is 275°—310°, the chief direction being the same as that of the till material, or 285°—290°.

According to Okko (1948) the oldest direction of striations in the area shown on the Kokkola map (sheet B 4) of superficial deposits is 285°—300°, the next 325°—340°, and the freshest 345°—360°, or nearly due north. Till fabric analyses in this region lead to the same conclusion.

The conclusions of the investigations above reported lead unanimously to the opinion that the glacial ice from the Oulujoki River valley at least to Kokkola advanced at first from the west and later shifted its direction of departure to the north. As to the transport of materials, the till fabric analyses made to date in the strip between Vihanti and Pyhäjoki (fig. 3) give proof only of transport from the direction 280—290°.

To the south of Pyhäjoki along the coastal plain of the Gulf of Bothnia, it would seem that the main orientation of the till material according to observations made hitherto is on the average, NW—SE, although even a westerly direction appears. (Okko 1948, Mölder 1948).

To the north of the Oulujoki River valley comparatively few observations on striations have been made, and no till fabric analyses at all. According to Helaakoski, the directions and order of age of striations are the same as for the Central Ostrobothnia coast up to Simo. Proceeding inland from the coast the observations made, attest the prevailing direction to be on the average WE, the same as that followed by the eskers of the region. Of the relative age of the striations, the observers have

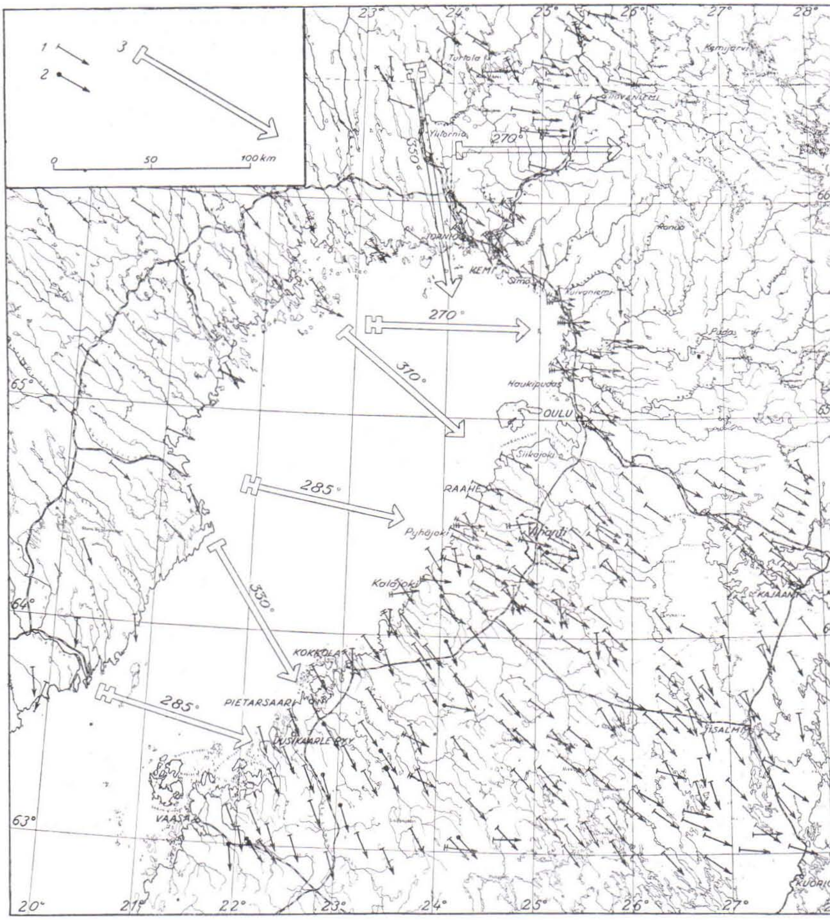

Fig. 3. The striations and till fabric of the northern and central part of the vicinities of the Gulf of Bothnia. 1. Arrow indicating the direction of the striae. The relative age of crossing striae is shown by the number of transverse lines on the arrow, which increases in proportion to age. 2. Arrow indicating the orientation of till stones. 3. General directions of flow of the glacial ice. The azimuth gives the upstream direction of the flow. — The map is a composite of the observations of different geologists: South Ostrobothnia (Mölder), Central Ostrobothnia (Okko, Helaakoski, Heinonen, and the author), North Ostrobothnia (Okko and the author). Observations made on the Swedish side have been taken from G. Lundqvist's publication (1943).

formed no sure opinion. Only in Stenberg's notes (1908) are there mentioned observations on striation about 20 kms to the east of Oulu, according to which the more northerly direction 312°, in the cross striations, would be older than the westerly 282°—295°. Here then the order of age would be the contraty to that of the Central Ostrobothnia coast and Vihanti. Since to Stenberg's single observations there cannot be attributed conclusive evidence, the age-order must still be considered uncertain, although the evidence gathered heretofore seems to show that the direction of departure of the glacial ice shifted even here from the west to the north as in Central Ostrobothnia.

In farthest recess of the Gulf of Finland and in the regions to the north of it we can on the basis of striations differentiate the various ages of the glacial ice movements. The northerly direction of departure is here the

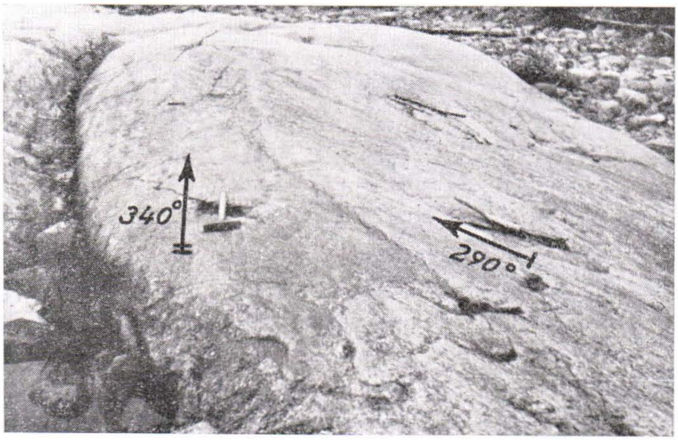

Fig. 4. Boss of bedrock abraded by glacial ice on the west bank of the Ounasjoki River at Marraskoski Rapide. Arrowe indicate the direction of flow of the glacier, and the number of degrees the upstream azimuth of the flow. The older erosional facet with its striae (340°) has been preserved on the lee side of the later facet (290°).

oldest. This is proved clearly by my own observations of cross-striation (fig. 4) and Okko's observations (1941). The movement of the ice has taken place in an age succession contrary to that of the Central and South Ostrobothnia coastal region.

On the Swedish side of the Tornio River valley the same glacial ice movements and age succession are evident as on the Finnish side. In the Vesterbotten coastal region the strongest erosion and direction of erosion of the glacial ice is on the average NW—SE. Approximately westerly direction appears also, but for the age order of the various directions there exist no certain proofs (Fredholm 1892, Granlund 1943, Högbom 1931, 1937, Lundqvist 1943, and oral information given by Okko).

CONCLUSIONS

MOVEMENTS OF GLACIAL ICE

Although the material presented above is insufficient for a final synthesis of movement of glacial ice, it nevertheless justifies the drawing of certain conclusions. Firstly, it is evident that the oldest advance of glacial ice in that part of the coast of the Gulf of Finland between Merenkurkku and Simo took place on the average from the west, from which direction of departure it shifted by degrees to the north, the heaviest erosion appearing on the average in the direction NW-SE.

Going north from Kemi the advance of the glacial ice took place in the opposite order. The relative ages of directions on the Swedish side of the coast are so far uncertain owing to the lack of till fabric analyses.

On the map (fig. 3) the relative age-order of the crossstriations is indicated by the number of transverse lines on the arrow, which increases in proportion to age. On the map there has been marked in addition the main directions of the glacial ice with large arrows.

The orientation of the glaciers depends upon the directions of the snowbearing winds (Enquist 1916, Flint 1947). In the initial stages of Fennoscandian glaciation, according to Enquist, snowbearing winds came from the west (fig. 5), and turned more to the NW when glaciation had reached

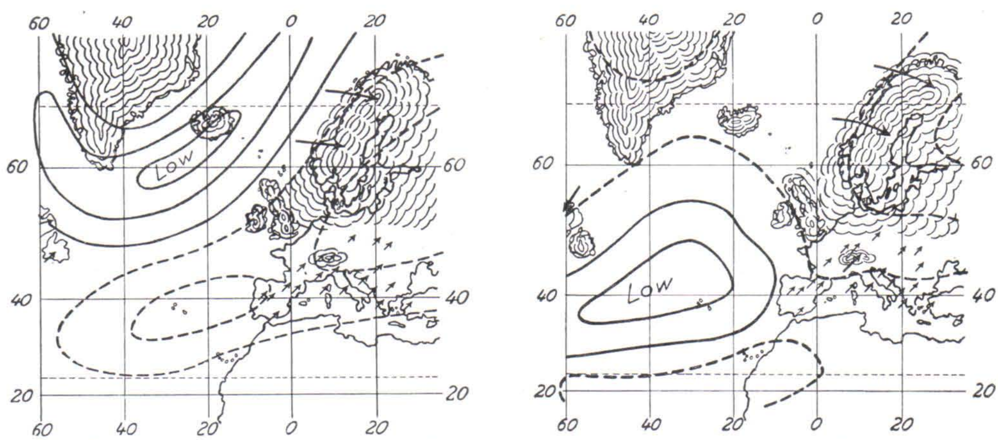

Fig. 5. In the figure to the left, distribution of atmospheric pressure areas at the beginning of glaciation; to the right, at the maximum of glaciation. The arrows indicate orientation of snowbearing winds and of glaciers. According to Fredrik Enquist (1916—17).

its maximum. To this was added the shifting of the ice divide 100—150 kms to the east side of the Scandinavian mountain crest. In the latitudes 64°—67° the ice divide ran on the average N 25° E, and turned then on reaching the Finnish side toward the east between the 67° and 68° latitude. To judge by the direction of the winds and the ice divide, one comes to the opinion that the direction of movement of the glacial ice was at first most strongly influenced by the Scandinavina ice divide and the west winds, because of which the movement of the ice took place in the Gulf of Bothnia regions in the initial stages of glaciation from the west and the northwest. At the same time that part of the ice divide in Finnish Lapland (between latitudes 67 and 68) lying W-E, began to influence the movement of the ice from north to south. These two direction components of the glacial movement met in the recesses of the Gulf of Finland at a time when the westerly movement of the ice and the transport of materials had already made its influence felt in Central Ostrobothnia, and carried the Vihanti pyrite cobbles to their place of discovery. The meeting of the two components resulted in an average NW—SE movement, which was strengthened further by the snowbearing winds having turned from the west to the northwest, bringing the ice sheet to the stage of maximum development (fig. 5).

On the basis of the foregoing it is easy to understand the shifting of the direction of departure of the glacial ice in Ostrobothnia from the west to the northwest, and in North Ostrobothnia on the other hand, from the north to the northwest, and that the average NW—SE direction in the areas in questions is most strongly evident in the erosional forms (fig. 3).

With the progressive disappearance of the glacial ice the conditions prevailing at the beginning stages of glaciation obtained again both as to climate and as to the orientation of the ice. On the basis of the ancient shores and of the sediments formed in stagnant water, it seems sure that the W—E ice divide of Finnish Lapland disappeared at the time when there was still ice in the recesses of the Gulf of Bothnia. In any case it is evident that it disappeared earlier than that part of the ice divide in Scandinavia. The orientation of the glacial ice was influenced in the final stages of melting only by the Scandinavian ice divide and the west winds (the atmospheric pressure centers were again shifting to their present positions), with the result that the latest movement of the glacial ice took place from the west and the northwest as did the oldest movement.

This conception would seem to agree with, above all, the regions to the north of the Oulunjoki River, where for example, the direction of the eskers is on the average W-E. It is evident that the oldest and the youngest movement of the ice from the west are difficult to distinguish between, and that to solve this question further investigations are needed yet. It can, however, be supposed that the movements of the glacial ice in its last stages were very weak and here and there had practically ceased, so that resultant erosional marks are evidently slight. On the other hand it is evident that the prevailing NW-SE movement has to a large measure wiped out the older signs of flow from the west, so that the erosional features caused by movement from the west are in both cases weak and easily to be confused with one another.

In the orientation of the till the difference of age is more easily recognizable. On the basis of investigations made up to the present writing it seems that the latest W-E directed movement of the glacial ice has not much affected the orientation of the material. The oldest movement cominging from the west and the northwest has, on the other hand, at least in places, remained the prevailing orientation of the till.

TRANSPORTATION OF THE PYRITE STONES

The arrangement of the rock fragments in the Rantala till with its pyrite stones indicates the direction of transportation. This direction 280°—290° upstream, is general in Central Ostrobothnia and belongs to the remotest time of advance of the glacial ice. Taking into consideration only the direction of transportation, the Vihanti cobbles could come even from the Swedish side of the Gulf, where a line drawn from the Vihanti area runs directly through the famous Skelleftå ore field, the sulphide ores and rocks of which resemble that picture which comes to mind when one attempts to reconstruct a corresponding ore field on the basis of the Vihanti rocks. To clear up the matter, samples of typical Vihanti till material — among them the rare porphyries — were sent to Dr. Olof Ödman, specialist in the bedrock of Skellefteå, Sweden, for examination. According to his statement, the stones in question were not to be found in the bedrock on the Swedish side, with the result that the transportation of pyrite cobbles thence seems to be improbable.

On the basis of the direction of transportation the motherlode in question may be on the coastal strip between Lake Alpuanjärvi and Pyhäjoki or lie on the bottom of the Gulf of Bothnia.

There is no indication to be found in the diaries of various geologists that pyrite stones of the Vihanti type have been found elsewhere in the coastal regions. The only possible exception is the quartz sandstone found by Mattila (field note 1936) among the shore stones of Kiviranta at Kalajoki. It is thoroughly cemented with pyrite. The Kalajoki cobble, however, is a surficial stone and of another type than the Vihanti pyrite cobbles. The coastal region of Kalajoki and Pyhäjoki should, however, be thoroughly examined with a view to the possible discovery of pyrite stones.

On a purely glacial-geological basis we arrive rather at the alternative that the Vihanti pyrite stones are of local origin. The coarse stone material in till is usually for the most part of local origin, transported only a few kilometres. This fact is known about all ancient glaciated regions, and becomes convincingly clear through the investigations of Hellaakoski (1930) and Okko (1941 and 1945) on Finnish esker and till materials, as well as from the investigations of Americans (Flint 1947). In the Vihanti case we have a thoroughly typical ground moraine till in the under part of which, furthermore, the pyrite stones were located. To judge by the clear orientation the till material has been carried directly to its present location by the glacial ice. A long-distance transportation by the icebergs has been in this case impossible. Besides, it is difficult to conceive that the relatively easily weathered pyrite stones could have undergone a long-distance transportation. How short and how restricted our pyrite cobble fans are regularly, is well known (Sauramo 1924).

The glacial ice could hardly have carried along much material from the

Gulf of Bothnia basin to the present Ostrobothnia coast. It is probable that the ice tongue at first moved in the direction of the basin, that is, rather to the south than to the west, and only then when the basin had filled with ice, the lowest parts of which anchored to the bottom, did the united glacial ice front move eastward and later southeastward over its bottom strata so that of the basal till it could not drag much along. If this hypothesis be correct, then in the Central Ostrobothnia coastal regions there are to be expected only exceptionally such stones as have been transported from the Gulf of Bothnia or from the Swedish side. This is especially applicable to ground moraine.

There still is to be taken into consideration the transportation of stones in several stages in the glacial and interglacial ages. At Vihanti there is, however, only one mantel of till, and the cobbles were located in the oldest part of it. Even if we were to think that the oldest strata had been totally eroded away, it is hardly probable that the pyrite stones should have been able to undergo a transportation of many stages and over a long period without weathering. It is furthermore to be remembered that the whole existence of interglacial ages is in Finland so obscure a question that reference to them at the present stage of research would lead us from a basis of observation to one of pure speculation.

The final direction of departure of the pyrite cobbles is in all surety 280°—290°, so that the outcrop is possibly located in a strip running in the stated direction, most probably in Vihanti itself, since the cobbles on the bases of glacial geology are estimated to be of local origin.

The sides of the strip of transportation I presume to be relatively close together, because on the level plains of Central Ostrobothnia the fanning out the cobbles must have taken place slowly.

Prospecting in the Vihanti area is only in its beginning. In this paper my chief purpose is to give suggestions as to how, in conditions obtaining this land, motherlodes of ore cobbles and boulders are to be traced on a glacial-geological basis. To attach importance, in addition to the surficial rocks, also to the thorough analysis of the till material in a vertical direction, wherein lies the most important question from where the till material has come. Indeed, the fact that in an area of granite bedrock, the direction of source of the material can be determined on the basis of the orientation of till material, as the Vihanti prospectings prove, offers great possibilities not only for the solving of questions of theory, but also for undertaking ore prospectings on the basis of glacial geology.

After the foregoing had been written, G. S. has made further ore prospectings at Vihanti. These prospectings, still in their initial phase, have brought to light sulphide ores, also of the Rantala-type, within the general limits of distribution of the Rantala-type till (fig. 2, p. 101). These results give strong support to the idea that the pyrite stones of Rantala till are of local origin as presented earlier. In the area concerned has also been found zinc sulphide ore of the same type as the sulphide stone found at Törmänperä (p. 98). The Törmänperä sulphide stone could thus have been transported from the Rantala-type till area, although in a slightly more northwesterly direction (310°) than the Rantala pyrite stones.

A second alternative is, that the Törmänperä sulphide stone has been carried in the main direction (280°—290°) of the glacial transportation in Vihanti. This direction drawn from Törmänperä runs through Korvenkylä area (diagrams 19—22, fig. 2, p. 101) and corresponds to a Törmänperä-type sulphide stone found in Korvenkylä at Juusola farm at the depth of one meter (a little to the South from the place of Diag. 19, fig. 2, p. 101) when diggin a well. The stone, discovered recently in the collections of G. S. has been send by Mr. J. Lumiaho in 1939. It is thus conceivable, assuming that both sulphide stones have been found in till, that new sulphide ore deposits could be discovered in Vihanti proceeding from Korvenkylä in the direction of 280°—290°. This hypothese should anyhow be taken into consideration in future ore prospecting in Vihanti.

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