Bulletin de la

Commission Géologique

de Finlande

N:o 241

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by Ilkka Laitakari

Geologinen tutkimuslaitos • Otaniemi 1969

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ON THE SET OF OLIVINE DIABASE DIKES IN HÄME, FINLAND

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WITH 40 FIGURES AND 4 TABLES IN TEXT AND
ONE APPENDED MAP

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ABSTRACT

A diabase dike set cutting the Archean metamorphic complex in Southern Finland is described. The group whose length is approximately 150 km consists of more than 100 dikes, the largest of which exceed 100 m in width. The main trend of the dikes is about N 60°W and the great majority are vertical or steeply dipping. The typical rock is high alumina olivine diabase with plagioclase, titanoaugite and olivine as main minerals. The autoliths and plagioclase megacrysts indicate that some crystallization of the magma took place before the intrusion of the dike set. The location of the megacrysts and inclusions near the upper contact reveals that gravitational differentiation occurred in the dikes. A number of rheomorphic dikes derived from different rocks of the metamorphic complex were found, the largest of which are about 30 cm wide and some tens of metres long. The age of the diabase dikes plausibly is similar to that of the rapakivi massifs of Southern Finland and the dikes may be even genetically related to the rapakivi. Quartzite xenoliths appear in many of the diabase dikes which may mean that quartzite is more abundant at greater depths in the Svecofennian metamorphic complex although it is fairly rare at the present erosion level.

TIIVISTELMÄ

Tutkimuksessa kuvataan Heinolan seudulta Kuruun ulottuvaa, yli 100 juonta käsittävää postmetamorfista diabaasijuoniparvea. Monet juonet ovat useiden kilometrien mittaisia ja useimmat kymmenien metrien, muutamat jopa yli 100:n metrin levyisiä. Ainakin suurimpia juonia lienee pidettävä basalttilaavaa purkaneiden tulivuorten tulokanavina. Diabaasin (Kuva 2) päämineraaleina ovat plagioklaasi, titanoaugiitti ja oliviini. Autoliitit (Kuva 25) ja plagioklaasihajarakeet (Kuvat 12 ja 24) osoittavat magmatilassa tapahtuneen kiteytymistä jo ennen niitä purkauksia, joiden tuloksena juoniparvi muodostui. Magmaa kevyempien hajarakeiden ja sulkeumien rikastuminen kaltevien juonten yläkontaktin puolelle näyttää tapahtuneen gravitatiivisesti. Jähmettymisen jälkeen diabaasiin muodostui rakoja, jotka välittömästi täyttyivät juonesta sivukiveen johtuneen lämmön vaikutuksesta osittain tai täysin sulaneella sivukivellä (Kuva 32). Juoniparvi lienee suunnilleen Etelä-Suomen rapakivimassiivien ikäinen. Sen syntyessä basalttimagmalla täyttyneen rakoparven aukeneminen saattaa myös liittyä rapakivimassiivien paikoilleen asettumiseen. Kvartsiittisulkeumien (Kuvat 29 ja 30) runsaus useissa juonissa viittaa siihen mahdollisuuteen, että kvartsiittia tutkimusalueella on syvemmällä runsaammin, vaikka se nykyisellä eroosiotasolla on jokseenkin harvinaista.

PREFACE

The present study was mainly carried out in connection with the mapping of pre-Quaternary rocks for the Geological Survey of Finland. The author is indebted to the Director of the Geological Survey, Prof. Vladi Marmo, and the Head of the Petrological Department, Prof. Ahti Simonen, for allowing this study to be performed as part of the official work and accepting it for publication in the series, Bulletin de la Commission géologique de Finlande.

In the field work I was assisted by Messrs Seppo Lahti, Leif Myrskog, Mag. Phil., Ahti Tanskanen, Jorma Porras, Juha Raippalinna and Kari Kemppainen. Unpublished information about diabase occurrences was given to me by Professors Aarne Äyräpää and K. J. Neuvonen and Messrs Klaus Säynäjärvi, Mag. Phil., Eero Nenonen, Mag. Phil., Erkki Ilvonen, Mag. Phil., and Erkki Viluksela, Mag. Phil.

In the mineralogical investigations and determination of mineral compositions I received assistance from Mrs. Toini Mikkola, Lic. Phil., Messrs Pekka Kallio, Mag. Phil., Kalevi Korsman, Mag. Phil., Göran Sandholm, Cand. Nat. Sci. and Reijo Niemelä. The radiometric age determinations were made by Dr. Olavi Kouvo and Mr. Matti Sakko, Mag. Phil. and the susceptibilities were measured by Mr. Uljas Hämäläinen. The technical part of the microphotographing was the charge of Mr. Erkki Halme. The chemical analyses were performed in the Chemistry Department of the Geological Survey. The maps and diagrams were redrawn by Miss Lea Marjomaa. The text was translated from Finnish into English by Mrs. Toini Mikkola and revised and corrected by Mrs Gillian Häkli. Dr. Brian Gulson critically reviewed the manuscript and made a number of useful suggestions.

I wish to express my appreciation to all the persons mentioned above for the assistance given to me.

Special thanks are due to Prof. K. J. Neuvonen. Our many excursions together in the area and our fruitful discussions developed my ideas in many ways about the formations which are the topic of this study. His remarks when he examined my thesis for the Lic. Phil. degree on the same topic were also of great value.

Otaniemi, May 1969.

Ilkka Laitakari

INTRODUCTION

The diabase dike set under consideration is located in the province of Häme (See the appended map). Its western end lies some 35 km N of Tampere and the eastern limit of the research area is around the town of Heinola. The known length of the dike set is about 150 km and the width, about 20 km. (The dikes of Vaheri have been neglected, for they are far outside the set proper.) Of the more than hundred diabase dikes found in the area, the broadest is some 250 m wide and the longest is at least 11 km. Most of the dikes are 5—50 m wide. They display a rather uniform and distinct trend and form a typical dike set, much like the swarms described from Sweden (e.g. Gorbatschev, 1961), Greenland (Emeleus, 1964; Bridgewater, 1967; Ayrton, 1963), Canada (Fahrig and Wanless, 1963) and USA (Prinz, 1964).

The oldest observations on diabases in the Häme area were made in connection with the general geological mapping on the scale 1: 400 000 in the 1890's. The diabase dikes then found were those of Huppionvuori (Sederholm, 1891, 1893), Ansio (Andersson, 1891; Frosterus, 1900, 1902, 1903), Nikkaroinen (Uoti, 1891), Petäjäsaari (Andersson, 1891) and Pähkinä (Arppe, 1891; Frosterus, 1900; called »Asikkala» by Frosterus, 1902 p. 74, 1903 p. 75). Sederholm (1893 p. 105) grouped the dikes of Huppionvuori and Ansio with the diabase of Satakunta. Frosterus (1902 p. 74) compared the diabase of Ansio with the gabbro of Keuruu although he was not certain that these rocks belonged to the same group. Furthermore he mentions the diabase of Petäjäsaari (called »Hinttola» by Frosterus, 1902 p. 74, 1903 p. 75) as being of the same type as that of Ansio.

After the general geological mapping of the area extensive geological investigations were started in the 1950's. In his two publications, Seitsaari (1951, 1954) describes the Huppionvuori dikes, found by Sederholm, and the Pääskylä dike in Längelmäki. In connection with their pegmatite investigations, Volborth (1954) and Vesasalo (1956) found some diabases in Eräjärvi, and in his study on the massif of Ahvenisto, Savolahti (1956 a, b) describes a dike he found near the rural church of Heinola. Later Savolahti (1964) also described the mineralogy and petrography of the Ansio diabase in Padasjoki.

The beginning of geological mapping on the scale 1: 100 000 (See index of the map sheets inserted in the appended map) heralded the start of systematic research. Some diabase dikes had already been found in the map sheet areas 2124, Viljakkala—Teisko (Simonen, 1952, 1953) and 2141, Kangasala (Matisto, 1964). The existence of the dike set proper was established by investigations carried out under the guidance of the author since 1963 in the map sheet areas of 2143, Padasjoki, 2144, Kaipola and 2142, Orivesi. The continuation of the set east of Lake Päijänne was verified by the investigations of Lehijärvi in map sheet areas 3112, Heinola and 3121, Sysmä.

The first attempt to give a total picture of the dike set were the articles on the subject published in Geologi (I. Laitakari, 1965 a, b). In his thesis for Lic. Phil. (I. Laitakari, 1966) the author described certain aspects of the dike set in greater detail than the present work, particularly the individual diabase occurrences.

The set of dikes can scarcely be confined to the research area and it is quite plausible that it continues outside the area. Particularly the diabases north of the Viipuri rapakivi massif (Savolahti, 1956 b; Lehijärvi and Tyrväinen, 1969; Simonen and Tyrväinen, 1965) could be genetically related to the diabases of Häme.

Owing to the paucity of outcrops it is quite possible that the collection of dikes represented on the appended map is incomplete. The absence of dikes on the map between Toikko and Huppionvuori and east of Nikkaroinen probably reflects the lack of mapping in these areas.

GEOLOGICAL ENVIRONMENT

Metamorphic complex

Even with the several detailed studies made of the research area (Seitsaari, 1951, 1954; de Waard, 1952; Savolahti, 1956 b; Vesasalo, 1956; Virkkunen, 1964) and three geological maps on a scale 1: 100 000 of its border areas (Simonen, 1952, 1953; Matisto, 1964; I. Laitakari, 1964), the general geological maps (Frosterus, 1900, 1902, 1903; Sederholm, 1903, 1911 c, 1913 a) still give the best outline of the overall geology. A generalized map of the bedrock of Southern Finland is inserted in the appended map.

The Svecofennian belt in which the main part of the diabase dike set is located is characterized by veined gneisses, mica schists and graywacke schists, in the northern part also by metavolcanic rocks. Quartzites and pyroxene gneisses are scarce in the area. Plutonic massifs of different sizes occur everywhere among the schists in the area. The most common type is porphyric granodiorite, but granites abound at the SE-end of the dike set and at the NW-end, which extends to the region of plutonic rocks in Central Finland. Particularly in Eräjärvi, granite pegmatites are fairly common. Gabbro occurs in places as massifs, several kilometres in diameter. Peridotites are less frequent.

The regional metamorphism of the bedrock of Southern Finland took place some 1900 million years ago (Kouvo and Tilton, 1966) in connection with the Svecofennidic folding.

In addition to the diabases proper, basic dike-like rocks belonging to the metamorphic complex have been found in many places. In most cases they are easily distinguished in the field from the diabases proper, for they are usually schistose or brecciated. Microscopic study further reveals alterations characteristic of the metamorphic rocks. Irrespective of their texture, the principal minerals in these rocks are generally plagioclase and green hornblende.

Ophitic texture is regularly seen as relics in the metadiabases although in most cases it is not possible to observe whether they were ever dikes. Most metadiabases occur as brecciated fragments in granitic rocks or as small outcrops whose relations with the surrounding rocks are ill-defined. On the north coast of Hopeaselkä in Asikkala (Arppe, 1891) a fine-grained blastophitic rock occurs as small bodies, in which hornblende and biotite fill the interstices between elongated plagioclase laths. The diabase west of the Kangasala church (Matisto, 1964) is similar, but of coarser grain size, and its dike character seems more probable. Plagioclase porphyrite, which before its metamorphism must have closely resembled diabase, occurs, for example on the western shores of Lake Vesijärvi (I. Laitakari, 1964), 7 km S of the Kuhmalahti church (Matisto, 1964) and west of Lake Löytäne in Längelmäki.

Seitsaari (1951) has described amphibolite dikes in the Orivesi area, and after his investigations a whole swarm of these have been exposed in a large road cut south of the Orivesi church. A similar dike was described by Aurola (1967, p. 29) near the Toikko diabase in Kuru.

Dikes of uralite porphyrite have been found in Virmaila, Padasjoki, where the dislocation of the dikes proves them to be older than the folding.

Postmetamorphic rocks

The most important of the rocks younger than the Svecofennian metamorphic complex in Southern Finland are the rapakivi granites. Besides the large rapakivi massifs of SE and SW Finland (cf. Savolahti, 1956 b p. 7; most of these massifs can be seen on the appended map of the present study) there are some smaller intrusions, the so called anorogenic granites, on the coast and in the archipelago of the Gulf of Finland. They are marked on the appended map with the same symbol as rapakivi granites. Besides the typical rapakivi, known for its potash feldspar ovoids mantled by plagioclase, the rapakivi massifs include other porphyric and even-grained granite types (Simonen 1960).

Diabases and other basic igneous rocks are associated with almost all rapakivi intrusions. In some cases they appear to be older than the rapakivi and in some cases younger. The horseshoe-shaped gabbro-anorthosite surrounding the Ahvenisto rapakivi massif (the rapakivi area close to the eastern border of the research area on the appended map) is older than rapakivi according to Frosterus (1902 p. 97, 1903 p. 99) and Savolahti (1956 b p. 79), as are the quartz diabases (Savolahti, 1956 b

p. 79) around the Viipuri rapakivi (the largest massif in SE Finland). The diabases around the Åland rapakivi include dikes both older (e.g. Eckerö; Sederholm, 1890 p. 468) and younger than the rapakivi (e.g. Föglö; Frosterus, 1893 p. 290; Wahl, 1906 and Märket; Sederholm, 1890 p. 468). The large olivine diabase dikes of Satakunta are younger than the rapakivis of the area (Gylling, 1888 p. 56). The extensive dikes of the Vaasa archipelago (Saksela, 1934) must also be included in the diabases associated with rapakivis because near them, on the sea floor, is a rapakivi area described by Veltheim (1962 p. 156). A. Laitakari (1942 p. 38) regards the dikes as contemporaneous with the diabases of Satakunta and this is supported by the paleomagnetic studies of Neuvonen (1965, 1966).

The diabase dikes marked on geological maps (Lehijärvi, 1964 a, b, and Härme, 1969) south of the research area are so distant that nothing can be said of any relationship between them and the Häme diabases. However, these dikes, or at least some of them, may well be contemporaneous with the dikes of the Häme area as they sometimes contain the same types of autoliths and megacrysts (cf. Saastamoinen, 1956 p. 33).

Quartz porphyry and granite porphyry dikes are also often associated with rapakivis and other anorogenic granites. Examples of such dikes may be observed in the Åland Islands (Hausen, 1964 p. 72) and around the granite of Onas (Borgström, 1907, 1947; Härme 1969). Numerous granite porphyries and quartz porphyries (Ramsay, 1890; Simonen and Tyrväinen, 1965; Wahl, 1925 p. 21) occur in connection with the rapakivi areas in SE Finland. Among them the dikes in the rural commune of Heinola (Frosterus, 1900, 1902 p. 80, 1903 p. 81; Savolahti, 1956 b p. 73; Lehijärvi and Tyrväinen, 1969) belong on the map apparently to the same dike set as the diabases of Häme.

Attention has been paid, in many localities, to the close relationship between the diabases and quartz porphyries associated with rapakivis. Saastamoinen (1956 p. 7) described quartz porphyry and diabase breccia dikes from Sipoo which had apparently intruded the same joint. A still closer connection between diabases and quartz porphyries is revealed by their occurrence in composite dikes (Kaitaro, 1953 p. 54; Frosterus, 1902 p. 81, 1903 p. 83). Likewise Ramsay (1890 p. 479) concluded that quartz porphyry and diabase are geologically related rocks. In the above areas where it was possible to establish age relations, the diabase was older than the quartz porphyry.

The above facts, verifiable mainly in the field and on the map, have led a fair number of investigators to consider the genetic relation of the basaltic magmas, which have formed the diabase dikes, and the granitic magmas which have produced the rapakivi massifs. Frosterus (1902 p. 98, 1903 p. 99) assumed that diabase and rapakivi were intruded from the same differentiated magma chamber. In his extensive study on the rocks of the Viipuri rapakivi area also Wahl (1925) came to the conclusion that it is a question of differentiation of the same parent magma. Sederholm (1928 p. 84) did not fully accept the opinion of Frosterus when he wrote concerning rapakivis: »Basic rocks occur closely associated with them, but it is doubtful, whether they are really, as has been assumed, differentiation products from the same magma». Wahl's studies might have moderated Sederholm's opinion as he later (Sederholm 1934 p. 62) wrote on the same rocks: ». . . that there may be certain connection lower down». Savolahti (1956 b p. 82, 1966 p. 174) regarded the gabbro-anorthosite of Ahvenisto to be so much older than rapakivi that they cannot have been formed from the same magma by means of crystallization differentiation. Referring to the similarities between the anorthosites and mangerites investigated by Phillpotts (1966), Kranck (1967) concluded that rapakivi granites and the associated anorthosites also are differentiation products of the same parent magma.

Sederholm (1895) described from Karvia, NW of the map appended to the present paper, a rock which he thought to be a quartz porphyry. However, the rock seems to have formed from the surrounding granite through dynamometamorphism. Thus the rock would not be genetically associated with the diabases in Häme.

The diabase dike swarms of Suomussalmi (Matisto, 1958 p. 89), Varpaisjärvi-Sonkajärvi (Wilkman, 1924) and Keuruu (Marmo and Mikkola, 1963) are not associated with rapakivi rocks and their relationship to the Häme diabases is unknown.

Besides the intrusive postmetamorphic rocks mentioned above, there occur in Southern Finland a number of sedimentary rocks, among which the Jotnian sandstone of Satakunta (A. Laitakari, 1925) forms a large regional unit. This sandstone is cut by the extensive diabase dikes mentioned earlier and the author considers it possible that the preservation of sandstone from erosion could be genetically connected with diabases. The sandstone area is a large depression, the origin of which can be assumed to be connected with the extrusion of vast amounts of magma from the chamber underneath.

Zones of faults and ruptures in the bedrock

In the research area, as for Precambrian areas in general, the bedrock is cut by numerous zones of joints and ruptures. They are visible, both in the field and more distinctly on maps and in aerial photos, as straight or gently curving valleys and drainage sequences. At the beginning of the century Frosterus (1902 p. 96) and Sederholm (1911 a, 1911 b, 1912, 1913 b, 1932) already noted regularities in the trends of the valleys and, particularly, the lake shores.

Eskola (1935, 1960) believed that the laumontite of Sarkasjärvi (near the name Liehu on the appended map), Kuhmoinen, belonged to the fault line which extends from the upper course of the Kymijoki river (the name Huovari on the map) through Kellosalmi and Lummene to Pitkävesi (the name Salinsaari on the map). He also regarded it as quite possible that zeolites may also occur in other fault lines. The presence of numerous zeolite erratics in Kuhmoinen, Padasjoki and Lammi suggests that the Sarkasjärvi district is not the only zeolite occurrence in this area.

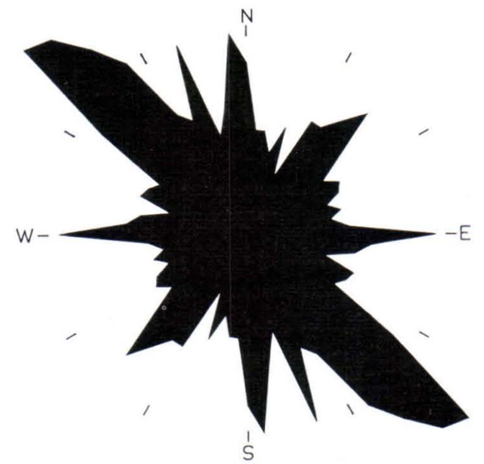

FIG. 1. Orientation diagram of valley trends assumed to reflect the jointing directions of the bedrock. The diagram is compiled on the basis of topographic maps (1 : 20 000) and aerial photographs. One unit in the diagram equals to 2 500 m or less of a valley or drainage trend. The diagram includes 1171 observed units.

Varying estimates for the age of the faults have been given by the authors mentioned above. Recently it has been suggested (Härme, 1961) that most of the fault lines are of Precambrian age, although later movements may have taken place.

The orientation diagram in Fig. 1 reveals the frequency of the valley trends in the topography of the Häme area. It is difficult to decide whether the most striking maximum N 40°—50°W is caused by a dominant rupture trend or that it is nearly parallel with the most prominent direction (~ N 40°W) of movement of the Quaternary continental ice sheet in this area.

The association of some diabase dikes with zones of rupture was first observed by Frosterus (1902). In his study of the diabase of Ansio, Savolahti (1964) pointed out that it was parallel to the fracture valleys of the district.

The relationship between the trends of the diabase dikes and those of the ruptured zones will be dealt with later.

DIABASE DIKES

Explanatory notes

An outline of the general features of the Häme dike set were given in the introductory chapter. The clearest concept of the set as a whole can be obtained from the appended map. Due to the scale the sizes of the smaller dikes are markedly exaggerated.

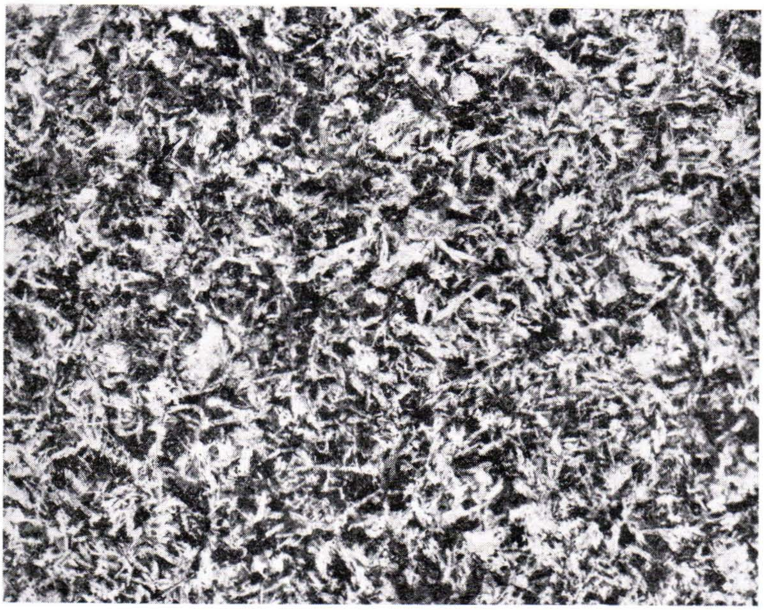

FIG. 2. Photomacrograph of a weathered diabase surface showing the typical ophitic texture of the rock. Haarajärvi (A), Kuhmalahti. Magn. 3 x.

The idea of marking the dikes of different width with different signs had to be abandoned because the true width of a great many dikes could not be determined, owing to the scarcity of outcrops. Thus a red line in the map means solely that diabase exists at that point. The true observations can be found in Table 1.

The names mentioned in Table 1 can be found on the appended map. The letters after the names mean the dikes in the same locality while the observations of the same dike made at different outcrops are distinguished by numbers. The number in the column »map sheet» means the symbol of the 1: 20 000 maps. Its first four numbers give the symbol of the 1: 100 000 map, which is also followed in the published geological maps. The index of map sheets can be seen in connection with the appended map. The numbers in the column of coordinates refer to the kilometre coordination used for topographic and geologic maps in Finland. The same coordination is also marked in the margins of the appended map. The numbers are given with sufficient accuracy to facilitate the location of each dike in the field.

The column »known length» gives an approximate idea of the length of the dike in the field. For the great majority of dikes it can be assumed that they are in fact much longer. The width is usually measured with a measuring tape and an exact number indicates that both contacts were successfully observed on the opposite sides of the dike. »>» means a measured minimum width when one or both contacts are unknown. »Trend» is measured from the map, especially as regards long dikes,

TABLE 1

Field observations of diabase dikes in Häme; r = abundant, p = scarce, s = sporadic.

Map sheet	Coordinates	Name of locality	Known length m	Known width m	Trend	Dip	Plagioclase megacrysts	Plagioclase phenocrysts	Autoliths	Quartzite xenoliths	Rheomorphic dikes	Cutting diabase dikes	Shearing zones
212409	6855.1 —485.4	Toikko .... A	50		N 40° W	60° SW	r	r					
»	6855.05—485.4	B	10		N 85° W								
»	6854.95—485.45	C	50	> 9	N 40° W		r	r	p	r	s		
213412	6799.8 —573.55	Röhnäkallio	40	2	N 45° W	90°		s					
214109	6827.58—520.38	Härmänsaari .. 1	1 000		N 65° W		r	p					
»	6827.2 —521.25	2		20	N 70° W	70° SW	p	r		s			
214109	6825.62—526.16	Mattilanniemi . 1	1 000	> 21	N 75° W	SW	r	r					
»	6825.43—527.05	2		> 14	N 80° W	70° S	r	r					
214112	6829.25—534.26	Iilivuori ...... A 1	700				r	r		r			
»	6829.2 —534.4	A 2		63	N 70° W								
»	6828.9 —534.8	A 3			N 35° W								
»	6829.22—534.15	B	10	2			s	r					
214112	6829.6 —537.2	Sinijärvi	2	0.2	N 40° W	80° SW		r					
214204	6837.14—513.92	Säynäjärvi 1	1 700										
»	6836.85—514.75	2		7	N 85° W	80° N	r	r			p		
»	6836.72—515.52	3		> 8									
214204	6838.2 —516.75	Huppionvuori . A	150	40	N 60° W	NE	p	p		p	p		
»	6837.6 —517.34	B 1	1 500	35	N 75° W	90°	p	p		p			
»	6837.36—518.08	B 2			N 60° W								
»	6837.2 —518.52	B 3						s					
»	6837.1 —519.27	C	50	2	W—E	85° S		p					
214207	6837.73—520.32	Venejoki	10	0.1	N 65° W	75° NE		r					
214207	6836.86—522.03	Solttila 1	300						s		p		
»	6836.81—522.18	2		20	N 65° W	90°		s					

214207	6832.35—527.4	Kaakkolammi . A 1	1 100	> 19	N 60° W								
»	6832.12—527.78	A 2		21	N 60° W								
»	6831.92—528.2	A 3			N 75° W		s	p		p			
»	6831.6 —527.3	B	25	0.8	N—S	80° W		p					
214207	6831.2 —529.1	Maijaanvuori .. 1	100										
»	6831.18—529.2	2		> 25	N 40° W	NE	r	r	p	r	p		p
214210	6839.12—537.6	Pääskylä	50	> 15	N 50° W								
214210	6835.23—531.22	Leväslahti 1	550	9	N 70° W	90°	s	p	s	p	s		
»	6835.0 —531.72	2		8	N 75° W		s	p					
214210	6833.04—534.42	Koskihoru ... 1	700	4.5	N 60° W			r			p		
»	6832.75—534.7	2		5			s	p					
»	6832.62—534.95	3		1.6			s	p			p		
214210	6830.9 —535.8	Viitaniemi	100	2	N 55° W	70° SW	s	p					
214210	6830.5 —538.95	Sinipilkka	30	3.4	N 45° W	80° NE	r	p	s		s	p	
214302	6819.26—543.16	Karinlahti 1	2 100	80	N 45° W								
»	6818.15—544.6	2			N 50° W								r
214302	6817.1 —546.5	Ansio 1	6 500		N 60° W								p
»	6816.45—547.65	2		> 100	N 50° W				s				
»	6815.02—549.18	3			N 50° W								
		(continues on map 214305)											
214303	6828.45—541.0	Pitkäkalliot ... A 1	150	9	N 65° W	80° SW		s					
»	6828.4 —541.0	A 2		> 8			s	p			p		
»	6828.38—541.25	B	10	6	N 5° E	90°							
»	6828.34—541.3	C	40	> 2	N 50° W	70° SW	r	r					
»	6828.32—541.37	D	4	0.1	N 25° W	75° SW							
»	6828.25—541.52	E	40	27	N 55° W	80° SW	r	r			p		p
»	6828.26—540.83	F	2	0.1	N 45° W			r					
214303	6828.2 —546.35	Saarilahti	20	> 1	N 5° W	50° W		r	s		p		
214303	6826.55—545.1	Kaukola	20	> 5				r					

TABLE 1, *continued*

Map sheet	Coordinates	Name of locality	Known length m	Known width m	Trend	Dip	Plagioclase megacrysts	Plagioclase phenocrysts	Autoliths	Quartzite xenoliths	Rheomorphic dikes	Cutting diabase dikes	Shearing zones
214303	6825.5 —544.98	Setälänlahti	2	> 0.1	N 65° W	90°							
214303	6825.9 —546.5	Haarajärvi .... A	80	15	N 55° W	70° NE	r	r	p				
»	6826.0 —546.6	B	30	0.1	N 5° E	80° W		p					
214303	6825.6 —547.8	Särkijärvi	200	0.9	N 55° W	75° SW		s					
214303	6825.85—548.62	Liehu	400	17	N 40° W	90°	s	r	s				
214303	6822.4 —544.75	Vehkajärvi	40	3.1	N 70° W	75° N	r	r	s				
214303	6820.95—541.85	Karivuori ..... A 1	700										
»	6820.8 —542.05	A 2		> 53	N 50° W	90°	r	r		p	p		
»	6820.45—542.4	A 3			N 45° W	90°	s						
»	6820.8 —542.05	B	20	0.3	N 35° W	90°	r	p			p		
214305	6817.7 —555.7	Rajalankangas	10	> 3	N 45° W	SW		r					
214305	6817.0 —556.4	Partakorpi	200	> 30	N 70° W								
		(continuation from map 214302)											
214305	6813.65—550.96	Ansio 4		> 60	N 55° W			s	s				p
214305	6812.85—552.9	Muorinkallio	500	> 80	N 50° W			p	s				
214305	6811.0 —555.25	Romo	700	> 50	N 50° W								
214305	6816.75—559.23	Torittu 1	2 200	> 30	W—E								
»	6816.7 —559.66	2		> 23									
»	6816.6 —559.96	3		> 35	N 80° W								
		(continues on map 214308)											

214306	6823.42—552.56	Anttila .... A	120	4	N 70° W	90°	s	s					
»	6823.26—552.7	B	70	3	N 75° W	90°	r	r				p	
»	6823.2 —552.68	C	20	> 10									
214306	6824.2 —554.86	Katajajärvi .... A	4	0.7	N 55° W	60° SW							
»	6824.2 —554.86	B	8	0.5	N 70° E	65° SE		s					
»	6824.2 —554.86	C	3	0.2	N 85° E	80° S		s					
214307	6806.84—569.1	Tuomasvuori . 1	2 100	> 50	N 55° W		s	p			p		
»	6806.68—569.3	2		> 45	N 55° W						p		
		(continues on map 214310)											
214308	6819.24—560.3	Saunavuori	500	> 42	N 60° W	80° NE							
214308	6818.28—562.48	Myllylahti .... A	60	> 40	N 45° W		s	s					
»	6818.25—562.45	B	3	0.3	N 40° W	85° NE		p					
		(continuation from map 214305)											
214308	6816.58—560.13	Torittu 4		> 59	N 80° W								
»	6816.45—560.75	5		> 45	N 85° W							p	
»	6816.42—561.12	6		64	W—E							p	
214308	6815.74—562.93	Munuajärvi	30	1.1	N 55° W	75° SW		p					
214308	6815.65—564.9	Koukkujärvi .. A 1	500	24	N 70° W	70° NE	p	r					
»	6815.52—565.22	A 2		> 20	N 70° W	55° NE	r	r	p	r	p		
»	6815.4 —565.1	B	100	12.5	N 80° W	90°	s	p		s			
214308	6815.42—566.42	Kellosalmi	40	> 25	N 65° W	80° NE		s					
214309	6820.7 —560.1	Harmoistenkaivo ...	100	45	N 40° W	90°		s					
		(continuation from map 214307)											
214310	6805.93—570.29	Tuomasvuori . 3			N 45° W		s		s				
»	6805.76—570.45	4			N 45° W			r					
214310	6804.77—572.16	Nuijasaari 1	2 100	> 60	N 60° W	SW	p	p					
»	6804.54—572.58	2			N 60° W		s						
»	6804.07—573.55	3		> 80	N 55° W	SW	p	p					

3 12460—69

TABLE 1, *continued*

Map sheet	Coordinates	Name of locality	Known length m	Known width m	Trend	Dip	Plagioclase megacrysts	Plagioclase phenocrysts	Autoliths	Quartzite xenoliths	Rheomorphic dikes	Cutting diabase dikes	Shearing zones
214310	6803.6 —575.1	Hirtniemi ..... A	30	6	N 45° W	90°		p					
»	6803.6 —575.1	B	10	1	N 45° W	90°		s					
»	6804.3 —574.8	C	80	> 12	N 85° W								
»	6804.35—575.08	D	40	> 30	N 75° W				s				
»	6804.36—575.4	E 1	2 100		N 45° W			r	p				
»	6804.22—575.62	E 2		44	N 45° W	90°		s					p
»	6803.82—576.04	E 3		65	N 50° W		s	s					
»	6802.92—577.04	E 4											
»	6804.27—575.68	F	10	0.5	N 50° W	90°		r					
214310	6801.82—579.76	Petäjäsaari 1	500				p	p					p
»	6801.7 —579.86	2			N 60° W		s	s	p				
»	6801.66—580.14	3		> 145									
214311	6816.96—574.44	Linnasaari .... A 1	1 300	> 35	N 85° W		s	p					
»	6816.9 —575.0	A 2		41	N 85° W	85° S	p	p	s		p		
»	6816.9 —575.7	A 3		34	N 85° W	85° S	p	p	s		p		
»	6816.94—575.68	B	10	> 10	W—E	90°		s			p		
»	6816.88—575.64	C	45	1	N 85° W	90°		p					
214311	6814.04—570.29	Virmaila 1	11 000	> 40	N 85° W	90°							
»	6814.0 —571.6	2		> 60	N 85° W	N							
»	6813.63—574.13	3			N 80° W								
214401	6838.5 —543.1	Vuorijärvi .... A	3	0.3	N 65° W	50° NE		p					
»	6838.1 —543.1	B	30	9	N 65° W			p					
214401	6836.8 —541.9	Pirttijärvi	40	19	W—E			p		s	p		
214401	6836.2 —546.15	Mutaisenlammi 1	30	1.3	N 45° W	90°		p					
»	6836.2 —546.15	2		1.3	W—E	70° N		p					
214401	6835.7 —547.8	Lepolahti	20	> 13	N 75° W	80° NE		p					

214401	6835.3 —549.4	Latopohja		30	> 5	N 75° W			s					
214401	6831.85—544.85	Salinsaari		100	> 25	N 45° W	SW	p	p	s		p		
214404	6832.25—557.05	Velisjärvi		40	11	N 85° E	80° S		p					
214412	6857.26—577.61	Vaheri	A	40	22	N 65° W	80° NE							
»	6857.56—576.86		B	30	0.4	N 60° W	65° SW							
»	6857.86—577.49		C	2	0.3	N 75° E	90°							
311203	6800.0 —423.03	Leveälahti	1	600		N 60° W			s			p		
»	6799.74—423.53		2		> 26				s					
311203	6799.0 —426.6	Huovari		6	> 6	N 50° W								
311206	6799.94—430.48	Hepomäki		100	9.5	N 70° W	90°							
311206	6799.55—431.85	Iso Niinilammi	A	30	11	N 60° W	90°		p			s		
»	6799.35—432.25		B	4	1.9	N 45° W	75° NE		p					
311206	6798.85—433.5	Vähä Kerjärvi .	1	200	8	N 45° W	80° NE	p	r					
»	6798.75—433.7		2		> 7	N 50° W	55° NE		p	p		p		
311206	6798.85—434.8	Soidinkallio		20	8	N 55° W			s					
311206	6797.95—435.3	Martinmäki		100	13	N 80° W	75° S	p	r					
311206	6798.23—435.82	Polkjärvi	A	100	20	N 55° W			s					
»	6798.08—435.9		B	2	0.1	N 55° W			s					
»	6798.08—435.9		C	2	0.5	N 55° W	90°		s					
»	6798.06—436.03		D	5	> 2			p	p					
311206	6797.2 —438.04	Pähkinä	1	300					s	p		p		
»	6797.1 —438.34		2		22	N 75° W	90°		s					
311206	6796.66—438.36	Tyystjoki	1	420	12	N 65° W			p					
»	6796.58—438.5		2		8	N 65° W						p		
»	6796.48—438.72		3		6	N 70° W	90°							
311209	6797.2 —440.12	Ohniemi	1	1 900								p		
»	6797.1 —440.26		2		> 25							p		
»	6796.12—441.34		3		25	N 50° W	70° NE		p			p		

TABLE 1, *continued*

Map sheet	Coordinates	Name of locality	Known length m	Known width m	Trend	Dip	Plagioclase megacrysts	Plagioclase phenocrysts	Autoliths	Quartzite xenoliths	Rheomorphic dikes	Cutting diabase dikes	Shearing zones
311209	6796.09—440.5	Kurjenniemi	400	24	N 40° W	90°		p	p				
311209	6795.3 —443.4	Sammallahti	40	0.3	N 85° E								
311209	6795.12—449.75	Rural church of 1	1 400	> 100			p	p	r		p		p
311212	6794.54—450.37	Heinola 2		250	N 45° W								
»	6794.22—450.66	3											
312101	6805.03—427.76	Yskelä	50	> 30									
312101	6803.05—525.8	Ahola 1	100	0.5	N 55° W	90°		p					
»	6803.02—525.88	2		3.5				p					
312101	6801.58—427.8	Riihilahti	50	13	N 55° W	80° NE	p	p					
312102	6813.6 —428.65	Vitko	2	> 2	N 40° W			s					
312102	6811.65—429.05	Nikkaroinen	100	> 65	N 85° W								
312104	6803.43—430.17	Hanjärvi 1	500	> 30	N 75° W								
»	6803.28—430.59	2			N 75° W								

but in most cases with a compass in the field. In the latter case the declination has been corrected, and the measurement then rounded to the next 5°. »Dip» is usually measured at the contact, but when this is not possible, from the fluidal texture or other structural features.

The concept of phenocryst means plagioclase crystals or fragments less than 5 cm, and megacryst over 5 cm in diameter in a finer-grained matrix.

In the following chapter diabase dikes of different sizes and types from various parts of the Häme area are described. The location, trend, width etc. of these dikes are given on the appended map and in Table 1.

Examples of diabase occurrences

Torittu—Partakorpi

The width of the diabase dike of Torittu is some 60 m and the dike could be followed in the field about 2 200 m. Less than 3 km to the west a very similar dike (Partakorpi) can be considered a continuation of the Torittu occurrence. In both dikes the diabase has spotted texture (Figs. 3 and 4) due mainly to plagioclase clusters, 1—2 cm in diameter. Olivine ($2V\alpha = 85°$) and augite ($2V\alpha = 42°—46°$, $c \wedge \gamma = 40°—41°$)

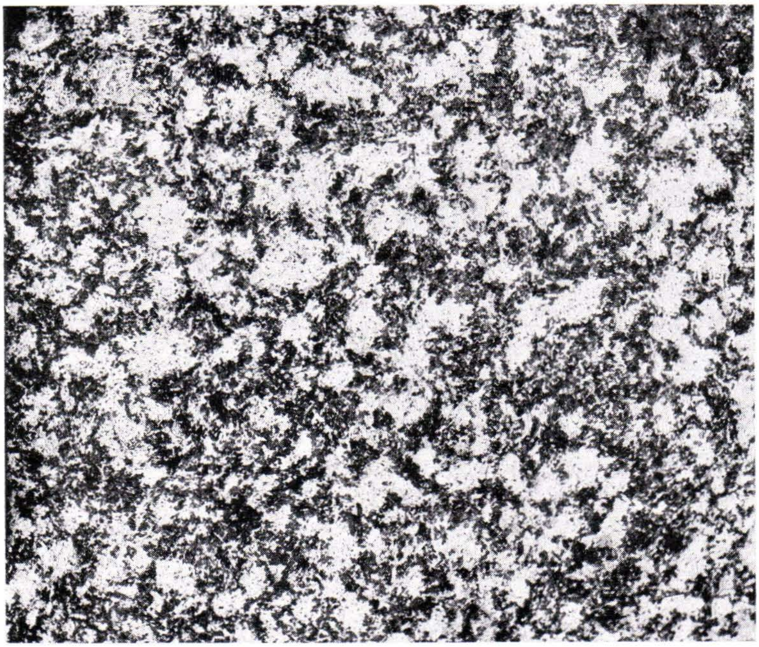

FIG. 3. The plagioclase spots of spotted diabase can best be seen in the weathered surfaces of the rocks. Torittu (2), Padasjoki. 1/2 nat. size.

fill the interstices between the laths. Two generations of plagioclase seem to exist. The main part occurs as laths forming the ophitic texture, and the crystals have a center of An_{55} while the borders are somewhat more albitic. The other crystals are smaller, are more altered and have a higher albite content. The border zones of these grains are richer in anorthite than their centers. Accessories are titanomagnetite, biotite, apatite, zircon and serpentine as the alteration product of olivine.

In three localities, all less than 10 m from the contact, fine-grained diabase dikes were observed (4—8 cm wide) cross-cutting the main diabase dike. Although these cross-cutting dikes have a distinctly finer grain size than that of the main dike, no chilled contacts were observed (Fig. 5). Plagioclase (An_{55}) is more abundant in the cross-cutting dikes.

The contacts of the main dike against the country rock are not sharp. The diabase displays, even to the naked eye, micrographic texture at the contact. Rheomorphic dikes, however, were not observed. The spotted texture characteristic of the central part of the dike does not occur at the borders where the diabase is also somewhat finer-grained. (See also Tables 2, 3 and 4.)

Rural church of Heinola

The diabase dike near the rural church of Heinola is at least 250 m wide and its known length is some 1 400 m. As such, it is the widest dike in the Häme area. Contacts were not found, but their position can be fairly accurately placed by means of morphology and adjacent exposures. The dike is truncated at both ends by fault zones. The SE end is covered by the small Kotajärvi Lake which forms a continuation to the long and narrow Lake Ala-Rääveli, and at the NW end there is a cliff with mylonite. It is not possible to determine the age relations of diabase and the fault zones, although in all probability, the faults are older than diabase. The dike appears as a rather strong anomaly on the aeromagnetic map, but there are no indications of its continuation outside the fault zones.

The Heinola diabase has a coarser grain size than that generally observed in the dike set. The plagioclase laths forming the ophitic texture are some 5—15 mm in length. In many places the larger plagioclase laths lie subparallel while the smaller laths between them show no orientation. Olivine and augite fill the interstices between the plagioclase laths. The rock also contains some biotite, hypersthene, ilmenite and apatite. Biotite occurs usually as a rim round the ilmenite grains. The hypersthene ($2V\gamma = 52°$) apparently crystallized earlier and was corroded at a later stage while augite ($2V\gamma = 42°$, $c \wedge \gamma = 40°$) appears as large, unaltered grains.

In some places, even close to the contact, megaophitic diabase has been observed. In this rock the plagioclase laths forming ophitic texture may attain the length of some 5—7 cm.

FIG. 4. A photomicrograph of spotted diabase. Partakorpi, Padasjoki. Magn. 6 x, nic. +.

FIG. 5. Contact of the Torittu (6) diabase and a cross cutting diabase dike. The width of the cutting dike is about 5 cm, and no chilled margins can be observed. Magn. 9 x, nic. +.

In the SE part of the dike little or no alteration has taken place. In the NW part of the dike the rock is heterogeneous. Near shearing zones in this area the minerals of diabase are somewhat altered; for example, olivine is completely serpentinized. The diabase also contains patches, several m^2 in area, resembling anorthosite and containing strongly saussuritized plagioclase laths exceeding 10 cm in length.

Two rheomorphic dikes have been observed. The smaller of these is about 30 cm wide and approximately at right angles to the trend of the diabase dike. The width of the larger one is about 95 cm and it lies almost parallel to the diabase dike. As this dike was found in only one small outcrop, the possibility of a fork cannot be excluded. The rheomorphic dike could thus be a remnant wedge of country rock, altered in situ. The material of both rheomorphic dikes is granitic as is the rock adjacent to the diabase dike.

Linnasaari

The width of the diabase dike in Linnasaari is some 40 m, and it is typical of the dikes of this size. The northern contact of the dike is seen morphologically as a cliff some 20 m high, about 200 m long and dipping to the north. On the eastern shore of the island there occurs an en bayonet structure. Here the dike is displaced by half its width to one side. The structure, as seen on the map (Fig. 7) indicates that it is not a fault, but the twists of the dike are associated with an opening mechanism of the joints at the time of intrusion.

The anorthite content of the plagioclase laths forming the ophitic texture (Fig. 6) varies from An_{58} in the center to An_{48} at the border. In addition to plagioclase the diabase contains olivine and augite, and minor amounts of biotite, apatite, ilmenite and magnetite. Serpentine is the alteration product of olivine. The mineral composition of the diabase is given in Table 3.

Near the N contact there are plagioclase phenocrysts, megacrysts and also a couple of anorthosite autoliths. Zoned mantles occur both around the phenocrysts and the autoliths (Fig. 8).

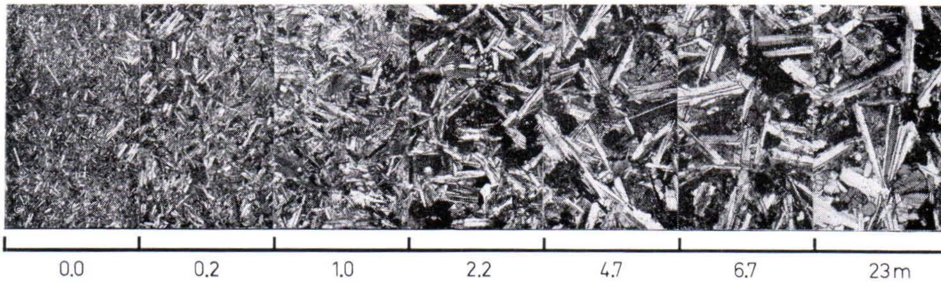

FIG. 6. Changing of the grain size from contact towards the center of the dike. The numbers give the distance from the S-contact of the dike in metres. Linnasaari (2), Padasjoki. Magn. 7 x.

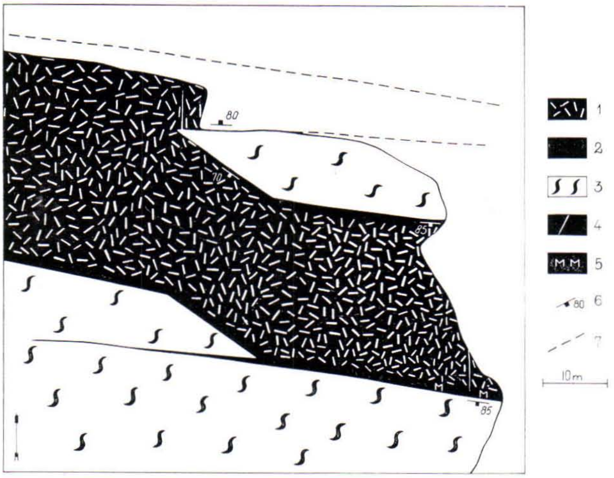

FIG. 7. A detailed map of the NE-edge of the Linnasaari island in Padasjoki. 1. diabase, 2. chilled margin of diabase, 3. migmatite rich in granite, 4. rheomorphic dike in diabase, 5. plagioclase mega-crysts, 6. direction and dip of the contact. 7. supposed contact under the lake floor. Note how the rheomorphic dike in the north cliff begins from the tip of the migmatite wedge where the contact effect was greatest between two diabase dikes. The rheomorphic dike in the east cliff seems to begin at the northern contact and not to reach to the southern contact of the diabase dike.

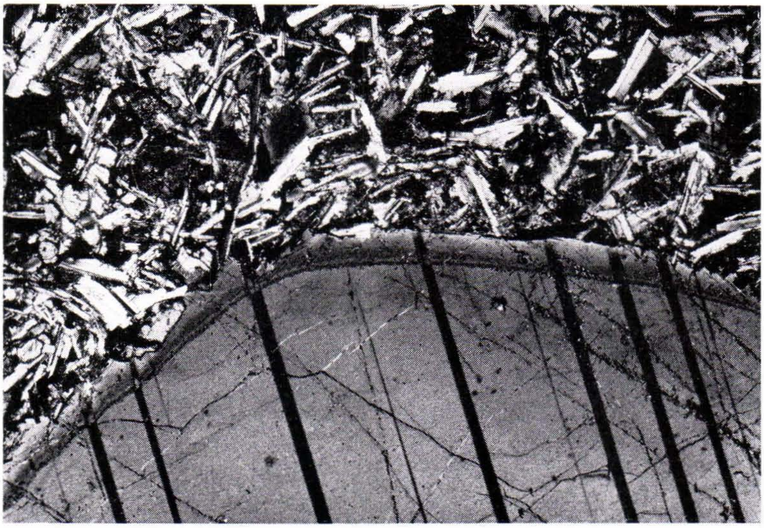

FIG. 8. A zoned mantle (inner rim An_{62} and outer rim An_{54}) is visible around a homogeneous plagioclase (An_{58}) megacryst. This mantle is slightly richer in anorthite than the zoned plagioclase laths (center An_{58} and rim An_{48}) of the matrix. Linnasaari, Padasjoki. Magn. 20 x, nic. +.

Three rheomorphic dikes are known in Linnasaari, where they cut the diabase dike almost at right angles. The most interesting dike is the one initiated from the tip of the wedge formed by the migmatitic country rock at the dike fork seen in Fig. 7. This dike can be followed for some 10 m in the diabase. Its width is about 30 cm near the contact and 10 cm at the distance of 10 m. Particularly at the tip of the wedge micrographic texture and other signs of partial melting caused by diabase are visible. Near this point the matrix of the rheomorphic dike is fine-grained and composed of feldspar, quartz and biotite. Scattered in the matrix there are also feldspar grains, 1—2 mm in diameter, and some quartz. The strongly altered feldspar in the matrix and in the larger grains is plagioclase and potassium feldspar. The matrix of the rheomorphic dike becomes more coarse-grained further from the starting point. The grain size is about 0.03 mm at a distance of 0.5 m from the contact of the diabase, and about 0.1 mm at a distance of 10 m from the contact. On the other hand, there is no distinct difference between the border and center parts of the dike. Larger feldspar and quartz grains grow scarcer in the rheomorphic dike further from the contact with the diabase dike and are almost lacking at a distance of 10 m. At the contact with the rheomorphic dike olivine has altered to brownish green biotite and serpentine. Alteration products of augite are finely dispersed biotite, colourless amphibole and sphene. Augite is absent in the diabase some 15 mm from the contact and olivine still further. Plagioclase is saussuritized near the contact.

Vähä Kerjärvi

The diabase dike of Vähä Kerjärvi is known in two outcrops some 200 m apart. The width of the dike is 8 m at the western outcrop, where its direction is N 50°W and dip 80°NE. The dike is fully visible across its breadth and its contacts against veined biotite gneiss are sharp. At both contacts there are 10 cm zones of fine-grained black diabase where phenocrysts are not visible to the naked eye. At the distance of 40—170 cm from the upper contact there are 2 × 5—3 × 13 cm phenocrysts between smaller plagioclase laths. On both sides of this zone the phenocrysts are smaller and fewer in number. The lath-shaped phenocrysts lie subparallel (as in Fig. 22) to the contact of the dike.

In the eastern outcrop the contact is visible for only a short distance and the dip is 55°NE. Plagioclase phenocrysts are scarce. An 8 cm diameter anorthosite autolith occurs in the diabase which consists of plagioclase (An_{57}) and some hypersthene. A 10 mm wide rheomorphic dike was observed in this outcrop, but its starting point is not observable. The matrix of this dike is fine-grained plagioclase, quartz and biotite with single grains of quartz, plagioclase and garnet a few millimetres in diameter. Plagioclase and garnet grains are strongly corroded and stained by alteration products.

Maijaanvuori

The diabase dike of Maijaanvuori in Eräjärvi is visible at two outcrops some 50 m apart. The NE contact of the dike can be seen in the E outcrop, but the SW contact is not exposed. The width is at least 25 m, but not greater than 50 m. The trend is N 40°W and the dip probably NE. The W outcrop is a medium-grained homogeneous diabase with no phenocrysts or xenoliths. The eastern outcrop resembles a breccia which, in addition to plagioclase megacrysts (Figs. 9 and 24), contains abundant xenoliths and autoliths of varying composition. Excluding the 2—4 m wide fine-grained contact zone, the entire outcrop is full of plagioclase megacrysts and phenocrysts. The main part of them are 4—6 cm in diameter, but even those over 10 cm in length are fairly common. The largest megacrysts are nearly idiomorphic (Fig. 24) but the majority of the smaller ones seem to be fragments of larger crystals.

There are abundant quartzite xenoliths (Fig. 30) in the same zone with megacrysts. They are usually well rounded and comprise, in the densest places, some 20 % of the total volume of the rock. The contacts of these xenoliths against diabase are sharp. Two types of quartzite occur, which differ mainly in colour. The more common type has a pale grey weathered surface and dark grey surface when fresh. The other type is white on both weathered and fresh surfaces.

Randomly distributed granite xenoliths, up to 50 cm diameter, were observed in the outcrop. The xenoliths several metres from the contact of the diabase seem partly melted and their contacts with the diabase are gradational. Near the xenoliths are narrow granite dikes less than 5 mm wide which are evidently of rheomorphic origin.

FIG. 9. A rheomorphic dike cutting diabase rich in plagioclase megacrysts. Maijaanvuori, Eräjärvi. The label is 12 cm long.

A fine-grained dike, about 20 cm wide, penetrates the diabase (Fig. 9). The principal minerals are plagioclase (An_{55}), biotite and quartz with laumontite occurring in the fissures of the dike. The dike is plausibly of rheomorphic origin, because the diorite forming the country rock is also fairly rich in biotite and the anorthite content of the plagioclase is similar in both rocks. The starting point of the dike at the contact of the diabase is not exposed.

Koukkujärvi

In the Koukkujärvi area two larger and several smaller diabase dikes are known. The northernmost dike is about 24 m wide. In the western part, where the dike is steeper (70°) it usually contains plagioclase phenocrysts a few centimetres in diameter, particularly near the upper contact. In contrast, in the eastern part, where the dip is more gentle (55°), the dike contains abundant megacrysts, phenocrysts and xenoliths which show evidence of gravitational settling (Fig. 10). Adjacent to the upper contact is a 2 m wide zone with almost no phenocrysts or xenoliths. At a distance of 2—4.5 m from the contact there is a zone crowded with quartzite xenoliths (Fig. 29), minor granite xenoliths and anorthosite autoliths. About 4.5 m from the contact a zone with abundant plagioclase megacrysts and phenocrysts begins. In the upper part of the zone these are on an average 4—5 cm in diameter but the largest attain a length of 30 cm. Away from the upper contact the size of the phenocrysts diminishes and their number decreases.

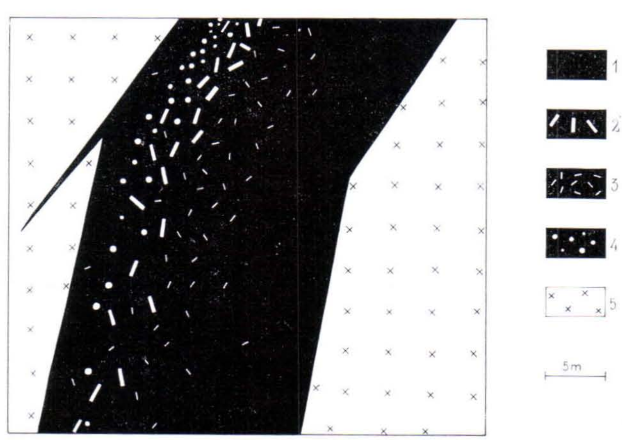

FIG. 10. A hypothetical vertical section across the diabase dike of the outcrop Koukkujärvi A 1. 1. diabase, 2. plagioclase megacrysts, 3. plagioclase phenocrysts, 4. quartzite xenoliths, 5. granite. The section shows the author's opinion of the grav itational accumulation of megacrysts and xenoliths in gently dipping parts of the dikes.

The quartzite xenoliths appear identical with the Maijaanvuori xenoliths, although at Koukkujärvi the xenoliths are not as well rounded. Most of the granite xenoliths are less than 10 cm in diameter and their contacts with the diabase are gradational. Small rheomorphic dikes have developed near some of the xenoliths.

In one locality at the northern contact several dikes of prehnite have been found. These dikes, usually 1—3 mm wide, continue on both sides of the contact forming a narrow micro-breccia zone (Fig. 38).

The smaller dikes of the area are nearly vertical and contain sporadically distributed plagioclase phenocrysts and quartzite xenoliths. The narrowest dikes are at least partly vitreous.

Vehkajärvi

The diabase dike of Vehkajärvi (Fig. 11) is exceptionally well exposed in a road cutting. The country rock is graywacke schist, cut by the diabase with straight, sharp contacts entirely independent of schistosity and bedding of the schist. The diabase dike is 3.1 m broad. The main rock is black fine-grained diabase which near the contacts consolidated to glass containing small needle-like plagioclase laths. The center of the dike has a 50 cm wide zone (Fig. 12) with abundant megacrysts and phenocrysts of plagioclase (An_{58}). The chemical composition of the dike matrix is given in Table 2 and that of the plagioclase megacrysts in Table 4.

FIG. 11. A general view of the 3.1 m wide diabase dike in Vehkajärvi, Kuhmalahti.

FIG. 12. Details from the center of the dike in Fig. 11. It can be seen from the picture that most of the plagioclase megacrysts are broken into fragments. The label is 12 cm long.

Anttila

The diabase dikes of Anttila form a dike set which includes one dike exceeding 10 m in width, two 3—4 m wide dikes and several smaller ones (Fig. 13). The broadest dike (C) is a medium-grained ophitic diabase, common throughout the area, and

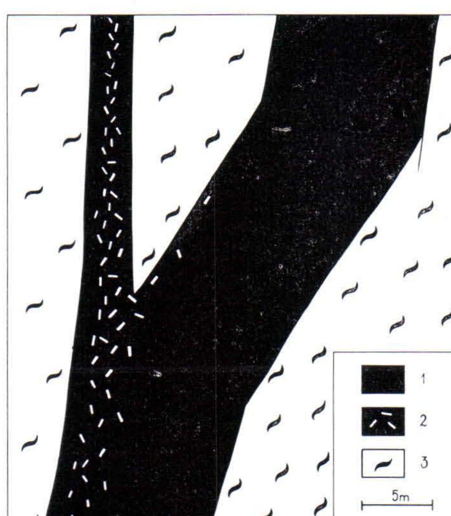

FIG. 13. A hypothetical vertical section across the dikes Anttila B (on the left) and C (on the right). 1. diabase, 2. plagioclase megacrysts and fragments, 3. veined gneiss. The section shows the author's opinion of the mechanism of gravitational accumulation of megacrysts in the forks of dipping dikes.

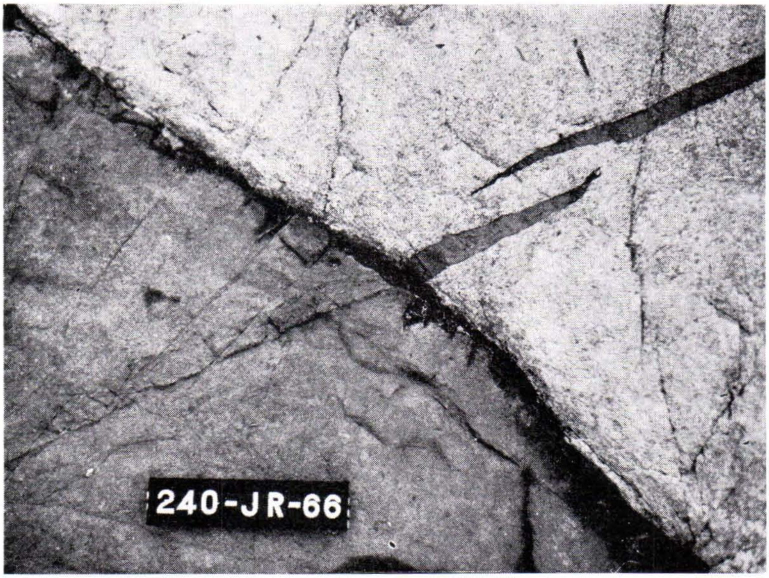

FIG. 14. From the center of a 3 m wide diabase dike (outside the picture at left) extends a 1.5 cm wide diabase dike through the border part of the main dike (above the label) into granite where a typical en echelon structure is visible. Anttila (B), Kuhmoinen. The label is 12 cm long.

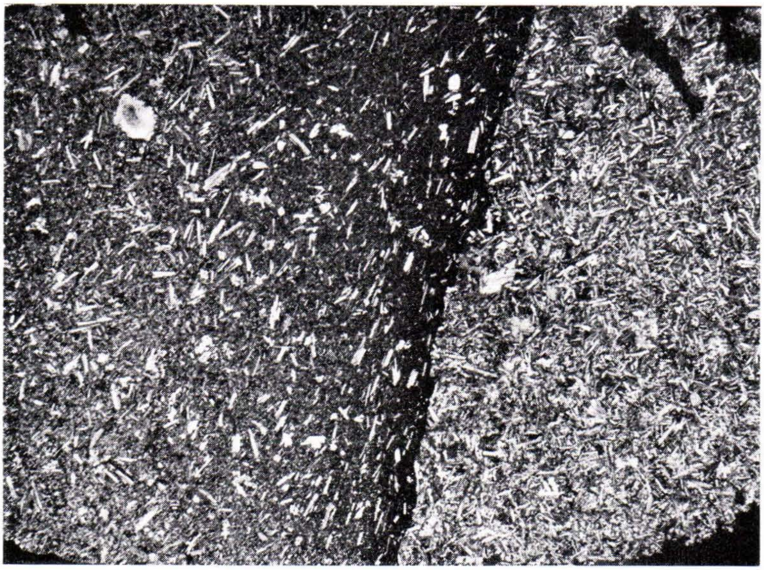

FIG. 15. At the contact of the smaller dike which cuts the border part of the main dike, a distinct chilled margin with fluidal texture appears. Anttila (B), Kuhmoinen. Magn. 4 x, nic. +.

without any phenocrysts or fragments. The 4 m wide dike (A) contains sporadically distributed plagioclase phenocrysts. The 3 m wide dike (B) is very similar to the Vehkajärvi dike. It contains abundant plagioclase megacrysts and phenocrysts, 2—15 cm in diameter, in the central part of the dike (Fig. 13).

A number of apophyses extend from this dike. Their starting point is clearly the central part; they penetrate the border zone and continue for several metres into the migmatitic country rock (Figs. 14 and 15).

At a dike fork there is a wedge of veined gneiss between two 3 m broad diabase dikes. At a width of 35 cm there is a distinct chilled contact in the diabase against the wedge, but at the width of 5 cm no dense variety can be observed in the border of diabase, and the contact itself is gradual along several millimetres. The veined gneiss is markedly altered in the entire wedge, particularly biotite is strongly recrystallized.

Munuajärvi

The diabase dike of Munuajärvi is 110 cm wide. It differs from the granodiorite surroundings as a channel covered by soil and lush vegetation (Fig. 16). Its contacts against granodiorite are sharp (Fig. 17). The dike rock is dark fine-grained diabase with sporadic plagioclase phenocrysts less than 2 cm in diameter. At its contacts the diabase is partly vitreous and does not seem to have caused any alterations in the country rock.

FIG. 16. Small diabase dikes are often visible in the exposed rocky terrain as low channels covered by soil and vegetation and are usually difficult to detect. Munuajärvi, Padasjoki.

FIG. 17. The dike of Fig. 16 with soil and vegetation removed.

Trend, structure and texture

The width of the dikes varies from 250 m to a few centimetres. Dikes with a width exceeding 90 m were measured in three places (the rural church of Heinola, Petäjäsaari and Ansio). In addition the width of at least seven dikes (Iilivuori A, Karinlahti, Muorinkallio, Torittu, Virmaila, Nuijasaari and Hirtniemi E) exceed 60 m.

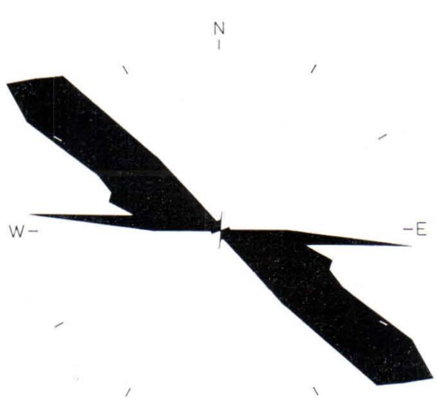

FIG. 18. Orientation diagram of all dikes of the Häme area; 193 observations of outcrops at least 250 m apart.

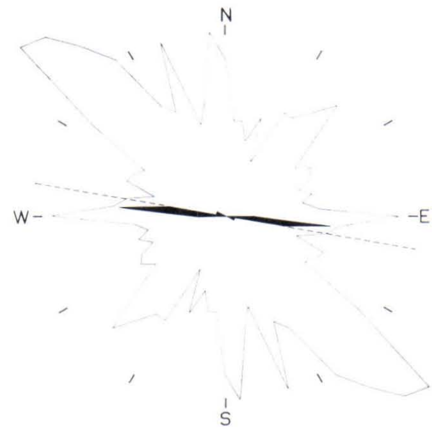

FIG. 19. Orientation diagram of spotted diabase (solid black; 22 observations at least 250 m apart). The dashed line gives the trend of the corresponding partial set and the solid line diagram is reproduced from Fig. 1.

Moreover, eleven dikes of width greater than 30 m are known. The frequencies of the dikes of various widths cannot be deduced from the above observations because only a few of the larger dikes are fully exposed. The majority of the smaller dikes seem to be apophyses of the larger ones (e.g. Karivuori B, Linnasaari C, Myllylahti B).

Diabase dikes cut the metamorphic complex irrespective of the schistosity and bedding of the country rock and the dike set has not been observed to have settled in any axial culmination of the metamorphic complex.

There are two distinct maxima in the trends of the dikes (Fig. 18). The stronger one is N 45°—60°W and the weaker one N 85°W. Several observations also lie in the area between these maxima (N 60°—85°W).

The contacts of the diabase are mainly straight although the contact observed at one outcrop seldom forms a direct continuation to the following one (e.g. Linnasaari A, Anttila B). If the dislocation is of the order of the dike width, it usually indicates an en bayonet structure (Figs. 7 and 21). If the dislocation is a multiple of the dike width then a normal en echelon structure is developed (e.g. between the dikes of Ansio and Muorinkallio and Fig. 14).

In three dikes (Sinipilkka, Anttila B and Torittu) diabase dikes cutting diabase were found. It can be clearly seen in the dikes of Anttila and Sinipilkka that they begin from the inner part of the main dike, cut the contact zone and continue as apophyses into the country rock (Fig. 14). The widest of these dikes is some 30 cm and they generally lie obliquely to the trend of the main dike. A similar dike has also been described by Wilkman (1938, p. 146) from the Varpaisjärvi area.

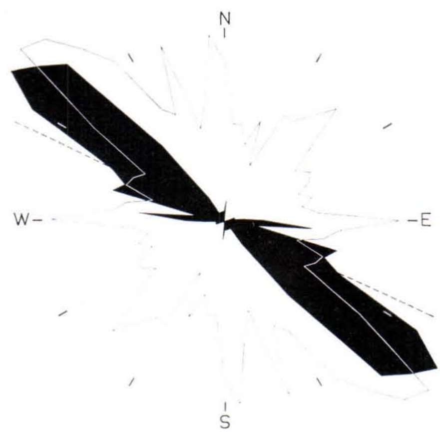

FIG. 20. Orientation diagram of the diabase dikes excluding the spotted type. The diagram is based on 171 observations. For further explanations see Fig. 19.

Contact breccia sensu stricto was not found anywhere in the diabase dikes. Instead, sporadic xenoliths of country rock occur, particularly in smaller dikes. The quartzite xenoliths observed in diabase will be treated later.

The location of plagioclase megacrysts and phenocrysts observed in numerous dikes displays certain regularities. The largest dikes contain sporadically distributed megacrysts. Next to the upper contact of 5—50 m wide dikes there is usually a zone almost devoid of phenocrysts and from there toward the center, a zone with abundant plagioclase megacrysts. Further from the upper contact the size and number of the mega- and phenocrysts diminishes (e.g. Mattilanniemi and Martinmäki). In dikes 1—4 m wide, the megacrysts have accumulated into a narrow zone in the central part (e.g. Vehkajärvi, Anttila B and Sinipilkka). Anorthosite autoliths, quartzite xenoliths and other bodies lighter than the surrounding magma are enriched in the diabase in the same way as the plagioclase crystals.

In two localities (Toikko C and Iilivuori A 1) outcrops have been found, measuring about 10 m across, containing abundant megacrysts and xenoliths. The relations of these outcrops to the contacts of the dike are unknown. It is possible that in these cases an accumulation of megacrysts and xenoliths occurred, similar to that in the dikes of Anttila and Koukkujärvi (Figs. 10 and 13).

The xenoliths lighter than the matrix are generally in the same zone as the plagioclase megacrysts. The only dike where they have been observed to form an individual zone is in Koukkujärvi (Figs. 10 and 29).

Small lath-shaped plagioclase phenocrysts usually lie parallel to the plane of the dikes as in Liehu (Fig. 22) and Vähä-Kerjärvi. This phenomenon can be used to determine trends of dikes when no contacts are visible.

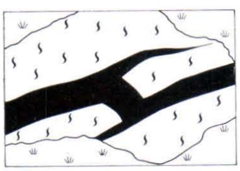

FIG. 21. A typical en bayonet structure in a diabase dike. Vuorijärvi (A), Kuhmoinen. The label is 12 cm long.

The narrow dikes and some of the contact phases excluding the diabases are distinctly ophitic (Figs 2 and 6). The interstices between the lath-shaped plagioclase crystals are filled with olivine and augite, the latter often forming large poikilitic grains. The grain size in the central parts is generally coarser in the larger dikes than in the narrower ones. Yet, the differences are so slight that the grain size does not yield any conclusions about the width of the dike. In dikes less than 20 m wide the grain size rapidly diminishes along the width of the dike, and in dikes less than 10 m wide the ophitic texture is barely detectable to the naked eye.

The contact varieties of the diabase dikes less than 2—3 m wide, look partly vitreous (e.g. Huppionvuori C). Even larger dikes often have chilled contacts (Fig. 6), but in some of the largest ones they seem to be weakly developed.

The rock in the dikes of Partakorpi, Torittu, Kellosalmi, Virmaila and Nikkaroinen is somewhat different from the common diabase type of the Häme area (Fig. 2). A characteristic of these types is the spotted texture seen in Figs. 3 and 4. The spots consist almost exclusively of plagioclase while in the interstices are abundant olivine and augite. Spotted diabase has only been observed in large dikes, all of which exceed 50 m in width. The contacts of these dikes were not observed to display fine-grained varieties, but the spotted texture seems to be lacking at the contacts. Plagioclase megacrysts have never been observed in spotted diabase and even small phenocrysts are very rare. Comparison of the orientation diagrams (Figs. 18—20) shows that the trend maximum (N 85°W) of the dikes of the spotted type coincides with the lesser maximum of the entire set.

FIG. 22. Typical flow structure in a weathered surface of porphyritic diabase. Liehu, Kuhmalahti. About natural size.

Chemical composition

In Table 2 three analyses of the diabases of the Häme area are given. No. 1 is a medium-grained homogeneous diabase type from a dike about 100 m wide, where phenocrysts are almost entirely absent. No. 2 is a spotted diabase from a dike which is at least 30 m wide but probably reaches some 60 m. No. 3 represents the matrix of a dike which contains abundant plagioclase megacrysts and fragments and is some 3 m wide.

The comparison of these compositions with some published diabase analyses reveals that diabase types associated with the Ahvenisto massif are very similar to the Häme diabases. Analysis 4 in Table 2 closely resembles that of the Ansio diabase while analysis 5 is very similar to the Vehkajärvi type. However, the Partakorpi type has no parallel with any other diabases analysed from Finland. The Satakunta and Vaasa diabases nos. 6 and 7 (Table 2), are similar to the Ansio type although they have a slightly lower Al_2O_3 content. The structurally similar diabases of the Eskilstuna region of Sweden have chemical composition (Analysis 13) closely resembling the Häme diabases. Compared to the average high-alumina basalts of Japan (Analysis 10) the Ansio diabase has a slightly higher Al_2O_3 content.

TABLE 2

Chemical composition of diabases and related rocks, the first three are from the Häme area.

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2 .	47.36	44.35	49.60	47.87	51.46	46.39	46.20	45.90	48.84	50.19	48.28	48.08	46.62
TiO_2 .	1.00	2.20	3.05	0.76	1.95	1.77	1.90	2.00	3.78	0.75	0.87	1.17	0.81
Al_2O_3	19.70	10.82	14.50	19.89	15.35	16.98	17.20	15.13	12.70	17.58	16.84	17.22	17.12
Fe_2O_3	0.75	1.71	2.04	0.93	1.53	1.97	2.08	1.84	5.12	2.84	4.36	1.32	2.64
FeO . .	10.46	18.61	11.98	9.82	12.37	10.55	11.95	14.69	9.47	7.19	6.17	8.44	9.45
MnO .	0.14	0.23	0.19	0.12	0.10	0.19	0.29	0.14	0.19	0.25	0.17	0.16	0.17
MgO .	8.34	12.44	4.03	7.30	4.42	7.59	7.10	5.69	4.32	7.39	7.73	8.62	9.31
CaO .	8.77	4.93	6.85	8.82	7.32	9.69	8.98	8.66	7.26	10.50	11.24	11.38	8.30
Na_2O	2.68	2.08	2.80	3.02	2.94	2.70	2.88	2.85	2.76	2.75	2.58	2.37	2.06
K_2O .	0.63	1.20	1.81	0.85	1.64	0.67	0.89	0.96	1.96	0.40	0.23	0.25	0.68
P_2O_5 .	0.15	0.54	0.85	0.28	0.79	0.40	0.01	0.21	1.19	0.14	0.07	0.10	0.12
CO_2 . .	0.00	0.00	0.53	—	—	0.00	—	—	—	—	—	—	—
H_2O+	0.43	0.53	1.28	0.46	0.56	0.87	1.10	1.20	1.74	—	0.72	1.01	2.38
H_2O-	0.03	0.04	0.09	0.02	0.04	0.15	0.14	0.60	0.94	—	0.82	0.05	0.16
S	—	0.06	0.14	—	—	—	—	—	—	—	—	—	0.08
	100.44	99.74	99.74	100.14	100.47	99.92	100.72	99.87	100.27	99.98	100.08	100.17	99.90

In addition ppm:

	1	2	3
Ba . . .	460	690	670
Cu . . .	50	41	78
Cr . . .	66	40	86
Li . . .	—	—	20
Ni . . .	93	140	28
Sr . . .	420	290	300
V	180	210	320
Zn . . .	—	—	100
Zr . . .	96	120	340

Molecular norms

	1	2	3
Q	—	—	3.1
Or . . .	4.0	7.3	11.2
Ab . . .	23.5	19.1	26.3
An . . .	39.5	17.0	22.6
Σ	67.0	43.4	63.2
Wo . .	1.0	1.8	1.4
En . . .	3.8	7.8	11.6
Fs . . .	2.2	5.6	13.8
Fo . . .	14.4	20.5	—
Fa . . .	9.0	14.9	—
Mt . . .	0.9	1.8	2.2
Il	1.4	3.1	4.5
Ap . . .	0.3	1.1	1.9
Cc . . .	—	—	1.4
	100.0	100.0	100.0

Niggli values

	1	2	3
si	103	89	132
al	25	13	23
fm . . .	48	71	47
c	20	10	20
alk . . .	7	6	10
k	0.14	0.28	0.30
mg . . .	0.57	0.52	0.34
ti	2	3	6
qz . . .	—25	—35	—8

1. Olivine diabase, Ansio (4), Padasjoki (Savolahti, 1964). Trace elements anal. (from a different sample) V. Hoffren and A. Löfgren.
2. Spotted olivine diabase, Partakorpi, Padasjoki. Anal. P. Ojanperä, trace elements R. Danielsson and V. Hoffren.
3. Ground mass of porphyritic diabase, Vehkajärvi, Kuhmalahti. Anal. A. Heikkinen, trace elements V. Hoffren and A. Löfgren.
4. Olivine diabase, Leppälahti, Mäntyharju (Savolahti, 1956 b).
5. Quartz diabase, Kelesjärvi, Jaala (Savolahti, 1956 b).
6. Olivine diabase, Kobberget Korsnäs (Nykänen, 1960 and Ervamaa, 1962).
7. Olivine diabase, Sorkka, Rauma (Kahma, 1951).
8. Olivine diabase, Suontaka, Laitila (Kahma, 1951).
9. Diabase, Möykkysaari, Lake Ladoga, USSR (Eskola, 1932).
10. Average high-alumina basalt of Japan (Kuno, 1960).
11. Warner olivine basalt, California (Kuno, 1965).
12. Chilled margin of Skaergaard intrusion, Greenland (Wager, 1960).
13. Olivine dolerite, Gustavsberg, Sweden (Gorbatschev, 1961).

Mineral composition

The diabases of the Häme area are olivine diabases in mineral composition. Their principal mineral is plagioclase which usually comprises more than 50 per cent of the total volume of the rock (Table 3). The rest is clinopyroxene and olivine in varying amounts. The modes of 16 different diabases are given in Table 3. Plagioclase occurring as megacrysts had to be omitted from the modes.

TABLE 3

Mineral composition of some diabases of the Häme dike set. (Determined by the point-counting method. At least 1 000 points were counted of each thin section.)

Locality	Plagio-clase	Potash feldspar	Clino-pyroxene	Ortho-pyroxene	Olivine	Biotite	Apatite	Opaques	Acces-sories
Iilivuori A 2	67.4	1.7	16.7		7.8	0.3	0.9	4.9	0.3
Huppionvuori B 1	68.2	0.7	9.7		13.5	1.2	1.1	5.1	0.5
Pääskylä	44.6	12.6	14.0		7.8	3.4	1.2	9.6	6.8
Karivuori A 2	66.4	0.7	9.5		17.3	1.1	0.9	3.9	0.2
Partakorpi	51.5		9.7	0.2	30.7	1.2	1.2	3.6	1.9
Ansio 4 (Savolahti 1964) ..	62.0		3.7		27.5		0.8	3.0	3.0
Torittu 5	56.7	1.3	7.3		31.5	0.8	0.8	1.4	0.2
Torittu 6 (diab. dike in diab.)	71.6		6.4		18.6	0.4	0.4	2.6	
Harmoistenkaivo	62.5		25.3		2.3	1.6	0.7	6.4	1.2
Nuijasaari 1	56.1	3.0	18.7		11.7	3.1	1.1	5.1	1.2
Hirtniemi E 2	57.5	0.1	21.1		12.5	2.2	0.9	5.7	
Petäjäsaari 3	69.0		16.6		7.5	1.4	1.1	4.4	
Linnasaari A 2	70.0		4.5		12.2	0.5	1.1	6.5	5.2
Virmaila 2	60.3	4.4	11.3		17.8	1.3	0.9	3.8	0.2
Leveälahti 2	59.9	4.3	14.0		5.7	2.2	1.1	9.2	3.6
Rural church of Heinola 2 .	40.0	1.7	6.0	8.9	37.5	1.6	0.5	3.6	0.2
average	60.2	1.9	12.2	0.6	16.4	1.4	0.9	4.9	1.5

The plagioclase of the matrix regularly appears as lath-shaped crystals. They are often distinctly zoned the center ranging within An_{58-68} and the rim decreasing in places to less than An_{45}. In the spotted diabase, the anorthite content is lower so that the center is about An_{55}. Additionally, this rock type seems to contain small corroded grains of plagioclase which represent an older generation. Because they are strongly saussuritized it was almost impossible to determine the anorthite content of these grains. In any case they seem to be richer in albite than the lath-shaped plagioclase.

From the dike of Tuomasvuori (2) the plagioclase of a normal ophitic diabase was partially analysed and gave the following values: $CaO = 7.00$, $Na_2O = 4.70$ and $K_2O = 1.07$. X-ray diffraction values indicate that the plagioclase is of the high temperature type (cf. Bambauer et al. 1967 p. 340, Smith and Gay 1958 p. 749).

The dominant pyroxene in the diabases is clinopyroxene, which occurs as large poikilitic grains. In thin section it is clearly reddish in colour and unaltered. According to the optical determinations, two kinds of clinopyroxene occur. Titanoaugite ($2V\gamma = 40°—49°$ and $c \wedge \gamma = 34°—44°$) is the predominant pyroxene. In four dikes (Pääskylä, Salinsaari, Torittu, Leveälahti) pigeonite ($2V\gamma = 18°—25°$ and $c \wedge \gamma =$

43°—45°) was also found. Hypersthene (2Vα∼52°) was observed in some dikes (e.g. Rural church of Heinola and Partakorpi) as a strongly altered relic. The chemical composition of two titanoaugites is given in Table 4.

Olivine (2Vα = 73°—85°) occurs regularly as grains smaller than clinopyroxene. The olivine grains likewise display poikilitic features although idiomorphic characteristics are also visible. In addition to independent grains, olivine often occurs as inclusions in titanoaugite. The chemical composition of the olivine from the Partakorpi dike is given in Table 4.

TABLE 4
Chemical composition of minerals.

	1	2	3	4
SiO_2	35.58	50.20	49.38	53.77
TiO_2	0.61	1.63	1.25	0.08
Al_2O_3	0.52	3.07	2.28	28.65
Fe_2O_3	2.69	2.42	2.24	0.08
FeO	36.00	10.30	11.62	0.32
MnO	0.45	0.21	0.29	0.01
MgO	23.29	13.60	13.86	0.20
CaO	0.49	18.19	17.98	11.30
Na_2O	0.10	0.48	0.50	4.58
K_2O	0.07	0.04	0.05	0.63
P_2O_5	0.16	0.18	0.19	0.02
CO_2	0.00	0.00	—	0.0
Rb_2O	—	—	—	0.0
SrO	—	—	—	0.1
BaO	—	—	—	0.02
H_2O+	0.22	0.10	0.23	0.14
H_2O-	0.02	0.00	0.02	0.06
	100.20	100.42	100.00	99.96

1. Olivine from the diabase of Partakorpi, Padasjoki. Anal. P. Ojanperä.
2. Augite from the diabase of Partakorpi, Padasjoki. Anal. P. Ojanperä.
3. Augite from the diabase of Ansio, Padasjoki. (Savolahti 1964).
4. Plagioclase megacryst from the diabase of Vehkajärvi, Kuhmalahti. Anal. P. Ojanperä and V. Hoffren.

Ilmenite is the most common of the opaque minerals. It is found as individual grains and skeletal or lamellar intergrowths with magnetite. Pyrrhotite often appears as minute grains whereas chalcopyrite is rarely found.

Biotite occurs particularly in coarser-grained diabases, often surrounding ilmenite grains. Potash feldspar is found most often in the vicinity of contacts and rheomorphic dikes. It occurs as allotriomorphic grains filling the interstices between other minerals.

Apatite is the most common accessory mineral. It often occurs as long, almost needle-shaped, crystals. In the dike of the rural church of Heinola, there are pleochroic haloes around apatite in biotite which suggests that the apatite in some diabases is radioactive. Quartz, sphene, zircon and green spinel (Savolahti 1964, p. 102) have rarely been found.

Secondary minerals are generally scarce in the diabases. Most alteration is usually associated with the contacts and shear zones. The most common secondary minerals are serpentine, chlorite, talc, epidote and hornblende while calcite, dolomite, laumontite and prehnite have been observed as fissure fillings.

Phenocrysts, megacrysts and autoliths

Plagioclase phenocrysts (Fig. 23), megacrysts and fragments have been observed in 83 of the 109 dikes of the Häme area, and in 39 dikes at least some of them exceed 5 cm in diameter. They can thus be regarded as an essential component of the dikes. The largest of the observed crystals (in the dikes of Maijaanvuori 2, Koukkujärvi A 2, Huppionvuori A, Toikko C and Sinipilkka) attain some 30 cm in length. The majority of the largest megacrysts are almost idiomorphic (Fig. 24) while the smaller ones are usually fragments of larger ones (Fig. 12). Additionally, in many dikes (e.g. Koskihoru 1; Liehu, Fig. 22; Vähä Kerjärvi 1 and Tyystjoki 1) there are smaller, lath-shaped plagioclase phenocrysts, 1—3 cm in length. All transitions between the fragments of large crystals and the small lath-shaped phenocrysts are known,

The anorthite content of the megacrysts and the fragments is commonly 55—60 %. Values exceeding this have been observed among the lath-shaped phenocrysts. Anorthite contents of less than 55 % generally occur in the altered phenocrysts, e.g. in the vicinity of shear zones or rheomorphic dikes.

FIG. 23. A typical porphyritic diabase. Some of the phenocrysts are idiomorphic and others are fragments of larger crystals. Härmänsaari (2), Orivesi. Magn. 3.5 x, nic. +.

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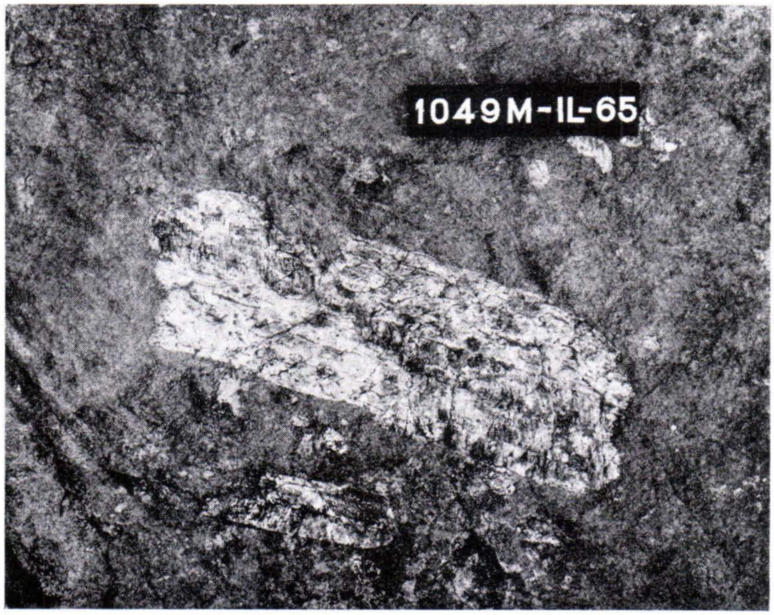

FIG. 24. One of the largest plagioclase megacrysts found in the research area. Maijaanvuori (2), Eräjärvi. The label is 12 cm long.

The chemical composition of a plagioclase megacryst from the Vehkajärvi dike is given in Table 5. The X-ray diffraction values indicate the plagioclase to be of the low temperature type. However, since this result was obtained from a dike only about 3 m wide, no general conclusions can be drawn for all the megacrysts in the area.

Optically, the megacrysts are fairly homogeneous, but there is often a mantle which has crystallized later. The example described from Linnasaari (Fig. 8) is fairly typical. The shape of the grain before the crystallization of the mantle is often visible as a zone containing small opaque inclusions along the inner rim of the mantle. Besides plagioclase no other phenocrysts were observed in the diabases of the Häme area.

As to the other diabases in Finland, there are plagioclase megacrysts in some dikes of the Åland Islands (Sederholm 1890 p. 462) the majority of which are fragmentary (Hausen, 1964 Pl. XIII).

In 19 dikes there are autoliths which are probably co-magmatic with diabase. They are usually less than 30 cm in diameter, but the dikes of Petäjäsaari (2), Ansio (2) and the rural church of Heinola (1) contain autoliths which are some meters in diameter. Macroscopically, some of these resemble coarse-grained diabase or diabase pegmatite while others are similar to anorthosite. However, such differences are not supported by microscopic examination. The main mineral of the autoliths is plagioclase (An_{48-53}). Its shape and grain size vary widely (Figs. 25—27), and because of saussuritization it is usually lighter in colour than the plagioclase of the diabase.

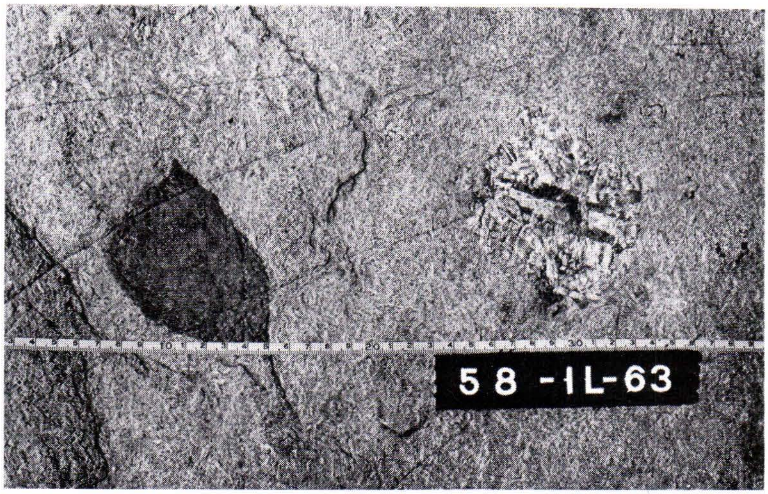

FIG. 25. Autoliths in diabase, at left dunite and at right coarse-grained hypersthene diabase. Tuomasvuori (3), Padasjoki.

FIG. 26. Photomicrograph of a typical autolith. The shape of the plagioclase laths are like those in diabase, but the texture is not ophitic as the dark minerals between the laths are absent. Petäjäsaari (2), Padasjoki. Magn. 4 x, nic. +.

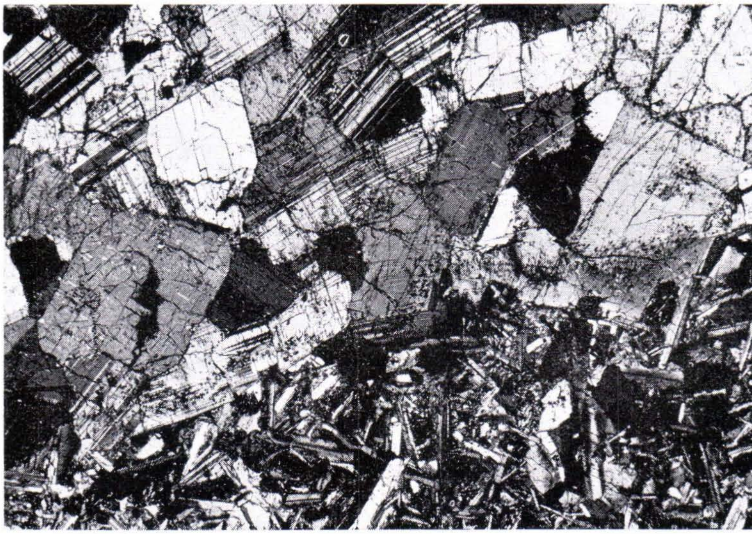

FIG. 27. Photomicrograph of an anorthosite inclusion in diabase. Linnasaari (A3), Padasjoki. Magn. 20 x, nic. +.

FIG. 28. Large hypersthene crystals in an anorthosite inclusion in diabase. Petäjäsaari, Padasjoki. The label is 12 cm long.

The predominant dark mineral of the autoliths is hypersthene ($2V\alpha = 60°—72°$). Its usual occurrence is as large allotriomorphic grains between the plagioclase crystals, but in the Petäjäsaari anorthosite it appears as crystals about 10 cm in diameter (Fig. 28). The margins of these large hypersthene crystals are strongly corroded and plagioclase penetrates the hypersthene crystals in a vermicular intergrowth. Some autoliths also contain olivine, and exceptionally olivine may form the principal dark mineral (e.g. Hirtniemi D). The secondary minerals in the autoliths are serpentine, chlorite and sometimes amphibole. The rock types described above closely resemble the rocks described by Savolahti (1956 b and 1966) from the gabbro-anorthosite massif of Ahvenisto.

In the dike of Tuomasvuori (3) a distinctly different autolith (Fig. 25) was observed. It is 9 cm in diameter and its contacts with diabase are sharp. The principal mineral of the autolith is olivine which occurs as roundish grains 1—2 mm in diameter. The interstices are filled with plagioclase (An_{56}), the amount of which is so minor that the rock can be called dunite.

In South Greenland many diabases and other basic intrusives with plagioclase megacrysts and anorthosite inclusions have been described (e.g. Bridgewater and Harry 1968, Watt 1968). Many of them display features very similar to those observed in the diabases of Häme, but even more similar are the mafic dikes described from Montana by Prinz (1964).

Quartzite xenoliths and their origin

The descriptions of the dikes from Koukkujärvi and Maijaanvuori and Table 1 reveal that many of the diabases contain quartzite xenoliths. They have been observed in 12 different dikes, abundantly in those of Toikko (C), Maijaanvuori (2), Iilivuori (A 1) and Koukkujärvi (A 2). All the dikes containing quartzite xenoliths occur west of Lake Päijänne. As the distance between the two extreme occurrences (Toikko

FIG. 29. Angular grey quartzite xenoliths. Koukkujärvi (A2), Padasjoki. The label is 12 cm long.

FIG. 30. Rounded white and grey quartzite xenoliths in diabase. Maijaanvuori (2), Eräjärvi. The label is 12 cm long.

and Koukkujärvi) is about 90 km and dikes containing quartzite xenoliths are fairly evenly scattered over this area, the phenomenon cannot be regarded as a local one.

The outcrops richest in quartzite xenoliths display them by the hundreds. They are usually angular (Fig. 29) or only slightly rounded, but the Maijaanvuori dike contains completely rounded xenoliths (Fig. 30). In most places the inclusions are 2—10 cm in diameter, but the largest ones (Koukkujärvi and Maijaanvuori) exceed 20 cm. The large xenoliths are strongly cracked whereas the small angular types are fragments of larger ones.

There are two types of xenoliths: grey and white. The grey ones are the most common, but the white xenoliths seem to be more resistant, because they are the largest ones observed.

The grey quartzite xenoliths are blastoclastic in texture (Fig. 31). In addition to quartz there are some grains consisting of very fine-grained clay-like material. The cement is formed of quartz, sericite, biotite, plagioclase and opaque minerals with apatite and zircon as accessories. The grains forming the blastoclastic texture are some 0.1—0.2 mm in diameter. The colour of the rock is probably due to the opaques in the cement.

Among the autoliths and xenoliths observed in the diabase dikes of the Häme area the quartzite xenoliths are distinct in that all the other common types are either co-magmatic with diabase or have been derived from the country rocks of the dikes. It is not possible to assume that the quartzite was derived from the country rocks

Fig. 31. Blastoclastic texture of a grey quartzite xenolith. Koukkujärvi (A2), Padasjoki. Magn. 12 x, nic. +.

because no quartzite of this type is known anywhere in the area, at least at the present erosion level. The insignificant quartzite occurences known in the area are clearly schistose and their texture is more strongly deformed than that of the quartzites occurring as xenoliths.

When seeking an explanation for the occurrence of quartzite xenoliths in the diabase dikes the following data should be noted. The rock is sedimentary, which can be seen from its texture. There is no evidence to suggest that the quartzite could be formed by contact metamorphism of some other sedimentary rock such as mica schist, which is more common in the area. Nor can they be a metamorphic product of sandstone or some other rock derived from upper horizons because the specific gravity of quartzite ($\sim$2.6) is much lower than that of the basaltic magma.

Leväslahti (1) is the only locality where a contact between diabase and quartzite has been exposed. However, the quartzite here is quite different from that of the xenoliths. The quartzite of Leväslahti is distinctly schistose and contains abundant sericite and some biotite. It is also somewhat finer in grain size than the quartzites typical of the xenoliths. Near the contact the diabase has incorporated some of the quartzite. In the interstices of the quartz grains occurs potash feldspar and the sericite is somewhat altered.

The author has come to the conclusion that the typical quartzite xenoliths are derived from quartzite occurrences below the present erosion level.

In the Karelides the quartzites belong to the lower sequence (e.g. Väyrynen 1933), but our knowledge about the deeper parts of the Svecofennides is too limited to allow any conclusions of the tectonic or stratigraphic position of quartzites that possibly occur below the present erosion level in Häme.

In Småland, Sweden, several diabases containing quartzite xenoliths have been observed, which according to descriptions (Stolpe, 1892, Blomberg, 1907 and Hedström, 1917) are similar to those in Häme. The Swedish geologists call these rocks diabase conglomerates. In the diabases of the Bredvik-Blixås district, which can be followed for some 30 km, the quartzite xenoliths occur in zones parallel to the dikes, and the size of the xenoliths varies within the same limits as in the Häme diabases. In type the xenoliths seem to belong to the Almesåkra formation through which the diabase intruded. Hedström (1917, p. 38) assumes the xenoliths to be rounded because they were derived from the conglomerates of the Almesåkra formation. The occurrence of shale and phyllite (Hedström, 1917, p. 30) among the quartzite xenoliths indicates that the quartzite xenoliths are not products of the contact metamorphism of other sedimentary rocks.

Contacts

Diabase dikes a few metres wide with vitreous or aphanitic contacts do not generally exert any noticeable influence upon their country rock. Minerals such as biotite, may, however, display signs of recrystallization. Volborth (1954, p. 12) noted that the narrow diabase dike of Viitaniemi has melted triplite and litiophilite. He gives their melting points as 1 060°—1 070°C and 1 120°C, respectively.

The contact of the larger dikes (which are several tens of metres wide) vary, possibly because of the different eruption rates and temperatures of the magma. Distinct indications of chemical reactions between the diabase and the country rock begin to appear with dikes of widths around 50 m: Their contacts may be gradational for a few centimetres (e.g. in Virmaila, where granodiorite forms the country rock). The diabase shows more alteration at the contact than in the centre of the dike — olivine is entirely serpentinized near the contact, plagioclase is saussuritized and often albitized to some extent. Micrographic texture is fairly common. The interstices between the minerals are often filled with calcite.

Where a wedge of country rock lies between the diabase dikes the contact effect is quite marked. For example, at the forking point described from Linnasaari (Fig. 7) the strong heating of country rock can be deduced from the absence of fine-grained contacts at the tip of the wedge and from the coarse-grained micrographic texture which often extends tens of centimetres from the contact. This must be ascribed to the influence of diabase as no similar texture has been observed anywhere else in the migmatites of the area.

The cooling of narrow (less than 3 m wide) dikes was so rapid that even the xenoliths of country rock remained almost unaltered (e.g. Munuajärvi and Iilivuori B). On the other hand, the xenoliths of the larger dikes appear to be strongly altered. The extent of the alteration is not directly comparable to the country rock because the xenoliths may have moved far within the diabase.

The diabase dike of Tyystjoki (8 m wide) contains a granodiorite xenolith over 50 cm in diameter, which macroscopically resembles the granodiorite country rock. The plagioclase ($\sim An_{25}$) and quartz grains of the xenolith are fresh, while the interstices contain a fine-grained mixture of biotite, quartz and chlorite. Coarse potash feldspar grains are slightly altered and biotite displays incipient chloritization.

Similar, although markedly stronger alterations, are to be seen in the Toikko dike, in granodiorite xenoliths a few tens of centimetres in diameter. Their partial melting is visible to the naked eye, since large plagioclase fragments are almost entirely enclosed inside the granodiorite xenoliths. Under the microscope it can be observed that the quartz grains are strongly deformed and the rims of the plagioclase and potash feldspar grains are diffuse. The interstices between the larger grains are filled with a fine-grained quartz-biotite mass and radial chlorite aggregates. In places, this matrix contains small lath-shaped plagioclase crystals suggesting that the diabase magma was mixed with the partially melted granodiorite.

Likewise in the Toikko diabase some reddish brown xenoliths (4—8 cm in diameter) resembling terra cotta were observed. They consist of a fine-grained quartz-sillimanite mixture in which the sillimanite aggregates are about 0.5 mm in diameter. The thermal metamorphism of these inclusions was so strong that one may only guess their origin. Apparently they were rocks with an Al-rich mineral such as andalusite or kyanite.

Rheomorphic dikes

The term rheomorphic is used here to denote all rocks considered to have been mobilized by the heat of intruded magma and then injected into it after the magma had solidified. The phenomenon has been described from innumerable basic intrusions all over the world and is more common than is generally considered, as pointed out by Frankel (1967).

In the Häme area some 40 rheomorphic dikes have been found in 26 diabase dikes (see Table 1). Five dikes 20—30 cm in width are known, but only one doubtful observation has been made of a dike exceeding this size (described from the rural church of Heinola, p. 24). Eight dikes can be followed over a distance of 5 m, the longest one exceeding 40 m in length (Fig. 32). Most of the rheomorphic dikes run almost perpendicular to the trends of the diabase dikes. Some smaller dikes start from xenoliths, but most seem to begin at the contacts of diabase dikes. Rheomorphic

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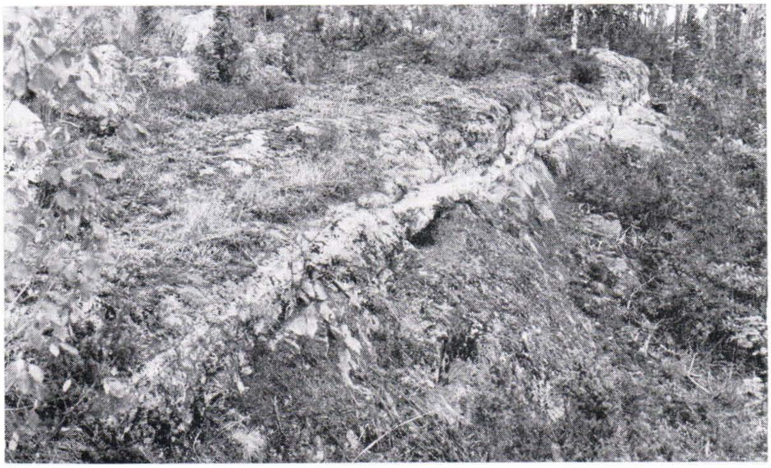

FIG. 32. A rheomorphic dike in diabase. Tuomasvuori (2), Padasjoki.

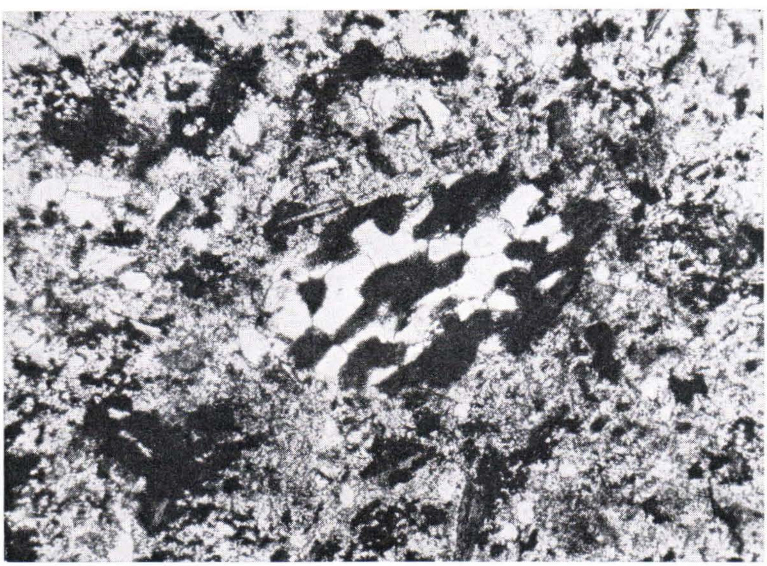

FIG. 33. A fragment of mica schist in a rheomorphic dike. Koskihoru (3), Längelmäki. Magn. 52 x, one nicol.

dikes starting from acid rocks like granite, granodiorite, veined gneiss or mica schist are more common but some dikes are also known from diorite (described from Maijaanvuori, p. 28) or intermediate metavolcanic rocks.

The mineral composition of rheomorphic dikes depends on the host rock. The main minerals in dikes beginning in granite or granodiorite are quartz and feldspars with some biotite, chlorite and hornblende. Dikes beginning in mica schists or gneisses

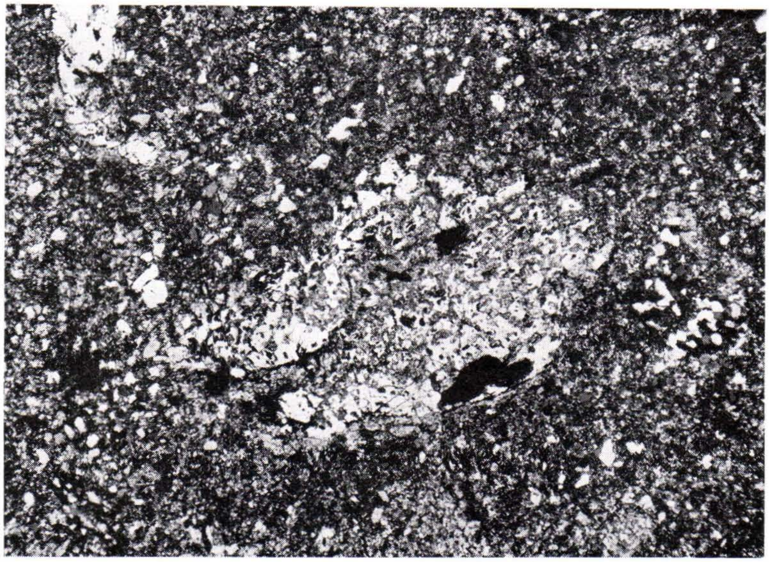

FIG. 34. A corroded and altered fragment of andalusite in a rheomorphic dike. The rheomorphic material consists of mobilized andalusite mica schist. Koskihoru (1), Eräjärvi. Magn. 10 x, nic. +.

are richer in biotite and chlorite. Part of the mineral grains seem to have crystallized in the dike but in most dikes there are rock (Fig. 33) and mineral fragments which were apparently introduced with the rheomorphic material. Garnet, andalusite (Fig. 34) and tourmaline are some of the relict minerals which have been found. The alteration products suggest that some of the feldspars are relict grains. There is no difference in grain size between the centre and the contacts of rheomorphic dikes but sometimes the grain size is coarser further from the starting point than at the outset of the dike. These phenomena may be accounted for by assuming that the diabase was still hot when the granitic material injected into it. Feldspars and quartz in the groundmass often display micrographic texture, which seems to be more common in the plagioclase (Fig. 35) than in the potash feldspar.

The contacts of large rheomorphic dikes (Figs. 9 and 32) are usually straight or gently undulating. In the centre of the diabase dikes the contacts can be diffuse (e.g. in Salinsaari) suggesting that the diabase may not have been fully solidified before the injection of granitic material. Smaller dikes are often tortuous and have minor off-shoots, particularly in the contact zone of diabase (Fig. 36). Near the contacts of rheomorphic dikes the diabase is always altered as was described e.g. from Linnasaari (p. 26).

The dikes described above are analogous with the palingenic dikes in the Satakunta diabases (A. Laitakari, 1928; Kahma, 1951).

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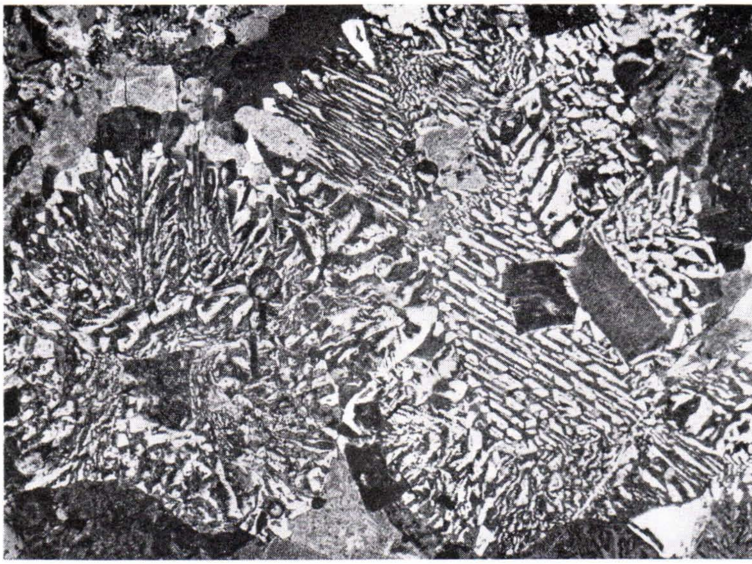

FIG. 35. Micrographic intergrowth of quartz and plagioclase (An_{10}) in a rheomorphic dike. Huppionvuori (A), Orivesi. Magn. 52 x, nic. +.

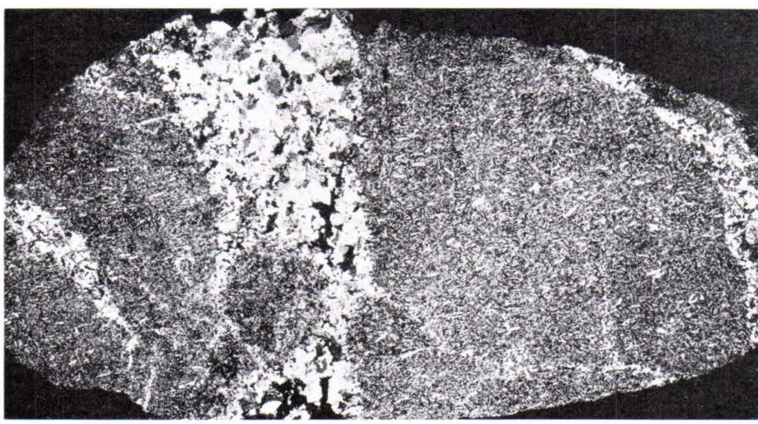

FIG. 36. Rheomorphic dikes of granitic material in diabase. Karivuori (B), Kuhmalahti. Magn. 3 x, nic. +.

Magnetic properties

The twenty susceptibility determinations made of the diabases of the area show a rather high deviation. However, most of them lie within the limits 500×10^{-6} and $5\,000 \times 10^{-6}$ (cgs). The high susceptibility values make it understandable that large dikes lying in magnetically uniform areas cause outstanding anomalies on the

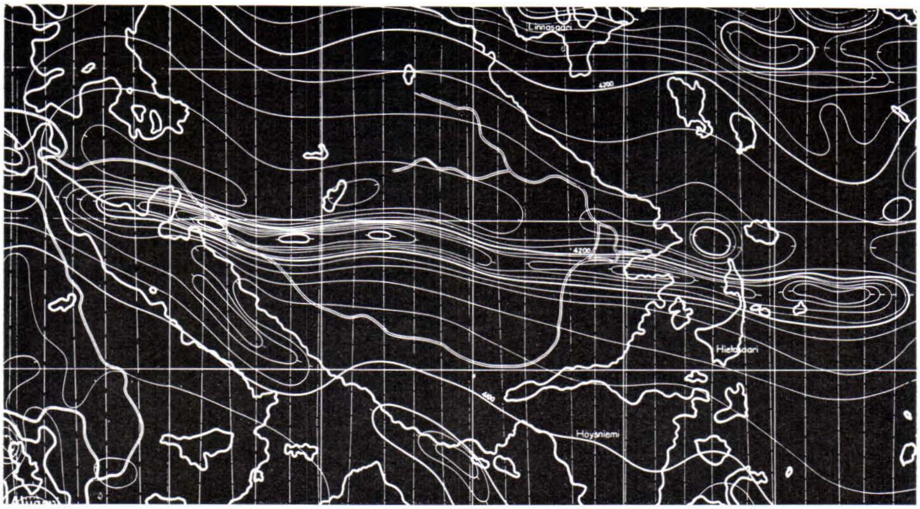

Fig. 37. A section of the aeromagnetic map of the Geological Survey of Finland (from sheet 2143) showing the anomaly caused by the diabase dike of Virmaila, which is about 80 m wide and lies in granodiorite. Scale 1 : 100 000.

aeromagnetic maps like that seen in Fig. 37. Lesser anomalies occur in the locations of several other dikes, but in the schist areas where the magnetic properties of the country rock vary a great deal, the anomalies caused by the diabase dikes cannot generally be distinguished.

Neuvonen (1967) has carried out paleomagnetic investigations of the diabases in the area. According to him the paleomagnetic pole of these diabases is located in northern Siberia at longitude 67.2° north and latitude 72.2° east. He thinks, however, that the small fraction of natural remanent magnetization found after de-magnetization has components of different origins. The measured directions cannot be considered with any certainty to be those of the original thermoremanent magnetization. The stable magnetization is, in those diabases which yielded the best paleomagnetic results, connected with the fine ulvite-magnetite intergrowth (Neuvonen 1969). The poor result of the Häme diabases in the paleomagnetic investigations may be due to the absence of these intergrowths.

Radiometric age determinations

The mineral ages were determined by O. Kouvo and M. Sakko using the lead-uranium method on samples of granodiorite from Tuomasvuori, Padasjoki (A243—GSF 67) and of a rheomorphic dike (A238—GSF 67) cross-cutting the Tuomasvuori (2) diabase. The lead-uranium ages were determined for the zircon and sphene concentrates from the granodiorite. The material from the rheomorphic dike did not include enough zircon so that the work was restricted to sphene. Lead and uranium were measured on a solid source, 9-inch, Nier-type mass spectrometer.

Because of the high common lead content of the sphene from the rheomorphic dike (isotopic abundances relative to ^{206}Pb: $^{204}Pb = 2.050$, $^{206}Pb = 100$, $^{207}Pb = 38.40$ and $^{208}Pb = 96.06$), two different assumed isotopic compositions were used for common lead — $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$, respectively: (a) 16.18, 15.52, and 36.01 (average rapakivi lead in Finland) and (b) 15.63, 15.38, and 35.49 (average Svecofennian lead, personal communication by O. Kouvo).

The calculated radiometric ages are as follows:

Sample		Mineral	Apparent ages (× 10^6 yr.) ^{206}Pb-^{238}U	^{207}Pb-^{235}U	^{207}Pb-^{206}Pb
A243	(granodiorite)	zircon	1 670	1 770	1 905
A243	»	sphene	1 440	1 620	1 865
A238	(rheomorphic	sphene (a)	1 545	1 585	1 620
	dike)	sphene (b)	1 570	1 620	1 670

Nearly all the isotopic lead-uranium ages recorded in the literature are discordant, which means that the various age values exceed the experimental errors. Two facts may be noted regarding these age comparisons: the ^{207}Pb-^{206}Pb age is usually higher than the lead-uranium ages and nearer to the real age and the age suite given by sphene is more concordant than that given by zircon.

It is customary to examine discordant ages by graphical methods on the concordia-discordia diagram developed by Wetherill, Nicolaysen, Tilton and Wasserburg. When plotted on such a diagram, both the zircon and sphene from the Tuomasvuori granodiorite show a typical Svecofennian age of 1 900 m.y. It is interesting that the sphene from this rock gives a less concordant age pattern than the zircon. The reason for this is unknown. The fairly low common lead content of both of these minerals is shown by the ratio $^{206}Pb/^{204}Pb$: 5 816 for zircon and 490 for sphene.

In spite of the high common lead content of sample A238, the isochron plot shows fairly close agreement between the ages obtained for the different assumed isotopic compositions mentioned above: 1670—1710 m.y. (rapakivi lead and Svecofennian lead respectively). Also the difference in the isotopic composition values of common lead employed makes very little difference to the degree of discordance.

From the standpoint of regional geology this single measurement indicates the same age limits as those obtained for the rapakivi granites in Fennoscandia.

Jointing, ruptures, morphology and weathering

No systematic observations were made of the jointing of diabase in the Häme area. However, a study of well exposed dikes has shown that the strongest maximum of jointing, especially in the large dikes, is in the direction of the dike. In smaller dikes the jointing perpendicular to the trend of the dike is better developed. This is in full agreement with the observations of Matisto (1957) in the Suomussalmi area. Observations of jointing were often used for determining the trend of the dikes where no contacts were exposed. The jointing is caused by the cooling of the dikes, which can be verified by the observation (e.g. in Koukkujärvi B) that the jointing of small apophyses also follows the trend of the main dike even if the apophyses run diagonally to it.

The rheomorphic dikes and diabase dikes cutting the diabase show that the first joints were formed in diabase immediately after the solidification of the rock and, in the contact zones even before the crystallization of the central part of the dikes.

In many places minerals have formed in the joints of diabase. The most common of these is serpentine (chrysotile), which forms narrow black fissure veins in almost every diabase dike. When a serpentine vein intersects an olivine grain the entire grain is serpentinized. In thicker serpentine veins some talc was also observed in its center (e.g. in Virmaila). In the dike of Tyystjoki (2) a serpentine vein cuts a small rheomorphic dike. The rheomorphic dike is thus older than the serpentine veins.

Another common mineral in the fissure veins is calcite. It seems to have crystallized in the open joints and apparently after the serpentine. Dolomite also forms fissure veins but it is much rarer than calcite.

Microbreccias (Fig. 38) were observed at the contacts of the Koukkujärvi (A 2) and Vaheri (A) dikes, where prehnite veins disrupt the fine-grained contact varieties of the diabases. At Koukkujärvi the dikes continue for several centimetres on both sides of the contact. Laumontite was found in the fissures of the rheomorphic dike cutting the diabase of Maijaanvuori (2).

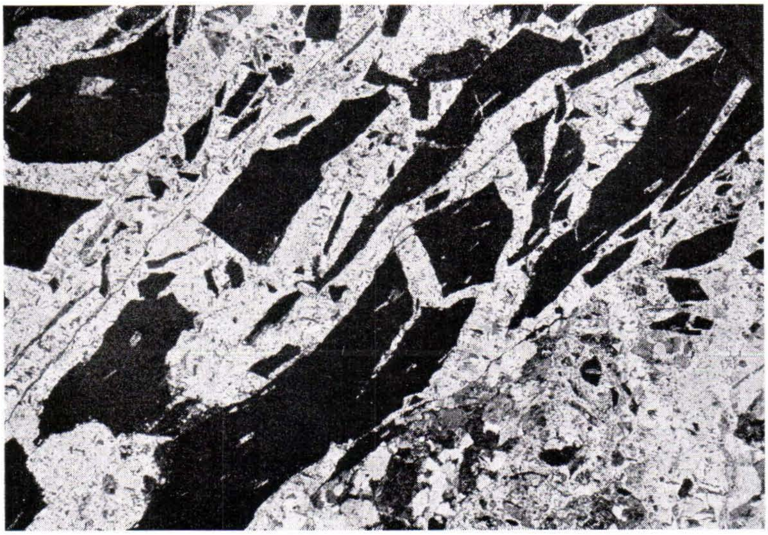

FIG. 38. Prehnite dikes forming microbreccia at the contact of diabase. Koukkujärvi (A2), Padasjoki. Magn. 10 x, nic. +.

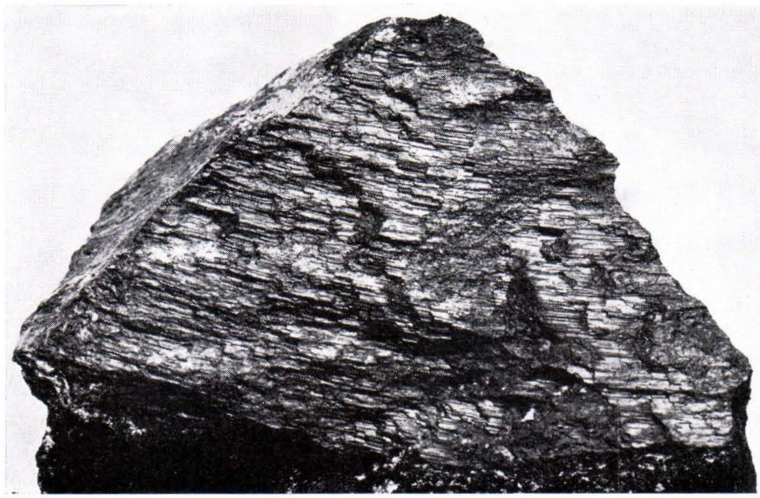

FIG. 39. Slickenside in diabase. Karinlahti (2), Luopioinen. Natural size.

Savolahti (1964) described rupture zones with a nearly N—S trend in the Ansio diabase. Zones of strong mylonitization and well developed slickensides (Fig. 39) have also been found in the Karinlahti (2) diabase where the ophitic texture is obliterated. Olivine has altered to serpentine and other secondary minerals are chlorite, epidote and calcite. In the shearing zones plagioclase is strongly altered and is also somewhat albitized. Small ruptures are present in many dikes, but the majority are not visible, as the ruptured zones are more liable to erosion and they are often covered by soil or water. In most cases displacement at the ruptured zones seems to be rather slight, and it seems plausible that the en echelon structures of the diabase dikes are not connected with these displacements. On the contrary their origin seems to be associated with the opening of the joints during the intrusions.

In morphology the large diabase dikes often appear as ridges rising from their surroundings (e.g. Ansio and Nuijasaari). It is even more common for a diabase dike to form a step on a slope dipping N or NE (e.g. Kaakkolammi, Karivuori and Linnasaari). This is evidently due to the fact that the diabase dike has protected from erosion, the rock to the south of it. There is a distinct angle between the trend of the diabase dikes (N 45—60°W) and the advance direction (~N 40°W) of the continental ice sheet.

Small dikes often appear in the exposures as channels covered by soil and lush vegetation (e.g. Munuajärvi Figs. 16 and 17, Särkijärvi and Vaheri C). This phenomenon seems to be a result of the intense jointing system of the dikes. For the same reason the contact zones of many larger dikes are eroded deeper (Fig. 40) than their surroundings. This hampers the investigation of the contact phenomena, particularly the outsets of many rheomorphic dikes.

FIG. 40. A typical contact of diabase dike, Kaakkolammi, Eräjärvi. Diabase (at right) has been eroded deeper than granite (at left). Although the contact may be located to within a few centimeters, the contact proper is usually covered by about 0.5 m overburden.

The weathering of the diabase surface facilitates a study of many structural features (Figs. 2, 3, 14, 22 and 25). Deep weathering is seldom encountered. It is possible that the strongly weathered diabase boulders found in Virmaila represent the uppermost horizon weathered in the preglacial time. It should be mentioned that in the Häme area preglacial weathering has been observed in other rocks, among others in a metadiabase in Länkipohja.

CONCLUSIONS

Crystallization history

Before the intrusion of the Häme diabase dike set, one or more chambers of basaltic magma evidently existed beneath the area. No conclusions can be drawn regarding the origin of these chambers, but considering the age of the dike set it seems plausible that the formation of the magma chambers is connected with the Svecofenno-Karelian folding.

The limited number of rock analyses prevents any far-reaching conclusions from being drawn about the differentiation trends of the magma. Compared to variation diagrams (Kuno, 1968) of well known areas, e.g. Skaergaard and Warner, analyses 1—3 in Table 2 reveal that the diabase of Ansio shows little or no differentiation and the diabase of Vehkajärvi is a typical differentiation product of the same magma type. Being the only phenocryst mineral, plagioclase evidently was the first crystalline phase to form in the magma. In some parts of the chamber the crystals were far enough apart, not to interfere with each other and grew under equilibrium conditions to megacrysts up to 30 cm or more in length. The crystallization of plagioclase depleted the residual magma of Al and Ca and enriched it in Fe and Mg. This in turn raised the specific gravity so that plagioclase crystals began to float upwards forming anorthosite at the top of the chambers. Hypersthene and olivine, sometimes present in the anorthosite autoliths, indicate that some ferro-magnesian minerals simultaneously crystallized. They settled obviously enriching the lower parts of the magma chamber in Fe and Mg. The magma type of Partakorpi may have formed during this stage of differentiation. A great number of plagioclase crystals remained suspended in the magma. This may have been caused by the varying composition and density of magma or by the viscosity which at lower levels was so high (Rittmann, 1962, p. 181) that the crystals had not enough time to reach the top of the chamber before eruption.

The temperature of the magma was not the same in all types of dikes. However, some conclusions can be drawn concerning the limits of temperature during the intrusions. The melting of lithiophilite at the contact of the Viitaniemi dike (see page 48) indicates that the temperature exceeded 1 120°C. Melting tests (Tilley et al., 1963) show that the plagioclase phase disappears at 1 140°—1 240°C when natural basalts are melted at a pressure of one atmosphere. With the crystallization of basalts the first silicate phase appears at 1 160°—1 240°C (Yoder and Tilley, 1962) irrespective of the type of primary silicate phase, and all major silicate phases begin crystallizing together at temperatures of 1 155°—1 170°C. Measured temperatures of basaltic lavas from active volcanoes are of the order of 1 200°C. Bearing in mind that plagioclase is the only phenocryst mineral in the Häme diabase and that in most cases it seems to have been the only crystalline silicate phase during intrusion, it can be deduced from the experimental data that the intrusion temperatures must have been rather close to 1 200°C. Eskola (1925, p. 325) arrived at nearly the same result when he investigated experimentally the crystallization temperatures of the Satakunta diabase. He found that crystallization began at about 1 200°C and on cooling over four days (from 1 160° to 1 154°C) it was almost completely crystallized.

During intrusion flowage differentiation (Bhattacharji and Smith, 1964) moved megacrysts and other solid bodies towards the center of the dike (Fig. 11). Simultaneously these bodies had a tendency to float into the upper parts of the dipping dikes (Fig. 10) and into upper side branches (Fig. 13). In large dikes the gravitational sorting of phenocrysts and megacrysts continued after the movement of magma ceased, but in small dikes the cooling was too rapid. The sorting of megacrysts, phenocrysts and inclusions observed in the Häme diabase can be explained by these phenomena.

The rarity of megacrysts and phenocrysts in chilled margins suggests that they had crystallized in the dike itself. However several features in the Häme area do not support this. Rather large plagioclase crystals have been observed in quite small (less than 10 cm wide) dikes (e.g. in apophyses of Anttila B, Huppionvuori C and Sinipilkka), which apparently solidified so rapidly that crystals several centimetres in diameter could not have formed in situ. The lack of zonal structure in megacrysts, disregarding the mantle, suggests that they were formed very slowly under equilibrium conditions. Likewise the fragmentation of crystals (Fig. 12), observed in numerous dikes, is hard to explain if it is assumed that the crystals were formed in situ.

When the main part of the magma had crystallized, cooling joints opened in the diabase. If such a joint reached the unsolidified central part of the dike the joint was immediately filled with liquid magma and thus the small diabase dikes (Fig. 14) cutting diabase were formed. Mostly, however, partly or completely molten country rock intruded into the joints. The rheomorphic character of these dikes (Fig. 32) is indicated by two facts: the outset of the dike at the contact is visible, or rock and mineral fragments (Figs. 33 and 34) derived from the country rock have been observed in the dikes.

Relation to the jointing of the country rock

The parallel or semiparallel sets of lineations visible on the appended map support the hypothesis that several deep faults controlled the intrusion of the Häme diabases. The trends of the sets, which are assumed to reflect the directions of the deep faults are marked in the diagrams (Figs. 19 and 20) as broken lines. Comparing these lines to the trends of the diabase dikes and the jointing maxima of the bedrock (Fig. 1; also marked in Figs. 19 and 20) reveals that on both diagrams the maximum of the dike trends is between the direction of the deep faults and the jointing maximum closest to it. This indicates that the magma most likely intruded along dikes that best agreed with the direction of the deep faults and that the jointing systems of the bedrock (Fig. 1) apparently are older than the diabase dikes.

The dike form of the diabase intrusions reveal that the present erosion level of the bedrock represents a depth zone in which jointing already existed during the intrusions. When continuing in other joints diabase dikes generally form en echelon (Appended map e.g. E of Padasjoki and Fig. 14) or en bayonet structures (Figs. 7 and 21) which are particularly characteristic of the dikes. These structures are apparently caused by an opening mechanism of the joints during intrusion. No features were observed to indicate that the en echelon structures were involved in faults which would have broken the dikes after intrusion.

Relation to rapakivi massifs

It is unlikely that enrichment of volatiles in the magma chambers could have led to the evolving of deep faults necessary to initiate the eruptions, as the crystallization of the magma was not sufficiently advanced. The location of the magma chambers was evidently so deep that active eruptions were not possible.

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When considering the location of the dike set on the geological map of southern Finland the thought cannot be avoided that the genesis of the dike set is somehow associated with the rapakivi intrusions. Similar opinions concerning other diabases have been discussed by several authors (see page 9). The continuation of the main part of the set is situated on the northern border of the Viipuri rapakivi massif and the continuation of the northern fork (Virmaila—Nikkaroinen) is on the northern border of the Ahvenisto rapakivi massif. Also the only age determination (see page 54) available at the moment coincides with that of the rapakivi massifs in southern Finland. Since these massifs are lighter than the surrounding bedrock, they may have risen at some stage during their emplacement. Such an upheaval may have caused the deep faults. This hypothesis is likewise sustained by the fact that the distance of the dikes farthest off the Viipuri rapakivi massif does not exceed the diameter of the massif.

As was mentioned previously (p. 9) most diabase dikes around the rapakivi areas of south-eastern Finland are considered to be older than rapakivi. In the author's opinion this does not necessarily disagree with the assumption that they belong to the same set as the Häme diabases and are genetically associated with rapakivi. It must be assumed that the emplacement of the rapakivi massifs disrupted the bedrock both above and at their margins. Some of the joints thus formed extended to liquid rapakivi magma and were filled with it. Others were filled with basaltic magma discharged through deep faults possibly involved in the emplacement of rapakivi. The upward movement of rapakivi apparently continued long enough to be able to cut diabase dikes that had formed at an earlier phase of the upheaval.

Within the scope of the present study it is not possible to say whether the part played by rapakivi in evolving the diabase dikes is restricted to the forming of deep faults and the opening of the joint systems, or whether the granitic and basaltic magmas were genetically related. No intermediate forms between rapakivi and diabase are known in the area, and even those granite porphyry dikes which seem to form a continuation of the diabase dike set in the rural parish of Heinola, are true rapakivi granites in composition. At the moment the author is not aware of any facts which would show any genetic connection between the magmas in question, but the significance of rapakivi in the forming of the deep faults and the opening of joint systems controlling the diabase intrusions, seems unquestionable.

REFERENCES

ANDERSSON, AUG. A. (1891) Dagbok [Field diary]. Geological Survey of Finland.

ARPPE, A. N. (1891) Geologisk Dagbok II, sommaren 1891 [Field diary]. Geological Survey of Finland.

AUROLA, ERKKI (1967) Kurun alueen rakennuskivet, Summary: Building stones of Kuru. Geologinen tutkimuslaitos, Geoteknillisiä julkaisuja No 71, 64 p.

AYRTON, STEPHEN NEVILLE (1963) A contribution to the geological investigations in the region of Ivigtut, SW Greenland. Grønlands Geol. Unders. Bull. 37, 139 p.

BAMBAUER, H. U., CORLETT, M., EBERHARD, E. and VISWANATHAN, K. (1967) Diagrams for the determination of plagioclases using X-ray powder methods. Schweiz. Min. Petr. Mitt., Bd. 47, pp. 333—349.

BHATTACHARJI, S. and SMITH, C. H. (1964) Flowage differentiation. Science, Vol. 145, No. 3628, pp. 150—153.

BLOMBERG, ALBERT (1907) Beskrifning till kartbladet Boxholm. Sveriges Geol. Unders. Ser. Aa. No. 140, 37 p.

BORGSTRÖM, L. H. (1907) Granitporphyr von Östersundom. Bull. Comm. géol. Finlande No. 22, 21 p.

—»— (1947) Granite-porphyry from Östersundom II. Compt. Rend. Soc. géol. Finlande No. 20, pp. 121—128; *also* Bull. Comm. géol. Finlande No. 140.

BRIDGEWATER, D. (1967) Feldspathic inclusions in the Gardar igneous rocks of South Greenland and their relevance to the formation of major anorthosites in the Canadian Shield. Canadian J. Earth Sci., Vol. 4, pp. 995—1014.

—»— and HARRY, W. T. (1968) Anorthosite xenoliths and plagioclase megacrysts in Precambrian intrusions of South Greenland. Meddelelser om Grønland, Bd. 185, No. 2, 243 p.

EMELEUS, C. H. (1964) The Grønnedal-Íka alkaline complex, South Greenland. Meddelelser om Grønland, Bd. 172, No. 3, 75 p.

ERVAMAA, PENTTI (1962) The Petolahti diabase and associated nickel—copper—pyrrhotite ore, Finland. Bull. Comm. géol. Finlande No. 199, 80 p.

ESKOLA, PENTTI (1925) Satakunnan diabasi. Satakunta, Kotiseutututkimuksia 5, pp. 321—326.

—»— (1932) On the origin of granitic magmas. Min. Petr. Mitt., Vol. 42, pp. 455—481.

—»— (1935) Kuhmoisten zeoliittiesiintymä ja sen mahdollinen suhde Päijänteen murroslaaksoihin; Summary: An occurrence of zeolite in the parish of Kuhmoinen, Central Finland, and its possible relation to the fracture lines in the basin of Lake Päijänne. Terra. Vsk. 47, pp. 170—177.

—»— (1960) Laumontite in Finland. The Indian Mineralogist, Vol. 1, pp. 29—41.

FAHRIG, W. F. and WANLESS, R. K. (1963) Age and significance of diabase dyke swarms of the Canadian Shield. Nature, Vol. 200, No. 4910, pp. 934—937.

FRANKEL, J. J. (1967) Forms and structures of intrusive basaltic rocks. Pp. 63—102 in »Basalts», Vol. 1; ed. by H. H. Hess and Arie Poldervaart. Interscience Publ.

FROSTERUS, BENJ. (1893) Om en diabas i Föglö i den åländska skärgården. Geol. Fören. i Stockholm Förh., Bd. 15, pp. 275—290.

FROSTERUS, BENJ. (1900) Vuorilajikartta [Pre-Quaternary rocks], sheet C 2, Mikkeli. [General geological map of Finland] 1 : 400 000.

—»— (1902) Beskrifning till bergartskartan C 2, S:t Michel, Résumé en français. [General geological map of Finland] 1 : 400 000. 114 p.

—»— (1903) Vuorilajikartan selitys C 2, Mikkeli. [General geological map of Finland] 1 : 400 000. 102 p.

GORBATSCHEV, G. (1961) Dolerites of the Eskilstuna region. Sveriges Geol. Unders., Ser. C, No. 580, 39 p.

GYLLING, HJALMAR (1888) Beskrifning till kartbladet No. 12, Nystad, 1 : 200 000. Finlands Geol. Unders. 91 p.

HÄRME, MAUNU (1961) On the fault lines in Finland. Compt. Rend. Soc. géol. Finlande No. 33, pp. 437—444; *also* Bull. Comm. géol. Finlande No. 196.

—»— (1969) Kallioperäkartta, Pre-Quaternary rocks, sheet 2143, Kerava. Geological map of Finland, 1 : 100 000.

HAUSEN, HANS (1964) Geologisk beskrivning över Landskapet Åland. Skrifter utgivna av Ålands Kulturstiftelse IV, 196 p.

HEDSTRÖM, HERMAN (1917) Beskrivning till kartbladet Eksjö. Sveriges Geol. Unders. Ser. Aa. No. 129, 107 p.

KAHMA, AARNO (1951) On contact phenomena of the Satakunta diabase. Bull. Comm. géol. Finlande No. 152, 84 p.

KAITARO, SIMO (1953) Geologic structure of the late pre-Cambrian intrusives in the Åva area, Åland Islands. Bull. Comm. géol. Finlande No. 162, 71 p.

KOUVO, OLAVI and TILTON, G. R. (1966) Mineral ages from the Finnish Precambrian. Journ. Geol., Vol. 74, pp. 421—442.

KRANCK, E. H. (1967) Anorthosite and rapakivi. Geologi, Vsk. 19, pp. 93—94.

KUNO, HISASHI (1960) High-alumina basalt. Journ. Petrol., Vol. 1, pp. 121—145.

—»— (1965) Fractionation trends of basalt magmas in lava flows. Journ. Petrol., Vol. 6, pp. 302—321

—»— (1968) Differentiation of basalt magmas. Pp. 623—688 in »Basalts» Vol. 2; ed. by H. H. Hess and Arie Poldervaart. Interscience publ.

LAITAKARI, AARNE (1925) Über das Jotnische Gebiet von Satakunta. Bull. Comm. géol. Finlande No. 73, 43 p.; *also* Fennia 45, No. 8.

—»— (1928) Palingenese am Kontakt des postjotnischen Olivindiabases. Fennia 50, No. 35, 25 p.

—»— (1942) Kivilajikartan selitys B 3, Vaasa. [General geological map of Finland] 1 : 400 000. 66 p.

LAITAKARI, ILKKA (1964) Kallioperäkartta, Pre-Quaternary rocks, sheet 2134, Lammi. Geological map of Finland, 1 : 100 000.

—»— (1965 a) Padasjoen—Oriveden seudun oliviinidiabaaseista, Summary: On olivine diabases of the Padasjoki—Orivesi area, Finland. Geologi, Vsk. 17, pp. 61—65.

—»— (1965 b) Svekofennidien syvimmät osat diabaasijuonten sulkeumien valossa, Summary: Deepest parts of the Svecofennides revealed by fragments in diabase dikes. Geologi, Vsk. 17, pp. 120—121.

—»— (1966) Heinolan—Padasjoen—Oriveden seudun diabaasijuoniparvi. Thesis, Geological institute, University of Turku, 157 p.

LEHIJÄRVI, MAUNO (1964 a) Kallioperäkartta, Pre-Quaternary rocks, sheet 3111, Lahti. Geological map of Finland, 1 : 100 000.

—»— (1964 b) Kallioperäkartan selitys 3111, Lahti; Summary: Explanation to the map of rocks. Geological map of Finland, 1 : 100 000. 40 p.

—»— and TYRVÄINEN, AIMO (1969) Kallioperäkartta, Pre-Quaternary rocks, sheet 3114, Vuohijärvi. Geological map of Finland, 1 : 100 000.

MARMO, VLADI and MIKKOLA, TOINI (1963) On diabase dikes at Keuruu, Central Finland. Compt. Rend. Soc. géol. Finlande No. 35, pp. 17—25; *also* Bull. Comm. géol. Finlande No. 212.

MATISTO, ARVO (1957) Diabaasijuonien rakoilusta. Geologi Vsk. 9, p. 94.

—»— (1958) Kivilajikartan selitys D 5, Suomussalmi, English summary. General geological map of Finland, 1 : 400 000. 115 p.

—»— (1964) Kallioperäkartta, Pre-Quaternary rocks, sheet 2141, Kangasala. Geological map of Finland, 1 : 100 000.

NEUVONEN, K. J. (1965) Paleomagnetism of the dike systems in Finland. I. Remanent magnetization of Jotnian olivine dolerites in Southwestern Finland. Compt. Rend. Soc. géol. Finlande, No. 37, pp. 153—168; *also* Bull. Comm. géol. Finlande No. 218.

—»— (1966) Paleomagnetism of the dike systems in Finland. II. Remanent magnetization of dolerites in Vaasa Archipelago. Compt. Rend. Soc. géol. Finlande, No. 38, pp. 275—281; *also* Bull. Comm. géol. Finlande, No. 222.

—»— (1967) Paleomagnetism of the dike systems in Finland. III. Remanent magnetization of diabase dikes in Häme, Finland. Compt. Rend. Soc. géol. Finlande, No. 39, pp. 95—100; *also* Bull. Comm. géol. Finlande No. 229.

—»— (1969) Paleomagneettisen tutkimuksen nykytilasta. Geologi Vsk. 21, pp. 33—34.

NYKÄNEN, OSMO (1960) Kallioperäkartan selitys 2142, Korsnäs; Summary: Explanation to the map of rocks. Geological map of Finland 1 : 100 000. 34 p.

PHILPOTTS, A. R. (1966) Origin of the anorthosite-mangerite rocks in southern Quebec. Journ. Petrol., Vol. 7, pp. 1—64.

PRINZ, MARTIN (1964) Geologic evolution of the Beartooth Mountains, Montana and Wyoming, Pt. 5: Mafic dike swarms of the Southern Beartooth Mountains. Geol. Soc. America Bull. Vol. 75, pp. 1217—1248.

RAMSAY, WILHELM (1890) Om Hoglands geologiska byggnad. Geol. Fören. i Stockholm Förh. Bd. 12, pp. 471—490.

RITTMANN, A. (1962) Volcanoes and their activity. Interscience Publ. 305 p.

SAASTAMOINEN, JYRY (1956) Graniittiporfyyri- ja breksiajuonista Etelä-Sipoossa. Thesis, Institute of Geology and Mineralogy, University of Helsinki, 55 p.

SAKSELA, MARTTI (1934) Kivilajikartta [Pre-Quaternary rocks], sheet B 3, Vaasa. [General geological map of Finland] 1 : 400 000.

SAVOLAHTI, ANTTI (1956 a) On the petrology of the Ahvenisto Massif. Dissertation, University of Helsinki, 79 p.

—»— (1956 b) The Ahvenisto Massif in Finland. Bull. Comm. géol. Finlande No. 174, 96 p.

—»— (1964) Olivine diabase dike of Ansio in Padasjoki, Finland. Compt. Rend. Soc. géol. Finlande No. 36, pp. 99—111; *also* Bull. Comm. géol. Finlande No. 215.

—»— (1966) The differentiation of gabbro-anorthosite intrusions and the formation of anorthosites. Compt. Rend. Soc. géol. Finlande No. 38, pp. 173—197; *also* Bull. Comm. géol. Finlande No. 222.

SEDERHOLM, J. J. (1890) Från Ålandsrapakivins västra gräns. Geol. Fören. i Stockholm Förh. Bd. 12, pp. 460—470.

—»— (1891) Dagbok 1891 [Field diary]. Geological Survey of Finland.

—»— (1893) Om bärggrunden i södra Finland. Fennia 8, No. 3, pp. 1—166.

—»— (1895) Ueber einen metamorphosirten praecambrischen Quarzporphyr von Karvia in der Provinz Åbo. Bull. Comm. géol. Finlande No. 2, 16 p.

—»— (1903) Vuorilajikartta [Pre-Quaternary rocks], sheet B 2, Tampere. [General geological map of Finland] 1 : 400 000.

—»— (1911 a) Murrosviivat ja niiden merkitys Fennoskandian geomorfologiassa, Suomen Kartasto 1910, Teksti I, Suomen Maantieteellinen Seura, pp. 67—80; *also in French*, Fennia 30, I.

—»— (1911 b) Päijänteen pohjan muoto. Suomen Kartasto 1910, Teksti I, Suomen Maantieteellinen Seura, pp. 1—4; *also in French*, Fennia 30, I.

SEDERHOLM, J. J. (1911 c) Beskrifning till bergartskartan B 2, Tammerfors, Résumé en français. [General geological map of Finland] 1 : 400 000. 121 p.

—»— (1912) Über Bruchlinien, mit besonderer Beziehung auf die Geomorphologie von Fennoscandia. Congrès Géologique International, Compte Rendu de la XI:e Session, Stockholm 1910, pp. 865—870.

—»— (1913 a) Vuorilajikartan selitys B 2, Tampere. [General geological map of Finland] 1 : 400 000. 122 p.

—»— (1913 b) Weitere Mitteilungen über Bruchspalten mit besonderer Beziehungen zur Geomorphologie von Fennoskandia. Bull. Comm. géol. Finlande No. 37, 66 p.; *also* Fennia 34, No. 4.

—»— (1928) On orbicular granites, spotted and nodular granites etc. and the rapakivi texture. Bull. Comm. géol. Finlande No. 83, 105 p.

—»— (1932) Über die Bodenkonfiguration des Päijännesees. Bull. Comm. géol. Finlande, No. 100, 23 p.; *also* Fennia 55, No. 3.

—»— (1934) On migmatites and associated pre-Cambrian rocks of Southwestern Finland, Part III. The Åland Islands. Bull. Comm. géol. Finlande No. 107, 68 p.

SEITSAARI, JUHANI (1951) The schist belt Northeast of Tampere in Finland. Bull. Comm. géol. Finlande No. 153, 120 p.

—»— (1954) The Västilä area of the Tampere schist belt. Compt. Rend. Soc. géol. Finlande, No. 27, pp. 95—106; *also* Bull. Comm. géol. Finlande No. 166.

SIMONEN, AHTI (1952) Kallioperäkartan selitys 2124, Viljakkala—Teisko; Summary: Explanation to the map of rocks. Geological map of Finland, 1 : 100 000. 74 p.

—»— (1953) Kallioperäkartta, Pre-Quaternary rocks, sheet 2124, Viljakkala—Teisko, Geological map of Finland, 1 : 100 000.

—»— (1960) Pre-Quaternary rocks in Finland. Bull. Comm. géol. Finlande No. 191, 49 p.

—»— and TYRVÄINEN, AIMO (1965) Kallioperäkartta, Pre-Quaternary rocks, sheet 3132, Savitaipale, Geological map of Finland, 1 : 100 000.

SMITH, J. V. and GAY, P. (1958) The powder patterns and lattice parameters of plagioclase feldspars. II. Min. Mag., Vol. 31, No. 240, pp. 744—761.

STOLPE, M. (1892) Beskrifning till kartbladet Nydala. Sveriges Geol. Unders. Ser. Ab. No. 14, 69 p.

TILLEY, C. E., YODER, H. S. and SCHAIRER, J. F. (1963) Melting relations of basalts. Papers from Geophys. Lab. Carnegie Inst. Washington, No. 1412, pp. 77—84.

UOTI, J. (1891) Päiväkirja [Field diary]. Geological Survey of Finland.

VÄYRYNEN, HEIKKI (1933) Über die Stratigraphie der Karelischen Formationen. Compt. Rend. Soc. géol. Finlande No. 6, pp. 54—78; *also* Bull. Comm. géol. Finlande No. 101.

VELTHEIM, VALTO (1962) On the pre-Quaternary geology of the bottom of the Bothnian Sea. Bull. Comm. géol. Finlande No. 200, 166 p.; *also* Merentutkimuslaitoksen julkaisu No. 202.

VESASALO, ARVO (1956) Selostus Eräjärvellä kesällä 1956 kartoitetusta alueesta. Manuscript, Geological Survey of Finland.

VIRKKUNEN, MARJATTA (1964) Pegmatiittitutkimuksia Eräjärvellä. Manuscript, Geological Survey of Finland.

VOLBORTH, A. (1954) Phosphatminerale aus dem Lithiumpegmatit von Viitaniemi, Eräjärvi, Zentral-Finnland. Ann. Acad. Sci. Fennicae, Ser. A. III, 39. 90 p.

DE WAARD, D. (1952) Structural analysis of the Kuhmoinen part of the Tampere Schist Zone in Finland I and II. Koninkl. Nederl. Akad. van Wetensch. — Amsterdam, Ser. B, 55, No. 1.

WAGER, L. R. (1960) The major element variation of the layered series of the Skaergaard intrusion and a re-estimation of the average composition of the hidden layered series and of the successive residual magmas. Journ. Petrol., Vol. 1, pp. 364—398.

WAHL, WALTER (1906) Über einen Magnesiumdiopsid führenden Diabas von Källsholm, Skärgård von Föglö, Ålandsinseln. Pp. 399—412, in Festschrift Harry Rosenbusch.

WAHL, WALTER (1925) Die Gesteine des Wiborger Rapakiwigebiets. Fennia 45, No. 20, 127 p.

WATT, W. STUART (1968) Petrology and geology of the Precambrian Gardar dykes on Qaersuarssuk, South Greenland. Geol. Surv. Greenland Rep. No. 14, 51 p.

WILKMAN, W. W. (1924) Om diabasgångar i mellersta Finland. Deutsches Referat. Bull. Comm. géol. Finlande No. 71, 35 p.; *also* Fennia 45, No. 3.

—»— (1938) Kivilajikartan selitys C 3, Kuopio, English summary. General geological map of Finland, 1 : 400 000. 171 p.

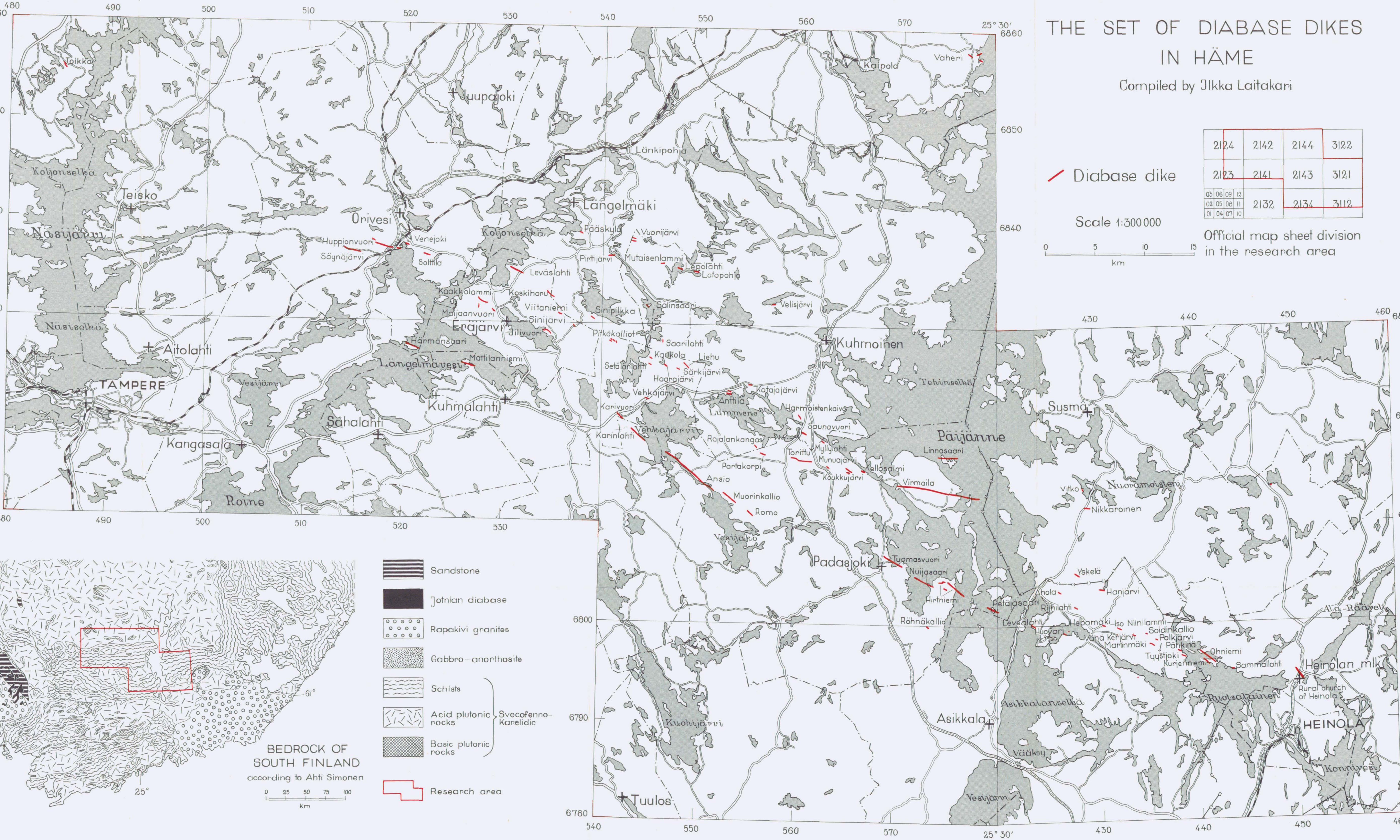
YODER, H. S. and TILLEY, C. E. (1962) Origin of basalt magmas: An experimental study of natural and synthetic rock systems. Journ. Petrol., Vol. 3, pp. 342—532.

ADDITION

While the manuscript was at the printers, diabase dikes were found in following localites:

Map sheet	Coordinates
214204	6837.22—511.40
	6839.58—514.22
	6839.74—514.38
214205	6840.10—514.86
311206	6799.64—435.66
312102	6814.36—428.43
	6810.05—428.73
312104	6800.85—430.80
	6800.68—433.40
	6800.55—433.55
	6800.16—434.75
	6800.05—434.90
312105	6811.68—430.33
	6811.67—430.60

These dikes are not included in the diagrams, text and appended map.


THE SET OF DIABASE DIKES
IN HÄME
Compiled by Ilkka Laitakari
Diabase dike
Scale 1:300 000
0 5 10 15
km
2124 2142 2144 3122
2123 2141 2143 3121
03 06 09 12
02 05 08 11
01 04 07 10
2132 2134 3112
Official map sheet division
in the research area
Sandstone
Jotnian diabase
Rapakivi granites
Gabbro-anorthosite
Schists
Acid plutonic rocks
Basic plutonic rocks
Svecofenno-Karelidic
Research area
BEDROCK OF
SOUTH FINLAND
according to Ahti Simonen
0 25 50 75 100
km
TAMPERE
HEINOLA
Päijänne
Kuhmoinen
Padasjoki
Asikkala
Sysmä
Orivesi
Längelmäki
Teisko
Aitolahti
Kangasala
Sahalahti
Kuhmalahti
Eräjärvi
Juupajoki
Tuulos
Heinolan mlk
Rural church of Heinola