

DISS. A'DAM G.U.

1941: NR. 25

Diss. A'dam Gem. Un.

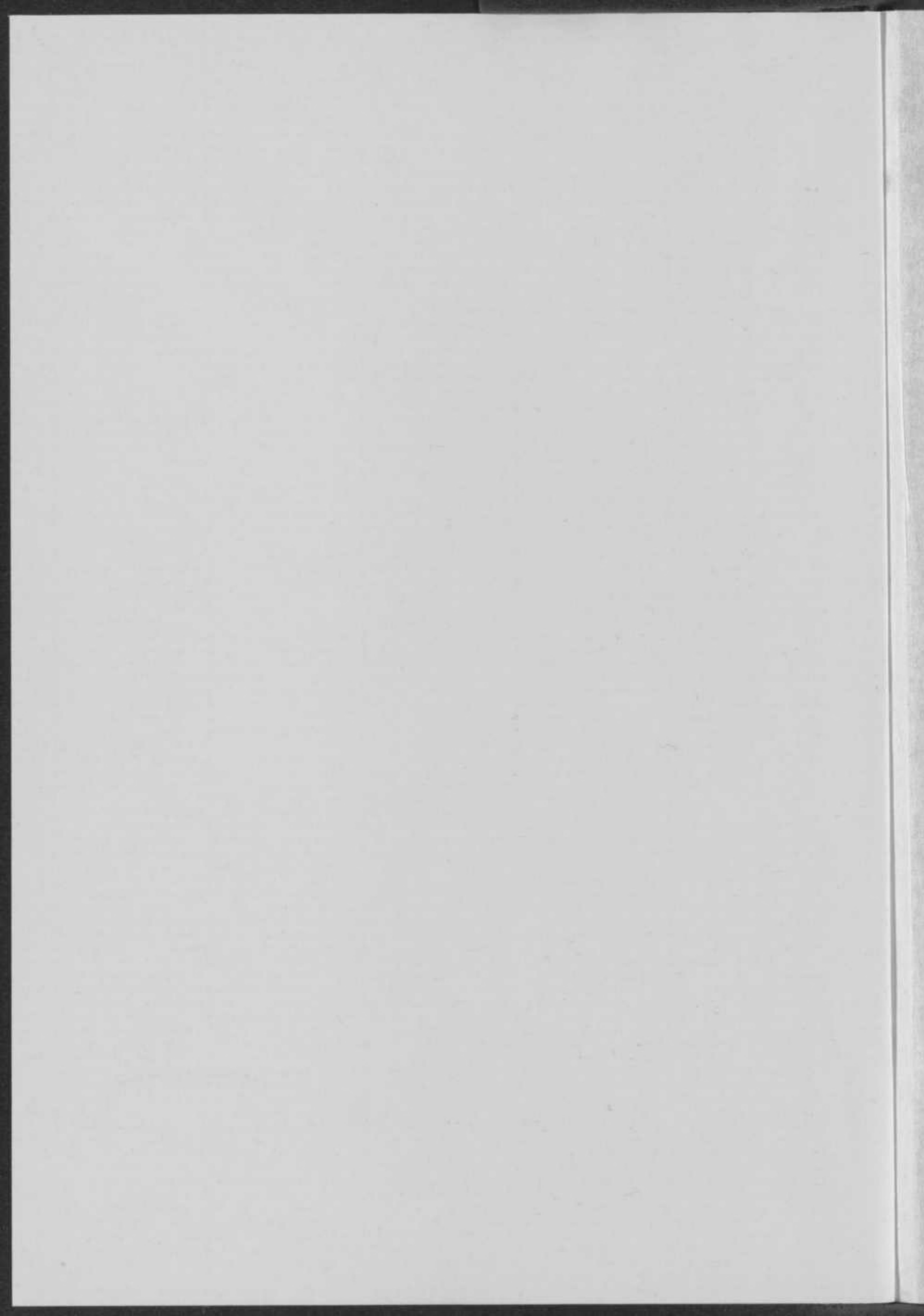
1941 nr. 23

Universiteit Leiden



1 667 769 7

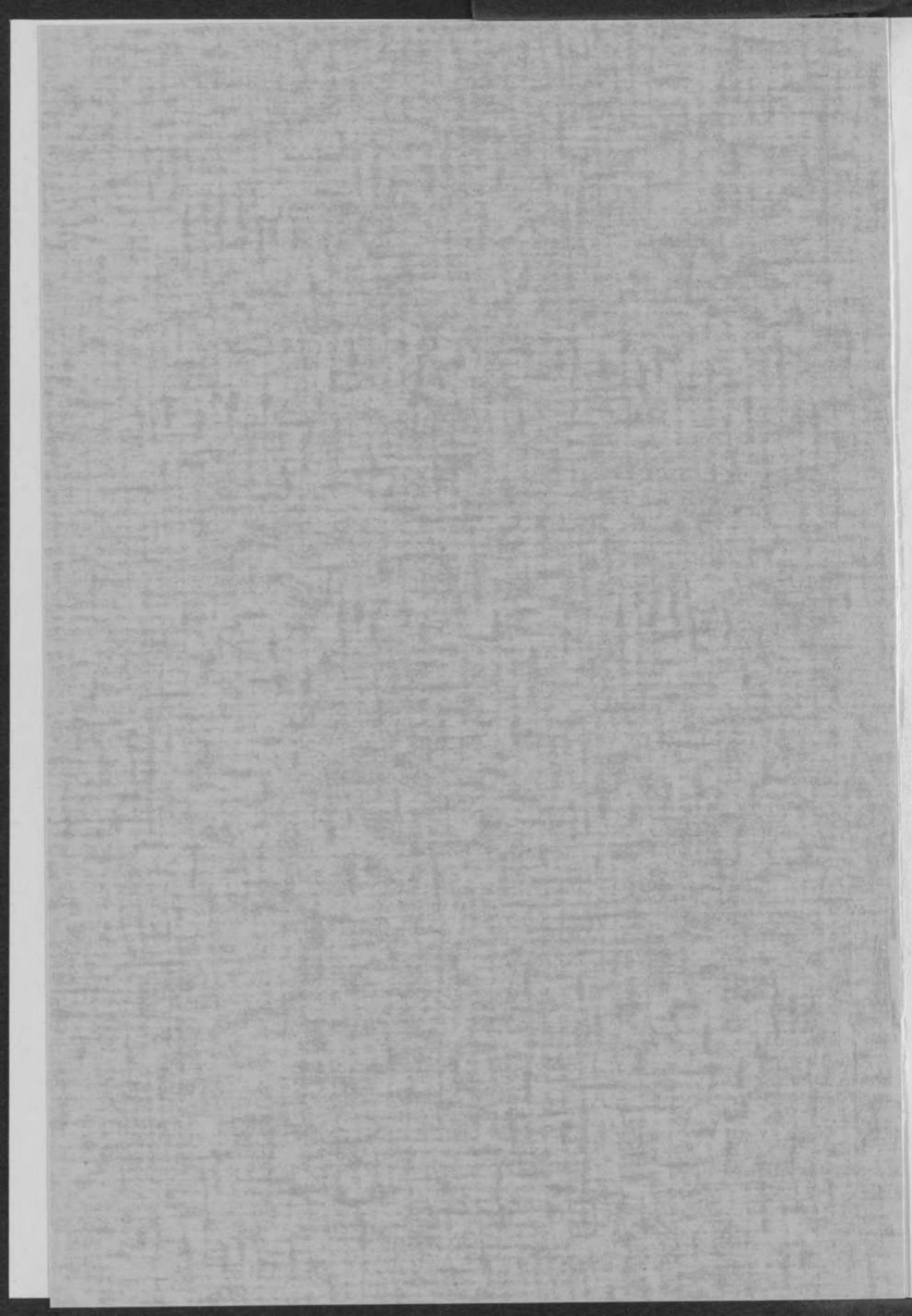


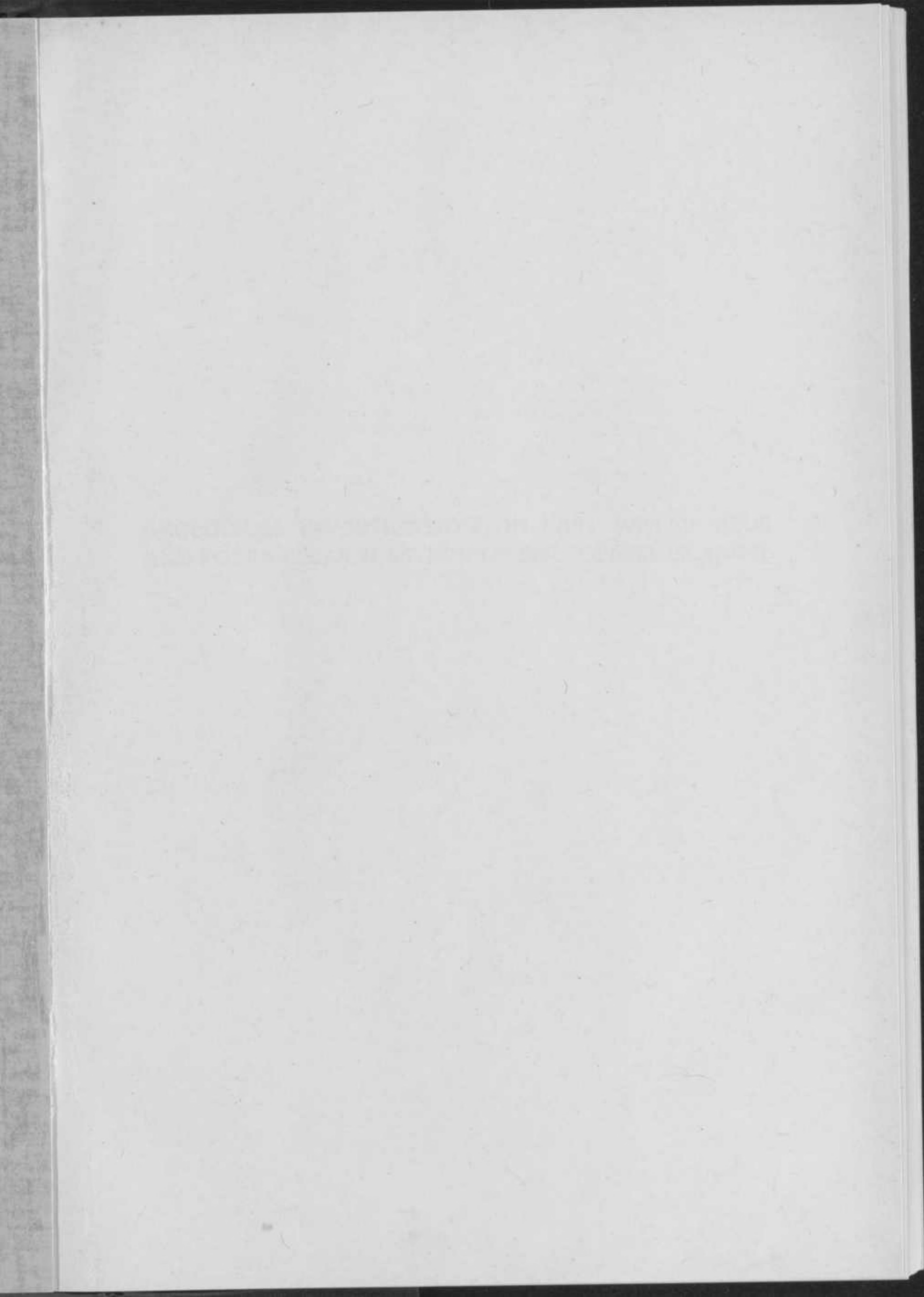


GEOLOGICAL INVESTIGATIONS IN EAST
WETAR, ALOR AND POERA BESAR
(EASTERN LESSER SOENDA ISLANDS)

J. HEERING

Uss. Amsterdam
1941.







GEOLOGICAL INVESTIGATIONS IN EAST WETAR, ALOR
AND POERA BESAR (EASTERN LESSER SOENDA ISLANDS).

GEOLOGICAL INVESTIGATIONS IN EAST WYOMING, ALONG
AND OTHER REAR (EASTERN) BORDER (1912)

GEOLOGICAL INVESTIGATIONS IN EAST WETAR, ALOR AND POERA BESAR

(EASTERN LESSER SOENDA ISLANDS)

ACADEMISCH PROEFSCHRIFT

TER VERKRIJGING VAN DEN GRAAD VAN
DOCTOR IN DE WIS- EN NATUURKUNDE
AAN DE UNIVERSITEIT VAN AMSTERDAM,
OP GEZAG VAN DEN RECTOR-MAGNIFICUS
DR. B. BROUWER, HOOGLEERAAR IN DE
FACULTEIT DER GENEESKUNDE, IN HET
OPENBAAR TE VERDEDIGEN IN DE AULA
DER UNIVERSITEIT OP WOENSDAG
4 JUNI 1941, DES NAMIDDAGS TE 3 UUR

DOOR

JAN HEERING

GEBOREN TE DEVENTER

AMSTERDAM — 1941

N.V. NOORD-HOLLANDSCHE UITGEVERS MAATSCHAPPIJ

* 49405

GEOLOGICAL INVESTIGATIONS IN EAST
WESTER, ALOR AND PORRA BEAR
WESTERN LEECH ISLANDS

JOHN H. HARRIS

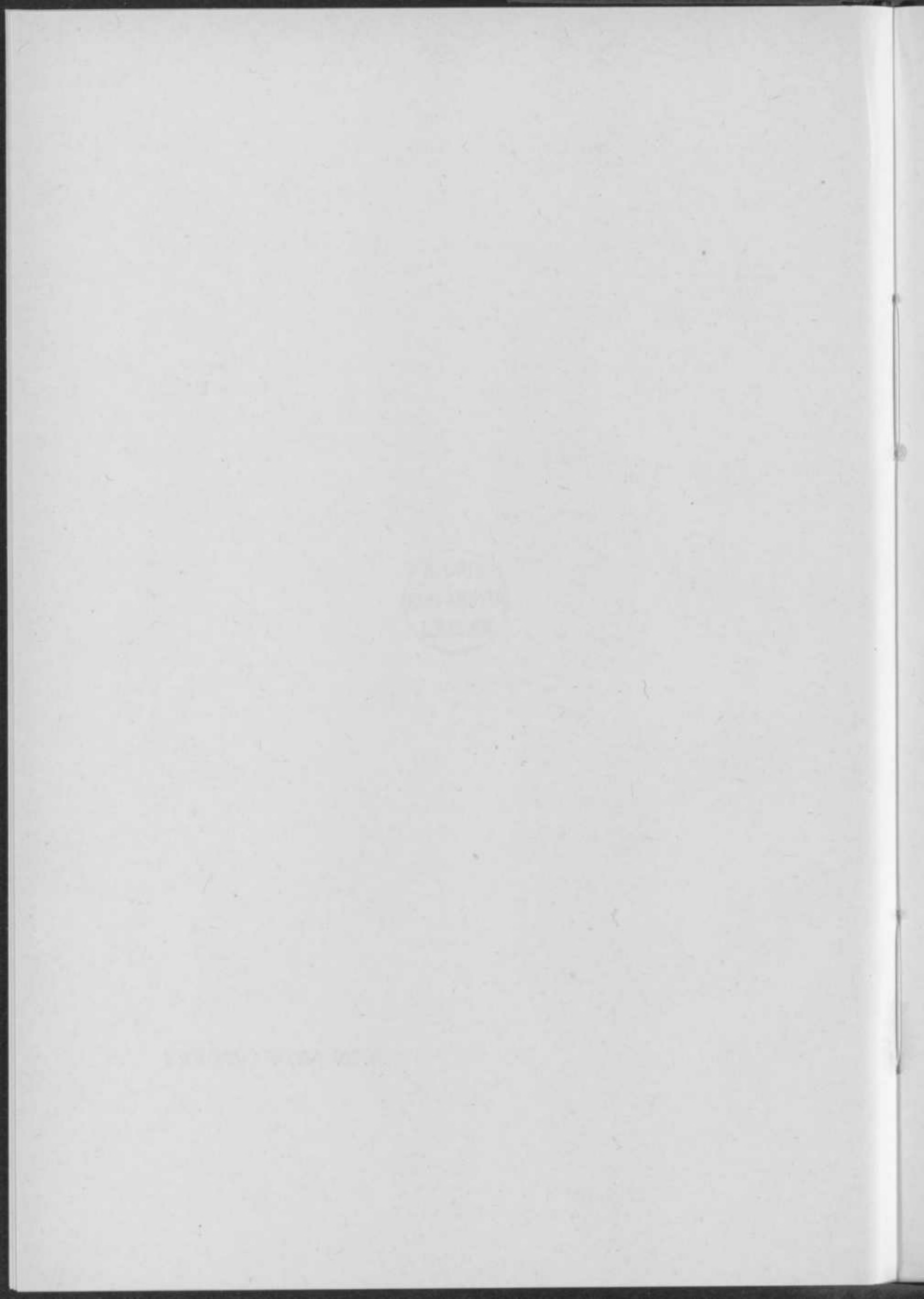
THE GEOLOGICAL SURVEY OF
MALAYA, SINGAPORE
AND THE STRAITS SETTLEMENTS
AND THE NORTHERN Borneo
EXPEDITION, 1908-1910
PART I. THE GEOLOGY OF
THE ALOR AND PORRA BEAR
ISLANDS, WESTERN LEECH
ISLANDS, MALAYA
AND THE STRAITS SETTLEMENTS
AND THE NORTHERN Borneo
EXPEDITION, 1908-1910



LIBRARY

THE GEOLOGICAL SURVEY OF
MALAYA, SINGAPORE
AND THE STRAITS SETTLEMENTS
AND THE NORTHERN Borneo
EXPEDITION, 1908-1910

AAN MIJN OUDERS



Bij het beëindigen van dit proefschrift betuig ik gaarne mijn dank aan allen, die tot mijn wetenschappelijke vorming hebben bijgedragen, vooral aan U, Hoogleraren en Docenten van de Faculteit der Wis- en Natuurkunde, in het bijzonder aan hen, die aan het Geologisch Instituut verbonden zijn.

Gevoelens van erkentelijkheid vervullen mij voor U, Hooggeleerde BROUWER en Promotor, voor de raadgevingen, welke ik van U mocht ontvangen gedurende de werkzaamheden in het veld en tijdens de uitwerking van de verzamelde gegevens, welke aanleiding hebben gegeven tot het schrijven van dit proefschrift.

Met groote dankbaarheid, Hooggeleerde GERTH, denk ik aan het aandeel, dat Gij in mijn wetenschappelijke vorming hebt gehad, in het bijzonder op het gebied der Stratigraphie en Palaeontologie.

Aan U, Zeer geachte VAN SAMBEEK, ben ik zeer verplicht voor het vele dat ik op geologisch gebied tijdens mijn schooljaren van U mocht leren, vooral gedurende onze tochten door Oost-Nederland en Westphalen.

Onze gezamenlijke reizen door Zweedsch Lapland en West-Europa, evenals de tijd van ons gemeenschappelijk bivak te Ilwakki (Wetar), waarbij ik bijzonder veel kameraadschap heb ondervonden van jou, JAN DE JONG, hebben de prettigste herinneringen bij mij achtergelaten.

The first thing I noticed when I stepped out of the car was the cold. It was a sharp contrast to the warm blanket I had been sitting under. I looked up at the sky, which was a pale, overcast grey. The air felt heavy, like it was holding its breath. I took a deep breath, trying to get used to the temperature. The ground beneath my feet was wet and slick, reflecting the light from the sky. I walked slowly, my boots making soft, muffled sounds. The silence around me was broken only by the distant hum of traffic and the occasional cough or sneeze. I felt a little disoriented, as if I had been transported to a new world. The buildings in the background were tall and modern, their windows reflecting the light. I tried to focus on the present, on the feel of the ground and the taste of the air. It was a strange experience, one I had never had before. I continued to walk, my mind racing with thoughts and questions. The world around me seemed so different, so unfamiliar. I was alone, yet I felt a sense of connection to everything around me. The cold was not so bad after all. It was a wake-up call, a reminder that I was here, in this world. I took another deep breath, feeling a sense of peace. The journey was over, but the memories would stay with me forever.

SAMENVATTING.

Dit proefschrift bevat de resultaten van mijn geologische onderzoekingen, welke werden verricht op Oost-Wetar, Centraal-Alor en Poera besar gedurende de maanden Augustus, September en October 1937.

Om een indruk te krijgen van de geologie werden eenige doorsteken dwars door de eilanden gemaakt, terwijl enkele gebieden meer in detail werden onderzocht. Eveneens werd getracht den ouderdom van de gesteenten vast te stellen, alsmede werden de verschijnselen bestudeerd, die verband houden met de bewegingen in den allerjongsten tijd, welke in dit gedeelte van den Oost-Indischen Archipel in gang zijn.

Oost-Wetar bestaat voor het grootste gedeelte uit effusief gesteenten, welke een submarien karakter dragen. Lava's met inschakelingen van mariene sedimenten, zooals kalksteen, mergels en tuffen, welke globigerinen bevatten, zijn van verschillende plaatsen van het eiland bekend geworden. Voor deze globigerinen-houdende sedimenten — evenals voor de lava's, welke in deze periode van sedimentatie uitvloeiden — wordt een jong-Tertiaire ouderdom aangenomen, mede in verband met de groote gelijkenis, welke deze sedimenten vertoonen met soortgelijke gesteenten van Timor en Rotti. Er werden geen aanwijzingen gevonden, die erop zouden kunnen wijzen, dat deze gesteenten ten deele ouder dan jong-Tertiair zouden kunnen zijn.

De effusiefgesteenten zijn te onderscheiden in rhyolieten, dacieten en kwarts-keratophyren, andesieten en keratophyren, basalten en dolerietische basalten en spilieten.

Van de lava's zijn de dacieten en andesieten (met hun gealbitiseerde equivalenten) sterk overheerschend op het eiland Wetar.

Het meest oostelijke gedeelte van het eiland — het gebied tusschen Tomliapat en Arwala — is geheel opgebouwd uit vitrophyrische dacieten, welke behalve phenocrysten van kwarts en plagioklaas, die van hyperstheen, ongeresorbeerde groene hoornblende en biotiet bevatten. De hoeveelheid phenocrysten van groene hoornblende is in sommige gesteenten bijzonder groot.

Glasrijke lava's zijn zeer algemeen; obsidianen (veelal met perlietische breuken), glaskorst-andesieten, lava's met pillow-structuren, glasbreccies en agglomeraten komen veel voor, met inschakelingen van kalken en

tuffen, welke globigerinen bevatten, duidend op het submariene karakter van deze gesteenten.

Basalten en dolerietische basalten, evenals spilieten zijn sterk in de minderheid.

Behalve de effusiva komen op het eiland dieptegesteenten voor, begeleid door talrijke gangen. Op Tandjoeng Illipoi en in het gebied van de M. Saoe werden granodiorieten en kwartsdiorieten gevonden, terwijl de ganggesteenten albiet-dolerieten en albiet-diabazen (soms gealbitiseerde kwarts-diabazen) en sanidien-albiet-rhyolieten (met cordieriet pseudomorphosen) zijn.

De cordieriet in deze rhyolietische lava's is één van de eerste uitkristallisatieproducten van het magma geweest. De aanwezigheid van dit mineraal kan worden verklaard, in analogie met de voorkomens van cordieriethoudende gesteenten op de eilanden Ambon (in dacietische lava's) en Ceram (in granieten), door algeheele assimilatie van vreemd gesteentemateriaal (bv. schisten of schalies) door het magma, waardoor Al-aanrijking in dit magma kon plaats vinden. Homoeogene en enallogene insluitsels, zooals deze voorkomen in de gesteenten van de genoemde eilanden, zijn in de rhyolieten van Wetar afwezig.

In het Meta Saoe-gebied treffen wij ook nog kwarts-albitieten en albitophyren aan, welke met groote waarschijnlijkheid kunnen worden opgevat als ganggesteenten in de granodiorieten.

De sanidien-albiet-rhyolieten komen eenerzijds voor als gangen in de granodioriet, op andere plaatsen evenwel hebben deze gesteenten meer het karakter van effusiefgesteenten, de granodioriet bedekkend. Structurele verschillen in deze twee typen gesteenten zijn echter zeer gering.

Een ander voorkomen van dieptegesteenten vinden wij in het dal van de M. Masapoen, eenige kilometers van de kust. Het zijn kwarts-augietdiorieten tot kwarts-gabbro's.

Contactverschijnselen in lava's, welke de dieptegesteenten bedekken, of waarin de dieptegesteenten intrusief zijn, zijn gering. Hydrothermale werking is merkbaar geweest. Albitisatie van de gesteenten in die gebieden waar dieptegesteenten voorkomen, is een opvallend verschijnsel.

Het grootste gedeelte van het eiland wordt omgeven door een levend rif, terwijl de kusten ten deele worden gevormd door opgeheven koraalkalkterrassen, als regel niet op die plaatsen waar rivieren in zee uitstroomen. Langs de kust zijn de rifkalken in verscheidene, duidelijke terrassen ontwikkeld. Terrassen op 5, 25 en 40 meter boven zee zijn algemeen, terwijl aan de Zuidoostkust een terras op ± 200 m duidelijk is ontwikkeld. In het centrale gedeelte van het eiland werd een rest van

een terras in koraalkalk gevonden op een hoogte van ± 450 m boven zee, in het gebied tusschen Tara en Toepoeti, eenige km ten Noorden van de waterscheiding (Goenoeng Poetih).

Hoogere terrassen, evenwel zonder koraalkalk, tot op 820 m hoogte, zijn door J. D. DE JONG (21) in het westelijk gedeelte van het eiland gevonden. In het midden van het eiland liggen de koraalkalken nagenoeg horizontaal, terwijl de kalken langs de kust, soms met ingeschakelde lagen, bestaande uit rolsteen van vulkanisch gesteenten, hellingen tot 30° zee-waarts vertoonen.

Er zijn verschillende verschijnselen, die duiden op een sterke rijzing — misschien kan beter worden gesproken van welving — in jongeren tijd. De aanwezigheid van de terrassen, waarvan de lagere slechts weinig door erosie zijn aangetast, zijn hiervoor een eerste aanwijzing. Maar ook de morphologie van de rivierdalen wijzen er op. De bovenloop van de rivieren is kort en vertoont veelal watervallen, de middenloop is slecht ontwikkeld, terwijl de benedenloop lang is. De groote rivieren bezitten in hun benedenloop cañonvormige dalen. Ingesneden consequente krommingen zijn waargenomen in den benedenloop van de M. Perai. Maar ook de „hangende” dalen, welke de kleine zijrivieren vertoonen, en de stroomversnellingen waarmee de grootere zijrivieren — door hun grootere erosieve kracht — in de hoofdriever uitmonden, zijn een aanduiding, dat het gebied in een relatief snel tempo wordt opgeheven.

Het centrale gedeelte van Alor werd onderzocht. Het is een diep ingesneden bergland, voor het grootste gedeelte opgebouwd uit vulkanische gesteenten. Rivierdalen van 300—400 meter diepte zijn geen zeldzaamheid. Zij worden begrensd door diep geërodeerde bergruggen met een gemiddelde kamhoogte van 1000 meter.

Het schiereiland Kebola (de „Vogelkop” genaamd), evenals het westelijkste gedeelte van Alor (dus het gebied ten Zuiden van de baai van Kebola) bestaan uit dikke lagen koraalkalk, den vulkanischen ondergrond bedekkend, en ontwikkeld in een reeks fraaie terrassen. Het hoogste terras ligt op ± 700 m boven zee in dit gebied en verleent er het aspect van een tafelland aan.

De vlakkere Noordkust van het eiland bezit terrassen met koraalkalk, in tegenstelling met de zeer steile Zuidkust, welke weliswaar terrassen vertoont, echter zonder koraalkalk. Ook het levende rif is slechts zeer plaatselijk ontwikkeld. Bij kampong Koenaman, eenige km van de Zuidkust landinwaarts gelegen, werd een terras op 700 m aangetroffen, bedekt door een dunne laag koraalkalk. Een rest van een terras werd ten Noor-

den van Langkoeroe gevonden op 1200 meter hoogte; het gesteente bestaat uit een conglomeratisch sediment. De rolsteen bestaan grotendeels uit pyroxeen-andesiet, verkit door fijner tufachtig en vergruisd lavamateriaal, waarin zich slecht bewaarde mariene fossielen bevinden (o.a. zeeëgelstekels, schelpresten en Gastropoden (? *Fissurella*)). Omtrent den ouderdom kan geen uitsluitsel worden gegeven, maar in analogie met afzettingen op aangrenzende eilanden is het toekennen van een jong-Tertiairen ouderdom aan deze gesteenten aangewezen.

Het centrale Alor bestaat voor het grootste gedeelte uit pyroxeen-andesiet; veelvuldig zijn deze lava's ontwikkeld als glasbreccies en glasagglomeraten, welke, evenals van Wetar bekend is geworden, een sub-marien karakter hebben. Ook op Alor zijn veelvuldig inschakelingen van tuffen, kalken en mergels, welke Globigerinen bevatten, gevonden. Vooral in het steile gebergte aan de Zuidkust zijn deze inschakelingen van mariene sedimenten talrijk. Op verschillende plaatsen worden de ruim 900 meter dikke pakketten glasbreccies en glasagglomeraten door deze Globigerinen-houdende sedimenten onderbroken.

Behalve de pyroxeen-andesieten werden glasrijke andesieten en basalten gevonden, terwijl kwarts-andesieten tot dacieten in sporadische ontsluitingen voorkomen. Andesieten, welke door hydrothermale oplossingen sterk zijn veranderd en gebleekt, zijn algemeen verbreid, vooral in het gebied van Langkoeroe (bovenloop van de S. Pomoto).

De depressie tusschen westelijk en centraal Alor, waarin de S. Boeraga naar 't Zuiden en de S. Kikilai naar 't Noorden stroomen, bestaat nagenoeg geheel uit mariene sedimenten (tuffen, kalken en schalies met Globigerinen), welke in het algemeen een vrij sterke helling hebben; in het midden van 't eiland $\pm 30^\circ$ W, terwijl naar 't Zuiden gaande de helling $\pm 30^\circ$ ZW en naar 't Noorden toe deze 25° — 30° NW wordt.

De koraalkalken, van de „Vogelkop” en westelijk Alor, liggen veelal horizontaal in het centrale gedeelte van deze gebieden; zij neigen echter bij de kusten ook meestal eenigszins zeewaarts.

Poera besar is een vulkaaneiland, 1015 m hoog. De vulkaanvorm van 't eiland is nog duidelijk zichtbaar, hoewel de vulkaan geen activiteit meer vertoont.

Een smal koraalkalkterras op een hoogte van ± 50 meter werd gevonden langs de oostkust van het eiland.

Aan de noordkust van het eiland is geen duidelijk terras ontwikkeld; nog eenige door erosie gespaarde blokken van koraalkalk zijn daar aanwezig.

De gesteenten op dit eiland verzameld, bestaan uit pyroxeen-andesieten en basalten.

CONTENTS.

	Page
INTRODUCTION	1
 WETAR.	
GEOGRAPHICAL OUTLINES	3
EARLIER INVESTIGATIONS	5
DESCRIPTION OF THE ROUTES	6
TARA-TOEPOETI TRAVERSE	6
THE COASTAL REGION BETWEEN THE VILLAGES TOEPOETI AND ILWAKKI	13
THE COASTAL REGION BETWEEN THE VILLAGES TOEPOETI AND MASAPOEN	14
MASAPOEN-MONING TRAVERSE	15
THE COASTAL REGION BETWEEN THE VILLAGES MONING AND OEHAH (NORTH COAST)	21
TOMLIAPAT-ARWALA TRAVERSE	21
DESCRIPTION OF ROCKS	23
ROCKS OF THE TARA-TOEPOETI TRAVERSE AND OF THE COASTAL PART BETWEEN THE VILLAGES TOEPOETI AND ILWAKKI	23
1. Dacites and quartz-keratophyres	23
2. Dacites to andesites	25
3. Andesites and keratophyres	26
4. Pyroxene-andesites to basalts	27
5. Dolerites and doleritic basalts	30
6. Spilitic rocks	35
7. Albite-diabases	37
ROCKS OF THE MASAPOEN-MONING TRAVERSE AND OF THE COASTAL PART BETWEEN THE VILLAGES TOEPOETI AND MASAPOEN	37
1. Dacites and quartz-keratophyres	37
2. Dacites to andesites; quartz-bearing keratophyres	41
3. Glass-rich andesites to pyroxene-andesites; keratophyres	42
4. Doleritic basalts	44
5. Dolerites and albite-diabases	45
6. Quartz-augite-diorites to quartz-gabbros	48
ROCKS OF THE COASTAL REGION BETWEEN MONING AND OEHAH	49
1. Rhyolites	49
2. Dacites	50
3. Pyroxene-andesites	50
4. Quartz-diorites	51
ROCKS OF THE TOMLIAPAT-ARWALA TRAVERSE	52
1. Vitrophyric dacites	52
2. Rhyolites	55

	Page
THE SURROUNDINGS OF ILWAKKI	56
A. TANDJOENG ILLIPOI	56
1. Granodiorites to quartz-diorites	59
2. Sanidine-albite-rhyolites	62
3. Albite-dolerites and albite-diabases	71
B. THE REGION BETWEEN THE LOWER COURSES OF THE M. SAOE AND M. HOEROE	72
1. Albite-rhyolites	74
2. Dacites	77
3. Pyroxene-andesites	78
4. Spilitic rocks	80
5. Dolerites and doleritic basalts	80
6. Quartz-albitites and albitophyres	81
7. Albitized quartz-diabases	85
8. Dioritic rocks	86
GENERAL GEOLOGICAL AND PETROLOGICAL REMARKS	88
1. Character and age of the rocks	88
2. Geological position and age of the granodiorites	88
3. The occurrence of unresorbed amphibole	89
4. The cordierite-bearing sanidine-albite-rhyolites	90
5. Tectonical and morphological considerations	91
ALOR.	
GEOGRAPHICAL OUTLINES	92
EARLIER INVESTIGATIONS	95
DESCRIPTION OF THE ROUTES	96
KALABAHI-LANGKOEROE ROUTE	96
REGION SOUTH WEST OF LANGKOEROE	100
LANGKOEROE-KOLOMANA ROUTE	100
ROUTE FROM LANGKOEROE IN THE DIRECTION OF TARAMANA (NORTH COAST)	101
LANGKOEROE-BATOELOLONG-KOEI ROUTE	101
THE SURROUNDINGS OF KOEI	104
KOEI-BOERAGA-KIKILAI ROUTE	104
DESCRIPTION OF ROCKS	107
1. Quartz-andesites to dacites	107
2. Glass-rich andesites	111
3. Pyroxene-andesites	111
4. Basalts	113
5. Hydrothermally altered andesites	114
6. Tuffaceous rocks	115
GEOLOGICAL SUMMARY	117
POERA BESAR.	
INTRODUCTION	119
DESCRIPTION OF ROCKS	122
1. Glass-rich andesites to pyroxene-andesites	122
2. Basalts	123
LITERATURE	124

INTRODUCTION.

As a member of the Geological Expedition of the University of Amsterdam to the Lesser Soenda Islands in 1937, under the direction of Prof. Dr. H. A. BROUWER, I studied the geology of the eastern part of Wetar, the central part of Alor and the small island of Poera besar.

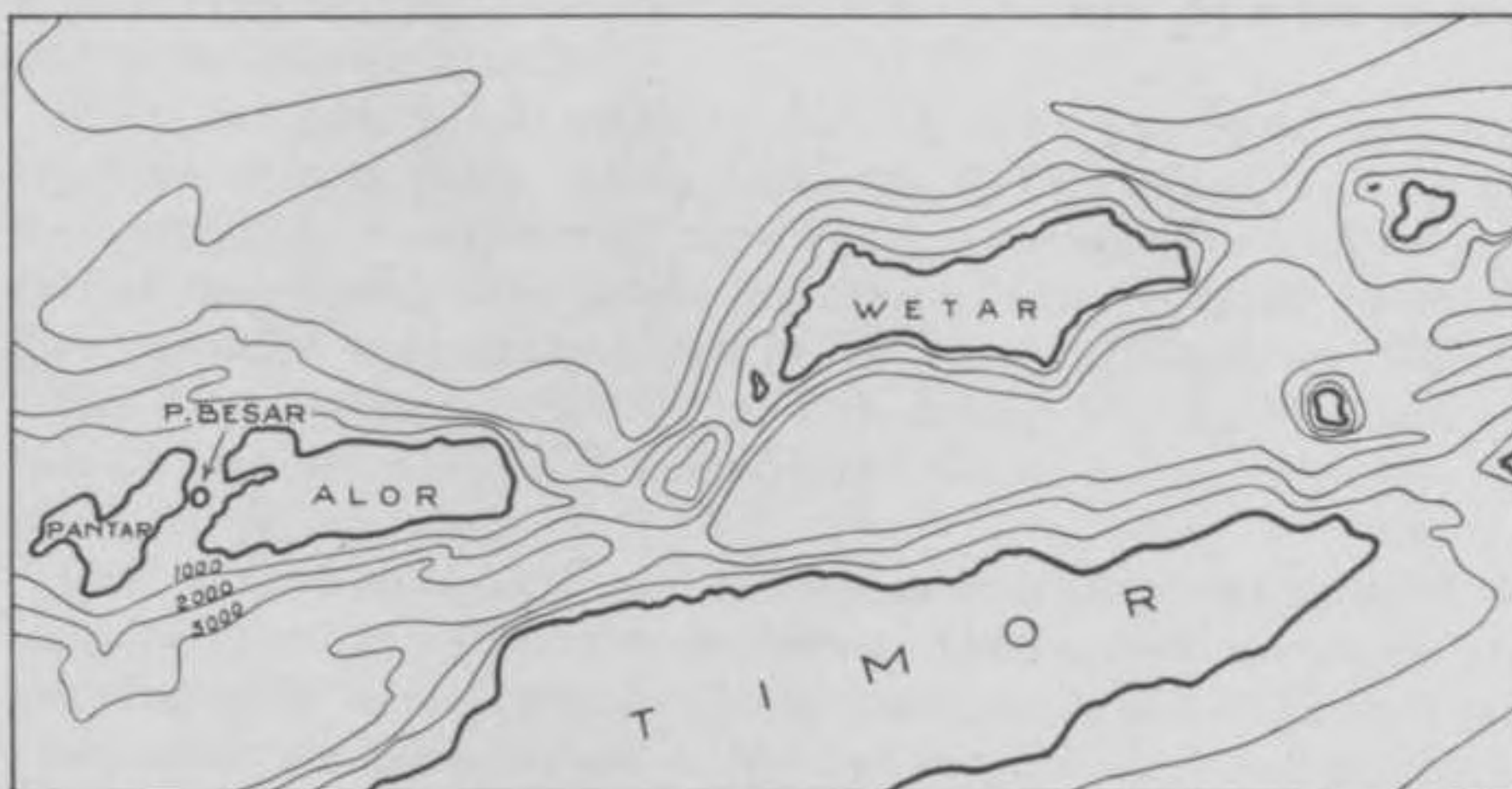


Fig. 1.

Isobathic contours around the islands of Wetar, Alor and Poera besar. 1 : 2.860000.
(Based on the bathymetric chart of the SNELLIUS-Expedition.)

I here wish to express my sincere gratitude to all, who gave me their advice and support during the work in the field and in the laboratory.

In the first place I feel most grateful indeed to Prof. Dr. H. A. BROUWER, for giving me the opportunity to study the almost unknown island of Wetar and thereafter making it possible for me to study the central part of Alor.

I am also thankful to Prof. Dr. H. GERTH, for being so kind as to give me his opinion on some palaeontological problems.

To Prof. Dr. G. L. SMIT SIBINGA I am much indebted for his valuable suggestions regarding some geomorphological problems.

I feel very much obliged to Dr. W. P. DE ROEVER for discussing various petrological questions with me.

I am very much indebted to the Government authorities of Timor and the Molukken, for their valuable help.

My investigations in the eastern part of Wetar were carried out in August and September 1937, in order to obtain an insight into the geology of this almost unknown island, whilst the islands of Alor and Poera besar were visited during October 1937.

WETAR.

GEOGRAPHICAL OUTLINES.

Because DE JONG (21) has already reported more fully on the island of Wetar, especially on the western part, a few remarks about the eastern part of the island may suffice.

As to the eastern half of the island, especially its central part is a mountainous land, possessing the highest tops of the island. This region is deeply cut by rivers, thereby providing a very capricious morphology. In this central part, even in the dry season, water is rather plentiful. The vegetation is generally dense. In the mountains *Eucalyptus alba* is rather frequent, but especially in the surroundings of the water-carrying rivers a very dense jungle of bamboo and rotan offer many difficulties to geological exploration.

Only in the coastal region and in those parts of the island where thick strata of raised reef limestones are present, the vegetation becomes less rich. Especially in these regions rich in limestones, which rocks are more porous than the lavas, the soil is less wet and Cactaceae and palmtrees become more frequent.

The eastern part of the island — the region between Tomliapat and Arwala — is extremely dry and desolate, especially towards the end of the dry season: alang-alang, palmtrees and a few Cactaceae cover this low, hilly region.

The island of Wetar mainly consists of volcanic products (lava rocks, volcanic breccias and agglomerates and tuffaceous rocks), sometimes with intercalated strata of limestones (*Globigerina*-limestones).

The lavas show the characteristics of submarine volcanism. Along the greater part of the coast distinct terraces of upheaved coral reef limestones are observable, except in the vicinity of the mouth of the large rivers.

Especially the SE and E coast show a well-developed terrace landscape. On the Tara-Toepoeti traverse — as has already been mentioned — a relic of a terrace on an estimated height of 450 metres was found.

Several large rivers, as the M. Mapoen, M. Masapoen, M. Perai, carry so much water that they are able to break through the pebble barrier, by which the smaller ones are barraged by the sea.

The lower courses of these rivers are well-developed. In the lower part up to the coast, they flow in a bed, formed by their own erosion material, which mainly consists of small pebbles of volcanic rocks. The middle courses of the rivers are very short and are poorly developed, while the upper courses show many waterfalls. Several small tributaries of the main rivers, the erosive force of which was considerably less during these upheaval of the island than that of the main rivers, debouch in these valleys with a cascade. They show a kind of "hanging" river valleys.

Another general phenomenon is the occurrence of cañon-like river valleys, which are present in the lower courses of the rivers.

The river valleys of the M. Sakir, M. Masapoen and M. Perai show these features. Narrow valleys, with a maximal width of 25 m, are bordered by nearly vertical walls of 100 to 200 metres high.

Hot springs, as were found in the M. Meron (between Lake Tihoe and the north coast) are very rare in the eastern part of the island.

The watershed winds in an east-west direction. Especially in the central part of the island the watershed lies far to the south of the middle, but more to the east it follows approximately the middle of the island.

All villages are situated along the coast, where the inhabitants live in dwellings built by the Government on the 5 m terrace. The principal village of E Wetar is Tomliapat on the SE coast. During a long time it has been the most important village of the island and the inhabitants traded with Chinese, who came along the coast with their junks and bought their coconuts and bees-wax; this bees-wax is collected by the natives in the mountains. The inhabitants are not very healthy. Malaria and framboesia occur very frequently, while filariasis, which causes elephantiasis of the legs, and lues are present in a less degree.

As topographical base the topographical map 1 : 150000 of 1911 of the island has been used. Nearly the entire interior of the island was wholly unknown; only a few routes had been followed before by military expeditions in 1910/'11.

EARLIER INVESTIGATIONS.

Comparitively little has been published so far on the geology of the island. The first geological data were collected by J. G. F. RIEDEL (26, p. 430). He described the island of Wetar "as being composed of sedimentary formations, turned upside down by volcanic actions..... The limestones are of triassic age.....".

In 1908 R. D. M. VERBEEK (35, p. 597) visited the island and collected some rock types from the south coast among which there were some granodiorites from Tandjoeng ¹⁾ Illipoi, described by that author.

In 1911 J. ELBERT (12, p. 211) visited this island during a short time. He travelled from Ilwakki to Talaga ²⁾ Tihoe and collected some types of rocks. Some other specimens were collected from Tandjoeng Illipoi by that explorer.

The rocks, collected by ELBERT, were described by SIMON (28) in 1913. As to the conclusions derived by ELBERT from his explorations, these must be considered as of dubious value.

There are no further data about the geology of the island.

¹⁾ Tandjoeng (Malaian) = cape.

²⁾ Talaga (Wetarese) = lake.

DESCRIPTION OF THE ROUTES.

Tara-Toepoeti traverse (see Map II).

The north coast, from Kampong ¹⁾ Tara to the East, consists for one part of a sandy beach, with black "sands", composed of sharply angular fragments of glassy rocks and obsidians, and for an other part of upheaved coral reef limestones. The first of our route is the way upriver through the bed of the Meta ²⁾ Lihoetahoe. About 250 m upstream from the deserted Kampong Tara (Tara lama ³⁾), there are good exposures of glass-encrusted andesites in the eastern wall of the river valley, partly dense rocks (H 34^x), partly with rather large vesicles (H 34).

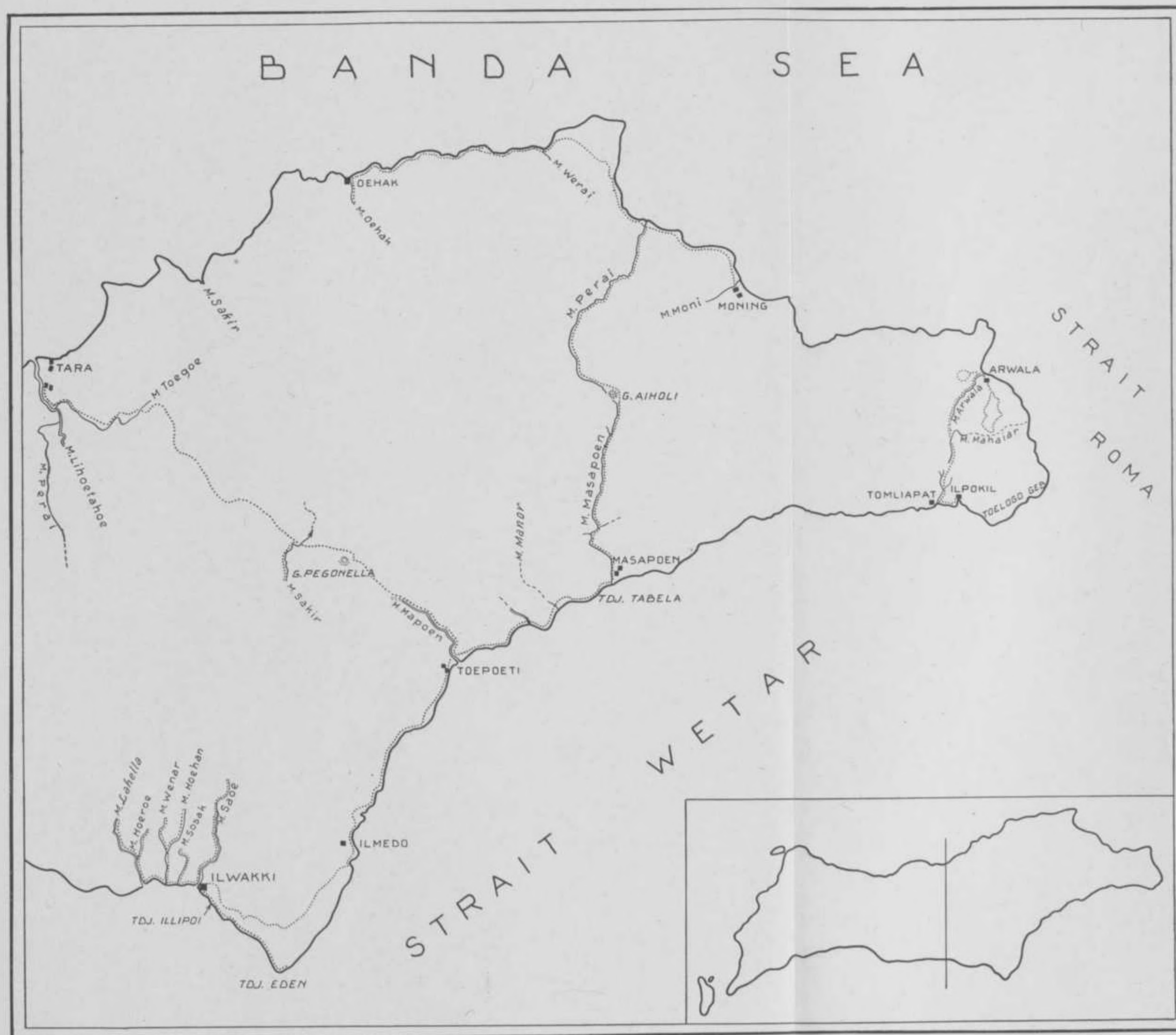
They have been mentioned already by J. D. DE JONG in his description of the Ilwakki-Tara traverse, which trip we made together. Several hundreds of metres to the South these rocks are alternating with tuffs and glassy andesites. Then we reach the place where the M. Toegoe joins the M. Lihoetahoe. From this point, where we have a beautiful view over the terrace landscape in a western direction, we follow the M. Toegoe upstream. At least four terraces are visible, but after we have come a few hundreds of metres higher up in the mountains, at least six terraces are observable. Our way follows the northern wall of the M. Toegoe, where we find dacites, which are alternating with strongly weathered glass-encrusted andesites. After walking half a kilometre we cross the river at a fordable place and continue our way on the southern wall of the river valley, where large exposures of obsidians are found. Perlitic structure is discernible in these rocks, as weathering along the spherical fractures has bleached the black coloured rocks (H 35). Further on, these perlites are alternating with nearly white rocks. These white to light grey rocks, which occur rather frequently on this traverse, must be considered as hydrated obsidians. The white colour is the consequence of the hydration of the glass. In other exposures we see that the upper zone of such a glass is whitened and that it gradually turns into black obsidians. Devitrified zones in dark glassy rocks are often light coloured bands as well (H 36^x). Infiltration of quartz is a common phenomenon in these rocks.

As we go further, the vegetation becomes rather dense in this region, so exposures of solid rocks are not abundant. 200 m from the place, where

¹⁾ Kampong (Malaian) = (native) village.

²⁾ Meta (abbreviated "M.") (Wetarese) = river.

³⁾ Lama (Malaian) = former, old.



East Wetar.

The routes followed are indicated by dotted lines.

Scale 1 : 300.000.

the devitrified glasses were found, light coloured quartz keratophyres were observed, which are alternating with fine grained dacites (H 37^x, H 37) exposed over a distance of about 300 m. Our path is ascending slowly, in the meantime we cross the river again and now follow a small path over the hills north of the river. Vegetation near the walls of the river has covered nearly all outcrops. These hills consist of glassy rocks, glass-encrusted andesites, interchanging with tuffs. Sometimes there are exposures in tuffs, in which large bombs with glass-crysts are embedded. When we descend again to the river, quartz-keratophyres with large quartz phenocrysts are found (as H 36), as well as greyish-white, fine granular dacites, over a distance of about 500 m (H 38^x). Now we are back in the riverbed, but after a few hundreds of metres the river becomes too deep, for which reason a path over the hills is chopped. In this region exposures in dacitic rocks are very common. A small tributary of the Meta Toegoe is passed, after which our way leads over steep mountainous ground, consisting of dark coloured glassy dacites with elongated vesicles and then again we go down to the M. Toegoe, which we now reach in its upper course. At this point dacites (H 39^x) are present, as well as dark glassy dacites (H 39). From here to the spring of the M. Toegoe, the same kind of rocks is dominating. From the place where the glassy dacites (H 39) were collected and where our bivouac was established, our way goes to the South east over steep hills and mountains, which show a considerably deep erosion by small rivers. The first part of the way goes in eastern direction to the M. Perakoei. The average height of the mountains is about 600 m. Glassy rocks, probably of dacitic composition, are common in this region. SSW of our way a massive mountain range with the Goenoeng¹⁾ Toegoe is visible. The outline of the mountain ridge is very capricious, which is characteristic of erosion of glassy lavas and glass-agglomerates and -breccias. Over a distance of about 800 m no outcrops are present, and through a dense vegetation of rotan, we arrive in the dry bed of the M. Perakoei. The southern wall of this river, which drains in SW direction, is formed by dense tuffaceous rocks. The mountain ranges are very steep here and deeply cut in. Obsidians and glass-encrusted andesites are frequent. There is often no mutual connection between the diverse types of lavas. Thereupon follows a region with large exposures of hard and dense dacitic rocks (H 40^x). After we descend 100 metres we pass the M. Edoe (M. Egoel or M. Igoel, both names are used) in which dacitic rocks are

¹⁾ Goenoeng (Malaian) = mountain.

still encountered. A pebble of a keratophyre (H 41 $\times$) was found here.

South east of this region the Goenoeng Illimetang (= G. Ilmetang) is situated. After our path has led over a steep hill, we arrive again in the dry bed of the M. Serakan, a tributary of the M. Egoel. The courses of all these rivers have a north eastern to eastern direction. Near the Meta Serakan quartz keratophyres are found. A few hundreds of metres further to the SE we are again in a tributary of the M. Igoel, in the upper course of the Meta Pariki. Here volcanic agglomerates and breccias, as well as tuffaceous rocks are present, rather weathered however. Another tributary of the M. Pariki, the Meta Toemoenan, is passed thereupon, but no outcrops are found here. In the region between this river and the upper course of the M. Raresika there are a few exposures in glassy rocks. Then andesites are found over a large area (H 43 $\times$). This rock type is very abundant along the entire traverse. Perlitic glasses cover these rocks at several localities. After we crossed the M. Gaendralan in which outcrops of pyroxene-andesites (H 43) occur, we have a view to the E-SE where we see the distinctly stratified white rocks of the Goenoeng Poetih¹⁾ and in the same direction the big, high mountain, called G. Illiloi. The vegetation becomes dense and a remarkable change in the types of plants and trees may be observed. Palmtrees and Cactaceae are rather abundant here, covering nearly every outcrop. So we arrive in the M. Sosak and in a tributary of this river, where our bivouac was made amidst dacitic lavas, which show columnar jointing.

The northern river wall is formed by the mountain Illimaoe, the obtuse summit of which is covered with tuffaceous rocks, with a dip of 20° E-NE. East of this mountain the Goenoeng Poetih is situated. We are separated from this flat, stratified, complex of rocks by a deep cañon. Over a hilly ground now the Meta Pera is visited, in which dacitic rocks are present again. After we have traversed a very dense tropical forest where no outcrops have been found at all, we again reach a river, the M. Hahipaoen. This river is abounding with water and has a rather large gradient. The walls of this river consist of thick layers of loose erosion material, containing several rock types in pebbles of strongly varying size. The small pebbles of a few centimetres in diameter consist for a good deal of angular fragments of glassy rocks. This erosion material must be considered as a kind of delta sediment. Then we leave the tributary of the M. Hahipaoen and as we are walking to the top of a hill, our path goes over thick layers of limestone. These, upheaved reef limestones, are

¹⁾ Poetih (Malaian) = white.

situated topographically upon the delta-deposits. Their dip is slight, varying from 5° to 8° NE, while the strike differs from $N 50^{\circ} W$ to $N 80^{\circ} W$.

When we arrive at the M. Koera a stratified complex of sandy material is found under these limestones, but the samples collected of these rocks and others were lost by an accident when climbing a very steep slope two days later. The pebbles of this river contain a great amount of these limestones, but downstream they disappear very rapidly. Over a distance of about 2300 m we are passing a region which is covered by these upheaved reef limestones, and which exhibits a relic of a terrace landscape at an estimated height of about 450 m above sea level. The Goenoeng Poetih can be considered without any doubt as a part of this terrace. Its layers are also nearly horizontally stratified. The change in vegetation, which was observed, must be attributed to the appearance of these limestones. As outcrops in this terrace, which rise from it as steep hills, volcanic rocks of dacitic and andesitic composition may be observed. Now our way goes over a very sharp ridge of a mountain range in SE direction to the M. Sakir. Only a few solid rock exposures are present in this region all of which consist of keratophyres (H 49 $\times$).

The Meta Sakir, which we reached in its upper course, where our bivouac was made, has been explored to his spring, in southern direction. The first part shows many exposures, in which several, differently orientated, systems of joints were observed. In consequence of erosion along these joints the rocks form thick plates, over which the water of the river falls down in large cascades. This region is densely vegetated and rather desolate. The river is followed for about 1.5 km, while several types of rocks are found here, without any distinct mutual connection. Over a distance of 200 m albite-diabases (H 49, H 50 $\times$) are found, keratophyres (H 50) are also present, locally with much pyrite and zeolitic material (H 51 $\times$, H 51). About half-way we reach the M. Kasanai, a western affluent and 100 m further to the South the M. Aimahoen, another tributary, coming from an eastern direction. As we have passed these two tributaries, spilitic rocks (H 52 $\times$), and more to the South dolerites (H 52), are encountered. Gradually the riverwater is distinguished under the large blocks and pebbles. The walls are formed by large blocks, many of which consist of glass breccias and glass agglomerates. Higher up in the valley we found no more exposures, and thereupon we returned to the bivouac.

The hill region between the M. Sakir and the M. Geak consists almost entirely of andesites (H 53 $\times$) only a small outcrop of doleritic basalts

PLATE I.

Fig. 1.

Waterfall in the upper course of the M. Perai (East Wetar).

Fig. 2.

Cañon-like river valley. The lower course of the M. Perai (East Wetar).

Fig. 3.

Columnar jointing in dacites. M. Mapoen (East Wetar).

Fig. 4.

*The slopes of the river valleys are covered with a dense jungle of bamboo.
(M. Masapoen, East Wetar.)*



Fig. 1.



Fig. 2.



Fig. 3.



Fig. 4.

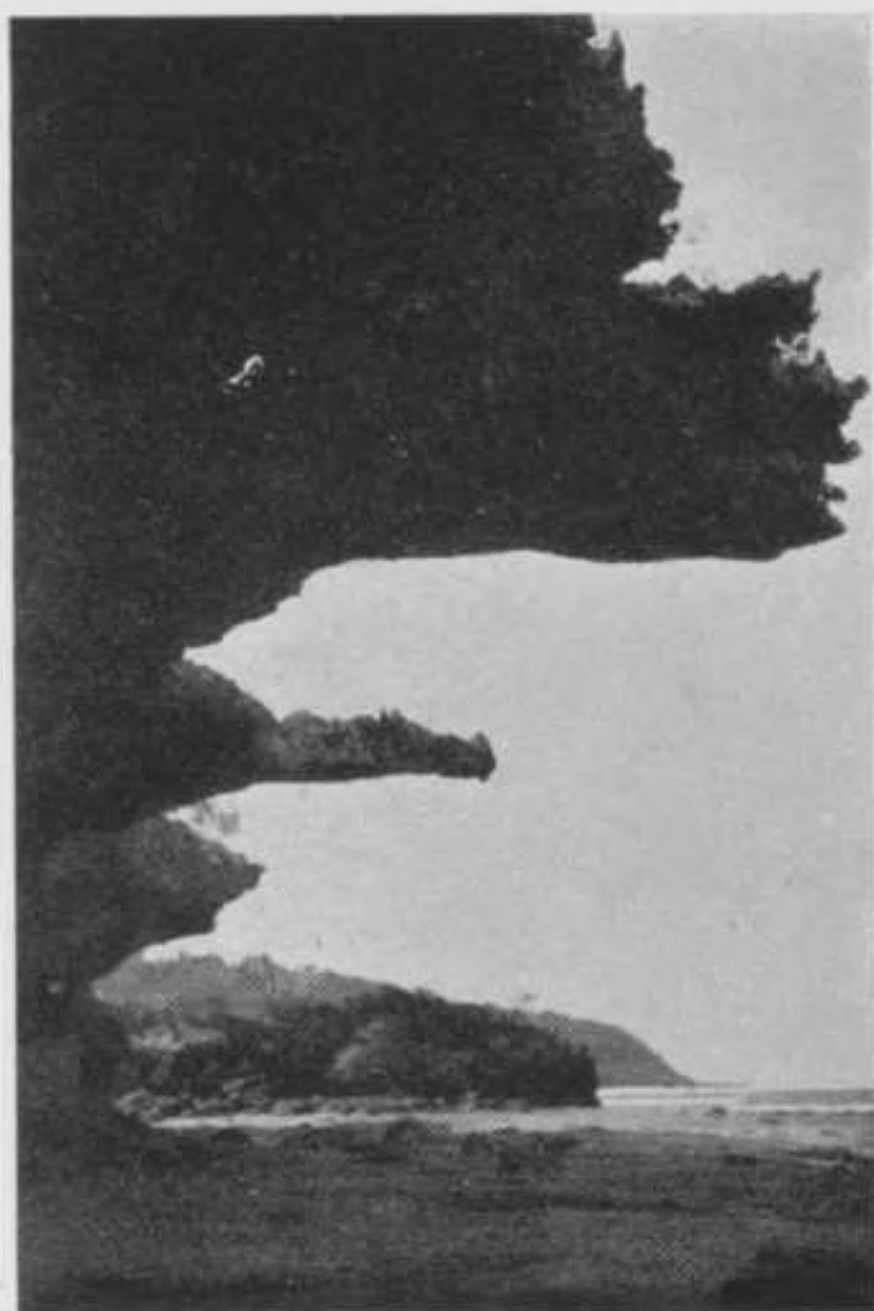


Fig. 1.



Fig. 2.



Fig. 3.

PLATE II.

Fig. 1.

Overhanging upheaved reef limestones strongly undermined by the sea.
(Near the village of Toepoeti, south coast of East Wetar.)

Fig. 2.

Upheaved reef limestones of Tandjoeng Illipoi (Wetar).

Fig. 3.

Capricious morphology of the mountains along the north coast. View from the village of Tara to the East.

(H 53) is situated between these andesites. Over a steep hill ridge we pass the M. Pikoeroe, the bed of which is full of large blocks of volcanic rocks. Nearly all the rivers we have passed on this way show the morphology of an upper course.

The region now bordered by the M. Gronoeng does not show any outcrop, but in the river bed solid rocks of albite-diabase (H 54 $\times$) are encountered. In the next 1000 m no rocks are exposed, as a consequence of the dense vegetation, among which *Eucalyptus alba* is very frequent. When we reach the Goenoeng Pegonella and SE of it the G. Sairoman, we are on the watershed of the island, at a height of about 600 m.

In the region between the watershed and the south coast all river courses we are passing, have a south western direction.

Before we reach the M. Hatoehahi, we find tuffs and strongly weathered dacitic rocks extending over a large area, further on alternating with andesites of the type H 53 $\times$. In the meantime we pass the upper courses of the M. Samarossa and the M. Tewija, which unite their courses half a kilometre South from our route. In the region between these two rivers, pyroxene-andesites (H 55 $\times$) with many joints are found. Not far SW from this locality, keratophyres are also present. When we reach the Meta Mapoen, in its lower course, we observe that the mountains, bordering this large, watery, river, are becoming more sloping and lower. At the place where we reach this river, the water is several metres deep, even at the end of the dry season.

Downstream the M. Mapoen to the coast, the riverwalls show large exposures. An outcrop of a dark coloured basalt is observed (H 57 $\times$); thereupon dacitic rocks are exposed over a large area (H 57, H 58 $\times$). Columnar jointing in these rocks is very frequent here. Often these columnar joints are radiating in all directions from one central point. These rocks are followed by dark volcanic breccias and agglomerates, probably of andesitic composition (H 58). Very large exposures in doleritic rocks, forming the walls of the river, are found amidst these dacites (H 59). Then glass-encrusted andesites and glass breccias occur, further on tuffs with bombs with slaggy surface (H 60 $\times$). Spilitic rocks (H 60) are encountered in a small outcrop covered by the dacites with columnar jointing (H 61 $\times$), which we can follow over a distance of 200 m. The river bed gradually becomes wider, while the water content is decreasing. There are large land-slides in basalts (H 61) over an area of about 800 m; thereupon glass-rich andesites and pyroxene-andesites (H 62 $\times$, H 62) and dolerites (H 63 $\times$) are exposed. Approximately 750 m from the coast thick layers of obsidians and glass-encrusted andesites with

flow-structure are found. Again one exposure in columnarly jointed dacites and then the upheaved reef limestone covers the lavas; the river is very wide here and near the Kampong Toepoeti, its bed is dry. Just like the M. Lihoetahoe, the M. Mapoen is not barraged by the sea with a pebble-barrier.

The coastal region between the villages Toepoeti and Ilwakki

(see Fig. 2).

Kampong Toepoeti is situated, as nearly all villages along the coast of Wetar, on the 5 m terrace, consisting of upheaved coral reef limestone.



Fig. 2.

This figure only shows the coastal region West of Tdj. Eden. Ilwakki is near Tdj. Illipoi.

Going in the direction of Ilwakki, the first part of our way is along the coast. A second terrace is visible, but it is rather strongly eroded. Its height is varying between 30 and 40 m. Thick plates of reef limestone, with many Gastropodes, in several varieties, are interchanging with layers, consisting of pebbles of volcanic rocks. Their dip is varying

between 25° and 30° SE to SW. The way to Ilwakki, via the deserted Kampong Ilmedo — about half-way — leads over the upheaved limestones. Outcrops of solid rocks are exceedingly rare in this region. Near Ilmedo the coast is left and now we make straight for Ilwakki, the central bivouac.

East of Tandjoeng Eden some rocks (diabases (H 72, H 73), sanidine-albite-rhyolites (H 70 $\times$, H 70) and spilites (H 73 $\times$)) were collected.

The coastal region between the villages Toepoeti and Masapoen (see Fig. 3).

Our way from Kampong Toepoeti to Masapoen leads for a great part along the coast. Only in those places where the sea, even during ebb-tide,

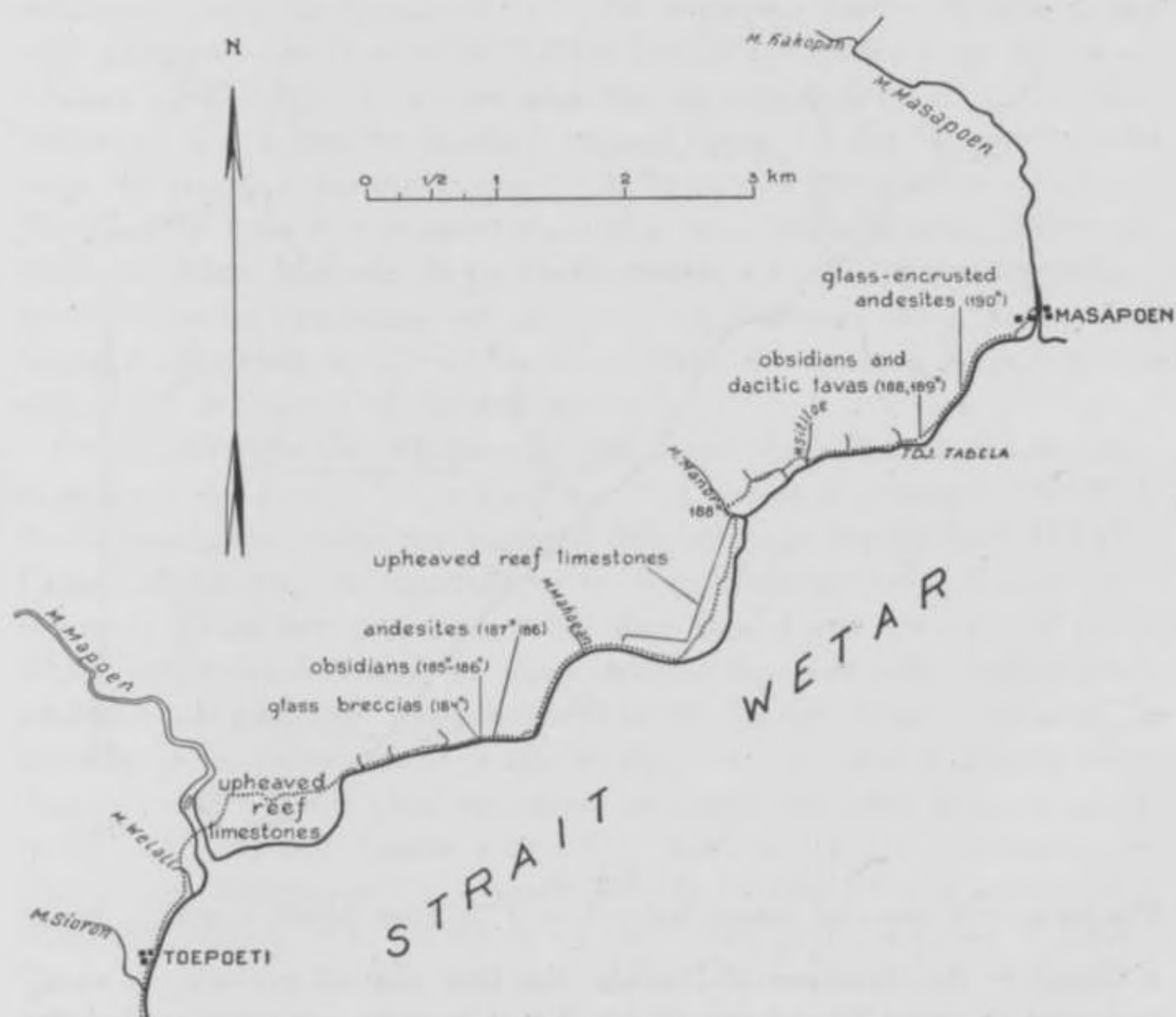


Fig. 3.

was bordered by steep walls of upheaved reef limestones, the way over these terraces was chosen.

The beach consists for the greater part of a wide coral reef. Of which the outer part is alive, while the landward-part is covered with pebbles. During the flood-tide the sea erodes the walls of the upheaved reef limestones and in consequence of this undermining actions they form overhanging upheaved fringing reefs (Plate II, fig. 1).

From Toepoeti our path goes first 1 km over the upheaved reef; then the beach is reached and after we have walked another kilometre the first exposure is observed in black glass breccias, cemented by light coloured opalous substance (H 184^x). Bordering upon these rocks partly devitrified black obsidians, are observed (H 185^x). Real black obsidians, sometimes with large elongated vesicles (H 186) are present as well, covered by more crystalline andesites with large cavities (H 187^x). A hundred metres further on in the direction of Masapoen, a small cape again exposes obsidians.

Sometimes these rocks are nearly white, in consequence of hydration of the glass. Our way goes along a large bay, in which the M. Mahoean debouches; landward this bay is bordered by walls of upheaved reef limestone. The M. Mahoean is barraged.

The mountains landward are very steep here. Among the pebbles of this river were collected obsidians, andesites and glass-encrusted andesites and albite-dolerites. The first two types are strongly dominating. Thereupon follows a region without outcrops, our way goes over the 30 m terrace, till we reach the M. Manor a river of the size of the M. Mapoen. This river too, is barraged (Plate III, fig. 1). Sample H 188^x, is collected here.

Going partly along the coast, partly over the terrace and after passing the mouth of the M. Setiloe we reach Tandjoeng Tabela, where obsidians and glassy lavas with a slightly porphyritic structure, are encountered. The obsidians have a granular appearance, in consequence of manifold perlitic fractures (H 188). Greyish coloured, dacitic rocks with columnar joints are exposed on several places along the coast (H 189^x). 300 m from these exposures glass-encrusted andesites (H 190^x) are present over a large area. Then we reach the small village Masapoen, situated on the eastern bank of the M. Masapoen.

Masapoen-Moning traverse (see Map III).

From the village Masapoen, situated on the south coast, we follow the M. Masapoen to the North. In the vicinity of the coast its wide, lower course is bordered by low walls, consisting of pebble material. In the vicinity of its mouth upheaved reef limestone as well as living coral reef

are absent. But steep mountain ranges here nearly reach to the coast, so after walking half a kilometre upriver, the walls of the river consist of 100 to 150 m high lava-rocks. First there is an exposure in hornblende-dacites with large, elongated vesicles. Higher up in the mountains these rocks are covered by glassy rocks, here rather weathered (H 192^x), further on distinct black obsidians, with flow structure (H 193^x). Sometimes these rocks are strongly brecciated (H 192, H 194^x). The dip of these thick layers of brecciated lavas is 10° S. The whole region, over a distance of 2 km from the coast, consists for the greater part of obsidians and lavas very rich in glass (of dacitic to andesitic composition).

Often these rocks are strongly jointed. After we passed a small tributary, coming from NE direction, glass-encrusted andesites (H 195^x) are found, covered by obsidians and very glassy andesites, sometimes rich in vesicles (H 195). Thereupon, for a distance of 2.5 km, we are walking through the river, which is gradually covered with larger blocks and pebbles, between high, steep walls of obsidians, glass-encrusted andesites and glassy dacites. Horizontal layers of white *Globigerina*-limestone (H 197^x) are alternating with these obsidians.

These sections, of alternating *Globigerina*-limestone and obsidians or tuffs, are observed at several places in Wetar and have been described by J. D. DE JONG (21) from the western part of the island. Frequently the lava flows have drifted, in consequence of which thick layers of glass breccias have been formed. In this region the pebbles H 196^x (vitric tuff) and H 197 (doleritic basalt) are collected. Both rock types are present here in considerable amounts among the pebbles, although the solid rocks have not been found.

The river has deeply cut in these glassy rocks and it is a characteristic feature of the whole region that the river is bordered by high, nearly vertical walls.

In the meantime we have passed some insignificant tributaries of the M. Masapoen, one of which is called the M. Kakopan, and still continually large outcrops of the same kind of rocks are visible (H 198^x, H 198, H 199^x). Sometimes they are infiltrated with opalous and chalcedonic substance (H 199). Here the river flows in a narrow valley, bordered by vertical precipices, while in consequence of enormous pieces of rock, covering the riverbed, which is abounding with water, geological investigation is particularly difficult in this region.

Then dacites (H 200^x) are observed, part of which occur as a very glassy variety with perlitic fractures (H 201^x). Somewhat further on

the dacitic rocks are strongly bleached, and are infiltrated with solutions rich in silica.

Quartz-bearing keratophyres (H 202^x) are frequent. Generally this type of rocks is light grey to light brown coloured and fine granular. Pyrite is locally very abundant in these rocks, which occur over a distance of about 500 m. As hard outcrop, over which the river cascades down a quartz-augite diorite to quartz-gabbro (H 202) is exposed over a distance of 325 m. Contacts with the surrounding and covering dacitic lavas (H 203) are present, but these zones are always strongly weathered, and consequently densely vegetated.

The dacites to quartz-bearing keratophyres, light grey of colour and containing much pyrite, are encountered over a distance of 1800 m to the North (H 204 to H 208). The glassy dacites in this region show beautiful perlitic structures. Then we must leave the river, as the water is several metres deep, and the precipices are vertical. The mountains which we pass consist of dark glass breccias (H 209^x to H 210). We come back into the main river via a small tributary. This tributary has cascades of 75 m high; the rocks from which the water comes down consist of columnarly jointed glassy dacites. Going further to the North we pass a region which shows exposures in dacites and quartz-bearing keratophyres only, over a distance of 4 km (H 212^x to H 214). Often these rocks show columnar joints. Several times we must leave the river, to find a path through the very capricious mountains. Gradually we reach the upper course of the river; very large rocky masses cover the riverbed and the water disappears below it. Now and then glassy andesites and glass-encrusted andesites are found, thereupon a silicified dacite-breccia (H 215^x, H 215). The river walls become lower, the content of pebbles decreases, a very dense vegetation of rotan and bamboo covers every outcrop. Again ascending some 150 m we arrive at the watershed at a height of about 650 m.

From the watershed we have a view to the North, where high mountain ranges are deeply cut in by erosion. Far to the North west from this point we see the high summit of the Lalaitoe mountains, straight in western direction the Aiholi mountains. The spring of the M. Masapoen, as well as of the M. Perai is situated in this mountain region. Descending from the watershed there are no outcrops in consequence of dense vegetation but this changes when we reach one of the springs of the M. Perai, where dacitic rocks are present again (H 218^x, H 218). Somewhat further on — the main direction is continually North — there are fine- to medium grained rocks, with small phenocrysts and spherulites. These

PLATE III.

Fig. 1.

The M. Manor (East Wetar).

The river (to the right) is barraged by the sea (to the left).

Fig. 2.

Terrace landscape on the south east coast of Wetar. (Several terraces of upheaved coral reef limestone are visible.)



Fig. 1.

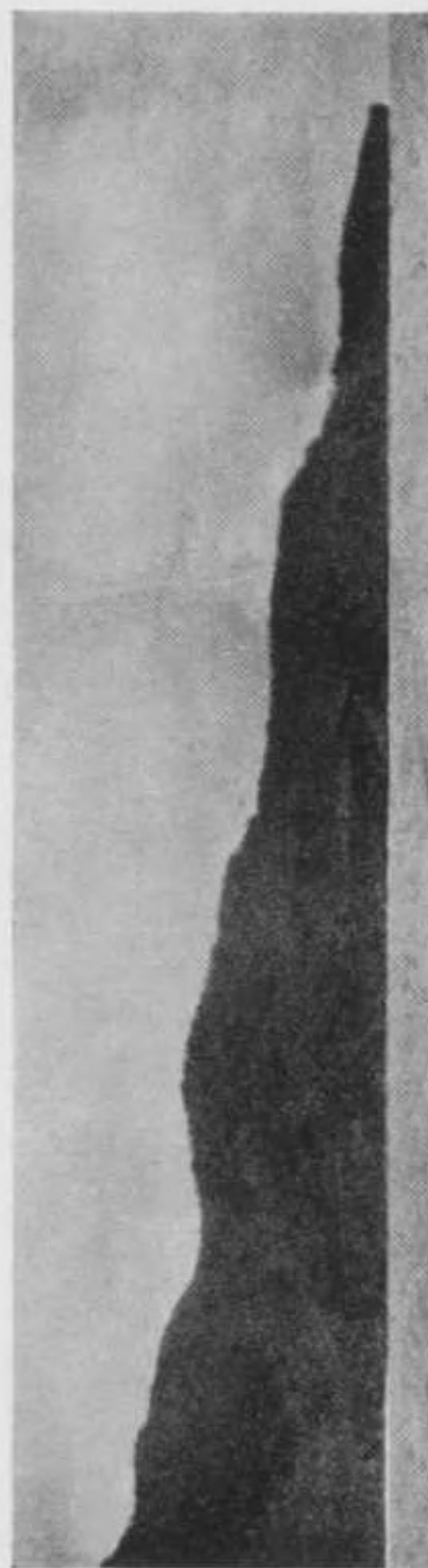


Fig. 2.



Fig. 1.



Fig. 2.



Fig. 3.

PLATE IV.

Fig. 1.

South coast of Wetar. View from Tandjoeng Illipoi to the East. The living reef is visible, during ebb-tide.

Fig. 2.

Upheaved reef limestones along the south coast of Wetar, East of Tandjoeng Illipoi.

Fig. 3.

Strongly eroded *sanidine-albite-rhyolites* of Tandjoeng Illipoi, Wetar.

(Photo H. A. BROUWER.)

rocks (H 219^x) are greenish-gray dacites to rhyolites, and we may observe them over a distance of 800 m in the walls of the river. Again we find ourselves in a region of dacites and quartz-bearing keratophyres (H 219 to H 223), which occur very frequently here and which form by far the dominating type in this region.

Several small tributaries have been passed, some of which debouch into the main river with a cascade. Columnar jointing is frequent. We are obliged to leave the river several times, for obstacles, of the type met in the M. Masapoen, are rather frequent here as well.

Gradually our way goes in north eastern direction. There is no change of types of volcanic rocks. Dacites form the only type in several varieties. Sometimes strong quartz-infiltrations may be observed. Part of the dacites are albitized, consequently they are called quartz-keratophyres and quartz-bearing keratophyres. In this region the samples H 224^x to H 232^x were collected. Then we cross a small tributary, which comes from a western direction. From this point andesites are more frequent. Greyish coloured, fine grained keratophyres (H 232) are alternating with andesites (H 233^x), which occur in big columns, due to a cooling effect. The river valley is very narrow here, nowhere more than 20 m wide and bordered by nearly vertical, 100 to 150 m high precipices. Thereupon we leave the river and over the northern mountain ridge we reach the river again half a kilometre further downstream; keratophyres (H 235^x) are present here over a large distance. The river has begun to flow quietly, the large blocks have gradually decreased in size; now small pebbles are present (among which is H 234). Once more the river is left and over a steep hilly ground, formed by strongly eroded and weathered andesites, in which there are dikes of albite-diabases (H 235), we reach the river again 300 m further, where outcrops are found of andesites rich in glass (H 236^x), keratophyres (H 236, H 237^x) and augite-andesites (H 238), while occasionally obsidians occur.

In this region we arrive in the lower course of the river, which in this part is rather strongly curving. The walls of the river decrease in height; they consist entirely of columnarly jointed andesites and keratophyres (H 240^x, H 242^x). There is one outcrop in strongly altered andesites, rich in pyrite, cut by dikes of dolerites which show an extremely strong jointing (H 240). Here, the river has stopped to curve and we follow it for a straight section of 1.5 km. It is bordered by very low hills of andesites and glass-encrusted andesites (H 243^x).

Then upheaved reef limestones cover the lavas and the river now runs

very slowly, bordered by walls of its pebbles and other erosion products. The M. Perai is not barraged.

Over the upheaved reef limestones, here developed in two terraces of a height of 5 and 25 m, we arrive at the village of Moning, situated on the east coast, 6.5 km South from the mouth of the Meta Perai.

The coastal region between the villages Moning and Oehak (north coast).

Moning is situated on a small river, the M. Moni. *Globigerina* limestones and marls are rather frequent here. A few hundreds of metres inland, they occur as thick walls along the M. Moni. They enclose pumice material, as well as glassy lava fragments.

From Moning we are going to the North along the coast, over the 5 m terrace and after we have passed the M. Gogi and the M. Perai, 400 m North from this river glass-encrusted andesites are exposed near the coast (H 243, H 244^x). This region consist generally of very glassy rocks. Thereupon our way goes in a western direction and over the 25 m terrace we reach the north coast, near the Meta Weraï.

From this point to the small village of Oehak, the whole coastal region is covered by upheaved limestones. Several types of rocks are collected here, which give us an idea of the diversity of the rocks of the inland mountains: dacites of varying types (H 244, H 250^x, H 250), quartz-diorites (H 245), rhyolites (H 248^x), augite-andesites (H 251^x), dolerites and volcanic agglomerates and breccias.

Bivouac was made near Tandjoeng Loeakka, in the vicinity of the Meta Sokar. This river is not barraged.

The next day we reached kampong Oehak. The walls of the Meta Oehak chiefly consist of dacites of several types, among which biotite-dacites are frequent.

Tomliapat-Arwala traverse (see Map IV).

The south east coast of the island shows steep upheaved coral reef limestones in at least six terraces. The highest terrace is situated about 200 m above sea level. Especially the coastal region South of the Toelogo mountains, East of the small village Ilpokil, shows well-developed terraces.

The first part of the route is in a northern direction, and the lower course of the Meta Tomliapat is followed. About 250 m from its mouth solid rocks are encountered, chiefly consisting of dacitic lavas (H 254^x, H 255^x). Often these dacites are banded; zones of strongly porphyritic

structure are alternating with very glassy zones. Especially the eastern wall is very steep and generally these dacites are covered with crystal- to lithic tuffs, with a white to light-grey colour (H 256).

These tuffs are rich in glass and pumice, in fragments with an average diameter of 1 cm. The glass substance is nearly colourless and sometimes translucent. In several places the thickness of these tuffs may reach up to 150 m. A few large blocks of vitrophyric dacites and rhyolites to dacites (H 256^x, H 257^x) are embedded in these rocks. Infiltration with solutions rich in silica is observable. Occasionally the river has seriously undermined the steep walls.

The western river wall is very low and mainly consists of river-deposits. Many detached blocks are present amidst the fine grained "sandy" substance, mainly consisting of glass-fragments.

1 km further we leave the river and after climbing a steep hill, which consists of bulbously eroded vitrophyres, we arrive on a gently hilly region about 150 to 200 m above sea level.

Alang-alang covers nearly every outcrop in this region, and similar vitrophyric dacites are found in the entire stretch. After we have passed the watershed many outcrops are found in the upper course of the M. Mahaiar.

These exposures show no great variety of rocktypes. Only dacites, with more or less vitrophyric structure, are exposed. Sometimes they show well-developed columnar jointing (H 258).

Going further to the North we leave the M. Mahaiar and thereafter no outcrops are met with over a distance of several hundreds of metres.

When the upper course of the M. Arwala is reached, solid rocks are frequently encountered. Strongly porphyritic lavas of a dark colour (H 263^x, H 263) are alternating with very dark and glassy dacitic rocks, with only a few phenocrysts (H 264^x). This rocktype is found over a distance of about 2500 m. Obsidians, with occasionally a varying amount of phenocrysts, are found as well.

The region East of this traverse was visited. No other rock types were found here.

The broad bay, on which the village of Arwala is situated, is bordered by a sandy beach, sometimes, especially to the North and to the South, interrupted by upheaved coral reef limestones, often developed in three terraces with a height of 5, 20 and 25 m respectively.

DESCRIPTION OF ROCKS.

ROCKS OF THE TARA-TOEPOETI TRAVERSE AND OF THE COASTAL PART BETWEEN THE VILLAGES TOEPOETI AND ILWAKKI.

These rocks may be classified as follows:

1. Dacites and quartz-keratophyres.
2. Dacites to andesites.
3. Andesites and keratophyres.
4. Pyroxene-andesites to basalts.
5. Dolerites and doleritic basalts.
6. Spilitic rocks.
7. Albite-diabases.

1. Dacites and quartz-keratophyres.

Volcanic rocks with quartz and plagioclase feldspar as the strongly dominating constituents have been found in several places of the traverse. The feldspar is mostly represented by andesine or albite, or by both of these acid plagioclases. The quartz-keratophyres have been formed out of the dacites by an albitization process of the feldspar. Quartz is present as phenocrysts or very abundant in the groundmass only. A slight quantity of alkali feldspar is often present in the groundmass. The content of dark minerals is slight.

The *dacites* (H 37, H 39×, H 59, H 61×).

Most of the types are light grey or light bluish-grey, sometimes nearly white rocks. The somewhat porphyritic development of the rocks is hardly recognizable in the samples. Under the microscope, they all show the same structure, except sample H 61×, which is somewhat different. Quartz is the strongly dominating constituent. Part of it forms phenocrysts, but quartz as smaller grains is also very abundant in the groundmass. Acid plagioclases are present as a few phenocrysts. Generally these dacites are poor in phenocrysts; the phenocrystic constituents are embedded in a groundmass, mainly consisting of quartz, with less feldspar.

The diameter of the phenocrystic quartzes may reach up to 1.2 mm, whilst the feldspars show a maximal length of 1.4 mm. Part of the quartz phenocrysts is idiomorphically developed, but they generally show

embayments in consequence of magmatic corrosion. Nearly all quartz phenocrysts possess a rim, 0.1 to 0.3 mm in diameter, which has the same optical orientation as the phenocrysts. These rims, which are parallel to the boundaries of the phenocryst may consist of different minerals; sometimes they only consist of quartz, with more or less minute inclusions, by which they are dirty brownish coloured, in other cases the rims consist of a quartz-felspar-intergrowth, but only sporadically they show distinct granophyric or micrographic intergrowths.

The quartz of these rims has the same optical orientation as the main individual: so simultaneous extinction between crossed incols may be observed.

The acid plagioclases, part of which are polysynthetically twinned, have a content of anorthite of 45 % (corresponding to basic-andesine). Twinning according to the Carlsbad-law is also present. The phenocrysts of quartz, as well as of plagioclase contain some small glass inclusions.

The groundmasses of these dacites are wholly crystallized, and consist of abundant quartz and less felspar. The quartz grains, with an average diameter of 0.3 mm, are often rounded, while the minute inclusions are frequently arranged in crystallographic directions. The large amount of dusty inclusions in the base, gives rise to considerable difficulties of its determination.

Between these quartz grains — which may be developed as indistinct spherulites as well, sometimes consisting of quartz only, in other cases of quartz with interstitial small felspar fibres — there is a very fine granular substance, which show diameters of 0.05 to 0.2 mm. This substance is composed of small quartz grains, laths of acid plagioclase and alkali felspar. The refractive indices of the alkali felspar are lower than that of Canada balsam and as there are granophyric intergrowths, it is probable that orthoclase is present.

Dark minerals are very rare in these dacites: only a few chlorite flakes may be observed. H 59 however exhibits a considerable number of fibres of strongly pleochroic biotite and less pleochroic amphibole. The green hornblende, as well as the biotite fibres, are small, their length may reach up to 0.04 mm.

Titanomagnetite, in a few grains, with isometric boundaries, occur. Part of it has altered into leucoxene or limonite. As secondary constituents of the rocks may be observed: sericite and carbonate (as alterationproducts of the felspars), chlorite, limonite and a few grains

of the epidote group. Opalous substance is not rare. As accessory mineral apatite occurs. Sporadically, some glass is present.

The mesostasis of many of these rocks appear to be wholly devitrified. The type H 61 $\times$, is an example of this phenomenon. The groundmass of this rock exhibits irregularly bounded, poikilitic quartz crystals, different in their optical orientation, so that by turning the table between crossed nicols, one sees a blotchy alternation of light and dark. And in these poikilitic quartz-crystals, probably allied with some alkali felspar, more or less parallel, small felspar laths with a composition of andesine are visible. These small felspar laths, with an average length of 0.03 mm, are sometimes twinned.

The pebble H 55 is a yellowish-white coloured rock. Only a few acid plagioclases, as phenocrysts, with a content of 30 % anorthite (oligoclase-andesine), occur in a fine grained spherulitic groundmass, consisting of quartz and felspar.

Phenocrysts of quartz are absent, but as the groundmass is exceedingly rich in this mineral, this rock can be safely classified as a dacite.

The *quartz-keratophyres* (H 36).

This sample shows a light grey coloured rock of porphyritic structure. Large phenocrysts of quartz, and of somewhat smaller, weathered plagioclases are embedded in a fine granular groundmass. The quartz phenocrysts may range in size up to 9 mm; they exhibit the same features as those described of the dacites. Only in this sample the rim of granophyre is failing. The plagioclases, up to 5 mm in length, are rather strongly altered. Polysynthetic twins occur. Extinction angles in the symmetric zone are 15°; the refractive indices are lower than that of Canada balsam. So we have to deal with albite. Most of the albite is cloudy. Sericitization of the plagioclase is frequent.

The groundmass is fine granular, with a more or less spherulitic to pseudo-spherulitic structure, and composed of quartz, acid plagioclase and alkali felspar. The diameter is varying between 0.01 and 0.03 mm. The secondary products are the same as have been mentioned of the dacites.

2. Dacites to andesites.

This type of rocks, which is not frequent on this traverse, in contrast to the Masapoen-Moning traverse, contains several samples of which it is not certain whether they belong to the dacites or to the andesites. In comparison with the dacites the amount of quartz has considerably

decreased, but it is still too much for classifying the rocks among the andesites. For the rest this rocktype shows much resemblance to the dacites.

Sample H 58 $\times$, shows a purple grey coloured rock, with a porphyritic structure. The groundmass of the rock is very dense. Phenocrysts of felspar occur, but are scanty; their composition is andesine-labradorite. The mesostasis contains abundant felspar, less quartz, very minute fibres of biotite and chlorite, and small grains of magnetite. The felspar of the groundmass is rather acid; only one of the quartz grains reaches a phenocrystic size. The structure of the base is microgranitic.

Secondary minerals are chlorite and epidote.

3. Andesites and keratophyres.

In this chapter types of rocks with an effusive character, in which plagioclase felspar is the strongly dominating constituent, will be described. The felspar is represented by andesine or albite, often by both of these acid plagioclases.

The keratophyres must be considered as albitized equivalents of the andesites. Several transition stages between these two types of rocks have been found.

Most of the andesites and keratophyres are rather fine grained with a greenish, greyish to brownish colour. The somewhat porphyritic structure is distinct in H 53 $\times$, scarcely recognizable, however, in other ones (for instance H 41 $\times$). Vesicles, filled up with chloritic, chalcedonic or opalous substance are frequent.

The *andesites* (H 53 $\times$, H 62).

Plagioclase is the strongly dominating constituent. The rocks with a porphyritic structure contain phenocrysts of plagioclase, embedded in a groundmass, mainly consisting of plagioclase and very subordinate allotriomorphic quartz. Pyroxene is very rare, as well as amphibole. In H 62 there are abundant small fibres (0.1 mm in size) of a dark mineral, which however has totally altered into hematite. Probably the original mineral was amphibole.

The diameter of the phenocrystic felspar may reach up to 1.8 mm, while the length of the groundmass-felspar is varying between 0.2 and 0.5 mm.

The phenocrysts of felspar are zonally structured plagioclases with a composition of basic andesine, while a narrow margin is medium-

andesine. The composition of the feldspar of the groundmass is more acid, commonly oligoclase-andesine. Part of these feldspars is twinned.

Most of the plagioclases are clear and unaltered. There are, however, a number of phenocrysts which are opalized entirely, except a narrow outer rim.

The quartz occurs in allotriomorphic grains, as a subordinate constituent of the rock; sometimes very indistinct pseudo-spherulitic bodies, consisting of quartz and feldspar, are visible in the groundmass. Magnetite shows small isometric crystals; the greater part has altered into hematite. Veins, filled up with hematite occur in sample H 62. As this sample is very rich in opal, we may speak of an opalized andesite.

Small prisms of apatite may be observed, but are extremely rare. Glass inclusions in the feldspar phenocrysts are rare. Glass is present in the groundmass, but in inconsiderable quantity.

The *keratophyres* (H 41×).

The rock is fine grained, with some cavities, filled up with chloritic minerals. Macroscopically this rock shows considerable resemblance to the albite-diabases. Under the microscope the rock is fine crystalline, equigranular, with only a few, small feldspar phenocrysts, which attain a diameter of 0.6 mm. These phenocrysts, as well as the feldspars of the groundmass of which they are the main constituent, are of albitic composition. All feldspars have a cloudy appearance. Other constituents are chlorite, quartz in small allotriomorphic crystals, small, isometric crystals of magnetite, carbonate, sericite and limonite, while glass is not frequent. Now and then the structure is sub-ophitic, and then this type shows much resemblance to the albite-diabases. But as the rock contains glass in the groundmass and is rather rich in cavities, while the amount of dark minerals is small, it has been classified among the *keratophyres*.

4. Pyroxene-andesites (with transitions to basalts).

Plagioclase is the dominating constituent of this group of rocks, but, in comparison with the andesites, its composition is more basic. That composition is generally labradorite, the basic cores often contain labradorite-bytownite.

The basic andesites generally contain a considerable amount of pyroxene. The basalts show pseudomorphs after olivine. Glass is common in the groundmass.

H 43, H 55 $\times$, H 62 $\times$: Sample H 55 $\times$ is a pebble from the M. Tewija. It is a dark, greyish green, equigranular rock. Macroscopically small felspar laths are recognizable.

Felspar is the dominating constituent. Part of the plagioclase is twinned; while it shows a weak zonary structure. The composition is basic andesine to acid labradorite in the cores. But in many cases these basic cores exhibit a cloudy appearance. This cloudy felspar in the cores has been determined as albite, and it has been originated by means of an albitization process. The polysynthetic twin lamellation of the unaltered margin is copied by the albite, but the extinction changes of sign. The felspar laths are arranged irregularly, their average length is 0.3 mm, a few may range up to 0.7 mm. Between the felspar laths the augite occurs as small grains of 0.2 mm in diameter. Sporadically the augites reach a phenocrystic size of 1.2 mm. The unaltered augite is colourless, but frequently it has been altered into a green coloured, often fibrous, but sometimes in distinct felty mineral substance, which is most probably chlorite. Another part of the augite has altered into carbonate.

Some quartz is present, generally as rounded grains, of slightly spherulitic appearance.

In other cases it shows crystallographic boundaries, when it is formed in cavities; so it is for the greater part of secondary origin. Besides magnetite some brown coloured glass is present in the groundmass. Occasionally the glass shows slight devitrification and then very small felspar laths are visible, but they are too small to determinate their composition. Chalcedony, carbonate and minerals of the epidote group are present.

This sample macroscopically shows great resemblance to the albite-diabases and albite-dolerites; but ophitic or sub-ophitic structure is absent.

H 43, is a dense, very fine crystalline, dark green coloured rock, with cavities filled up with quartz and opal. Several veinlets consisting of a colourless mineral cut through the rock. Microscopical investigation of the thin section reveals that it exhibits an indistinct flow structure. The felspar laths attain a length of 0.4 mm. Main constituents are plagioclase and augite, of very small size. Small grains of titanomagnetite are scattered through the groundmass, which is rich in light coloured glass. As secondary minerals quartz, opal, a colourless, somewhat fibrous mineral, perhaps a zeolite, and yellowish carbonate, probably ankerite, may be mentioned. The plagioclases are frequently twinned; zonary

structure is an exception. Their composition is acid labradorite. The cavities have been filled up with secondary minerals, partly with quartz and opal, which occur as orbicular grains. They often have crystallized at the end of a feldspar lath. Another part of the cavities contains yellow to yellowbrown coloured carbonate, or a colourless zeolitic substance. Both of these minerals are sometimes crystallized as spherulitic aggregates.

The colourless mineral, which is probably a zeolite, has a birefringence like that of quartz, the fibres are length-slow, while the refractive indices are equal to that of Canada balsam.

Sample H 62 $\times$, a pebble from the M. Mapoen. The rock is fine-to medium grained and dark green coloured. Feldspar and pyroxene as phenocrysts are recognizable. This type is much coarser grained than the rock, earlier described.

A somewhat porphyritic structure is observable. Scanty phenocrysts of plagioclase and augite, both of which may reach up to 1.5 mm, occur in a mesostasis, which chiefly contains plagioclase, augite, titanomagnetite and subordinate glass. The feldspar phenocrysts exhibit zoned structure; basic cores with a composition of labradorite-bytownite with more acid margins with an anorthite content of about 50 %. Twins occur frequently, according to the Carlsbad- and albite laws.

Distinct albitization phenomena of part of the feldspar phenocrysts, as described of sample H 55 $\times$, can be noticed in this rock too.

The extinction angle of the margin is much larger than that of the albitic core, whilst it has a reverse sign. The albite has a cloudy appearance. The albite occurs in veinlets, and also as alteration product along fractures in the feldspar. The augites are present as glomeroporphyritic aggregates.

The mesostasis shows slightly albitized plagioclases, with a composition of labradorite, while the diameter is varying from 0.2 to 0.9 mm. Besides plagioclase, augite is rather abundant, in irregular bounded grains. Titanomagnetite is abundant too, whilst it reaches up to phenocrystic size.

Between these minerals, glass occurs, dirty greenish coloured and partly devitrified. Chlorite as alteration product of the augite, brown of colour, hardly showing any birefringence, has defiled the rock.

Other alteration products are translucent, redbrown hematite; part of the magnetite has altered into hematite, which has also been infiltrated along cracks in the feldspars and augites.

H 61 and H 57 $\times$: These dark grey rocks have a porphyritic structure.

Their groundmass is fine crystalline, with less cavities.

Under the microscope the thin section shows a very dirty appearance. Porphyritic structure is not conspicuous. Only a few plagioclases attain the double diameter of the large amount of feldspars, which build the groundmass. The average length is about half a millimetre. The scarcely zonal structured plagioclases, with a composition of andesine-labradorite, have altered considerably, partly into carbonate, whilst insignificant albitization occurs. Nearly all augites have been decomposed and altered into carbonate. Plagioclase laths are wedging out in the carbonate pseudomorphs after augite, so a subophitic structure is of local occurrence. Generally the feldspars are arbitrarily directed. The original augite, has a diameter of 0.4 mm. Pseudomorphs after olivine are not rare. They show idiomorphic boundaries. Often their outer zone consists of oxidic iron ore, while the rest of the crystal has altered into very fine serpentinous aggregates, occasionally into brownish chloritic substance, which appears nearly isotropic between crossed nicols.

The diameter of these phenocrysts ranges up to 0.8 mm. Magnetite, as isometric grains, as well as ilmenite tables are rather abundant in the base. Light green to lightbrown coloured glass is present in considerable amounts.

Secondary minerals are serpentine and chlorite, and also quartz, in rounded grains. These half-orbicular grains of quartz have enclosed minute, undeterminable inclusions in zones parallel to their outer boundaries.

5. Dolerites and doleritic basalts.

Field observation did not lead to a conclusion about the fact, whether the rocks here described represent intrusive or extrusive rocks. HOLMES says:

"In a general way dolerite is distinguished from basalt by its coarser grain and the absence of glass; specifically by its holocrystalline character and the development of ophitic structure. In practice, however, there are many cases, in which it is difficult, if not impossible, to make an unequivocal choice between the terms basalt and dolerite, since there is not, or cannot be, any definable line drawn between them. As field terms, however, these names are generally restricted to extrusive and intrusive rocks respectively."

The difference between the dolerites and the doleritic basalts from the investigated region, consist in that the former rock type is holocrystalline, with an "intrusive" character, while the doleritic basalts show greater

similarity to effusive rocks; their base contains a considerable amount of glass. They have been called doleritic basalts, since they have a distinct subophitic structure and in this way they differ from the basalts, described in the preceding chapter.

H 63 $\times$. *Dolerite*. It is a medium grained, holocrystalline rock, light-brown coloured, in which feldspar is the strongly dominating constituent, although macroscopically pyroxene is also visible.

Microscopical investigation reveals that among the feldspars and pyroxenes there are a number of which the size is somewhat larger than in the remaining part of the rock, although one can hardly speak of a porphyritic structure. Glomeroporphyritic aggregates of these minerals occur. The diameters of these large feldspars may range up to 2 mm, whilst the pyroxenes are somewhat smaller in size.

Part of the larger feldspar individuals are untwinned and show distinct zonal structure. Sometimes a plagioclase, of different optical orientation, forms the centre of such an individual. The remaining part of the rock consists of abundant plagioclase, pyroxene, rather less titanomagnetite, chlorite and some quartz. The plagioclase laths may reach up to 1 mm. Part of these feldspars as well as of those of phenocrystic size, are twinned. Zonal structure in the smaller individuals is not distinct, while their composition is medium-labradorite. (The content of anorthite is about 60 %). The zonally structured larger ones show alternating zones of basic and slightly more acid composition ranging from basic labradorite to acid labradorite.

Although plagioclase is the most important constituent of the rock, pyroxene is present in a very considerable amount. The state of the light-green coloured augites is rather fresh; their rims, however, are generally altered into a brownish to greenish coloured, slightly pleochroic substance. This substance is often fibrous and consists of amphibole and chlorite. In other cases redbrown limonite forms the rims or is present along fractures in the crystals.

Besides augite, hypersthene may be noticed as well; but it has rather often altered into oxidic iron ore. The greater part of the magnetite has altered into limonitic substance.

Some quartz, as interstitial grains, is present. It occasionally contains numerous minute glass inclusions.

Sericite occurs as alteration product of the plagioclase. Sub-ophitic structure is hardly visible, but not absent in this rock.

PLATE V.

Fig. 1.

Obsidian (H 35) from the Tara-Toepoeti traverse, Wetar.
The rock shows perlitic fractures. Ordinary light (17 $\times$).

Fig. 2.

Same rock as fig. 1.

Devitrification along the perlitic fractures becomes distinct between crossed nicols (17 $\times$).



Fig. 1.

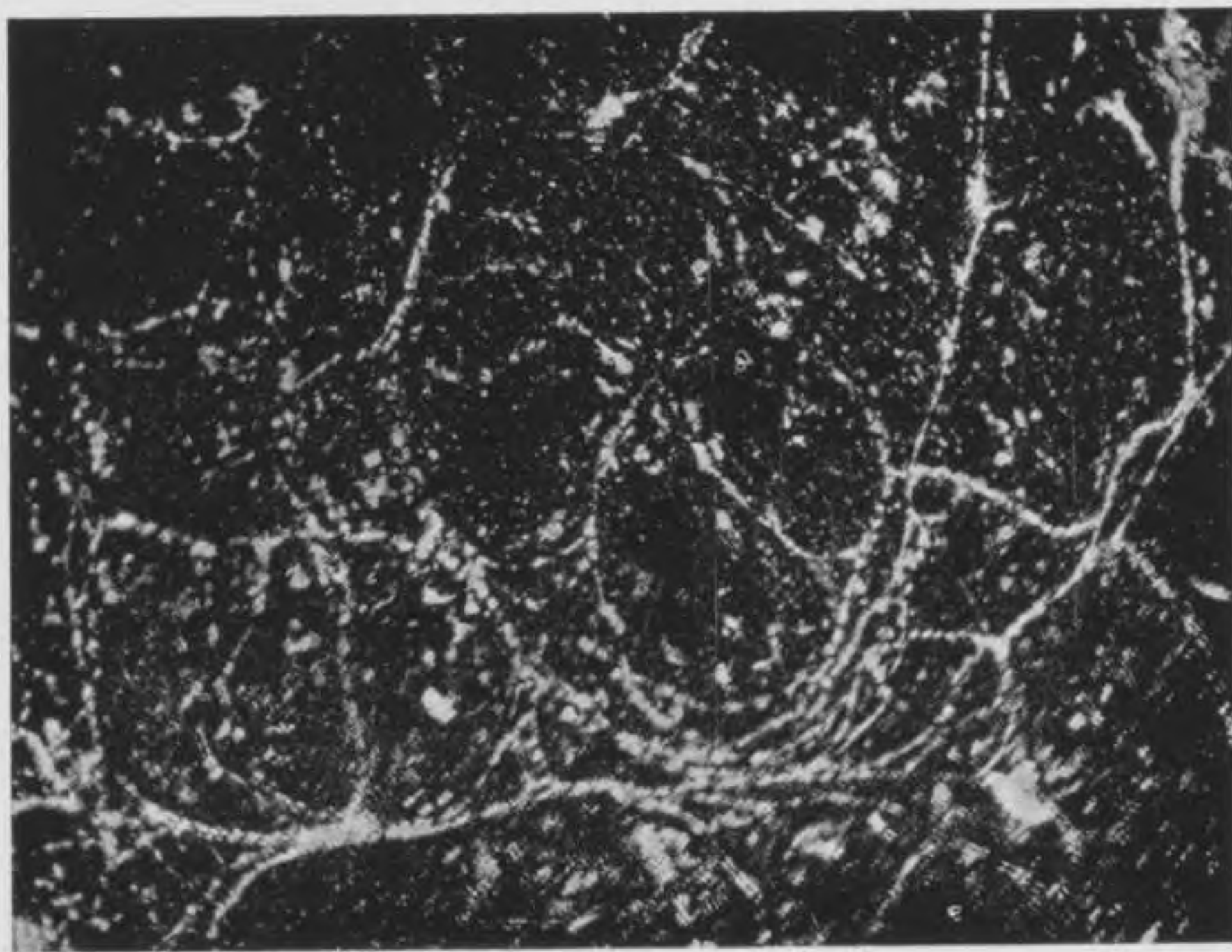


Fig. 2.



Fig. 1.

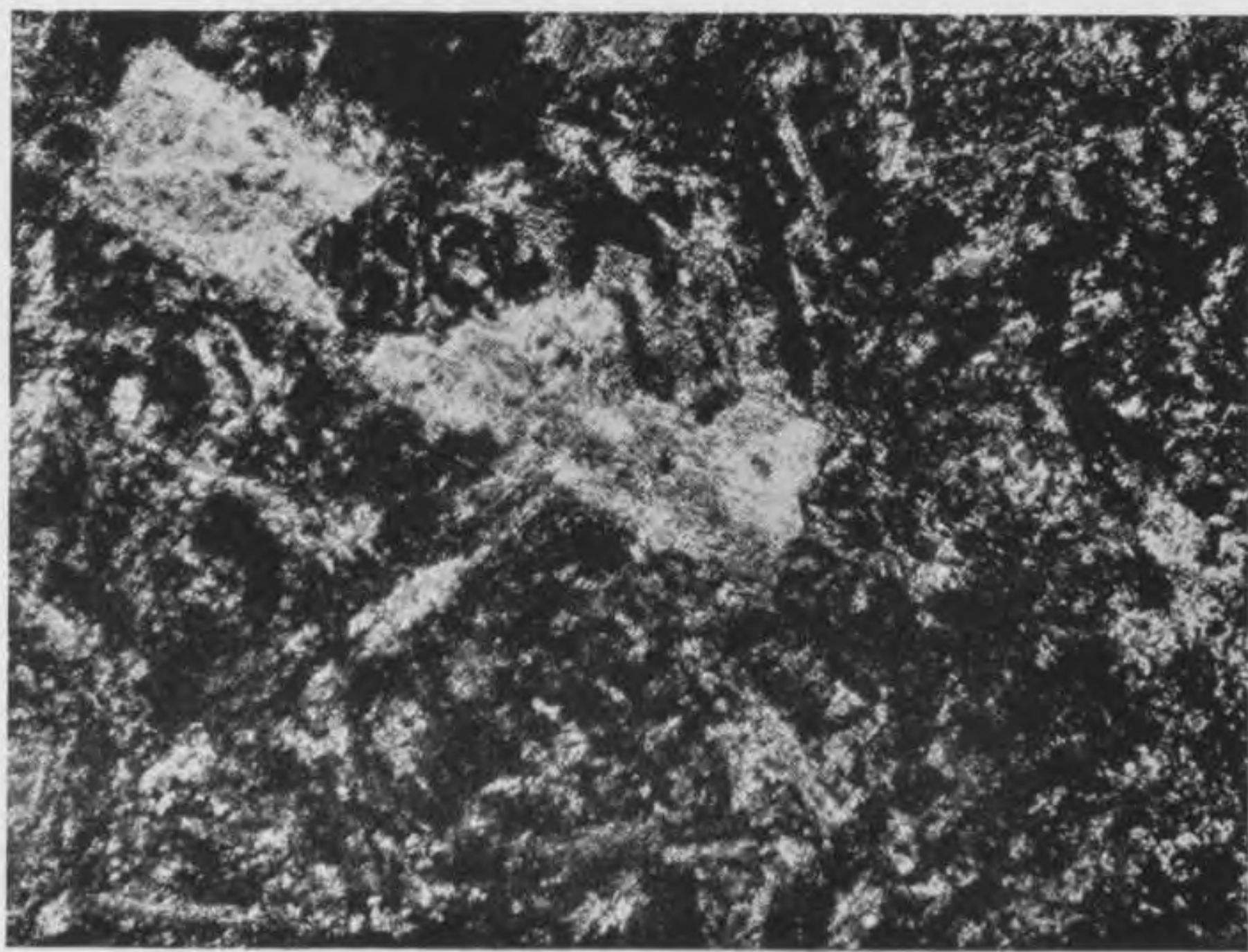


Fig. 2.

PLATE VI.

Fig. 1.

Doleritic basalt (H 53), from the Tara-Toepoeti traverse, Wetar. The rock shows a very distinct subophitic structure. Note the irregular extinction of the augite. Nicols crossed (58 $\times$).

Fig. 2.

Spilite (H 52 $\times$) from the Tara-Toepoeti traverse (Wetar), with a slight porphyritic habit. The albitic felspar is very cloudy. A pseudomorph after olivine has been partly enclosed by a phenocryst of albite. Nicols crossed (93 $\times$).

Samples H 59 $\times$, H 52. These samples must be considered as gradations between the dolerites and the doleritic basalts. They are very dark green rocks, fine- to medium grained, in which felspar is macroscopically visible.

Under the microscope they show a rather equigranular rock type consisting almost totally of felspar laths with interstitial glass substance. These rocks show considerable resemblance to the type just described, except that porphyritic development fails entirely.

The plagioclases are zonally structured and their composition varies from oligoclase-andesine at their most acid rims to labradorite-bytownite (the content of anorthite is about 70 %) in their basic cores. The average size is about 1 mm.

In sample H 52, augite as well as hypersthene occurs, 1 mm in diameter. Contrary to H 59 $\times$, in which hypersthene is lacking, the pyroxenes are for a good deal fresh. The augite of H 59 $\times$ has almost totally altered into a chloritic substance, brown of colour; may be chlorite, rich in iron. Part of the chlorite is strongly pleochroic from blue green to yellow green. Sometimes the fibres are radially arranged. But generally they show a dirty brown mass, while in the centres of these masses often small remnants of fresh augite are visible. Part of this brown substance consists of glass, which is entirely devitrified. These greenish to brownish coloured chloritic substance is present, along manifold fractures in the plagioclases.

Quartz in a few grains is observable, as well as some alkali felspar, but could not be safely determined, although the presence of micrographic intergrowths would be an indication for its existence. Titanomagnetite may be noticed in an almost equal amount as in the first described type. Tables of ilmenite are occasionally present in the felspars.

Samples H 53 and H 87 (H 87 is a pebble from the M. Saoe). *Doleritic basalts* (Plate VI, fig. 1).

The doleritic basalts are dark greyish green coloured rocks, with a brown weathering crust, in which dark brown phenocrysts are present. Both rocks are fresh.

The main constituents of the rocks are: plagioclase, augite and magnetite. The groundmass consists of lightbrown coloured glass. Plagioclase and augite occur in almost equal quantities. The slender felspar laths, 0.5 mm in length, are wedging out into the augite, where they are enclosed by this mineral; a distinct subophitic to ophitic structure is produced. The greater part of the felspar laths are twinned; in fact a small part is untwinned. Most of them show very sharp boundaries. Zonal structure is rare. Their composition is labradorite (with an anorthite content of

60 %). Some acid zones of the zonally structured individuals have a composition of medium andesine. The augite light green to colourless, up to 0.3 mm in diameter. The individuals show an arcuate development, with corresponding varying extinction angles. It is most probably due to rapid crystallization. Similar phenomena of the augites were observed in some doleritic rocks and will be described further on, in the glass-encrusted andesites (p. 78).

Besides these two minerals — plagioclase and augite — larger and smaller patches are found, consisting of secondary minerals: carbonate, quartz, limonitic and serpentinous substance and a sometimes spherulitic colourless mineral, the birefringence of which is very weak, while the refractive indices are much lower than that of Canada balsam.

The boundaries of these patches may sometimes suggest that they form pseudomorphs after an original feldspar mineral, but mostly their form is irregular.

Also carbonate occurs as spherulitic aggregates.

In H 87 some quartz occurs, as well as alkali feldspar, which has intergrown with quartz. These granophyric, occasionally somewhat rounded masses, have often crystallized around the extremity of a feldspar lath. These minerals are the last crystallization products of the magma. Very subordinate magnetite occurs in idiomorphic sections. The glass substance in the groundmass is clear and does not show any sign of devitrification.

6. Spilitic rocks.

Although field observations could not yield any decision thereon, those basic albite-bearing rocks are described, that are to be considered as effusive rocks. Spilitic rocks of the type defined are found on this traverse in two samples (H 60, H 52^x), which have a varying appearance.

Sample H 52^x. *Spilite*.

A porphyritic, bluish-grey coloured rock, with small dull-white feldspar phenocrysts in a fine grained groundmass.

Feldspar phenocrysts, ranging up to 0.9 mm in length, are present in a groundmass, which contains abundant small feldspar laths and minute grains of oxidic iron ore. The phenocrysts are acid plagioclases with the composition of albite. They have a cloudy appearance, while part of them is brownish coloured, in consequence of kaolinization. Polysynthetic twinning is rather frequent. The extinction angles are rather small, in sections of the symmetrical zone they range up to about 16°. The arrangement of the slender feldspar laths of the groundmass — 0.1 to 0.4 mm

in length — is in some places a striking feature. DE ROEVER¹⁾, who described the same feature in the spilitic rocks of the Moetis-region (Timor), says:

"These are bunched together in delicate, slightly diverging aggregates, which seem to be branching and rebranching several times, always showing small angles between adjacent felspar laths."

The length of these fir-tree-like felspar aggregates, may range up to 0.6 mm.

Between these branched albite laths, abundant, very small particles of oxidic iron ore occur, which probably consist of magnetite. Chlorite is present in rather considerable amounts; it must be understood as the alteration product of augite, which still occurs in a few unaltered fragments. Pseudomorphs after olivine are observable (Plate VI, fig. 2). They consist of black oxidic iron compounds, ferruginous serpentine and chloritic substance. The original euhedral crystals of olivine have altered entirely and may attain a diameter of 1 mm. Minerals of the epidote group occur, as well as titanite, which has for the greater part altered in to leucoxene. Small flakes of sericite, as well as carbonate, occur as decomposition products of the plagioclases.

The structure of the rock is partly sub-ophitic, partly sub-variolitic.

H 60, *Spilite*.

This type contains fresh phenocrysts of pyroxene in a very fine ground-mass, which is greyish-green of colour. Acid plagioclase of albitic composition is the predominating constituent of the rock. The average size of the felspar laths is about 0.15 mm, some may reach dimensions of 0.5 mm, but one may hardly speak of a porphyritic development of the rock. The plagioclases are partly twinned, sometimes polysynthetically.

In this almost equigranular rock, rather many phenocrysts of augite occur. Often the crystals, with an average diameter of 0.8 mm, are glomeroporphyritically accumulated. Sometimes the crystals show a peculiar arcuate development, a phenomenon which has already been described in the dolerites and doleritic basalts. Magnetite in minute grains is abundant, but occurs less than in the first described rock.

Slightly devitrified material is found, often brownish coloured. Several cavities are filled up with carbonate.

As secondary minerals chlorite and limonite may also be mentioned.

¹⁾ loc. cit.

The albite-laths of the groundmass have similar tree-like development as in H 52 $\times$. Pseudomorphs after olivine, however, fail in this rock. The structure of this sample is ophitic to sub-ophitic, sometimes sub-variolitic.

This type shows a slight resemblance to the doleritic basalts.

7. Albite-diabases.

H 49, H 50 $\times$, Albite-diabases: These rocks will be described as albite-diabases; their geological position in the field could not be ascertained as hypabyssal. Often they show rather great resemblance to keratophyres.

They are fine grained, greyish or greenish coloured rocks. Macroscopically pyrite is visible.

The rocks consist of small, slender feldspar laths and flakes of chlorite, both with an average diameter of 0.3 mm. The feldspars, which have a composition of albite, are rarely twinned. They are very cloudy. The amount of chlorite is almost equal to that of the plagioclase. Some eight-sided, idiomorphic sections, now consisting of more or less spherulitic chlorite, show that we should consider the chlorite as an alteration product of the pyroxenes. Isometric grains of magnetite, as well as the secondary constituents carbonate, minerals of the epidote group and some quartz are present.

The structure is partly sub-ophitic. This type shows much resemblance to the Illipoi-albite-diabases and the albitized quartz-diabases of the Meta Saoe, and will be more fully described there.

ROCKS OF THE MASAPOEN-MONING TRAVERSE AND OF THE COASTAL PART BETWEEN THE VILLAGES TOEPOETI AND MASAPOEN.

These rocks may be classified as follows:

1. Dacites and quartz-keratophyres.
2. Dacites to andesites; quartz-bearing keratophyres.
3. Glass-rich andesites to pyroxene-andesites; keratophyres.
4. Doleritic basalts.
5. Dolerites and albite-diabases.
6. Quartz-augite-diorites to quartz-gabbros.

1. Dacites and quartz-keratophyres.

There are several types of dacitic rocks found in this traverse. One type will be described which is characterized by a fine grained groundmass in which phenocrysts of quartz and acid plagioclase occur; in other samples the quartz phenocrysts are wanting, but the groundmass is very

rich in this mineral, often as pseudo-spherulitic aggregates. A second type does not exhibit any phenocrysts and consists of a fine grained, often distinctly devitrified mass. Nearly all these dacites are infiltrated with solutions rich in silica.

The first type:

Sample H 196 is a light greenish coloured, very dense, glassy rock, with a few phenocrysts. Rocks like this sample are frequent in the region between Tomliapat and Arwala.

Zonal plagioclases of an acid-labradoritic composition with slightly more acid margins, and with a maximal size of 2 mm, as well as quartz-phenocrysts are lying in a groundmass consisting of small, 0.01 to 0.1 mm large pseudo-spherulites of quartz and alkali feldspar, which are fairly abundant.

The idiomorphically developed phenocrysts of quartz show the well-known turbid zone of quartz, alternating with fibres of alkali feldspar. Opalization is a common feature in this rock. Opal pseudomorphs after plagioclase and pyroxene are observable. Except the few entirely altered pyroxenes of phenocrystic size, dark minerals are wanting.

The samples H 191 and H 189 $\times$ are amphibole-dacites. Though these rocks differ macroscopically from the one just described, under the microscope their structures show much resemblance.

These greyish rocks are rich in cavities, while in the fine grained base, besides phenocrysts of acid plagioclase and exceptionally of quartz, a fairly considerable content of dark minerals is present. Phenocrysts of hypersthene and amphibole, with an average length of 1 mm, are observable. In H 189 $\times$ the hypersthene is dominating over the green hornblende. Generally the amphibole is resorbed to slight degree.

The plagioclase is medium-labradorite with more acid margins, while the plagioclase laths in the groundmass of sample H 189 $\times$ have a composition of basic oligoclase. The groundmass of these rocks however contains a good deal of pseudo-spherulites of quartz, and is similar to that of H 196.

Sample H 183 is a pebble from the South coast. As all feldspars are entirely albitized, this rock is a quartz-keratophyre.

Besides among the phenocrysts, the quartz is strongly prevailing in the groundmass as rounded grains of 0.05 to 0.15 mm in size. Apparently considerable silicification has taken place. Chlorite, limonite, carbonate, leucoxene as well as pistacite are secondary constituents of the rock. Strongly pleochroic orthite is also present.

H 219^x has a somewhat porphyritic habit, caused by plagioclase, with a composition of medium andesine, and quartz of phenocrystic size. Both minerals occur in idiomorphic sections; the lozenge shaped sections of quartz show turbid rims of micrographic intergrowths of quartz and alkali felspar. A large amount of well-developed spherulites, of an average diameter of 0.5 mm, occur. In the groundmass the spherulites partly consist of radially arranged fibres of quartz interlamellated with thin fibres of alkali felspar. Sometimes only the core, but in many cases the entire spherulite shows micrographic intergrowths of these minerals. Although phenocrysts of alkali felspar are wanting, this rock, for its chemical composition, possibly may be considered, as a transition to the rhyolites.

The second type: (H 194, H 212, H 189).

These samples should be considered as strongly devitrified glasses. In consequence of hydration the original black glasses have been bleached: so white to light grey coloured rocks are frequent.

Part of these rocks — the pebble H 189 is a good example — exhibit fluidal structure; the layers, which are indicated by more devitrified zones, rich in micro- and pseudo-spherulites and quartz aggregates are strongly folded. Silicification is a general phenomenon. Mostly these rocks are rather dense, with very flat, elongated vesicles.

Sample H 212 is an almost white rock, with a very dense structure. Only a few small felspar phenocrysts, with a composition of secondary albite, occur in a groundmass, consisting of small felspar laths with a fluidal structure, which are enclosed by large poikilitic quartz crystals. The composition of the groundmass-felspar is acid oligoclase. The large poikilitic quartz crystals are irregularly bounded and optically differently orientated (Plate VII, fig. 2).

Similar features were described in dacitic rocks (H 61^x) of the Tara-Toepoeti traverse. J. D. DE JONG (21) describes these features of rocks of Western-Wetar, while VAN VOORTHUYSEN (36) illustrated similar structures in dacites in his publication about the Amfoan region in NW Timor (Fatoe Mosoe).

Sample H 194 greatly resembles the preceding type, but in this sample the plagioclases of the groundmass, are acid oligoclase, while the thin laths are irregularly arranged. The plagioclases of phenocrystic size, are basic oligoclase. Veinlets as well as cavities are filled up with quartz.

In consequence of strong silicification the sample H 189, does not show this structure very distinctly.

The feature just described should be considered as a devitrification phenomenon. It may be that it represents some stage of the devitrification process. So if this process continues, this structure will disappear again.

These rocks contain apatite as accessory mineral. Chloritic substance is rare, while tridymite will possibly be present. Dark minerals are exceedingly rare.

The samples H 212 $\times$, H 226, strongly resemble the just described type, and they are transition types to the group, to which H 200 $\times$, H 207, H 214 belong, and which shows a fine granular groundmass of quartz, alkali feldspar and acid plagioclases. The few phenocrysts of feldspar have a composition of andesine.

Generally the rocks are rather dirty, in consequence of much fine-divided limonitic and chloritic substance.

In H 200 $\times$, small fibres of biotite are observable in a fairly large quantity.

Samples H 207 $\times$ and H 215 $\times$, breccias of dacitic rocks: The second sample is a breccia of light-grey coloured dacite fragments, which belong to the fine-granular type, very rich in quartz. The entire breccia is strongly infiltrated with silica. The quartz phenocrysts show turbid borders.

The breccia H 207 $\times$ is a black glassy dacite, the fragments of which are partly devitrified; so one part shows "poikilitic quartz crystals", while another part is fine grained. Replacement of feldspar by quartz is observable. As secondary constituent, carbonate is present.

To the group of the dacites are also reckoned the obsidians, as these rocks are often in connection with dacitic rocks; sometimes they alternate with dacites.

The samples H 184 $\times$ and H 186 are black obsidians; the first one is a breccia of glass. Both rocks, neither of which do show any structure, are strongly infiltrated with yellow to brown coloured opalous substance.

H 186 contains very small feldspar laths, with a composition of bytownite to anorthite, while microlites are abundant, of a size of 0.01 to 0.03 mm and smaller.

Besides these minerals, small grains of monoclinic pyroxene as well as small isometric crystals of magnetite are present in considerable quantity. Rosette-shaped aggregates of feldspar laths may be observed.

The glass-sherds of the obsidian-breccia H 184 $\times$, contain flow-structured feldspar laths of a composition of basic andesine, with a maximal length of 0.05 mm.

Sample H 35, a perlitic glass from the Tara-Toepoeti traverse, will also be described here. The glass shows slight devitrification along the perlitic fractures. These zones show an increase of microlites and a weak refringence. The small plagioclase laths, with a composition of andesine, show a flow structure (Plate V, fig. 1).

2. Dacites to andesites; quartz-bearing keratophyres.

These rocks should be considered as a transition group between the dacites (c.q. quartz-keratophyres) and the andesites (c.q. keratophyres). The content of quartz, which occurs in the mesostasis only, is decreased with respect to the dacites, while the amount of femic minerals (in these cases always chloritic substance) is increased. The feldspars are acid plagioclases; the most basic of which belongs to andesine, whilst albite is also present.

Dacites to andesites.

These rocks, represented by the samples H 217, H 221, H 222^x and H 202^x, H 203, are very finely granular, light grey coloured rocks. Pyrite, as small cubics, is fairly abundant in all these rocks.

In the fine grained groundmass a few phenocrysts of plagioclase occur, but they hardly give the rock a porphyritic habit. Often these phenocrysts are strongly decomposed into chlorite, carbonate and kaoline.

The groundmasses of these rocks are rich in quartz grains, often irregularly bounded, and contain some small feldspar laths. But often their diameter is too small for determination, so it is not always possible to make out whether dacite to andesite or a quartz-bearing keratophyre is present. As albitization in these rocks is a general feature, many of them belong to the last group.

Quartz infiltration frequently occurs. Chlorite, often a ferriferous variety, is rather abundant in all the rocks.

Pyrite, limonite, leucoxene, kaoline, sericite, carbonate, chlorite and minerals of the epidote group are secondary constituents.

Apatite is accessory.

Quartz-bearing keratophyres.

This type of rocks is common in this part of the route. Generally they are fine grained, holocrystalline rocks, sometimes, however, some glass occurs in the base. There are a number of samples which show a slightly porphyritic habit, another part is even grained. Especially the last group shows strong resemblance to the albite-diabases. Macroscopically they

cannot be distinguished from them, except in such cases where there is a strongly porphyritic structure or fluidal structure. Under the microscope these rocks show a similar resemblance. A difference between these rocks and the albite-diabases and albitized quartz-diabases is the subophitic to ophitic structure which characterizes the latter group of rocks.

An important part of the quartz in these rocks is of secondary origin. Quartz phenocrysts are wanting.

H 233, H 235^x and H 240^x are typical examples of these rocks. The greyish, fine grained rocks are particularly rich in small, slender felspar laths. These acid plagioclases — which are frequently twinned according to the Carlsbad- and albite laws — are albite, while their diameter is about 0.5 mm. The content of chlorite, partly present as alteration product of femic constituents, is large. Albite and chlorite are the dominating constituents, while quartz occurs partly interstitially between these minerals, partly however as fillings of cavities. In the latter case it is of secondary origin.

The samples H 235^x, as well as H 234^x, are somewhat porphyritically structured. In a somewhat devitrified groundmass, albite laths of phenocrystic size occur. In these two rocks the quantity of oxidic iron ore, is diminished with respect to H 240^x.

To this group of rocks must be also reckoned the samples H 213 and H 214^x. They show striking resemblance to the albite-diabases. Field observations did not lead to any decision. They are somewhat coarser grained; the felspar laths may attain a length of 1 mm. Partly they exhibit a sub-ophitic structure, which becomes indistinct in consequence of strong alteration of the rocks. But as abundant small cavities are present in the rocks, and occasionally an indistinct fluidal structure is observable as well, these rocks are classified amongst the extrusives.

A normal content of interstitial quartz is present in these rocks. In sample H 213 part of the plagioclases is non-albitized. The original felspar has a composition of medium andesine. The content of idiomorphic grains of oxidic iron ore, with leucoxenitic alteration, is moderate.

3. Glass-rich andesites to pyroxene-andesites; keratophyres.

Glass-rich andesites to pyroxene-andesites (H 187^x, H 238, H 233^x).

Sample H 187^x is a very hard, greyish green rock, with large elongated vesicles, in which a great number of small crystals have developed. Under the microscope the rock consists of parallel structured small, slender

felspar laths, 0.1 mm in length; part of these plagioclases is twinned, while the composition is of medium andesine. Between these felspar laths a base of slightly devitrified glass is found. Rather seldom spherulitic aggregates are present; probably they consist for a good deal of quartz, but this could not be proved with certainty.

Micrographic intergrowths of quartz and alkali felspar are wanting. Magnetite is scattered through the rocks in very minute grains. Along the borders of the vesicles, often 10 cm in length, a large number of isometric crystals of analcite occurs. The refractive indices of this mineral are considerably lower than that of Canada balsam, while the birefringence is very weak. By means of microchemical reactions it was proved that the mineral was analcite. Besides this mineral, opal is frequent in the cavities. Masses of fine fibres of biotite or chlorite, may be observed as well. This rock has been called an andesite, although in view of the basicity of the plagioclase and the very small amount of dark minerals, one might decide to a dacite or quartz-andesite.

H 238 is another type of andesite. It is a darkgreen, dense rock with abundant cavities, filled up with a white, silky gleaming fibrous mineral. In the slice this mineral is colourless and isotropic, sometimes however it shows a very weak birefringence. Its refractive indices are lower than that of Canada balsam. Possibly it is zeolite.

This rock is rich in plagioclase, of medium labradoritic composition and pyroxene; augite as well as hypersthene occur and may reach a diameter of 0.4 mm. Part of the plagioclases is opalized. The glassy base is dark green coloured. Opal and chalcedony both occur, often as fillings of cavities, the latter mineral mostly in spherical bodies.

This type inclines to the pyroxene-andesites.

Sample H 233^x show strong resemblance to the preceding type but this rock is finer grained, while the amount of pyroxene — both augite and hypersthene are present — has increased.

The cavities in this rock are filled up with chloritic minerals.

The border of such a cavity consists of well-developed spherulites of green coloured chlorite. This variety is pleochroic from light to dark green, while the interference colours are low.

The rest of the cavity is filled up with larger fibres of a brownish coloured chlorite. This variety is strongly pleochroic from light yellowish brown to dark brown; its interference colours are rather high. Probably we have to deal here with a ferriferous variety. Magnetite is rather frequent. The glassy base is weakly devitrified.

Keratophyres (H 232).

This is a dark green rock, fine grained, with a very dark border of still denser structure, which zone is opaque under the microscope. The rock itself consists of small felspar laths of albitic composition, which are situated in a dirty, glassy base. The felspar laths generally attain a diameter of 0.3 mm; some of them are 0.6 mm in size, but they do not give the rock a porphyritic structure. The extremities of the felspar laths are frequently swallow-tailed. Alteration of the albite into carbonate is a common feature.

4. Doleritic basalts.

H 197. *Doleritic quartz-basalt*.

This rock strongly resembles the doleritic basalts, which were described from the Tara-Toepoeti traverse (p. 34). It is a rather fine grained rock, of green colour, with sub-ophitic structure. The plagioclase laths are wedging out in the pyroxene, where they are enclosed by this mineral. The zonally structured plagioclases, which are often twinned, are basic labradorite, with slightly more acid margins. Augite is frequent, but occurs in smaller amounts than the plagioclases. It partly shows idiomorphic sections, with a diameter equal to that of plagioclase: up to approximately 0.5 mm. The augite, which is sometimes twinned according to (100), is occasionally arcuate, but often this feature is not clearly indicated by the crystal boundaries or by the cleavage cracks and in that case it is recognizable by means of queer extinctions in the crystals. Similar features are described in the doleritic basalts from the Tara-Toepoeti traverse. Hypersthene is present in a few crystals; there are intergrowths between this mineral and the augite, where the augite encloses the hypersthene.

Possibly there are pseudomorphs after olivine, but these could not be determined with certainty. Idiomorphic boundaries, which may indicate olivine, are observable, while these phenocrysts have greatly altered into chloritic and serpentinous substance; the irregular fractures in the crystals are filled up with strongly birefringent ferriferous serpentine.

Quartz is present as well, and as it is the last crystallization product, it is filling up the interstices between the other minerals. Often it is found together with the rosettes of micrographic intergrowths of quartz and alkali felspar.

Oxidic iron ore in small grains, in limited quantity, and titanite, with leucoxic alteration, are present, but rare. Veinlets, filled up with carbonate, quartz and opal, are cutting through the rock. The content of

glass and slightly devitrified glassy substance is very subordinate in this rock. As quartz is not exceptional and of primary origin, the rock has been called doleritic quartz-basalt.

5. Dolerites and albite-diabases.

H 240. *Dolerite*.

This is a bluish-green coloured, holocrystalline rock, with partly subophitic structure.

Plagioclase and augite are observable in almost equal quantities. Arcuate development of the augite crystals, with correspondingly varying extinction angles, is a common feature.

The slender felspar laths, 0.4 to 0.9 mm in length, are plagioclases with zonal structure. The basic cores have a composition of bytownite-anorthite; the more acid margins are of basic labradorite. Twinning is common.

Part of the augite show idiomorphic development; the average diameter is 0.5 mm. Chloritization is a common phenomenon in this rock. The outer border of the augite crystals, but sometimes the whole individual has altered into chlorite (penninite is frequent). But often the basic cores of the plagioclase contain a considerable quantity of chloritic fibres. Magnetite is fairly abundant, often with leucoxenitic alteration. The alteration products in this rock are the same as have been described in other dolerites.

H 235 and H 216, respectively albite-diabase and albitized quartz-diabase. These rocks should be considered as altered dolerites as will be pointed out in the chapter on Tandjoeng Illipoi (p. 71). In sample H 216, the plagioclase is only partly albitized. The original zonal plagioclase has a composition of basic labradorite, with more acid margins. Albitization phenomena, as described before in other rocks, may be observed. Similar features were described fully by BAILY and GRABHAM. Unaltered augite-fragments are present as well in this rock. Interstitial quartz is not rare.

H 235 on the contrary, is a typical albite-diabase, with felspar as dominating constituent of the rock. The average length of the slender albites is 0.4 mm. Some plagioclases are of phenocrystic size, but especially these large individuals are strongly decomposed. Carbonate pseudomorphs after pyroxene are manifold, but some unaltered fragments of augite are still distinguishable. For the rest, the rocks perfectly agree with already described albite-diabases.

PLATE VII.

Fig. 1.

Quartz-augite-diorite to quartz-gabbro (H 202) from the Masapoen-Moning traverse (Wetar). Around the top of some laths of the basic plagioclase felspar, micrographic intergrowths of quartz and alkali felspar are found. The dark tabular needles in these intergrowths are most probably ilmenite. Nicols crossed (76 $\times$).

Fig. 2.

Example of devitrification of glassy lavas (H 212, *dacite*, Masapoen-Moning traverse, E. Wetar). Poikilitic quartz crystals in which directed small laths of plagioclase are enclosed. Nicols crossed (87 $\times$).

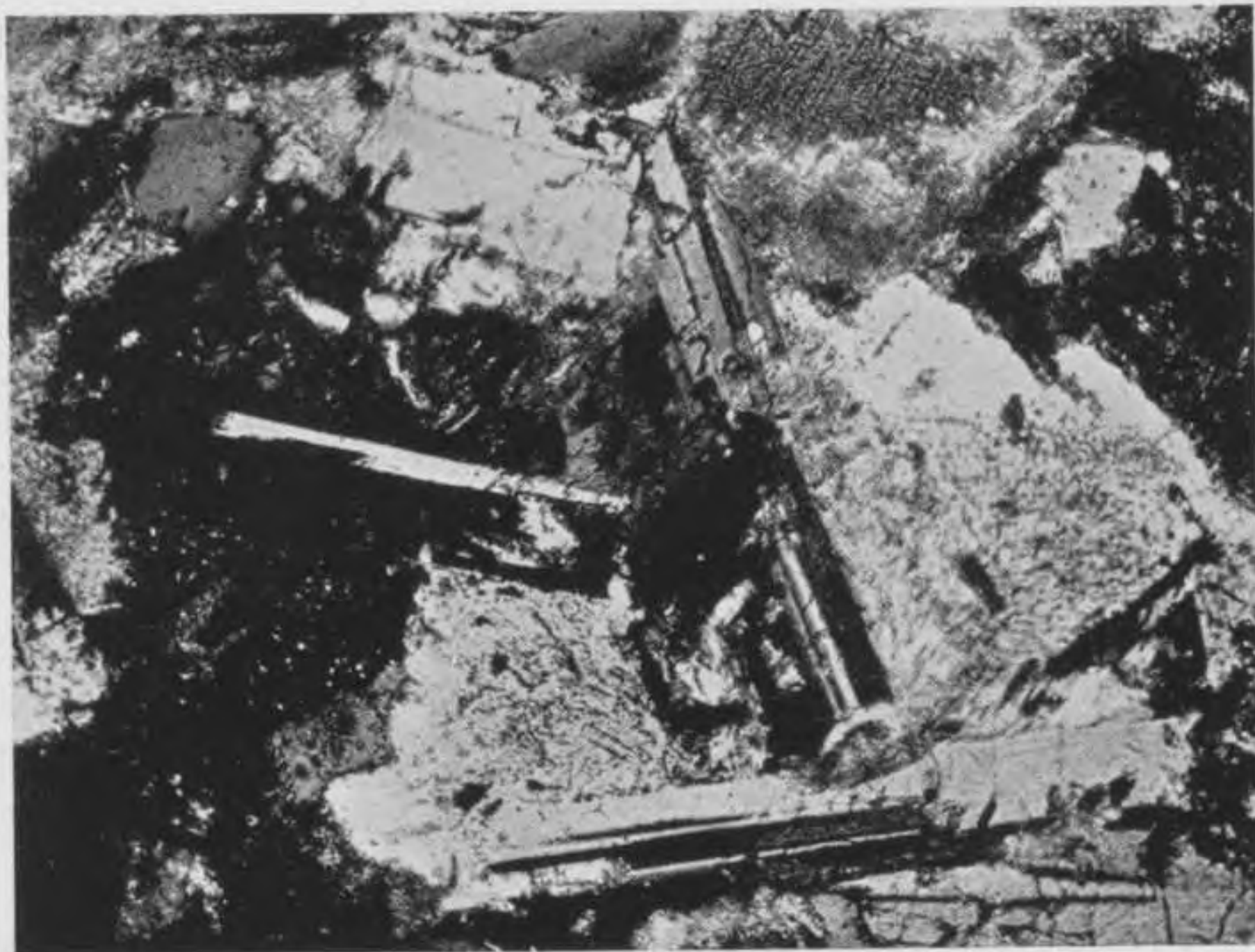


Fig. 1.

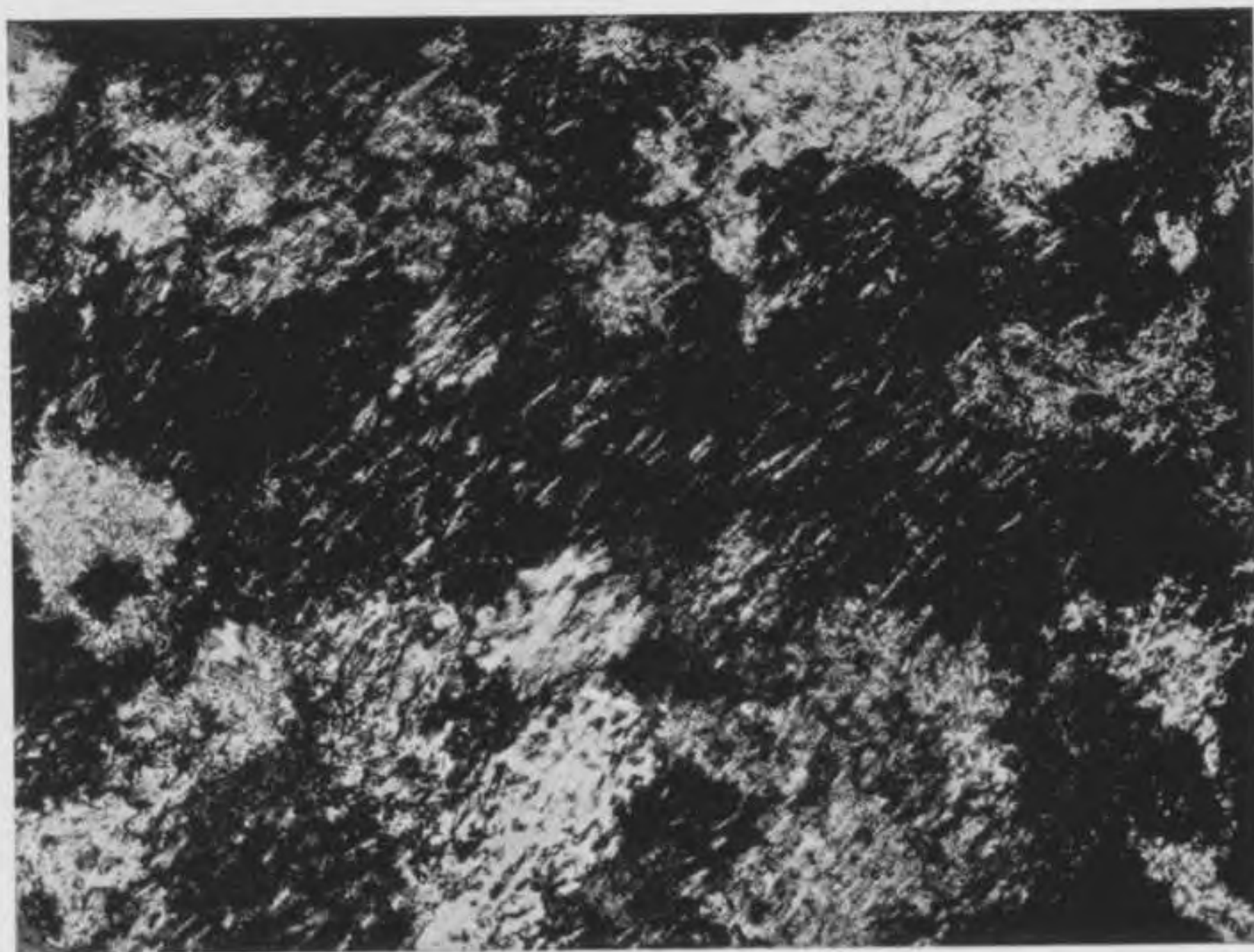


Fig. 2.

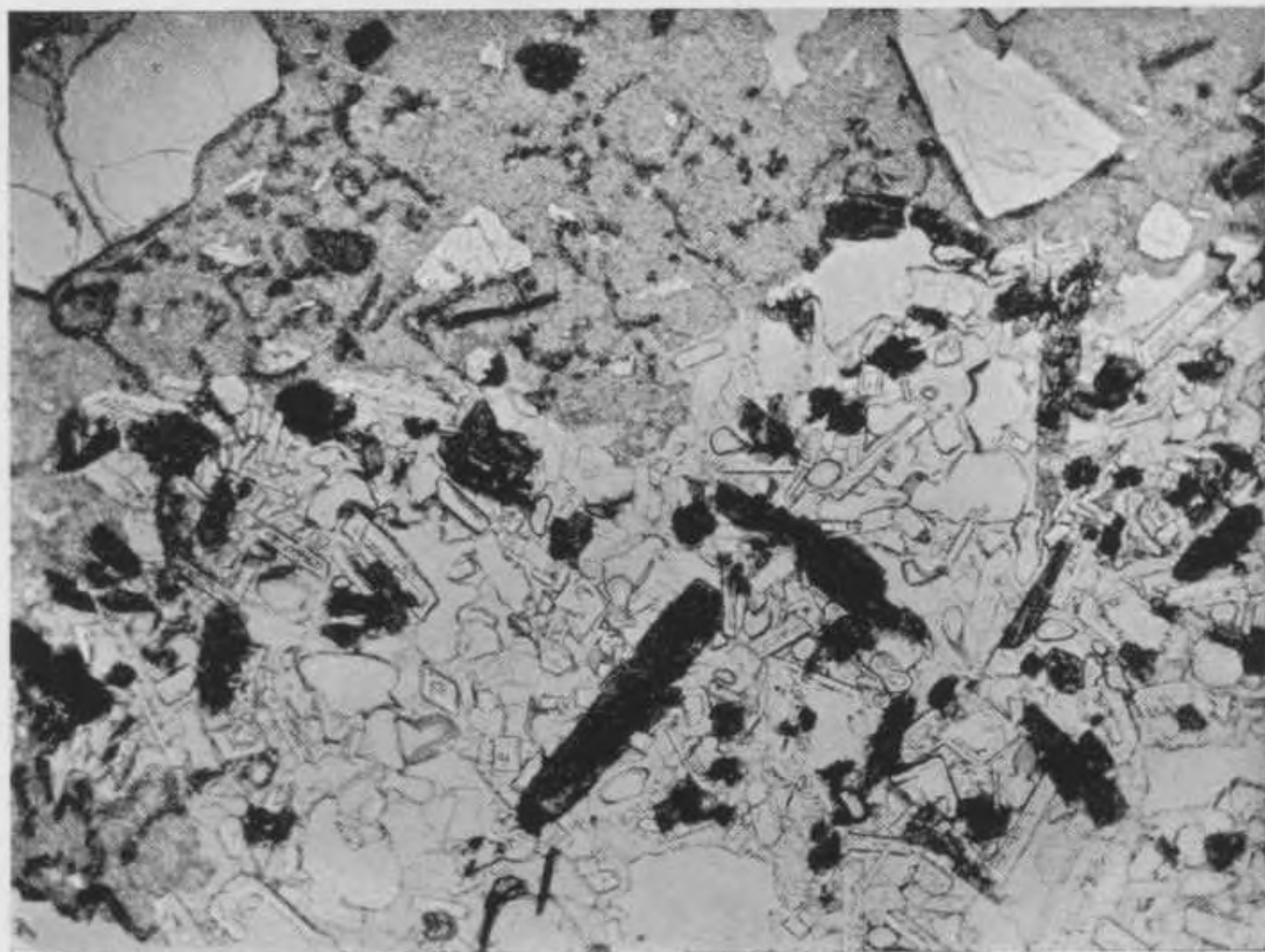


Fig. 1.

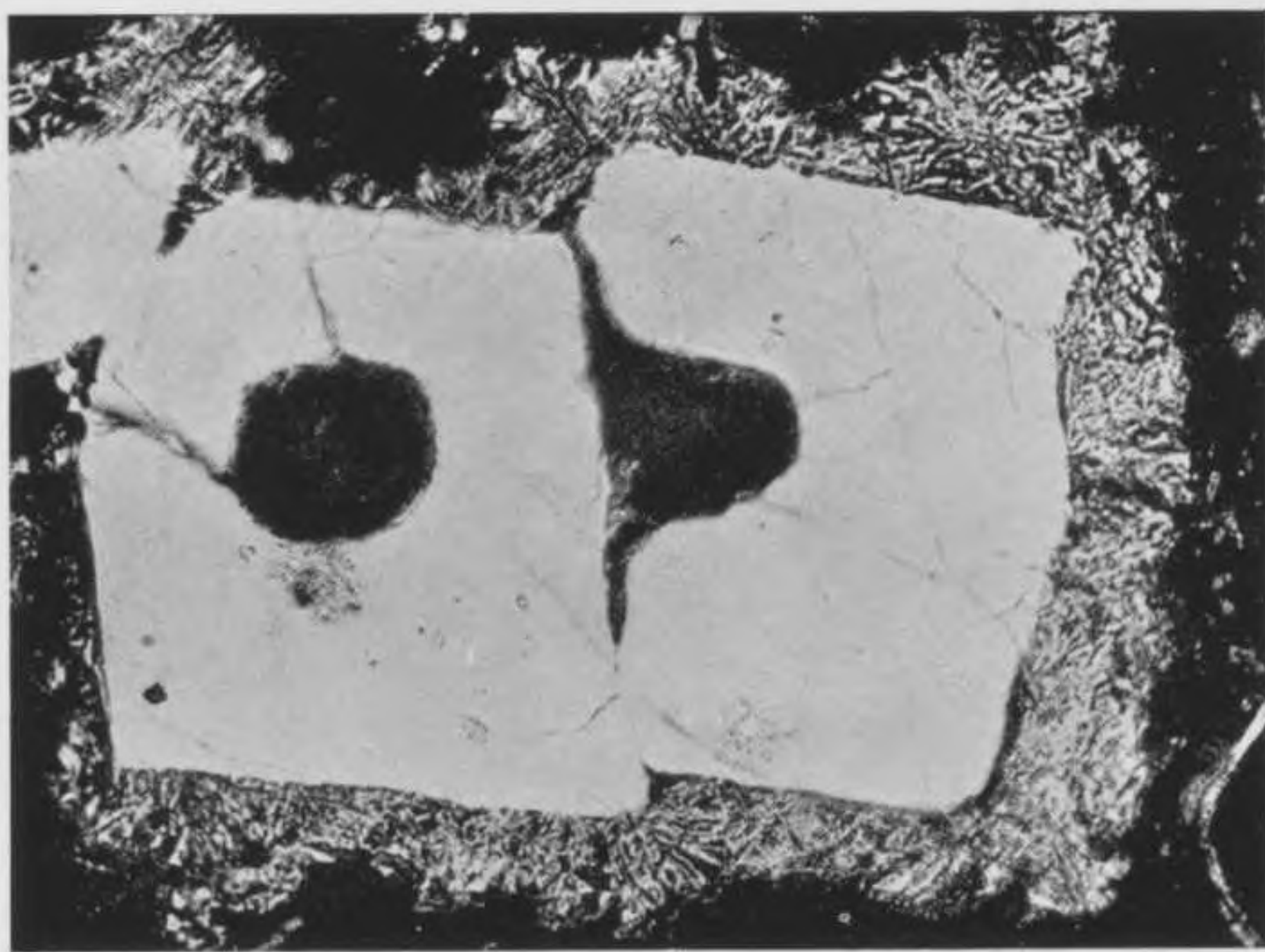


Fig. 2.

PLATE VIII.

Fig. 1.

Vitrophyric dacite with a homoeogeneous glassy inclusion (H 274), from the Tomliapat-Arwala region (E Wetar). The lower part of the photograph shows the glassy inclusion rich in unresorbed green amphibole. Ordinary light (18.5 $\times$).

Fig. 2.

Corroded phenocrysts of quartz with a rim of micrographic intergrowths of quartz and alkali felspar. The inlets in the quartz crystals are filled with glass of the groundmass.

Rhyolite (H 278) from the Tomliapat-Arwala region (E Wetar).

Nicols crossed (104 $\times$).

6. Quartz-augite-diorites to quartz-gabbros.

H 202 and H 188^x, *quartz-augite-diorites to quartz-gabbros*.

Sample H 202 is a medium grained, holocrystalline, dark coloured rock. Macroscopically pyroxene and feldspar are recognizable, while pyrite is locally fairly abundant.

Microscopical determination shows an even grained rock, with crystals of an average diameter of 1.2 mm, and feldspar, pyroxene and quartz as main constituents, while magnetite, ilmenite, pyrite and amphibole are present as accessories. As secondary constituents chlorite, carbonate, leucoxene and minerals of the epidote group occur.

The amount of dark minerals is somewhat lesser than 50 %. Most feldspars are twinned, zonally structured plagioclases, with a composition of medium anorthite (the anorthite content is about 95 %); the more acid margins have maximally a composition of medium andesine.

Apparently two generations of feldspar are present. The elder one is the zonally structured plagioclase just mentioned, but the second generation, the younger one, is generally untwinned and has a composition of andesine.

A general feature in this rock is the occurrence of rosettes of micrographically intergrown quartz and alkali feldspar, which attain diameters of 0.5 mm and even more. These rosettes are often found at the end of a feldspar lath. These rosettes are rather conspicuous, while they have a cloudy, turbid appearance. Part of them do not show any intergrowth at all, although they are cloudy. Probably very thin fibres of alkali feldspar are present in the quartz. Irregularly, but rather frequently, somewhat radially grouped, very thin needles of ilmenite occur in these rosettes (Plate VII, fig. 1).

These rosettes of quartz and alkali feldspar are the last crystallization products of the magma, consequently the microscope shows them filling the interstices between the other minerals. Originally augite was present in considerable quantity, but part of it has been chloritized and some crystals show total alteration into carbonate.

Green hornblende is observable, partly as subhedral fibres, partly as borders around the pyroxenes. This mineral too, has altered into carbonate and chlorite (penninite).

Some crystals of ilmenite, almost 1 mm in diameter, have a skeleton development. Between the dissiminated tabular crystals, often in elongated sections, very small grains of titanite will be found. Both minerals have more or less altered into leucoxene.

Pyrite, in isometric sections, is of secondary origin. Part of the quartz is undoubtedly secondary as well.

Sample H 188^x is considered as a fine crystalline gabbroid rock and although the structure is not ophitic or sub-ophitic, it shows some resemblance to the dolerites. The feldspar is medium labradorite; the crystals show distinct albitization phenomena. The albite is again cloudy. The content of augite has decreased with respect to the preceding sample.

This rock resembles rather strongly the preceding one; in this rock, too, fan-shaped intergrowths between quartz and alkali feldspar are present, but they do not enclose needles of ilmenite in large quantity.

ROCKS OF THE COASTAL REGION BETWEEN MONING AND OEHAK.

Description of some pebbles, which were collected along the coast on the traject Moning-Oehak.

Among the pebbles are found:

1. Rhyolites.
2. Dacites.
3. Pyroxene-andesites.
4. Quartz-diorites.

1. *Rhyolite* (H 248^x).

It is a porphyritic rock, light grey of colour. Under the microscope phenocrysts of quartz and feldspar are observable. The groundmass of this rock shows strong resemblance to the base of some dacitic rocks from the traverse Masapoen-Moning (described in that chapter: "the second type of dacites"), as well as with H 61^x, a dacite from the Tara-Toepoeti traverse. So poikilitic quartz crystals which enclose small feldspar laths, occur.

The feldspars consist of sanidine as well as of acid plagioclase, with a composition of medium andesine. The sanidine phenocrysts are idiomorphic and their euhedral crystals, which are translucent and have a glassy appearance, are macroscopically observable in the rock. Their diameter may range up to 5 mm. Quartz phenocrysts, with lozenge-shaped sections, occur as well. Small turbid zones can be observed on their outer borders, which consist of quartz and alkali feldspar. The groundmass, with the structure just described, consists chiefly of quartz and alkali feldspar, some acid plagioclase laths and slightly pleochroic fibres of biotite.

The content of oxidic iron ore is inconsiderable, while carbonate as secondary constituent is present in fine divided grains.

2. *Dacites* (H 244, H 250, H 250^x).

Part of these rocks are vitrophyric dacites, which have been found in great amount along the north coast; they will be described from the eastern part of Wetar, so from the region Tomliapat-Arwala. So their description may be very short here. The three samples represent three different types.

Sample H 244 is a strongly porphyritic rock with phenocrysts of plagioclase, quartz, biotite and green hornblende.

The plagioclase is basic andesine with slightly more acid margins, while quartz occurs, with inlets in consequence of magmatic corrosion. Biotite has distinctly bent fibres and the green hornblende has very narrow opacitic borders.

The groundmass consists of glass, with somewhat pseudo-spherulitic structure.

Sample H 250 is a totally crystallized rock, with a groundmass which mainly consists of alkali feldspar, further it contains quartz and sometimes, some laths of acid plagioclase. Small fibres of biotite are fairly abundant in this base, as well as minute grains of oxidic iron ore. Phenocrysts are acid plagioclase, which has weakly zonal structure and which is basic andesine with slightly more acid margins of oligoclase-andesine. Green hornblende, with resorption-rims, and subordinate biotite, occur as phenocrysts as well.

Sample H 250^x, on the contrary shows a groundmass, which is a real glass with very minute incipient crystals of rodlike aggregates. A distinct flow structure is marked by somewhat larger crystals (up to 0.05 mm in length). These slender crystal fibres could be determined as strongly pleochroic biotite. A few plagioclase phenocrysts, with a composition of basic andesine occur, while phenocrysts of quartz are lacking. Zircon is an accessory mineral in this rock. Perlitic fractures are present in the glassy base.

3. *Pyroxene-andesite* (H 251^x).

In a dark coloured groundmass, phenocrysts of feldspar and pyroxene, in almost equal quantities, are formed.

The feldspars are plagioclases with a composition of medium labradorite. This mineral, as well as the pyroxene, which mainly consists of augite, is idiomorphically developed.

The plagioclases often show glomeroporphyritic aggregates.

In the groundmass, which contains a considerable content of glass, augite in small grains is dominating. Besides this mineral, small laths of

plagioclase, with a composition of medium labradorite, are observable.

Part of the augite crystals is arcuate, with correspondingly varying extinction directions. In some places of the slice, the augite shows phenomena, similar to those described in the glass-encrusted andesites (p. 79), and which are probably due to rapid crystallization. The felspar laths may reach up to 0.1 mm in length. Minute grains of oxidic iron ore are rather abundant.

To this group of rocks should also be reckoned the glass-encrusted andesites, which have been found as pebbles and as solid rocks.

4. *Quartz-diorite* (H 245).

It is a holocrystalline rock, medium grained and light coloured. Felspar is dominating, while a rather small quantity of dark minerals is observable.

The subhedral plagioclases are often twinned according to the albite and Carlsbad-laws; they are for the greater part zonally structured. The composition is varying from acid labradorite in the core to albite in the more acid margins. Often there is a rather sharp border between the basic cores and the albite margins. The phenomenon may be especially observed between crossed nicols, although the boundary is not always sharp. Within the albite itself a zonal structure is also visible with more acid felspar in the outer margins of the entire crystals. This is clear evidence for the fact that we have to deal here not with a replacement process, but with normal, primary crystallization. Albitization phenomena are observable as well, but in very inconsiderable amount. Small veinlets of albite occur in the more basic plagioclases, as albitizing solutions have penetrated into these crystals along fractures.

Besides felspar, quartz is fairly abundant. Part of the quartz replaces the plagioclase. Distinct veins of quartz occur in the plagioclase. Replacement by quartz is a general feature in this rock.

The green hornblende occurs as irregularly bounded crystals in this rock. There are no idiomorphic boundaries. Its size varies from 1 to 1.5 mm. Alteration products of the amphibole are chlorite and carbonate, while part of this mineral has been replaced by quartz. Magnetite, in idiomorphic grains is rather frequent. Apatite is present in a few grains.

Titanite, partly with leucoxic alteration, is frequent; the interference figure shows a strong dispersion $r > v$.

Minerals of the epidote group are observable as well; part of the epidote is interstitial, part of it replaces the felspar.

As alteration product of the felspar, sericite occurs.

ROCKS OF THE TOMLIAPAT-ARWALA TRAVERSE.

The rocks of the Tomliapat-Arwala traverse may be classified as follows:

1. Vitrophyric dacites.
2. Rhyolites.

Vitrophyric dacites (H 263 $\times$, H 263).

A strongly porphyritic, dark blue coloured lava with a glassy base. Phenocrysts of quartz (with a maximal size of about 1 cm), feldspar and feldic minerals are macroscopically observable. The quartz phenocrysts, which are rather rare in these rocks, are clear; often they are strongly fractured, whilst along these cracks glassy substance has penetrated. Glass inclusions are also present. The feldspars are zonally structured plagioclases. Twinning is common. Part of the phenocrysts contains numerous glass- and liquid inclusions, often arranged according to crystallographic directions. The composition of the plagioclase varies from basic andesine in the cores to oligoclase-andesine in the more acid margins. Many alternating zones of slightly different basicity and with a slight increase of acidity towards the margin may be observed. A few individuals have enclosed so many grains of glass and oxidic iron ore that only a very narrow rim of clear plagioclase has been left on the outside of the crystals. A more or less glomeroporphyritic structure is present. Of the dark minerals pyroxene is the most frequent; hypersthene is fairly abundant, but augite occurs as well. The hypersthene is occasionally surrounded by a rim of green hornblende or biotite. Phenocrysts of these two minerals are also noticeable; part of them shows resorption phenomena and consequently they contain opacitic borders, which consist of small grains of hypersthene and magnetite.

Biotite sometimes encloses green hornblende. Generally these phenocrysts are much smaller in size than the quartz and plagioclase. Titanomagnetite occurs in isometric sections about 0.3 mm in diameter, in considerable amount, often associated with the dark minerals. Especially the pyroxenes are accumulated.

Apatite, as accessory mineral, occurs in prismatic sections; sometimes it is enclosed by biotite.

The groundmass consists of glass with a large number of small feldspar laths and microlites. The composition of these feldspars is difficult to determine, owing to their size, 0.01 to 0.08 mm, but in some case medium andesine was found. Small grains of the dark minerals, which occur as phenocrysts too, are present in the groundmass in moderate quantity.

Flow structure is exhibited by more or less directed felspar laths. Chloritic, perhaps some serpentinous substance occurs as fillings of the cavities.

The samples H 264^x and H 264, 265, 266^x represent another type of vitrophyric dacites. These are very dark bluish coloured lavas, very rich in glass, in which the amount of phenocrysts is notably smaller with respect to the just described rocktype. Plagioclase is dominating. Phenocrysts of this mineral with a maximal diameter of 3.5 mm, show zonal structure. Their composition varies from basic to medium labradorite, with alternating zones of basic and slightly more acid composition. Phenocrysts are rather exceptional; they show strong magmatic corrosion.

As femic constituents may be mentioned pyroxene and green hornblende in almost equal amounts. Hypersthene and augite both occur in fresh, unaltered sections; often in glomeroporphyritic aggregates. Most of the amphiboles have suffered total resorption, and have altered into opacite, which consist of a mixture of very minute grains of oxidic iron ore and pyroxene.

Often these amphiboles — which are frequently idiomorphically developed — enclose pyroxene, chiefly hypersthene.

The groundmass, which is rich in glass, contains a considerable quantity of small, (0.1 mm long), slender felspar laths, with a composition of acid andesine.

Many isometric grains of titanomagnetite, the diameter of which may range up to 1 mm, are scattered through the rock.

Another group of vitrophyric dacites (H 267 to H 271, H 274, H 282^x to H 289^x) macroscopically shows some differences from the first type. Contrary to this type, they are very light grey coloured rocks. An almost equal amount of phenocrysts is present, which causes a strongly porphyritic habit.

Especially H 267 is rich in hypersthene. Generally the plagioclases show many alternating zones of basic and slightly more acid composition, ranging from basic andesine to basic oligoclase. In these rocks, quartz phenocrysts are observable, but they are not frequent. For the rest the content of dark minerals agrees with that of the just described rocks, their mutual proportion in quantity however may vary somewhat. The glassy groundmass is partly pseudo-spherulitic and contains a considerable amount of quartz. Resorption borders around the amphibole are, however, absent. Sample H 281 shows glomeroporphyritic aggregates of plagioclase, with a composition of medium andesine.

Sometimes the outer margin of these accumulations contains a border of minute glass inclusions, often arranged parallel to the direction of the

c-axis, but parallel to the boundaries where the plagioclase individuals touch each other, these inclusions are absent.

As described in the other types, the mutual proportions in quantity of the feldspars, the quartz and the dark minerals is nearly constant for all these samples.

All these rocks contain an, although varying in quantity, always noticeable amount of vesicles, contrary to the samples H 273 and H 282^x.

These are greyish green to brown coloured rocks, very rich in glass, with clear phenocrysts of feldspar and quartz, which are sharply defined against the glassy base. The rocks are very dense and hard and have a conchoidal fracture.

In this type quartz phenocrysts are abundant; they are strongly corroded. The plagioclase is acid labradorite with most acid margins with a composition of medium andesine.

Among the dark constituents, — the same minerals as those, which were described in the other types —, the lamellae of the biotite are occasionally bent at their ends. The groundmasses of these two samples are somewhat different. Sample H 273 has a glassy base with a beginning crystallization, which is demonstrated by the presence of minute microlites, while the other rock is rich in pseudo-spherulites; most of these small, rounded grains are quartz.

H 260, is a pebble of the Meta Mahaiar. It is a black obsidian of probably dacitic composition.

It contains phenocrysts of quartz and feldspar. Again the quartz is corroded; the feldspar is zonally structured plagioclase with a composition of andesine.

Dark constituents are in order of decreasing quantity: biotite, green hornblende and hypersthene. Magnetite is not frequent, while apatite and zircon are rare. Resorption borders of the amphibole are absent.

A flow structure is indicated by more or less devitrified zones. The groundmass which forms the greater part of the rock is a real glass, without spherulites or microlites, while perlitic fractures occur.

Sample H 254^x is a greyish green dacitic rock, rather rich in glass, with a banded structure. Strongly porphyritic bands are alternating with fine grained zones.

The porphyritic bands of this rock greatly resemble the fully described porphyritic vitrophyres of dacitic composition. Besides phenocrysts of quartz and feldspar, green hornblende occurs as the only dark constituent. Often these phenocrysts of amphibole are strongly resorbed and the entire individuals are built up of opacite, consisting of small grains of magnetite

and pyroxene. The groundmass is rich in glass, with many small pseudo-spherulites, 0.01 to 0.05 mm in diameter, and chiefly consisting of quartz.

In the fine grained zones the phenocrysts are strongly decreasing. The rock chiefly consists of glass, with a large number of pseudo-spherulitic and spherulitic bodies.

These vitrophyric dacites contain a considerable quantity of small, generally only a few centimetres large, homoeogeneous inclusions. These inclusions consist of a glassy base, in which plagioclase and amphibole are mainly found as phenocrysts. Biotite is present in moderate amount, while hypersthene is very rare and always surrounded by a border of green hornblende. Resorption-borders of the green amphibole are entirely absent (Plate VIII, fig. 1).

The plagioclase occurs in short-prismatic sections. The generally zonally structured individuals, have a composition which varies from basic labradorite in the cores to albite-oligoclase in the most acid margins.

J. D. DE JONG described these inclusions more fully in vitrophyric dacites from western Wetar.

Rhyolite (H 278). The structure of this rock is almost similar to the rhyolites which will be described from Tandjoeng Illipoi.

Phenocrysts of quartz and felspar, with an average diameter of 0.8 mm are found in an entirely crystallized groundmass. Especially quartz phenocrysts are abundant. The individuals, which are often present in hexagonal or lozenge-shaped sections, have a border of granophyre, 0.1 to 0.3 mm in diameter (Plate VIII, fig. 2). The quartz of the granophyric intergrowths shows simultaneous extinction with the main crystal. The weakly zonally structured plagioclases are andesine, with slightly more acid margins of oligoclase-andesine. Orthoclase in phenocrystic individuals is present as well.

The groundmass is very fine grained; glass is absent. Quartz and alkali felspars are the main constituents. A moderate amount of well-developed spherulites is observable; occasionally a small quartz grain is found in the centre of these individuals, which consist of alternating fibres of quartz and alkali felspar.

Chloritic fibres are fairly abundant in this rock. Magnetite and apatite are present as well in small amounts.

Albitization of the felspars is a dominating feature.

THE SURROUNDINGS OF ILWAKKI.

- A. Tandjoeng Illipoi.
- B. The region between the lower courses of the M. Sae and M. Hoe-ro, near the south coast.

A. TANDJOENG ILLIPOI.

Tandjoeng Illipoi is situated SE of the central bivouac Ilwakki, the most important village of the island. It is a small hill, the base of which stretches out in the sea as a cape. The height is about 70 metres; the top is covered with coral reef limestone. Along a small part of its base at the coast, intrusive- and dike rocks are exposed. The greater part, however, is covered by upheaved reef limestone. The mutual relations of the exposed rocks are not very distinct. Granodiorites are frequent here, with more basic quartz-dioritic differentiates. Generally these rocks are fine grained, while a somewhat porphyritic appearance is shown by the quartz-diorites.

Another member is a strongly porphyritic, light greyish coloured rock. Sometimes this rock type occurs as dikes in the granodiorites, in other places the relation with the granodiorites is very indistinct and the rocks makes the impression of being a lava, covering the granodiorites. It is difficult to say whether the rocks represent dike- or effusive rocks, and it is most probable that both occur, without showing much difference. Some sections show these rocks doubtless as dike rocks (Fig. 4).

This rock, as will be seen in the chapter on petrography, has been called sanidine-albite-rhyolite (containing pseudomorphs after cordierite).

As the third group of rocks in this region a typical dike-rock may be mentioned. It is dark bluish-green coloured, fine grained rock. The fresh rock type has been called albite-dolerite, while the strongly decomposed variety agrees with the albite-diabases. These dolerites (diabases) occur as dikes, of varying thickness, ranging from 10 cm up to several metres in the granodiorites, and in the rhyolites as well. As to the succession of intrusion of the dike-rocks, it may be stated here that both have intruded the granodiorite more or less contemporaneously. Field observations revealed that inclusions of doleritic composition occur in the rhyolites and, conversely, inclusions of rhyolites are present in the dolerites. The contact planes between the dikes and the granodiorite are sharp; contact phenomena between the diverse rocks have not been obser-

ved. As to the mutual relations between the intrusive rocks and the lavas, with which the island is covered, no field observations could be obtained. In the region where the former rocks are exposed, they are covered with reef limestones. As we shall see later on, contacts between lavas and intrusive rocks are also lacking in the region of the M. Saoe.

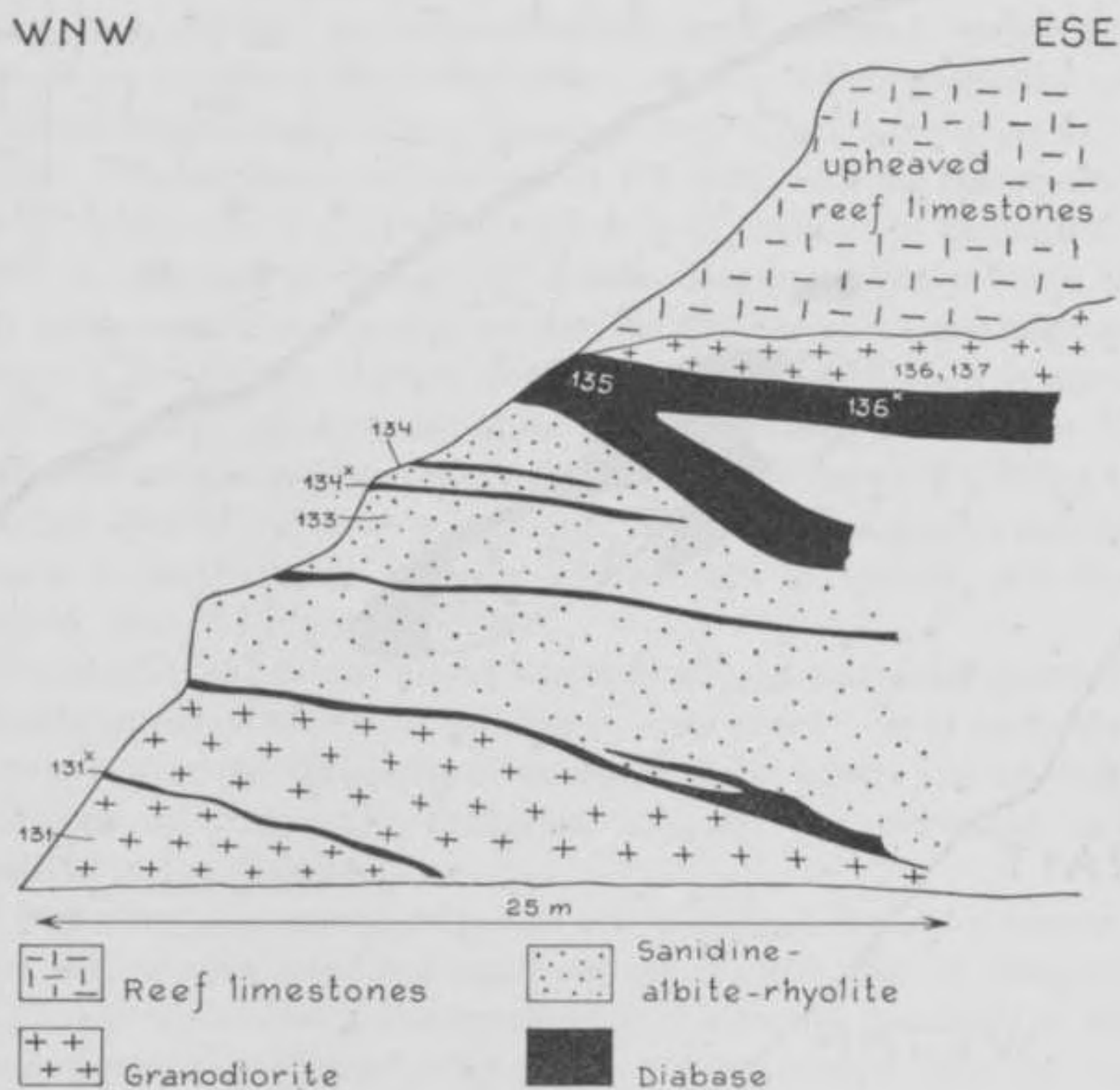


Fig. 4.

Section A (see Fig. 6). Tandjoeng Illipoi, Wetar. Granodiorite with dikes of sanidine-albite-rhyolite and diabase.

The whole complex of rocks has been fractured considerably; so many joints cut through the rocks.

PETROGRAPHY:

The igneous rocks of the investigated region are classified as follows:

1. Granodiorites to quartz-diorites.
2. Sanidine-albite-rhyolites.
3. Albite-dolerites and albite-diabases.

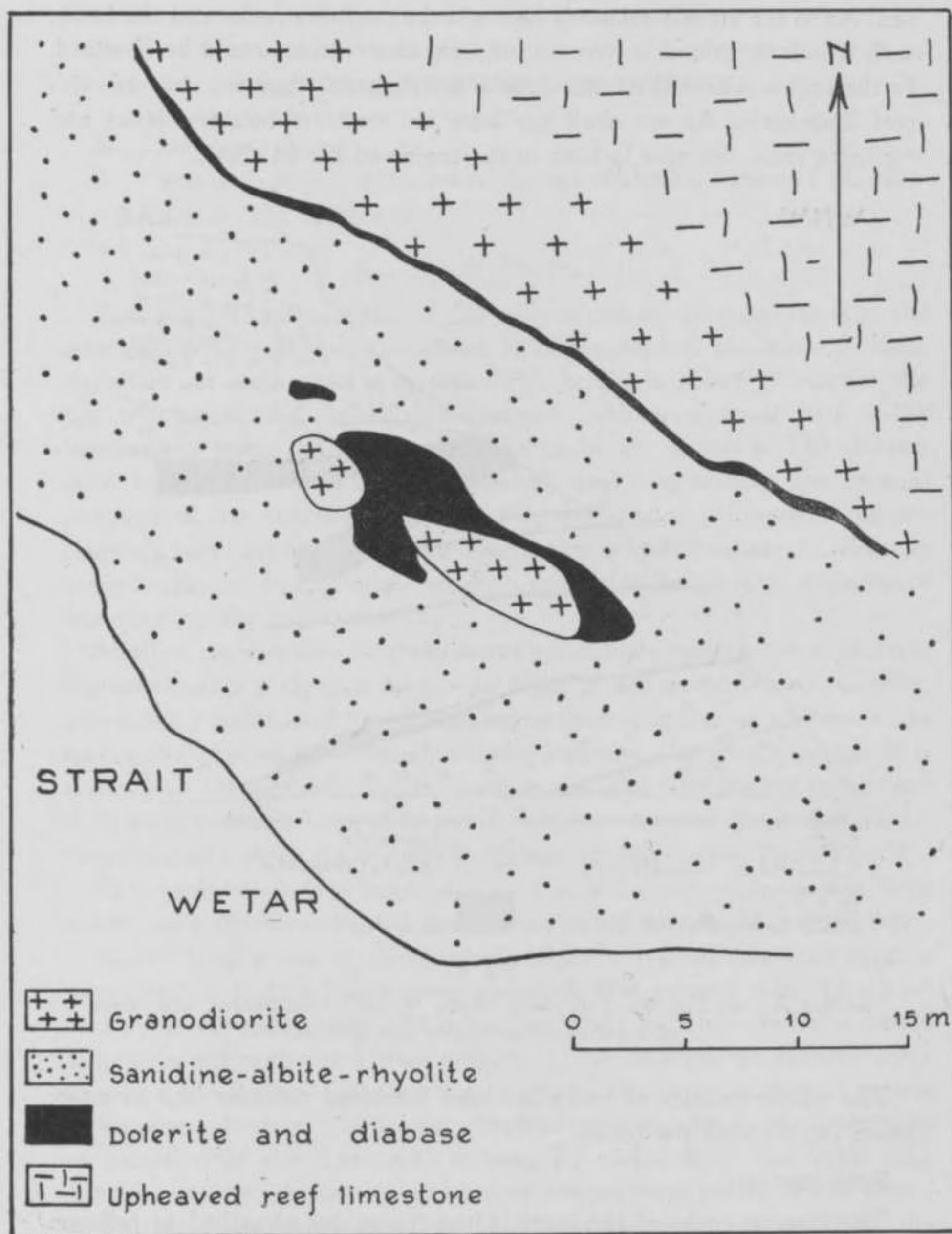


Fig. 5.

Geological sketchmap near B (see Fig. 6). Tandjoeng Illipoi, Wetar.

1. Granodiorites to quartz-diorites.

a. *The granodiorites* (H 164^x, H 164, H 166).

In these rocks acid plagioclase is strongly dominating over alkali feldspar. Alkali feldspar — albite as well as potash feldspar — are present, but generally not abundant.

The granodiorites are holocrystalline, even grained, yellowish-grey coloured rocks with a hypidiomorphic structure. Macroscopically quartz, weathered feldspar and biotite are recognizable. Quartz occurs as anhedral crystals, with an average diameter of 1.2 mm; most of the crystals are broken, while the fractures are filled with secondary carbonate. The quartz is clear and contains only a subordinate amount of very minute glass inclusions. The feldspars are for the greater part acid plagioclases; sometimes they show weakly zonal structure, whilst their composition varies from andesine (the anorthite content ranging up to about 45 %) in the core, to albite-oligoclase in the margin. Twinning according to the Carlsbad- and albite laws is frequent. Under the microscope the feldspar appears to have rather strongly altered into muscovitic and kaolinic products, as well as into carbonate.

It seems that the alkali feldspar has been altered most, and consequently its determination is often difficult, but in some cases it could be determined safely as orthoclase. Granophyric intergrowths of quartz and alkali feldspar occur, but are rare. The orthoclase crystals are sometimes twinned according to the Carlsbad-law.

A beginning albitization, especially of the alkali (potash) feldspar, was found. The cloudy spots and small strings of albite, can be recognized in occasionally clear, less altered orthoclase. Generally the albite is seen as irregular veinlets within the plagioclase, but this feature does not come to the front.

Quartz and feldspar are present in almost equal amounts, sometimes the feldspar is dominating. The most important dark constituent is biotite, strongly pleochroic from very dark brown to bright yellowish-brown. In consequence of decomposition the biotite often shows green colouring; there are many gradations to chloritic minerals. This mineral shows large cleavage sections, as well as large accumulations of smaller fibres. Part of the biotite has been replaced by quartz so that poikilitic biotite crystals occur more or less inundated by quartz. A considerable amount of grains of oxidic iron ore is scattered through the biotite, while many lenticles of minerals of the epidote group are enclosed by this mineral. Epidote, pleochroic from colourless to yellowish-green, with vivid interfer-

ence colours, as well as weakly birefringent members of the epidote group with ultra blue interference colours are present.

Green hornblende occurs, but only in a few crystals. It is pleochroic from pale green to dark green. The crystals are irregularly bounded.

As accessories orthite, apatite and zircon should be mentioned. Orthite, which is rather frequent, occurs in grains of 0.2 mm in diameter, and exhibits a strong pleochroism from light brown to very dark brown. Apatite, in slender prismatic sections, is sometimes enclosed by zircon.

Sericite, kaoline and carbonate are the main secondary products, but chlorite, limonite and minerals of the epidote group occur too. As a result of tectonic stresses a weak undulose extinction is recognizable within the quartz. The fractures in the quartz and felspar, as well as the bent shapes of some biotites are due to the same phenomenon.

As has already been stated quartz-diorites also occur. All gradations between granodiorites and quartz-diorites are present. Macroscopically a gradual increase of dark minerals is observed, going from the common granodiorite to the quartz-diorites. Some types, showing these gradual transitions, will be described successively:

Sample H 139^x agrees with a normal granodiorite — the main type just described. The diameter of the grains varies between 1.5 and 3.5 mm. The basic cores of the plagioclases have altered totally into muscovite, carbonate and fine grains of minerals of the epidote group. The plagioclase shows zonal structure and has a composition of basic andesine in the cores to albite-oligoclase in the outer margin. Some plagioclase crystals contain a large number of small quartz grains, irregularly arranged. This phenomenon should be regarded as a replacement of felspar by quartz. Often wisps of plagioclases (sometimes entirely albitized) in a "sea" of quartz are seen. GILLULY (15, p. 65) and FREEMAN (13, p. 687) both described similar replacement phenomena in granites and quartz diorites.

Biotite, as we saw, is the characteristic dark mineral of this rock type, although green hornblende is present in very subordinate amounts.

H 139. This sample exhibits an increase of the dark constituents, especially of the green hornblende.

The proportion between quartz and felspar is the same (perhaps somewhat more felspar) as in H 139^x. The felspars have altered in a similar manner as in the preceding sample, and are consequently difficult to determine.

The dark minerals consist of green hornblende with biotite in smaller amount. Some crystals of amphibole show good idiomorphic boundaries; twinning according to (100) is not common. In general the amphibole is

fresh, this in contrast to the biotite; but the cores of the large crystals are bleached. Biotite is rich in grains of magnetite and minerals of the epidote group. When it is unaltered the biotite occurs in ragged flakes. Sometimes this mineral surrounds the green hornblende.

Similar secondary products as well as accessory constituents, except orthite, as in H 139^x, are present here.

H 138^x shows a further increase of green hornblende and a decrease of biotite. The dimensions of the amphibole are generally considerably smaller, except some large crystals of 1 to 1.5 mm in length. Alteration of these dark minerals into chlorite is common. A decrease of the amount of quartz may be observed, whilst the plagioclase becomes somewhat more basic in its cores. Acid labradorite (with an anorthite content of 55 %) in the cores, is common in this rock. Alkali feldspar is present, but only in small amount. Probably it is albite, but this could not be determined with certainty. But seeing that small veinlets of albite do occur in the unaltered plagioclases, it is probable that the entirely decomposed alkali feldspars are of albitic composition. A general feature is that the orthoclases are attacked sooner by albitizing solutions than the plagioclase.

The secondary constituents are again the same as in H 139^x, as well as the accessories. Titanite partly altered into leucoxene may be observed in small grains in this rock.

b. The quartz-diorites (H 137, H 149^x).

This type has a somewhat porphyritic character, in consequence of the size of the plagioclases, which may attain a length of 5 mm. All of them have strongly altered into muscovite. Large, poikilitic quartz crystals inundated with feldspar laths and fibres of green hornblende are present. The zonally structured plagioclase shows twinning according to the albite- and Carlsbad laws, sometimes according to the Pericline law. Their composition ranges from albite-oligoclase in the margin up to medium-labradorite in the cores (with an anorthite content of 60 %). Fluid- and glass inclusions in the feldspar and quartz are rare. Similar replacement by quartz as has been mentioned of sample H 139^x, may be observed in this rock. It is not certain whether orthoclase is lacking. Some fragments would suggest the presence of this mineral in inconsiderable amount. The dark minerals are pyroxene, amphibole and biotite. The pyroxene is colourless to light green augite, which is present in a few idiomorphic crystals, always surrounded by a rim of green hornblende. Most of these augite crystals are strongly decomposed, as they are the most labile constituents of the rock. In some cases the entire augite crystal

has altered into pale green to colourless amphibole (probably the actinolite variety), which then shows the same optical orientation as the surrounding rim of green hornblende, as it shows simultaneous extinction. Other pyroxene crystals have entirely altered into carbonate. Along fractures in the fresh, unaltered parts of the augite, uralitization has taken place and consequently finely divided fibres and fluffy material, consisting of colourless to greenish-brown coloured amphibole together with limonitic substance and very fine grained carbonate may be observed.

Sometimes a distinct herringbone structure is visible in the augite.

The greatest part of the dark minerals is formed by the green hornblende, partly as idiomorphic crystals, partly as subhedral accumulations. Twinning is seldom. The average diameter is about 1.5 mm, but crystals of 0.5 mm are rather frequent.

The amphibole and the felspar will have crystallized about simultaneously. Amphibole includes plagioclase and conversely. They have impeded each other's growth during the crystallization, except the large plagioclase-crystals. In a few cases amphibole is present in the cores of these large phenocrysts, in other places the outer border of these crystals contain many small amphibole fibres.

Biotite occurs in a few corroded crystals. This mineral, as well as the amphibole shows alteration into chlorite (penninite).

Summarizing a gradual transition from granodiorite to quartz-diorite is shown. A gradual increase of the basicity of the plagioclases occurs from medium to basic andesine in the granodiorites to medium labradorite in the quartz-diorites. An important increase of the dark minerals, particularly of the green hornblende is observed and in the quartz-diorite the appearance of augite. The decrease of the amount of quartz may also be mentioned. Lastly there is the decrease and the approximate disappearance of the biotite, as well as the decrease of the orthoclase content.

The quartz-diorites must be considered as basic differentiates from the magma. They occur as bulbous tubers or as elongated lenticles in the granodioritic rocks up to several meters in size.

2. Sanidine-albite-rhyolites.

As has been stated before the geological position of these rocks is somewhat dubious. In several cases they are distinct dike-rocks, but sometimes their position is indistinct and then they appear to be effusive rocks. These types show slight differences and therefore we can distinguish two types of rhyolites. The first type is that of which it is known with certainty

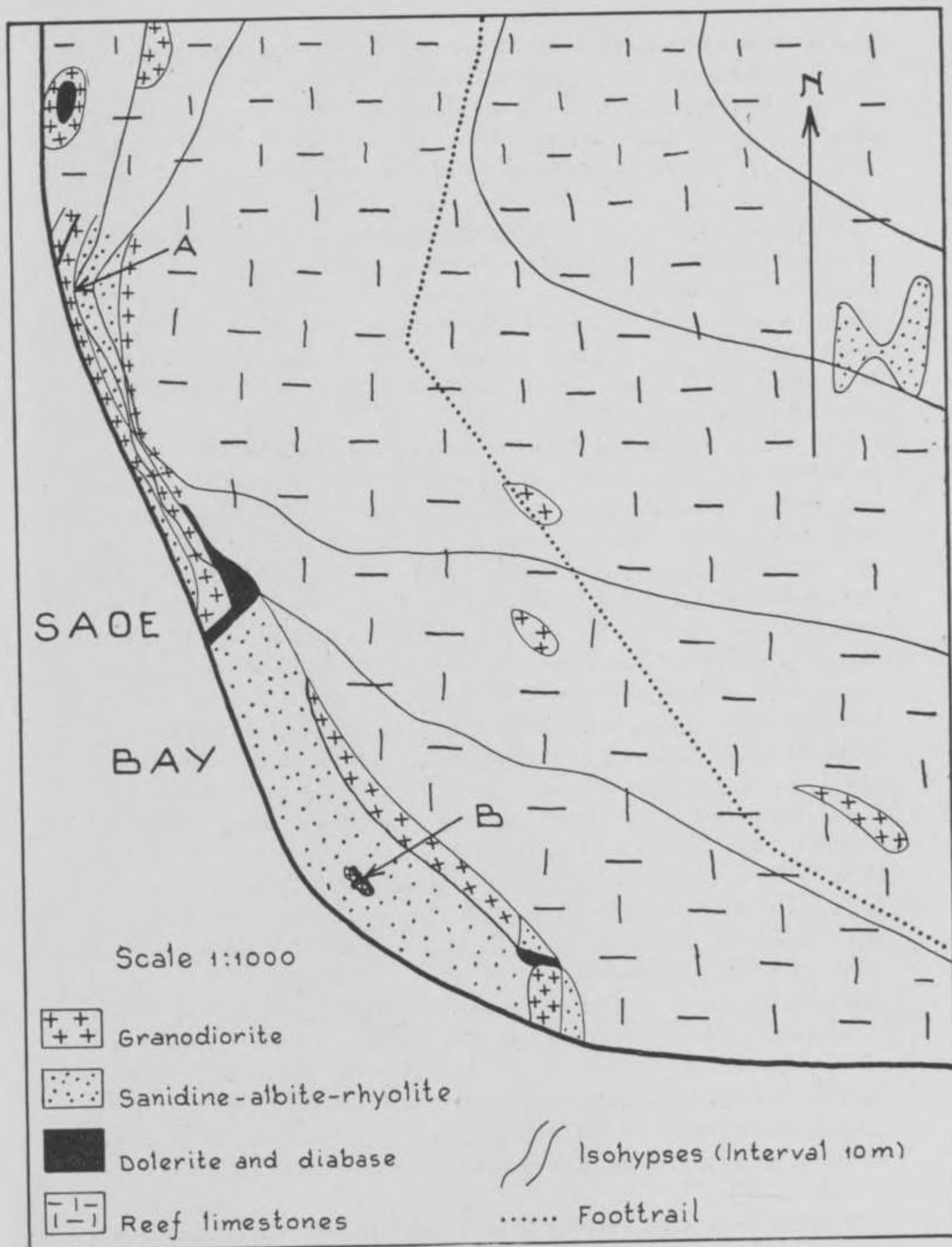


Fig. 6.

Geological sketchmap of Tandjoeng Illipoi, Wetar. Scale 1:1000.

A and B indicate the location of Fig. 4 and Fig. 5.

that it occurs as dikes, while the second type corresponds with those rocks of which the geological position is dubious.

The first type (H 177 $\times$, H 134, H 133, H 167) is a porphyritic light grey to greyish-green coloured rock. Macroscopically it exhibits phenocrysts of quartz, felspar, biotite and pseudomorphs after cordierite in a felsitic groundmass.

The quartz phenocrysts, which are dominating over the felspars, show idiomorphic boundaries as well as corroded outlines partly with rounded angles, another part with large embayments, while now and then only skeletons of quartz have resulted. Most of the phenocrysts are clear; a small part, however, contains minute liquid- or/and glass inclusions. Undulose extinction may be observed, but is rare. The diameters vary from 0.5 to 1.5 mm.

The felspar has for a great part idiomorphically developed. Part of it is twinned according to the albite- and Carlsbad laws, rather seldom it is twinned on the Pericline law. The felspars all have a cloudy appearance so as to obscure the exact value of the refringence. But both refractive indices are lower than that of Canada balsam. We can distinguish acid plagioclase as well as alkali felspar. The acid plagioclase was determined as albite¹⁾. The other alkali felspar is a potash felspar. Determinations with the U. St. show that this felspar is biaxial and negative with a very small axial angle ($2V = 6^\circ$); this would point to sanidine. Carlsbad twins in the sanidine occur. Kaolinisation has coloured the felspars brownish; partly they have altered into sericite and carbonate. The biotite is strongly pleochroic from dark brown to light yellowish brown. A great part has altered into chlorite. Often the chlorite is represented by the penninite-variety, with ultra-blue interference colours. Many dull brown grains of limonite are scattered through the biotite and chloritized biotite. The average diameter of the mineral grains in the groundmass is about 0.02 mm. This groundmass consists of very small felspar laths of albitic composition, but the greater part is formed by a fine grained aggregate of quartz and alkali felspar (probably potash felspar), in which many small flakes of sericite and chlorite, as well as small grains of carbonate occur. Magnetite occurs rather seldom, while apatite is somewhat more frequent. Secondary products are carbonate, sericite, chlorite, kaoline and minerals of the epidote group. The latter, in a few grains, occurs as an alteration product of the felspars.

¹⁾ When the term albite is used, it means that the composition of the felspar is generally varying between albite and albite-oligoclase.

The second type (H 172, H 173, H 175×, H 70×).

Macroscopically this type is different from the just described one. In a brownish coloured fine-to medium grained, holocrystalline groundmass large feldspar phenocrysts (up to 8 mm in length), quartz of somewhat smaller dimensions, some feldspar minerals and pseudomorphs after cordierite are present. This type has a strongly porphyritic structure. The quartz phenocrysts show the same features as in the first type; magmatic corrosion is abundant. Very small fluid- or glass inclusions are present in the same amount as in the first type.

The feldspars in this rock are the same: Acid plagioclase and potash feldspar. The sanidine phenocrysts range in diameter up to 8 mm; their core is very clear, while they have rather broad rims of cloudy, greyish-white albite.

Along veinlets, little fractures and cleavage planes, the albite has penetrated into the core of smaller sanidine phenocrysts, and often has altered these entirely. In some places we may speak of perthites and antiperthites, for sometimes albite individuals with only small fragments and spots of potash feldspar may be observed. Doubtless this phenomenon is of secondary origin. As we shall see afterwards, there are other phenomena which will confirm this opinion.

The acid plagioclases, of albitic position, are polysynthetically twinned. The extinction angles in sections of the symmetrical zone range up to about 14° ; where observable, the refractive indices are lower than that of Canada balsam.

The amount of biotite in this type is slightly larger, than in the first type. Part of it has altered into chlorite (penninite).

The groundmass is of different structure in comparison with the first type, although the chemical composition of the whole rock will be equal. Part of the groundmass is formed by numerous granophyric intergrowths of quartz and alkali feldspar. A rather common phenomenon is a rim of granophyre around the quartz phenocrysts, which have often developed in lozenge shaped sections.

Little albite laths are abundant in the groundmass. As in the first type apatite occurs in small prismatic individuals. The secondary products are sericite, kaoline, carbonate, minerals of the epidote group, leucoxene, limonite and chlorite. Many feldspars are brownish coloured and cloudy, in consequence of kaolinization and albitization. The groundmass of this type is phanerocrystalline.

The pseudomorphs after cordierite.

The pseudomorphs after cordierite in these rocks show well-shaped idiomorphic boundaries. Already macroscopically the short prismatic crystals, which may attain a diameter of 6 to 7 mm, are distinguishable. Their colour is always bluish-green to greyish-green. Prismatic sections are quadrangular (Plate X, fig. 2), base sections six-sided (Plate X, fig. 1), then often with rounded angles.

Twins are rather frequent. Many individuals show on their base the well-known penetration twins with (110) as twinning plane. The separation between the singular fields is often sharp, but there are examples, where these singular fields enclose more or less regular parts of the neighbouring individuals. It was already stated that only pseudomorphs after cordierite occur, except in one case where in the centre of a pseudomorph, a fragment of unaltered cordierite is present. With U. St. it was determined that the cordierite was biaxial and negative with $2V = 76^\circ$. The birefringence is low, approximately corresponding with that of quartz. Pleochroism is absent.

Several inclusions are found in these pseudomorphs, chiefly represented by apatite, less by zircon or some particles of oxidic iron ore and rather rarely by rutile. Partly the rutile is enclosed as thin prismatic crystals by apatite. In some pseudomorphs dark yellowish-brown rims around the zircon crystals can be observed. WEINSCHENK (37, p. 128) points out that pleochroic haloes in pseudomorphs after cordierite will be preserved as yellowish-brown coloured spots.

The alteration of cordierite, which produces several different pseudomorphs, has been studied by several authors, chiefly by WICHMANN (38, p. 675) and GAREISS (14, p. 1). These authors came to about similar results. WICHMANN studied the whole course of the process and found that the cordierite does not alter into muscovite at once, but that between the fresh cordierite and the endproduct, there is a stage, where the original mineral becomes isotropic. WICHMANN called this substance "Zwischensubstanz". Generally the alteration process of the Illipoi-cordierites agrees with the phenomena studied by WICHMANN and GAREISS. The isotropic substance may be observed in several places in the pseudomorphs, and is always yellowish-grey to yellowish-brown, sometimes dark brown coloured. Most of the cordierites show a further phase of alteration with more or less large rims and veins of muscovitic (sometimes pinitic or sericitic) and chloritic substance, while the isotropic substance is often present in the core of the pseudomorphs. Serpentinous

material as decomposition product could be observed as well. Part of the cordierites has completely altered into the endproducts. In the slices their colour varies from greyish-yellow to brown. The greater part of the pseudomorphs consists of greenish to brownish coloured chloritic flakes, with very small extinction angles and with low birefringence. Frequently the fibres are indefinitely arranged, sometimes however they show distinct parallelism in particular parts. In other cases the whole pseudomorph consists of parallel fibres, so that an almost simultaneous extinction may be observed.

Finely divided, brown limonitic substance occasionally forms the margin of the pseudomorphs.

Similar pseudomorphs after cordierite have been studied by H. DE JONG (20) in cordierite-bearing rocks from the Kaibobo-region (Western Ceram,



Fig. 7.

PLATE IX.

Fig. 1.

Pseudomorph after cordierite, in a sanidine-albite-rhyolite from Tdj. Illipoi, Wetar. The alteration products are minerals of the epidote group, radially arranged. Between the tabular aggregates some chloritic substance is found. Ordinary light (37×).

Fig. 2.

Phenocryst of sanidine with a rim of albite (turbid zone) in a sanidine-albite-rhyolite from Tdj. Illipoi, Wetar. Right below, a somewhat corroded quartz crystal. Below in the middle, a small pseudomorph after cordierite has been enclosed by the felspar. Nicols crossed (17.5×).

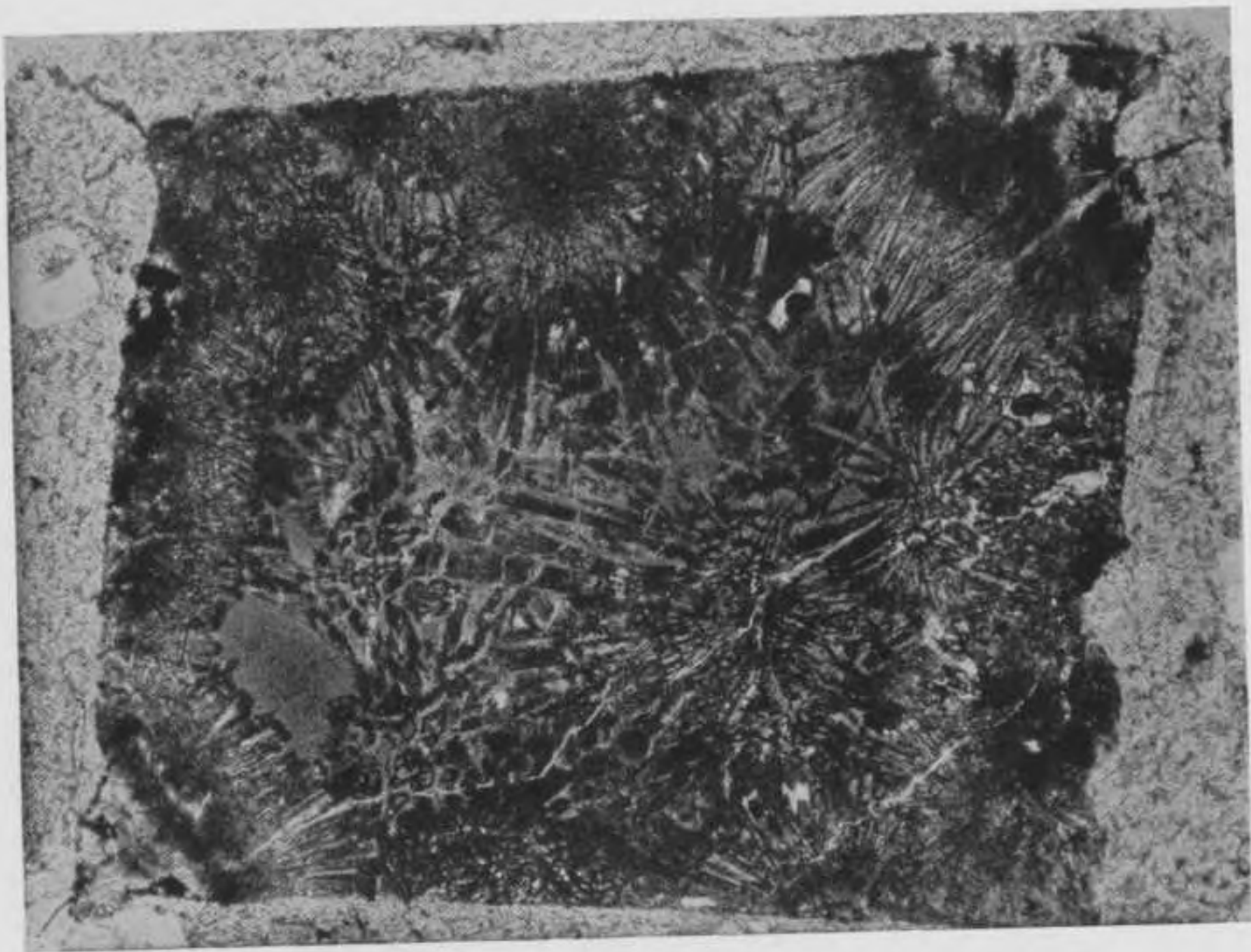


Fig. 1.

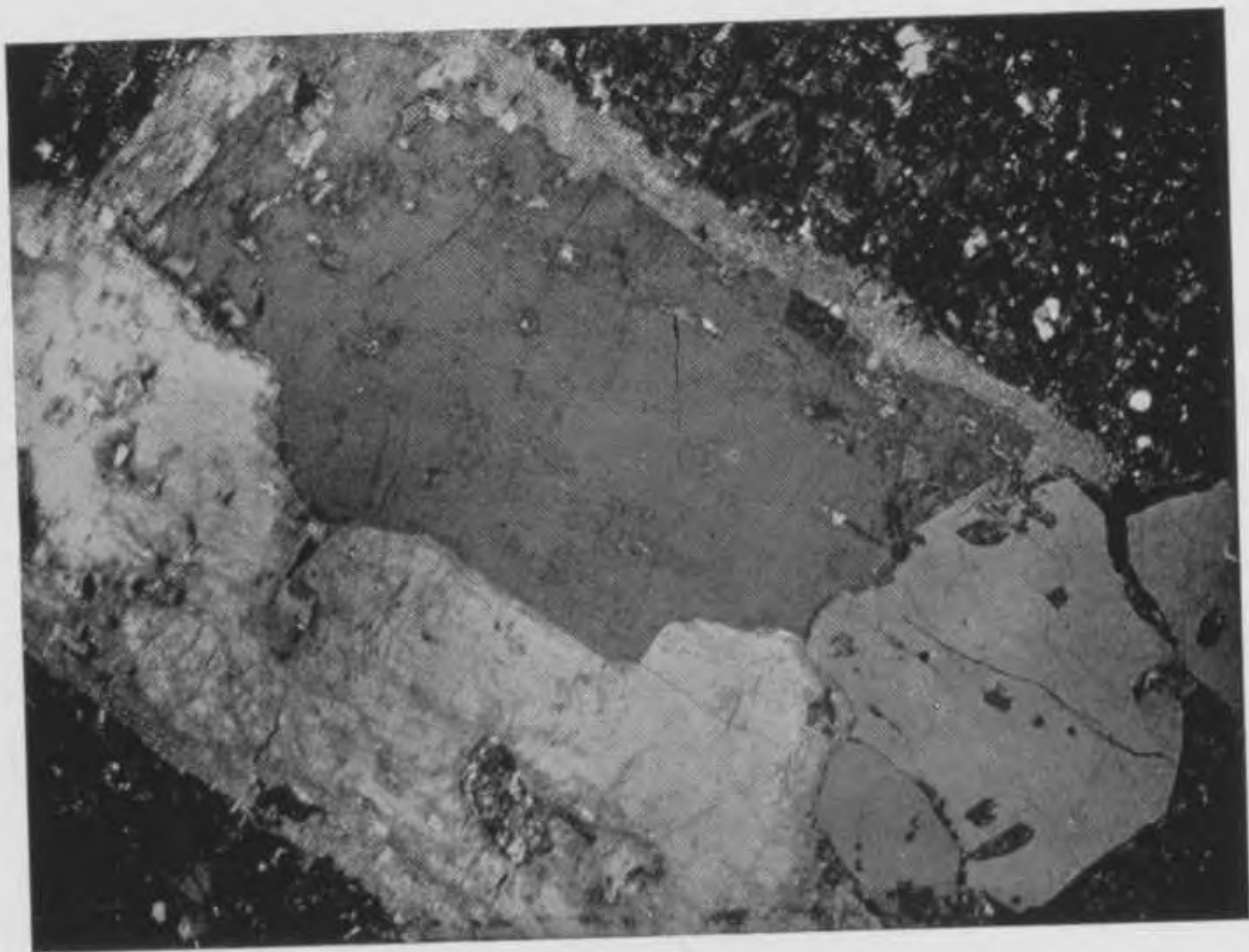


Fig. 2.



Fig. 1.



Fig. 2.

PLATE X.

Fig. 1.

A six-sided base section of cordierite, altered into muscovite and chlorite. The surrounding groundmass consists for the greater part of micrographic intergrowths of quartz and alkali felspar. Sanidine-albite-rhyolite from Tdj. Illipoi, Wetar. Nicols crossed (125×).

Fig. 2.

Prismatic sections of pseudomorphs after cordierite in sanidine-albite-rhyolite from Tdj. Illipoi, Wetar. The rectangular bordered, clear parts in the centre of the crystal are built up of isotropic substance, whilst the rest of the pseudomorphs consist of chloritic and muscovitic fibrous alteration products. Ordinary light (71×).

N. E. I.). In sample H 177 $\times$ a pseudomorph after cordierite shows a rather broad margin, consisting of alkali felspar (most probably albite) and green coloured, strongly pleochroic chlorite. On the border between this zone and the core there follows a narrow strip of sericitic fibres, whilst the core itself contains alternating strips of colourless sericite and darkbrown to yellow coloured chlorite, together with the isotropic substance (Fig. 7). Another pseudomorph in sample H 134 shows a short prismatic individual, consisting of minerals of the epidote group, arranged in radial groups (Plate IX, fig. 1). Epidote (pistacite) with interference colours which may range up to the third order, and weakly birefringent members of the epidote group with ultra-blue interference colours are present.

There are columnar aggregates, elongated in the direction of the b-axis and sections cut perpendicular to "b", with lozenge shaped boundaries, and between these crystals, an almost isotropic chloritic substance, will be found.

As to the pseudomorph in H 177 $\times$ it is probable that first the whole crystal has altered into muscovitic and chloritic fibres, except some isotropic substance, and that afterwards albitizing solutions have intruded, in consequence of which the margin, consisting of alkali felspar, has developed. BENSON (6, p. 596) describes keratophyres of the Tamworth district with albite pseudomorphs after pyroxene. It is possible that similar metasomatic processes, as have been suggested by BENSON, have played an important part in the Illipoi-cordierites. As to sample H 134 it should be stated that there is only one example of epidote pseudomorphs after cordierite, while in all other pseudomorphs this mineral is lacking. In this case, too, it is most probable that first the whole phenocryst has altered into chloritic and isotropic substance, while the minerals of the epidote group were formed afterwards. Perhaps we have to deal with a local concentration of epidote minerals. The amount of lime required for the formation of the epidote may have been furnished by the albitized plagioclases, which were probably present in the rhyolites. It remains unsufficiently explained why only one of such pseudomorphs has been found.

In these Illipoi-rhyolites the cordierites may be regarded as one of the earliest crystallization products, as pseudomorphs of cordierite are enclosed by quartz and sanidine phenocrysts (Plate IX, fig. 2). Sporadically the cordierite has been corroded; then the embayments are filled up with groundmass material, chiefly with quartz and albite.

In consequence of the supply of alkaline solutions from the magma the various alteration products of the cordierites have been originated. That

alkaline solutions have circulated in these rocks, is shown by the excellent albitizing phenomena, which occur in the sanidine-phenocrysts.

3. Albite-dolerites and albite-diabases.

The rocks from Tandjoeng Illipoi described here are undoubtedly dike-rocks.

As we saw in other regions, there are analogous rock types of which it is not known whether they represent hypabyssal or effusive rocks.

The main difference between dolerites and diabases is that the first mentioned type has fresh augite and plagioclase, in contrast to the diabases, where these constituents are very decomposed. In general one considers the diabases as strongly altered dolerites. Their structure is identical; ophitic to sub-ophitic structure is present in both types. But the fresh augite of the dolerites has entirely altered into chlorite in the diabases.

In this region the dolerites as well as the diabases have acid plagioclase, with a composition of albite. Although there is no evidence for it, one is bound to accept a secondary origin of the albite. In the diabases these albite laths show other alteration processes as will be described further on.

Dolerites (H 135 and H 136^x).

They are fine grained, holocrystalline rocks, with a dark blue-green colour. Microscopical investigation of thin sections reveals that they exhibit a sub-ophitic structure. The felspar laths may attain a length of 0.7 mm, while the average diameter of the pyroxene is 0.4 mm, sometimes 0.7 mm.

Besides plagioclase and augite, titanomagnetite and chloritic substance are frequent.

The felspar is albite, which is very cloudy in consequence of kaolinization, but this is caused by the presence of minute fibres of chlorite as well. Alteration into carbonate and sericite, as well as into minerals of the epidote group occur.

Generally the augite is fresh; only a slight alteration along the borders of this mineral is observable. The somewhat brown coloured borders mainly consist of chlorite, but occasionally a fibrous amphibole is present. These brownish alteration products give a dirty impression to the rock.

Besides that of augite, the content of chlorite is rather considerable; often the variety penninite can be observed.

The titanomagnetite, which is practically unaltered, is present in minute, 0.05 to 0.1 mm, grains with idiomorphic boundaries.

Albite-diabases (H 167×, H 162, H 174×).

These rocks are fine grained and holocrystalline, with a dark green colour. They are less fresh than the just described albite dolerites, from which they only differ by the presence of more alteration products.

Microscopically they show the same structure as the just described rocks.

The acid plagioclase is albite. Polysynthetic twins occur. All the feldspars have a cloudy appearance, caused by the alteration products kaoline and chlorite.

Pyroxene is absent, whilst chlorite occurs in considerable quantity. Another difference from the albite-dolerites is the occurrence of some quartz in the diabases. Part of it is of secondary origin and has been infiltrated, but another part is undoubtedly interstitial, and should be considered as one of the last crystallization products of the magma. The quartz is wanting in the albite-dolerites from this region, but from other parts of the island quartz-dolerites have been described.

Oxidic iron ore is present in equal amount as in the former rock type. Other secondary products are carbonate, sericite, minerals of the epidote group and limonite.

Several gradations between these two types of rocks occur, dependent on the grade of alteration of the rocks.

B. THE REGION BETWEEN THE LOWER COURSES OF THE M. SAOE AND M. HOEROE (see Map V).

This region is hilly, with a maximal height of about 150 m. The M. Saoe shows many exposures in granodiorites, in which a large number of dikes

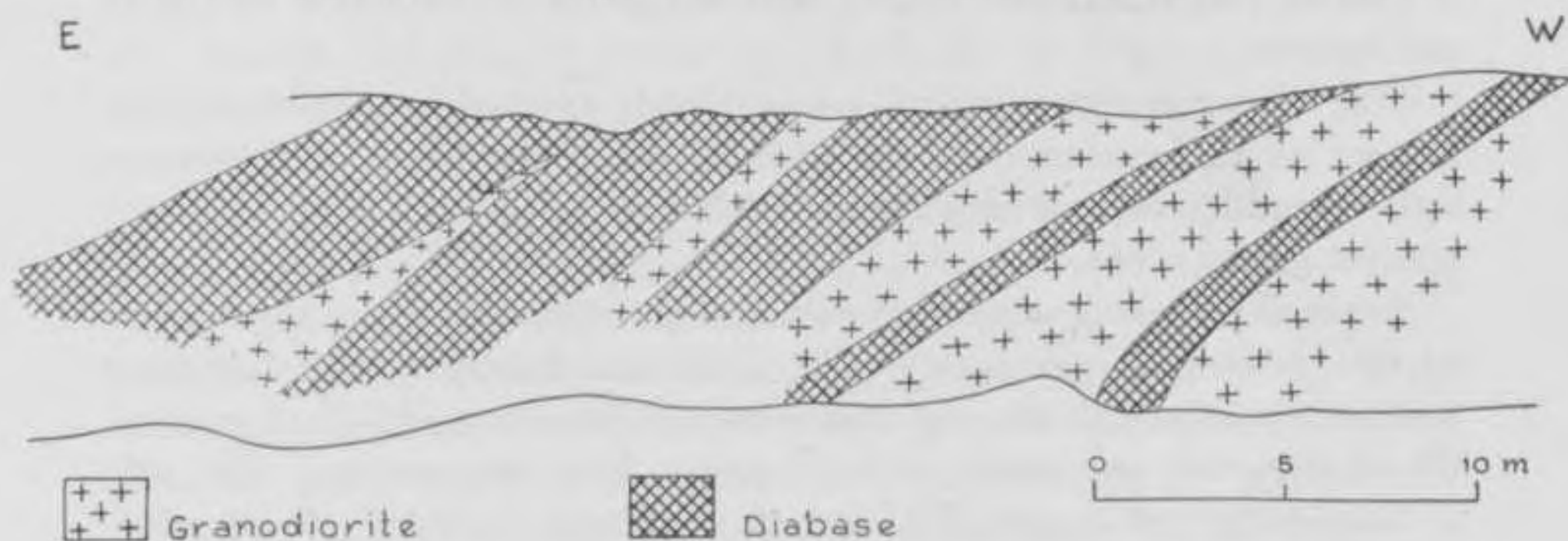


Fig. 8.

Left bank of the M. Saoe (Wetar) (1 km from its mouth).

Dikes of diabase in granodiorite.

are present. Dikes of albite-dolerites and albitized quartz diabases and of sanidine-albite-rhyolites are found, while quartz-albitites and albitophyres also occur.

Sometimes these intrusive rocks are covered by lavas, as e.g. about 1500 m from the coast upriver, where quartz-keratophyres (H 79 $\times$) and dacite-breccias (H 77 $\times$) cover granodiorites. Further to the North, the M. Sae shows several exposures in albite-rhyolites (H 81, 82, 82 $\times$), while in this region a small tributary, the M. Saoerahan was passed. 1 km North from this river outcrops of dacites (H 83 $\times$) and quartz keratophyres (H 83) were found.

Going from the M. Sae in western direction some smaller rivers are passed. The M. Sosai, the M. Hoehan and M. Wenar give good exposures of solid rocks in their river valleys.

The country between these river valleys is mostly covered with raised reef limestones; the terraces of 5, 25 and 40 m are rather well-developed here.

The M. Sosai, which we reach first, shows a large exposure in volcanic

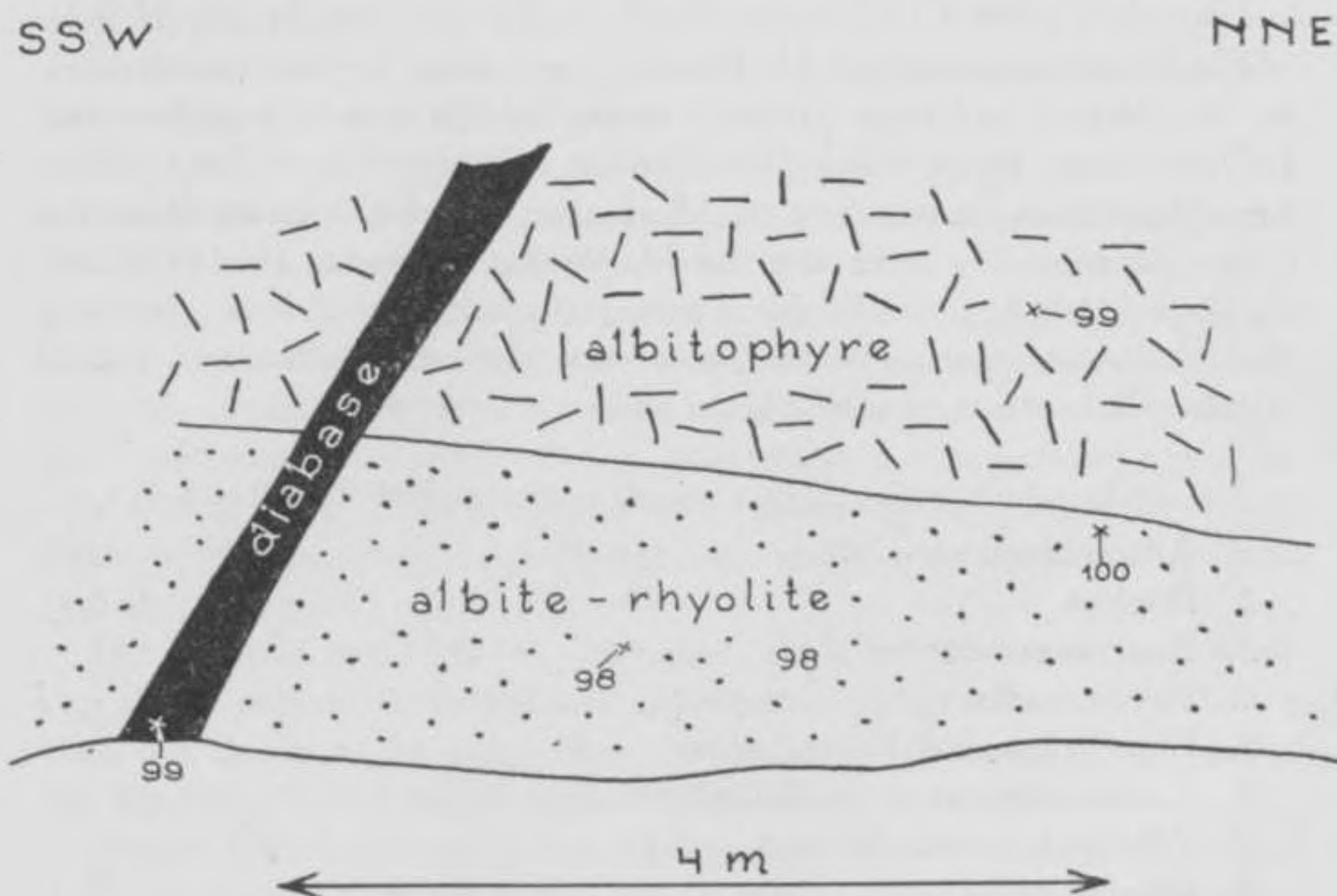


Fig. 9.

Right bank of the M. Sae (Wetar) (1750 m from its mouth). Dikes of diabase, albite-rhyolite and albitophyre.

agglomerates (H 117). About 1250 m from the coast sanidine-albite-rhyolites and albite-diabases are found. Whether they occur here as dikes, could not be determined with certainty, because large masses of erosion material cover the walls of the river, but higher up in the mountains, albite-diabases (H 117 $\times$, H 87 $\times$, H 141 $\times$, H 146) are found, which occur as dikes in granodioritic rocks (H 144, H 145 $\times$). In the upper part of the lower course of the M. Hoehan dikes of diabase (H 141, H 143) are rather frequent.

When we follow the M. Hoehan to the North, the small tributary, the M. Koase, is passed and after we leave the M. Saklapat, which is another small tributary of the M. Hoehan, the hills between this river and the M. Saoe are investigated.

Albite-rhyolites (H 144 $\times$) and albite-diabases (H 142 $\times$), as well as dacites (H 146 $\times$) are found.

The region between the M. Wenar and the M. Hoehan shows exposures in similar rocks. Especially granodioritic rocks are rather frequent here, with dikes of sanidine-albite-rhyolites (H 89, H 88 $\times$, H 118).

In the small valley of the M. Wenar, andesitic lavas (H 119, H 118 $\times$) are denuded, while 1.5 km to the South similar rocks are found (H 142).

The lower course of the M. Hoeroe was visited for the second time, for this stretch had been explored earlier by the author, together with J. D. DE JONG, when making the traverse from Ilwakki to Tara. About 2 km North from the mouth of the M. Hoeroe, we leave the river and in the region between this river and the M. Wenar andesites (H 115 $\times$) and rhyolites (H 114 $\times$) are found. These rocks are very rich in glass and show columnar joints. Dacitic lavas are also observable, but mutual relations between the various lavas have not been detected.

The rocks which occur in this region are classified as follows:

1. Albite-rhyolites.
2. Dacites.
3. Pyroxene-andesites.
4. Spilitic rocks.
5. Dolerites and doleritic basalts.
6. Quartz-albitites and albitophyres.
7. Albitized quartz-diabases.
8. Dioritic rocks.

1. Albite-rhyolites.

In this chapter those extrusive rocks will be classified as rhyolites,

which show phenocrysts of quartz, sanidine and less frequently acid plagioclase, which have been albitized for the greater part in a groundmass, which often contains a considerable amount of glass. Femic minerals are present in small quantity. The structure of the groundmass is quite variable.

Some types of albite-rhyolites occur in this region.

Both types, which were described from Tandjoeng Illipoi, are found again in this region. Sample H 82 represents the second type from Illipoi, but is finer crystalline, while pseudomorphs after cordierite also occur.

A third type, represented by H 89, is rich in spherulites. Of this sample it is not sure that it belongs to the rhyolites, as there are many gradations between albite-rhyolites and quartz-keratophyres. But macroscopically, H 89 in its structure, rather resembles the rhyolites.

Most of the albite-rhyolites, described from this region, show that all sanidine-phenocrysts have been altered into albite by an albitization process.

Samples H 98 and H 81, representing the second type of Illipoi may be described very briefly. They exhibit a similar structure macro- as well as microscopically.

Almost all feldspars have altered into albite. Indistinct perthitic structure is shown by part of the phenocrysts.

The quartz phenocrysts of sample H 98, occasionally contain a considerable amount of liquid inclusions, part of them with a libell. In this sample apatite, in idiomorphic columns, occurs rather frequently, while rutile is very rare. As in the Illipoi-rhyolites, the quartz phenocrysts are strongly corroded and have large inlets, filled up by groundmass constituents. Some phenocrysts however are still idiomorphic and show hexagonal and lozenge-shaped sections. Micrographic intergrowths are abundant. Large rims of these micrographic intergrowths around the quartz phenocrysts are present; sometimes the quartz phenocrysts show felty coronas.

The rhyolitic lava H 98, has an outer zone which is rich in glass, while the central part of the lava shows an entirely crystallized rocktype. Going from this centre to the outer zone an increase of glass and a decrease of the mineral size and of the amount of phenocrysts is observed.

Sample H 100 contains a few phenocrysts of acid plagioclase, with a composition of albite; while the glassy groundmass is rich in spherulites and pseudo-spherulites and minute feldspar laths. The feldspar phenocrysts may attain a diameter of 0.6 mm. The refractive indices of the feldspar in the groundmass are lower than that of Canada balsam, so agreeing

with those of alkali felspar. The pseudo-spherulites and spherulites consist of quartz and alkali felspar; their diameter is about 0.05 to 0.15 mm. Part of the glass substance is devitrified into these minerals.

In contrast with the just described rocks, sample H 82, which also represents the second type of Illipoi-rhyolites, contains pseudomorphs after cordierite. These pseudomorphs, which are of the same size as those from Illipoi, consist of chloritic flakes (penninite is present). Inclusions of other minerals are absent in these pseudomorphs.

For the rest the rock shows similar features as the Illipoi-rocks.

Another type of albite-rhyolites is represented by H 89. It is a fine grained, brown speckled rock. Microscopical investigation reveals that the structure is spherulitic. Some phenocrysts of albite, up to 1.8 mm in length, occur, while quartz as phenocryst is rare. Twinning of the plagioclase, according to the albite- and Carlsbad laws is common.

Almost the whole rock is built up by spherulitic individuals, which have an average diameter of 0.3 mm. These fine spherulites are composed of very slender laths and fibres, which are radially arranged and consist of quartz and alkali felspar, alternating with each other. Many spherulites show micrographic intergrowths, but in those cases the regular radial arrangement disappears. Felty coronas, consisting of small fibres of both these minerals, may be observed around the quartz phenocrysts. The alkali felspar of the groundmass and that of the spherulites is clear, this in contrast to the cloudy appearance of the albite.

Limonitic substance, brownred of colour, is rather abundant in the rock, which affords the rock a brown-spotted appearance. Sericitic flakes, as alteration product of the felspar, occur in noticeable amount.

The samples H 82 $\times$ and H 88 $\times$ are somewhat different from the main type. The light greyish- to white coloured rocks, with an indistinct porphyritic structure, are practically free from femic minerals.

H 88 $\times$ contains phenocrysts of felspar, nearly all of them albitized, still sanidine, too, occurs. Quartz phenocrysts are in the minority. The only constituents of the groundmass are quartz and alkali felspar. The structure of the rock is quite variable. There are parts of the rock which show micrographic structure, while other parts consist of irregularly bounded, poikilitic quartz crystals, in which small felspar laths are embedded. The quartz contains a few liquid inclusions, while the cloudy albite phenocrysts have slightly altered into kaoline.

Besides these two structures in these rocks, spherulites as described from H 89, are found scattered through the mass, but they are less well-developed.

Of these two samples it is not certain whether they occur as dikes or as extrusives. These rocks show a strong resemblance to the kali-tordrilites, described by SPURR (30), and representing a rock which has a porphyritic structure, with a fine grained or aphanitic groundmass, while the only mineral components are quartz and alkali felspar.

As already stated by JOHANNSEN (19, Vol. I, p. 61) there are numerous rhyolites, which undoubtedly belong to this family.

2. Dacites.

Two types of dacite are present. The first type (H 88) corresponds with the dacitic vitrophyres, which are described from the eastern part of Wetar. The greater part of the rock consists of glass, with a number of phenocrysts. Phenocrysts of quartz and felspar are present; the quartzes are strongly fractured, while the cracks are filled with glass. Magmatic corrosion, and consequently large inlets, as well as glass- and liquid inclusions are frequent. The plagioclase is medium labradorite without zonal structure. Its diameter reaches up to 1.5 mm. The black glass of the groundmass consists of a great number of small felspar laths, but they are undeterminable as to their composition, as they often have the size of microlites (0.01 to 0.05 mm). Locally flow structure may be observed in the rock. A few grains of magnetite, as well as small crystals of augite and green hornblende occur. A few strongly altered phenocrysts, probably of hypersthene, are observable. Alteration into serpentinous substance occurs.

The second type, represented by the samples H 107^x, H 107, H 109 and H 115, is rich in spherulites and pseudo-spherulites. Generally these rocks are fine granular, greyish coloured rocks. Macroscopically spherulites are observable, as well as some phenocrysts of felspar. Small cavities are abundant in these rocks.

The phenocrysts of plagioclase are more or less regularly zoned: basic and more acid zones alternate several times. Their composition is acid labradorite, with slightly more acid margins of medium andesine. Twinning is abundant. Quartz phenocrysts are very rare.

The groundmass consists for the greater part of pseudo-spherulitic individuals and less well-developed spherulites, situated amidst green coloured glass, which is obscured by microlites and minute grains of oxidic iron ore, as well as by thin flakes of a dark mineral, possibly biotite. The crystalline constituents of the groundmass consist of quartz and alkali felspar. The habit of the spherulites agrees with those, which were described fully from the region Masapoen-Moning. Their diameter

is maximal 0.25 mm, but the size of the pseudo-spherulites is between 0.01 and 0.1 mm. Micrographic intergrowths are present as well (Plate XII, fig. 1).

The glassy groundmass of H 109 is strongly defiled by oxidic iron ore.

The felspar of H 115 is an oligoclase-andesine. Quartz is present as phenocrysts, in large amount. The groundmass is almost entirely crystallized, and shows similar features as the just described samples. Micrographic intergrowths are very common. Probably this rock may be reckoned to the rhyolites as well.

3. Pyroxene-andesites.

This type of andesites includes all glass-encrusted andesites. These lavas have been found in many regions of Wetar, especially along the south coast between Toepoeti and Masapoen, on the traverse Masapoen-Moning, as well as along the eastern coast North of Moning. From the region between Tara and Toepoeti they were mentioned already.

Macroscopically they are bluish-grey to ash-coloured rocks (H 102 $\times$), generally without phenocrysts, while they often show a black glass crust with a maximal thickness of 1 cm. Numerous small, spherical cavities, usually empty, are observable. Sometimes a few augite phenocrysts occur, which show hardly any signs of alteration. Their diameter is about 0.4 mm.

The crystals are often conspicuously arcuate, with correspondingly varying extinction directions. Only a few plagioclase phenocrysts occur, partly twinned. The felspar laths are wedging out in the augites, when they are enclosed by this mineral, as a result of simultaneous crystallization. Felspar microlites occur in the rock; as we shall see further on these microlites as well as the phenocrysts serve as crystallization centra.

The mesostasis contains glass, in which a large number of particular small prisms and globulites of brown coloured augite is present. The pyroxene which must be considered as augite because of its very oblique extinctions, shows a peculiar development. A striking phenomenon is the occurrence of radial arrangements of augite prisms set upon an arcuate stem, which consists of the same mineral. Often microlites of felspar, but phenocrysts of this mineral too, serve as a stem. Sometimes a pectiniform aggregate of augite prisms has grown around a felspar lath. Within the somewhat larger crystals an arcuate development is observable.

The minute augite globulites are in connection with each other; a fact which is shown by the simultaneous or regular varying extinctions within the aggregates. These globulites must therefore be considered as skeletons

of augite prisms, which are bunched together in radial or feathery arrangement.

Most probably the peculiar development of the augite will be due to rapid crystallization.

Feathery development of augite from Hawaiian basalts has been described and illustrated by E. S. DANA (9, p. 441).

MÖHLE (25), KIKUCHI (22), BENSON (6) and BALSILLIE (1) have described analogous phenomena and recently DE ROEVER (27, p. 149), described and illustrated these features from spilitic rocks, basalts and spilite-augitites of the Moetis region (Netherlands Timor).

The glass crust contains only a few globulites of augite, but somewhat more phenocrysts of this mineral. There is a regular increase of this globulitically developed augite, from the glass crust to the centre of the rock. The rock under the glass crust sometimes consists almost entirely of the augite globulites; in those cases we can speak of augitic augite-andesite. Very subordinate are the amounts of feldspar laths and microlites in some samples. The above described features are shown more or less perfectly by all glass-encrusted andesites.

The feldspar has a composition of basic labradorite; many of the individuals are twinned.

Pebbles H 101 and H 102 are pyroxene-andesites as well. These rocks are very frequent among the pebbles of the south coast. Sample H 101 is a fine granular, grey rock with large vesicles, filled with chalcedony and quartz.

In a glassy groundmass, small feldspar laths occur, with a diameter of up to 0.3 mm, while their composition is basic andesine. Twinning is frequent. As feldspar constituent, green hornblende is present in small fibres, whilst magnetite in isometric sections is scattered through the rock.

The vesicles are filled with quartz and chalcedony. The last mentioned mineral occurs in very fine radiating fibres, and more or less complete spherulites with round or polygonal outlines filling the entire cavity.

Sample H 102 is a fine grained rock, rich in small cavities, with phenocrysts of pyroxene. Both augite and hypersthene occur with a maximal diameter of 1.5 mm; sometimes a rim of augite around the hypersthene is observable. The augite occasionally shows zonal structure, but arcuate development is present as well. Small grains of pyroxene are frequent in the groundmass, while magnetite is rare.

Phenocrysts of feldspar are rare; the composition of the twinned plagioclases is medium labradorite, while the small feldspar laths in the groundmass, which occur in a large number, with an average size of 0.07 mm,

are basic andesine glass, almost colourless to light brown, is present in considerable amount.

4. Spilitic rocks.

Although the locality, where sample H 73^x was found, is somewhat East of Tandjoeng Illipoi, near the coast, the rock will be described in this chapter. The sample exhibits a dark grey coloured dense and aphanitic rock. Yellow-brown coloured quartz has been infiltrated rather frequently.

Under the microscope this rock shows a considerable resemblance to the spilites, which were described from the Tara-Toepoeti traverse. The rock is rich in slender albite laths and chlorite; the structure is sub-variolitic, partly sub-ophitic; the albite-laths, 0.3 à 0.4 mm in diameter, are wedging out in the chlorite, when they are enclosed by this mineral. The chlorite must be considered as altered pyroxene. A tree-like development of the albite laths is observable in this rock. Very minute grains of oxidic iron ore, probably magnetite, are found in great numbers between these branched laths of albite.

Pseudomorphs after olivine are probably present. Idiomorphic boundaries of olivine crystals are found, which now have entirely altered into carbonate and quartz. The diameters of the pseudomorphs after olivine are about 0.1 mm.

The quartz of the pseudomorphs occasionally consists of several grains, which show a different optical orientation. Besides in the pseudomorphs, the quartz is rather abundantly present as fillings of the cavities in the rock: carbonate is present in considerable amount.

5. Dolerites and doleritic basalts.

Dolerites are represented in the M. Sae region by pebbles, as well as by solid rocks. Their conformity with the dolerites of Tandjoeng Illipoi is striking. No samples will be described here, for their microscopical features are entirely similar to those of the Illipoi rocks.

Only one doleritic basalt was found as pebble in the Meta Hoehan (H 87). This sample shows considerable conformity with the doleritic basalts from the Tara-Toepoeti traverse, which have been described in the chapter on the petrography of that region.

As has been mentioned already concerning Tandjoeng Illipoi, many dolerites are strongly decomposed. Their pyroxenes have disappeared, only chloritic substance is present, while the feldspar is albite. These rocks are classified among the albitized quartz-diabases.

6. Quartz-albitites and albitophyres.

The geological occurrence of the samples, described in this chapter is only known for a few rocks. Sometimes they occur as dikes, cutting through albite-diabases. Dikes of quartz-albitites and albite-diabase are present in an area in which quartz-diorites are frequent. Another part of the above mentioned rocks is found without in exposures where the geological position could not be determined. Probably the quartz-albitites and albitophyres form small intrusive masses and so are to be considered as hypabyssal rocks.

The terms albitite and quartz-albitite are used here in the sense as given by TURNER (33) resp. TILLEY (32). VON ECKERMANN (10, p. 414) has introduced the term "Albitophyre" in a new sense, different from the albitophyre, given by COQUAND (7). VON ECKERMANN believes that the graphic structure, as opposed to the granular one as other normal albite-quartz rocks, is sufficiently characteristic to justify the introduction of a special name for this new type. Thus the dominant structure of the albitophyres is micropegmatitic, grading into more coarsely granophyric. Occasionally the symplectitic intergrowths are radially grouped around idiomorphic albite-laths.

Albite and quartz are the essential minerals.

HOLMQUIST called these rocktypes "albite-pegmatites", but it seems better to use no names like albite-pegmatite, soda-granite, albite-granite, or terms derived from these, to designate rocks, with intrusive character, with albite as the main constituent.

JOHANNSEN (19) has already drawn attention to this.

Quartz-albitites (H 101 $\times$, H 74 $\times$).

The structure of the several rocks may differ rather much. Sample H 101 $\times$ has a granitic structure, and is rather coarse grained, with veins of quartz. H 74 $\times$, to the contrary, is a fine grained, somewhat speckled, green coloured rock, of a somewhat porphyritic structure, with small phenocrysts of feldspar. Under the microscope the main constituents of these rocks appear to be alkali feldspar and quartz. The alkali feldspar is albite. As in so many cases, in this rock there are no remnants of more basic plagioclases or other alkali feldspars. The albitization has been completed, for one must suppose that the albite in this rock has originated by an albitization process, and is not of primary origin. The replacement of other minerals by quartz, is also a metasomatic process, like the albitization (Plate XI, fig. 2).

Albite is replaced by quartz on a large scale. In this rock the quartz

PLATE XI.

Fig. 1.

Albitophyre from the M. Sae region, Wetar. The photograph shows micrographic intergrowths of quartz and alkali felspar, grown round laths of albite.

Nicols crossed (68 $\times$).

Fig. 2.

Quartz-albitite from the Meta Sae region (Wetar). The photograph shows the replacement phenomena in this rock. Replacement of albite (turbid) by quartz (clear). The quartz shows lobed edges against the albite and presents convex contacts toward it in very involved patterns extending through the felspar. Nicols crossed (56.5 $\times$).

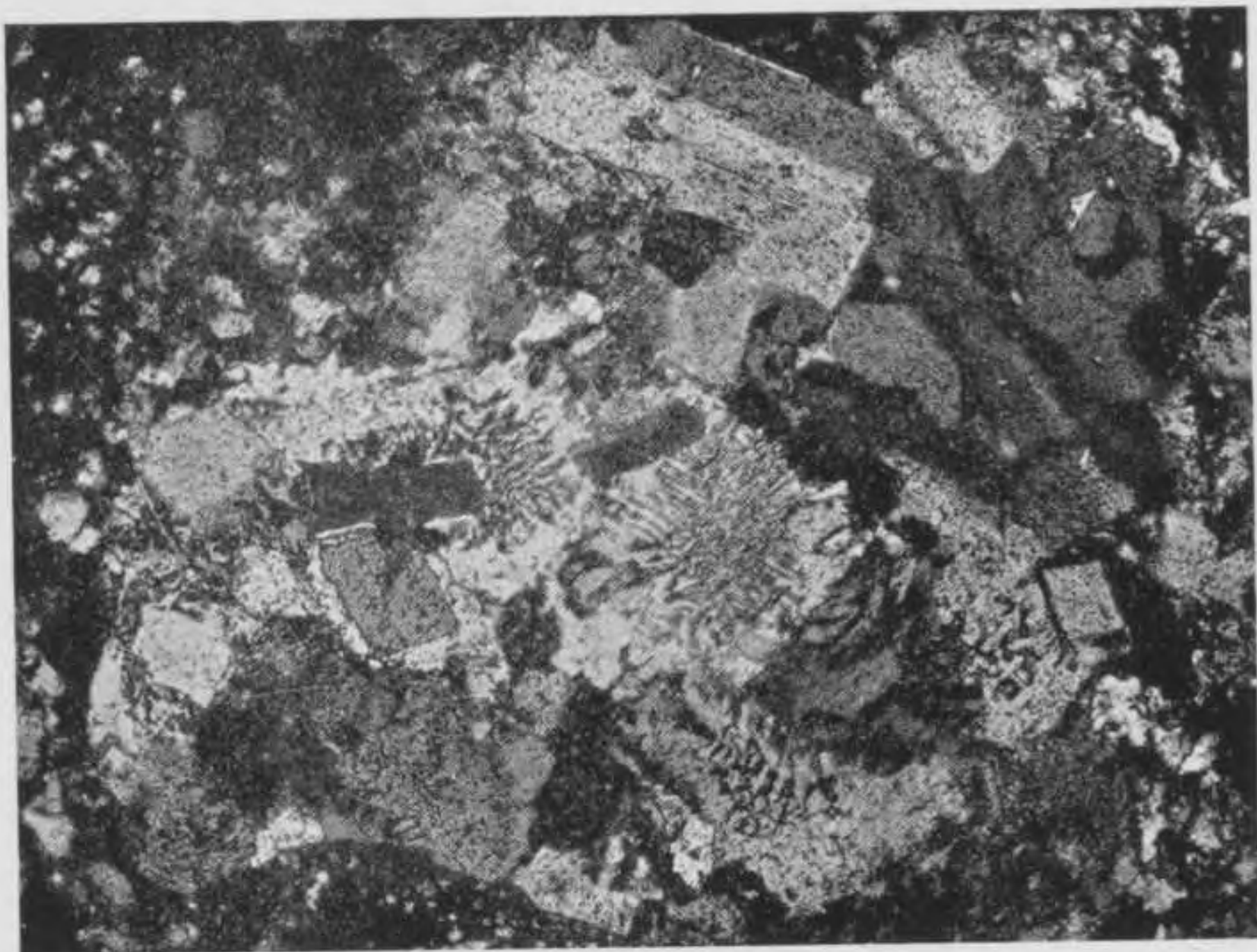


Fig. 1.

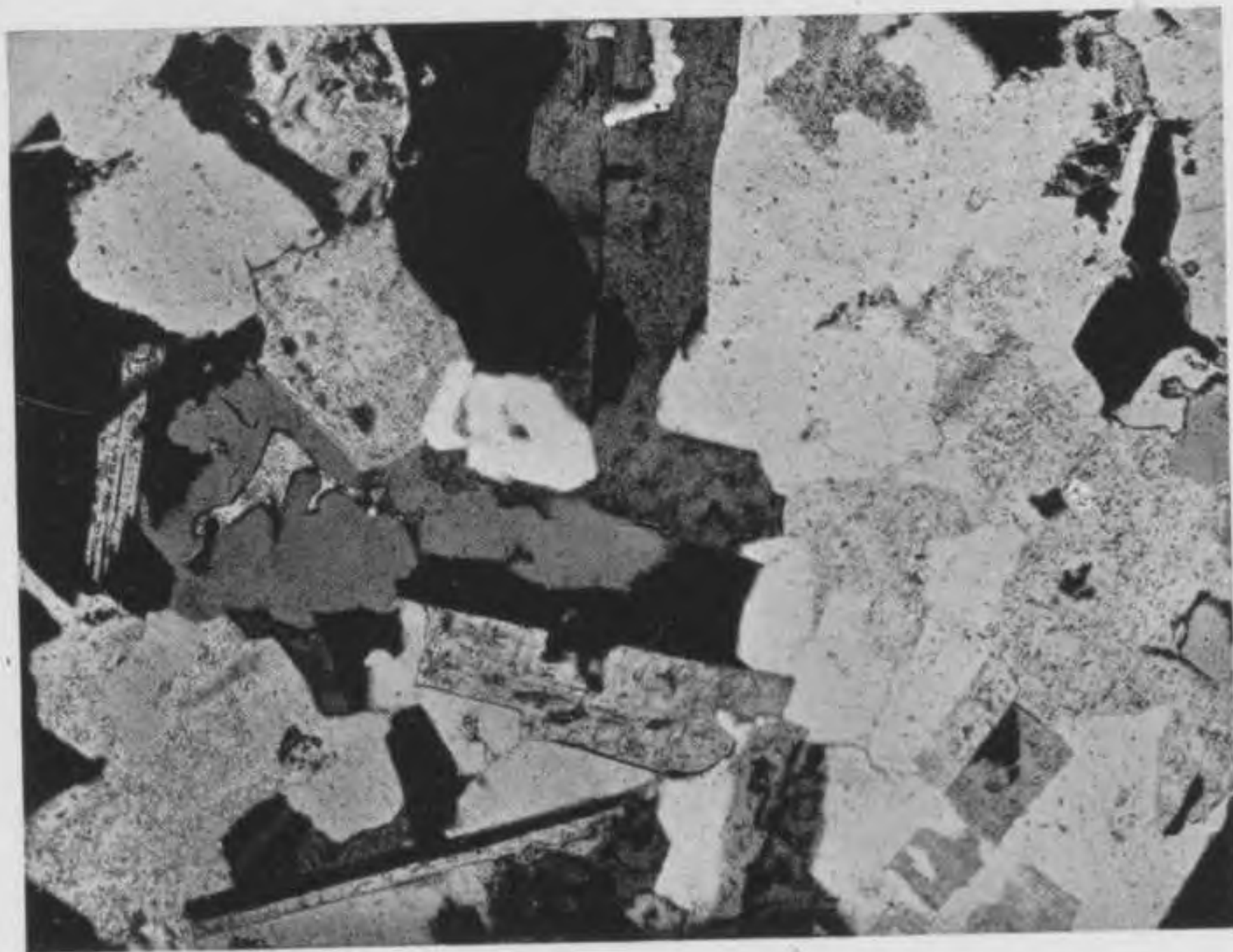


Fig. 2.

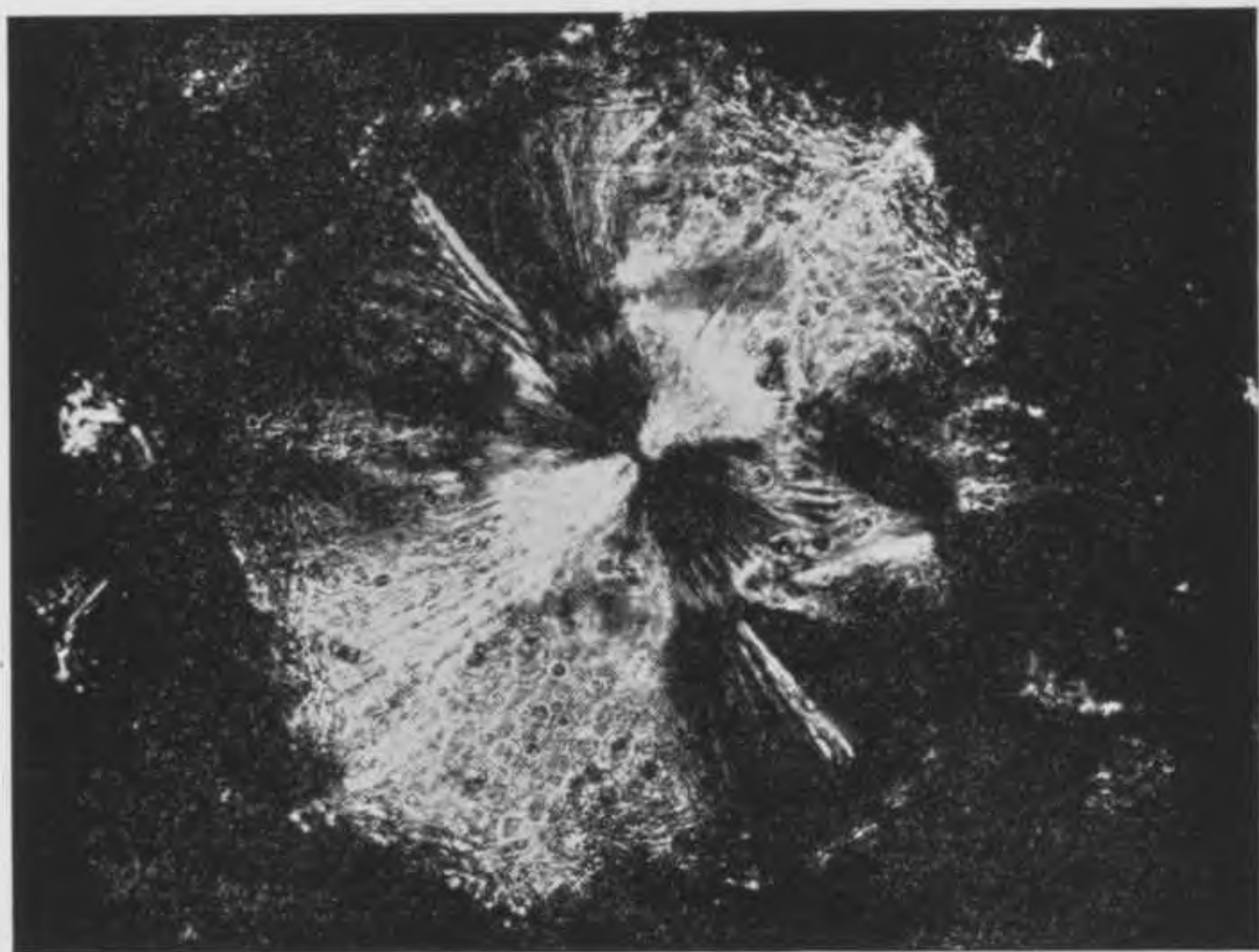


Fig. 1.



Fig. 2.

PLATE XII.

Fig. 1.

Spherulite in a dacite (H 107) from the M. Hoeroe region (Wetar). The spherulitic body consists of micrographically intergrown quartz and alkali felspar.

Nicols crossed (375 $\times$).

Fig. 2.

Radial arrangement of augite-prisms, set upon a spiral stem, consisting of the same mineral. *Pyroxene-andesite* (H 408) from the south coast of Alor, near Silalaboei.

Ordinary light (126 $\times$).

has different habits. Part of it is simply interstitial to the feldspars, but most of the quartz individuals have lobed edges against the feldspar and present convex contacts toward it in very involved patterns extending through the feldspar. Another part occurs in patches isolated within feldspars; a third part again veins and cuts all other minerals.

Analogous phenomena of replacement of feldspar by quartz have been described by GILLULY (15) and FREEMAN (13).

GILLULY says:

"The verminiform, lobate and venous disposition of the quartz of the albite granite is characteristic, and all gradations from thin tongues of quartz in albite to stringers and wisps of albite in a "sea" of quartz, are to be seen..... The fact that the lobes of quartz are dominantly orientated with their convexity toward the feldspar is believed to be significant of replacement."

Similar features can be described of the quartz-albitites. In some cases the replacement has been accomplished in a manner that a kind of very coarse granophyric structure has resulted. In those cases the rock shows some resemblance to the albitophyres.

Often there are only wisps of albite amidst the quartz, of which the greater part of the rock consists. Probably there will be one or other relation between the brecciation of the rocks and the strong replacement by quartz. It is possible that the brecciation furnished channels of access for the solutions rich in silica.

Besides quartz and albite, some biotite, partly altered into chlorite, occurs. Oxidic iron ore, probably magnetite, is observable in small amount, while carbonate, sericite and a few mineral grains of the epidote group, are present as alteration products of the feldspars.

There are several rocks, which show resemblance to the albitites and quartz-albitites. Perhaps there are other rocks, which also belong to this group, but these are described in the chapter on the albite-rhyolites, owing to their resemblance to those effusive rocks. Especially in those cases where phenocrysts of quartz and sanidine are lacking in the rhyolites, the resemblance is great. The structure of some medium grained albite-rhyolites, in which all feldspars consist of albite, and the structure of some quartz-keratophyres, as well as their mineralogical composition, agrees in many respects with those of the quartz-albitites. Sample H 74^x is an example of these types.

Albitophyres (H 99).

The rock has a distinctly brecciated appearance, but still it is very dense. Infiltration and replacement by quartz of this greyish-green coloured rock seems to have affected it to a considerable extent.

Angular pieces, with a size of 0.5 to 2 cm, are cemented in a finer grained mass. The angular pieces as well as the finer grained groundmass are of the same mineral association, namely quartz and albite. Under the microscope the rock has the appearance of a breccia. Mineral fragments of various sizes are present.

The dominant structure is micrographic, sometimes showing some resemblance to myrmekite. Occasionally it is more coarsely granophyric. As has been stated before, the symplectitic intergrowths are radially grouped around the partly idiomorphic laths of albite. On the other hand, xenomorphic-granular structures with lath-shaped feldspar may be observed. Part of the albite-crystals is replaced by quartz, through which pseudo-graphic structure has originated. Analogous features as have been observed in the quartz-albitites, concerning the replacement of albite by quartz, are present in this rock. Besides these phenomena, the micrographic structure is predominating and earns for this rock the name of albitophyre (Plate XI, fig. 1).

7. Albitized quartz-diabases.

A good deal of these rocks occurs as dikes in the granodiorites of the Meta Saoe region. But there is another group, of which one cannot say with any certainty that they are extrusive or hypabyssal rocks. Field observations did not give any certainty on this point. Some types show considerable resemblance to the keratophyres and quartz-bearing keratophyres, but as they mostly exhibit a sub-ophitic structure they are described in this chapter.

H 71×, H 76, H 87×, H 83.

These samples naturally show great resemblance to the albite-diabases of Tandjoeng Illipoi.

These rocks are very fine grained, holocrystalline, greenish- to yellowish-brown coloured rocks, with occasionally a somewhat porphyritic appearance.

Albite and chlorite are the main constituents, while quartz is occasionally present in large amounts. The albite is rather dirty, in consequence of kaolinization. The average length of the albite laths is 0.5 mm. Part of the quartz is of secondary origin; sometimes it replaces the albite.

All samples contain a varying amount of oxidic iron ore, often as isometric sections of magnetite, which partly has altered into limonite. Those rocks, which show a porphyritic habit, contain phenocrysts of albite of 1.2 mm in size.

Some types, very rich in quartz, show great similarity to the quartz-

bearing keratophyres, especially when the sub-ophitic structure is indistinct.

8. Dioritic rocks.

The dioritic rocks are divided into two types. The first type, the quartz-diorites, shows important resemblance to that type of rocks, which has been described from Tandjoeng Illipoi. They occur over a large area in the Meta Sae. The second type, on the contrary, is only found as pebbles in the M. Sae and the M. Hoeroe, as well as in the small rivers between them. They are much more coarser grained in comparison with the first group, but quartz is wanting.

The *quartz-diorites* (H 74, H 75 $\times$). This type of rocks has been described more fully from Tdj. Illipoi. A short characteristic of the rocks from the M. Sae will be given here.

In these holocrystalline, even grained rocks, the main constituents are quartz, felspar and amphibole, which are macroscopically distinguishable.

The quartz, showing a somewhat undulose extinction and bearing a number of small inclusions, and plagioclase are present in almost equal amount. Polysynthetic twinning of the plagioclase is frequent. The almost always zonally structured individuals are medium labradorite with more acid margins of a composition of medium andesine. Part of the amphibole occurs in idiomorphic individuals, often, however, an accumulation of optically differently orientated crystals is observable. Alteration into chlorite, part of which occurs as spherulitic aggregates, is a common feature. Biotite is absent in these rocks.

Some augite, strongly decomposed into carbonate and partly into a brownish coloured felty amphibole, as a result of uralitization, occur, but always surrounded by a rim of green amphibole. Magnetite, as idiomorphic grains is not abundant, while apatite and titanite are accessory. Alteration products of the plagioclases are minerals of the epidote group and sericite.

The *diorites*. (H 110 $\times$, H 110, H 111 $\times$).

These samples are coarse grained, holocrystalline rocks, with large accumulations of amphibole, while the rest of the rocks consists of rather decomposed, dull-white, felspars.

These two minerals are the main constituents of the rock, which are present in almost equal amounts.

The strongly pleochroic brownish and greenish hornblende, partly

occurs in well-shaped, idiomorphic crystals. Twinning according to (100) is not rare. Chloritization is common.

The feldspars, which are approximately of the same size as the amphiboles and so may rise up to 6 mm in length, are interstitial to the idiomorphic amphiboles. The plagioclases, often twinned according to the albite- and Carlsbad-laws, and zonally structured, are medium bytownite, with more acid margins of basic labradorite. Sericitization of the feldspars may be observed on a large scale, as well as albitization, especially of the basic cores.

In other samples (H 111 $\times$, H 110) all feldspars are entirely albitized. Small, elongated sections of ilmenite, sometimes as irregularly bounded grains or with skeleton-development occur. Apatite is not frequent.

The just mentioned two samples H 111 $\times$, H 110, are diorites in contact with very fine grained, nearly black diabasic rocks.

The two samples are entirely decomposed and, some unaltered amphiboles excepted, consist only of secondary constituents. All feldspars are albitized, and have altered into kaoline; the greater part of the amphibole has altered into chlorite (penninite); minerals of the epidote group are locally plentiful. Partly as idiomorphic crystals, partly as spherulitic aggregates, which have been especially filled up small veins.

The diabasic rocks consist chiefly of small albite laths and chlorite, with an important quantity of small grains of minerals of the epidote group, while the average diameter of the constituents is 0.03 mm.

GENERAL GEOLOGICAL AND PETROLOGICAL REMARKS.

1. Character and age of the rocks:

The investigations made in the island of Wetar have proved that it is built up largely of effusive rocks (rhyolites, dacites and quartz-keratophyres, andesites and keratophyres, pyroxene-andesites, basalts and doleritic basalts and spilites), which generally show a submarine character, and there are indications that volcanic activity has ceased before the submarine lavas were raised above sea-level.

There are only a few localities where intrusive rocks have been found. Tandjoeng Illipoi and the M. Sae region show granodioritic rocks with quartz-dioritic differentiates, while the accompanying dikes are albite-dolerites and albite-diabases (sometimes albitized quartz-diabases), sanidine-albite-rhyolites, quartz-albitites and albitophyres.

In the lower course of the M. Masapoen an occurrence of quartz-augite-diorite to quartz-gabbro has been found.

In several places of the island the lavas alternate with marly limestones and tuffs, which contain Globigerinidae. As to the age of these limestones and tuffs, and of the effusive rocks, which have been extruded in this period of sedimentation, no exact data can be given; but owing to their striking resemblance to similar rock complexes described from NE Timor by SIMONS (29, p. 33) and from the island of Rotti by BROUWER (3, p. 75), they may be supposed to be of very young-Tertiary age.

2. Geological position and age of the granodiorites:

The granodiorites with their accompanying dikes, from Tdj. Illipoi and from the M. Sae region, do not show distinct contacts with the lava rocks, although they occur amidst them. There is no evidence at all for the supposition that these intrusive rocks are older than the lavas of the island, which, as was already discussed, are considered to be of young-Tertiary age.

As to the geological position of these rocks we have to consider them as corresponding with a somewhat deeper level, now uncovered by erosion.

Thermal metamorphism caused by the intrusion of the granodiorite and strong hydrothermal action — as has been found in the island of Alor — is absent from Wetar.

Hydrothermal action, as accompanying feature of the intrusion of the

granodiorites is, although less strong than that found in the island of Alor, present. Especially in the regions where granodiorites or — as was found on the Masapoen-Moning traverse — quartz-augite-diorites to quartz-gabbros, occur, albitization processes play an important part in the intrusive rocks themselves as well as in the surrounding and covering lavas. But also the replacement by quartz of other minerals, especially of the feldspars, is a common feature. It has been described for instance from the quartz-albitites and albitophyres from the M. Sae region, whilst these replacement phenomena are also observable in the intrusive rock masses. Generally quartz infiltration is a common feature in these regions. Features caused by hydrothermal actions are rare or almost absent in areas where intrusive rocks fail. So the most eastern part of the island, where large flows of vitrophyric dacites are present, as well as in several parts of the traverses.

3. The occurrence of unresorbed amphibole:

A striking feature is the occurrence of fresh, green amphibole in the vitrophyric dacites from East Wetar. Generally one can say that the dacitic rocks contain a varying amount of amphibole, whilst this mineral is only very rarely present in the glass-rich andesites, pyroxene-andesites and basalts of the island. Several authors have discussed the problem of the unresorbed amphiboles in effusive rocks.

The following facts may be observed:

The vitrophyric dacites, so lava rocks with a large amount of glass may be considered as to be originated by submarine volcanism. The rocks are intercalated with tuffs and *Globigerina* limestones. This fact, as well as the large amount of glass may be evidence for this supposition.

In these rocks green amphiboles occur, which do not show resorption effects. In those rocks, the groundmass of which shows more or less crystallization products (spherulites or pseudo-spherulites of a quartz-feldspar substance), the amphiboles, however, show an opacitic border.

Generally the dacites of this region contain many vesicles while at some localities they may show a somewhat pumiceous habit. So these lavas have been rich in gases.

Besides the green amphibole, the dacites contain hypersthene and biotite as phenocrysts, while generally the monoclinic pyroxene is very subordinate as phenocryst.

Some connection between the submarine eruption of the lavas of Wetar, which were rich in gases, and the occurrence of unresorbed amphibole seems to be clear, a feature which has already been mentioned

by BROUWER (2, p. 46) from the Mahengetan North of Celebes. KUENEN (24, p. 318) has reported another mode of occurrence from the Panangoengan (Java).

From West Wetar J. D. DE JONG described similar rocks and discussed the relation between submarine eruption and the occurrence of unresorbed amphibole.

4. The cordierite-bearing sanidine-albite-rhyolites:

Besides from Wetar, cordierite-bearing rocks are reported from some other islands of the inner row of the Lesser Soenda islands (Ambon and Ceram).

Summarizing, the features in these three regions are the following:

From the island of Ambon, bronzite-biotite-dacites with cordierite are reported by SCHROEDER VAN DER KOLK (31, p. 1), VERBEEK (34, p. 203) and BROUWER (4, p. 74), as already mentioned.

The cordierite is, according to BROUWER, present in these rocks in enallogeneous and homoeogeneus inclusions, while another part of the cordierite crystals should be considered to have originated as direct crystallization product of the magma.

From Western Ceram H. DE JONG described cordierite-bearing granites, -pegmatites, -gneisses and -hornfelses. According to said author the granodiorites in that region, have assimilated older sedimentary rocks (crystalline schists, mica-schists). So a great part of the inclusions is of enallogeneous origin. But there is also a part of the cordierites, for which direct crystallization from the magma must be accepted. H. DE JONG described well-developed cordierite crystals, enclosed by orthoclase.

From Wetar, cordierite crystals (mostly pseudomorphs after this mineral) are only known from the sanidine-albite-rhyolites. Homoeogeneus and enallogeneous inclusions fail in these rocks and, as was already discussed by the present author (17), direct crystallization from the magma seems to be clear; it is one of the first crystallization products and some cordierite crystals are enclosed by sanidine phenocrysts.

Although the occurrence of cordierite in the rocks from the three regions, just mentioned, is somewhat different, there is one general feature, which they have in common, namely that all rocks in which they occur have assimilated foreign rock material, which in sometimes entirely, in other localities only partly, assimilated.

For the rhyolites from Wetar we may assume that the assimilation of foreign rock material has been complete and has resulted in crystallization of cordierite as one of the earliest minerals.

5. Tectonical and morphological considerations:

The uplift of the island is of recent date; several arguments for the supposition that the island has actually undergone a comparatively rapid uplift are present:

- a. The occurrence of several terraces along the coast (with a considerable sea-ward dip, up to 30°), and relics of higher upheaved terraces in the interior of the island. Examples of relics of upheaved reef limestone terraces to a height of about 450 m were found in the Tara-Toepoeti traverse, a few kilometres to the North of the watershed (Goenoeng Poetih), while J. D. DE JONG (21) reports still higher situated terraces, although without reef limestones, from the western part of Wetar. The terraces along the south-, east- and north coast are rather continuous and respectively 5, 25 and 40 metres high, but individually they show considerable variations in height. Along the SE coast and North coast further a terrace occurs about 200 m above sea level, while some other terraces at varying heights are but locally developed.
- b. The cañon-like valleys of the main rivers, in their lower courses.
- c. Several still "hanging" river valleys, shown by the small tributaries of these main rivers, whereas the larger tributaries already show rapids and small cascades.
- d. The enforced, consequent curves in the upper part of the lower course of the M. Perai (East-Wetar), while the lower part of the river, up to the coast, shows no anomaly whatever.

ALOR.

GEOGRAPHICAL OUTLINES.

The island of Alor, in the northern row of the Lesser Soenda Islands, is bounded to the North by the Banda sea, to the South by the Sawoe sea, while to the West and to the East it is separated by narrow straits from Pantar and Wetar respectively.

In Strait Pantar, bordering the West side of the island some small islands, Poera besar, Treweg, Reta, Ternate and Sika are situated.

North of the bay of Kebola the peninsula Kebola, also called "Vogelkop", is situated, which peninsula has a communication with the rest of the island by the Kebola-isthmus of a length of 5 km and a width of 1.5 km. This Kebola-isthmus is a low land which rises only a few metres above sealevel (the greatest height is 45 m). This low land consists of very young sedimentary deposits; it came into existence by uplift in recent times. On other than geological grounds, D. BROUWER (5, p. 5), as a result of his anthropological investigations concludes also, that the Kebola peninsula has been connected with the main island of Alor in recent times.

The main island is formed by a deeply incised, mountainous volcanic land. Locally it is covered with thick layers of raised coral reef limestones, forming several terraces (at least five), by which the island acquires the appearance of a deeply dissected table-land.

The watershed between the areas, draining to the North (Banda sea) and those which drain to the South (Sawoe sea), stretches in an east-west direction over the island, and is found to be somewhat south of the middle of the island. The average height of the mountain ridges is about 1000 m. HARTMANN (16) distinguished a western-, a central- and an eastern part of Alor ¹⁾.

West-Alor shows great resemblance to the "Vogelkop". Large, extensive, mostly horizontally stratified terraces of upheaved reef limestones and tuffs are present in these regions. South, as well as North of the bay of Kebola these terraces are well-developed, often 5 terraces are visible, the highest of which lies 700 metres above sea level. Near the coast

¹⁾ By permission of the Head of the Mining Department at Bandoeng some data have been taken from the non-published report "Alor" by M. HARTMANN.

volcanic rocks are frequently found which rocks are often covered with these limestones. Near the coast many breccias and lava flows are encountered. The upheaved limestones are almost everywhere stratified horizontally, although in the vicinity of the coast they show slight dips sea-ward. This western part was not visible by the writer.

It is separated from the central part of Alor, which was explored by the writer, by a peculiar depression, which is found between Kikilai (bay of Kebola) and Boeraga (Sawoe-sea). The highest region is formed by the watershed.

HARTMANN presumes this depression to be a fault zone, which is perpendicular to the east-west directed mountains.

Central Alor is bordered to the West by this depression and to the East by a line about 40 km remote from this depression in eastern direction.

Here the watershed is found in the middle of the island. Relics of extinguished volcanoes are found in this region: the Roeilate-, Mainang- and Paitoko volcanoes.

The mountains consist of southern and northern ridges on which occasionally relics of volcanoes occur.

According to HARTMANN the erosion has reached an advanced stage. The morphology of the island shows a greater maturity than was observed in the island of Wetar, from which we now know that the erosion stage is rather young.

The base of this central part consists of volcanic breccias and agglomerates and tuffs, which attain a very great thickness in the southern part. Thicknesses of 700 to 800 metres, only consisting of glass breccias and agglomerates are not rare. In contrast to the north coast, the south coast, which is very steep and which is bordered by the very deep Sawoe sea, only locally shows fringing reefs.

The terraces which are present along the south coast are formed by the volcanic breccias and agglomerates and/or tuffs. Only in a few places upheaved reef limestone is present. In the neighbourhood of the small native village of Koenaman a reef limestone at a height of 700 m is observable.

The river valleys frequently attain a depth of 300 to 400 m.

The country is rather barren. Only near the north coast there are some forests, but the greater part of the island is strongly deforested by the natives.

The natives are rather primitive. Their agriculture is still for a part

exhausting cultivation, a practice which goes hand in hand with deforestation.

The region near the south coast is very poor in water. Isolated trees of *Eucalyptus* are found on the huge masses of glass agglomerates and breccias.

East Alor contains the highest mountains of the island (the G. Kojokojo and the G. Potomana, 1765 m); it was not visited by the writer.

The island is rather densely populated if compared for instance with Wetar. The population amounts to about 80.000. Most of the native villages ("kampongs") are situated on the summit of the mountains and frequently these villages are surrounded by a dense hedge of *Cactaceae*.

D. BROUWER (5, p. 104) has reported more fully about the hygienic conditions.

As topographical base the map of the Topographical Service — scale 1 : 100.000 — of 1932 of the island was used.

EARLIER INVESTIGATIONS.

In 1908 R. D. M. VERBEEK (35, p. 430) gave a description of some types of rocks, which were collected by the natives, but no localities where these samples occur as solid rocks were mentioned. Besides lava rocks (olivine-bearing pyroxene-andesites, pyroxene-mica-hornblende-andesites, pyroxene-andesites, basalts) VERBEEK mentions a granitite, rich in plagioclase, collected in the vicinity of the village of Koei (south coast, W. Alor).

In 1927 H. EHRAT (11, p. 450) described a granodiorite from the "Granitfeld Kui". We did not find back this locality. As no locality, where these rocks were collected, is indicated, this publication is of questionable value.

In 1931 M. HARTMANN (16) visited the island. The geological results of this investigation have not been published. By permission of the Head of the Mining Department at Bandoeng some data, derived from this report, are mentioned in the present publication.

DESCRIPTION OF THE ROUTES.

Kalabahi-Langkoeroe route:

We cross the bay of Kebola, from Kalabahi, which is the residence of the military and civil commander of the island, to Welai; both villages are situated on the lowest reef limestone terrace, which borders this bay. Its height is only a few metres above sea level.

Going to Welai we pass over this terrace and when our way goes in southeastern direction to Selawati, a very steep hilly region lies before us. We now have to ascend about 700 m; frequently the upheaved reef limestone, which here forms the highest terrace at 700 m along the bay of Kebola, is intact, though occasionally lava rocks are uncovered. By several ups and downs we pass Laimoeti and Lomamasang and arrive at Maining. This part of the route shows very good exposures in solid rocks, but all are of the same kind: glassy andesites, sometimes with flow-structure, locally containing many vesicles and occasionally brecciated or exhibiting perlitic fractures (H 300 to H 304^x). Thereafter we reach the G. Mainang, which according to HARTMANN (16) shows a caldeira. An almost horizontal, flat bottom, rather circular, with a diameter of 3.5 km at a height of 800 m, is surrounded by rather steep walls of about 1250 m, which only consist of volcanic rocks. Most of the volcanic rocks are bluish-black andesites, more or less rich in glass (H 305, H 306^x, H 306), alternating with tuffs, while some volcanic bombs were collected, which mainly consist of greyish-violet coloured pyroxene-andesites, which are often more crystallized than the dark andesitic lavas, except their glassy crusts.

For the greater part the horse tracks, which are in good condition, are used to traverse the island. In many hair-pins they ascend the steep river valleys. The use of these horse tracks, enabled me to study many exposures of solid rocks.

When we leave this circular, flat bottom of the Mainang caldeira, in the direction of Kalaisi, we first pass the steep walls which enclose the caldeira, where several pyroxene-andesites are found (H 307^x) as well as glassy andesites and basalts (H 307 to H 309), which, as we shall see, are very frequent all over the island.

After we have passed the G. Mainang, along the path to the native village of Kalaisi, crystalline pyroxene-andesites (H 310, 311^x) are found.

Exposures in rocks of pyroxene-andesitic to basaltic composition are also present here (H 311). These types of rocks which alternate with normal glassy andesites, cover a large area, till we reach the village of Langkoeta, situated at a height of 1100 m. In the mountains above this village, hydrothermally altered andesites are very frequent (from H 314^x to H 315).

Silicification and kaolinization processes have altered the andesites in a considerable measure. Sometimes an important replacement by carbonate is observable. The whole region is rich in these types of altered andesites: 800 m before we reach the village of Silaifoei there are still hydrothermally altered andesites (H 317^x to H 319); sometimes their colour is greyish or yellowish, but they are often yellowish-brown. In consequence of these hydrothermal processes the dark coloured glassy lavas are strongly bleached and often devitrified. Four hundred metres further, in the direction of Silaifoei, strongly porphyritic andesites (H 320, H 321^x, H 323^x) are found. They are alternating with these hydrothermally altered andesites, (H 321, H 322^x, H 322). Thereupon we find a small exposure in pyroxene andesites (H 323), which show strong resemblance to the samples H 308 and H 309. They are very dark glassy rocks, rich in pyroxene.

The way from Silaifoei to Langkoeroe has several ups and downs. After we leave the first mentioned village, which is situated at a height of 750 m, we descend to about 400 m, where a small dry riverbed is crossed and then we ascend to Sidimana, 900 m high. As mentioned already the river valleys are often 300 to 400 m deep and bordered by rather steep walls. The first part of this route shows large exposures in yellowish-brown coloured tuffs (H 324, H 324^x), then follow again many exposures in hydrothermally altered andesites (H 325 to H 326), which are very frequent in a large area around Langkoeroe. Somewhat higher up in the mountains along the road, fresh pyroxene-andesites, which are very dense and black, build these mountains (H 326). Often the andesites are very decomposed and bleached. Saussarization and kaolinization of these lavas is a common feature in this region (H 327 to H 329^x).

When we have passed the village of Dalamana we again descend to a small river, a tributary of the Sali¹⁾ Pomoto, which drains in a southern direction; many outcrops of the glassy pyroxene-andesites are observed (H 332^x to H 334) and after ascending its eastern wall higher up, we still find similar lavas (H 336^x to H 338) building the mountain, whilst some exposures of amphibole-pyroxene-andesites to dacites, of a dark

¹⁾ Sali (abbreviated: S.) = river.

PLATE XIII.

Fig. 1.

South coast of Alor, between the villages of Koei and Boeraga.

Fig. 2.

South coast of Alor, near the village of Koei. The lowest terrace, consisting of glass breccias and agglomerates is visible during ebb-tide.

Fig. 3.

Glass breccias and agglomerates, North of the village of Koei. (South coast of Alor.)



Fig. 1.



Fig. 2.



Fig. 3.



Fig. 1.



Fig. 2.



Fig. 3.

PLATE XIV.

Fig. 1.

Kampong Lomamassang. The village is surrounded by capricious mountain ranges of volcanic rocks.

Fig. 2.

Deeply eroded landscape in the central part of Alor.

Fig. 3.

Kampong Talawa, built upon extensive tuffaceous deposits.

grey colour and a porphyritic habit (H 335 $\times$, H 338 $\times$, H 341 $\times$) are found.

Then we arrive at the native village of Langkoeroe.

From Langkoeroe, where there is a permanent military bivouac as a centre, some daytours were made.

Region southwest of Langkoeroe:

A small right tributary of the S. Pomoto was explored southwest of Langkoeroe. HARTMANN also explored this region, for the research of silver and lead ores, which were found however in very inconsiderable quantities.

We found strongly hydrothermally altered andesites (H 340 $\times$, H 344 $\times$, H 345 $\times$ and H 341, H 342 $\times$, H 345) in the upper course of the small river Pomoto. The andesites, altered by hydrothermal solutions, are rich in pyrite, and in these rocks HARTMANN found some silver and lead ores. More to the South in the valley of this river a gradual change to normal pyroxene-andesites is observable ¹⁾.

Langkoeroe-Kolomana route:

Another daytour was made from Langkoeroe to Kolomana i.e. in the direction of the village of Paitoko, which is situated on the south coast.

The first part of this route shows many exposures in these hydrothermally altered andesites (H 346 to H 350). Many of these andesites are strongly bleached. Carbonate, chlorite and minerals of the epidote group are very frequent, while kaolinization is a common feature. Thereupon, in the region where the S. Manaika and its tributary cross our way, glassy andesites with a varying amount of pyroxene and felspar are present (H 351 $\times$ to H 353 $\times$ and H 354 $\times$, H 354) along the entire way to Kolomana. Only over a distance of about 300 m southeast from the S. Manaika, hydrothermally altered andesites (H 353) are still found. South of the village of Kolomana, which is situated on the summit of a hill, in the direction of Paitoko, we are in the region of the south coast, which is built of glassy agglomerates and breccias which rocks show a composition of that of the pyroxene-andesites. The way to Paitoko follows the valley of the S. Areloe.

In the region between Asaba and Kolomana there is possibly a small caldeira, whilst a terrace is observed near the coast at a height of about 250 m above sea level.

¹⁾ These strong alterations of the andesites point to the neighbourhood of intrusive rocks, which, however, we did not find exposed. HARTMANN mentions in his list of rocks from Alor one sample of "granodiorite with contactrock", southwest of Langkoeroe.

Route from Langkoeroe in the direction of Taramana (north coast).

Thereupon an investigation was made from Langkoeroe in a NNE direction, along the horse track to Taramana (north coast). Over a distance of 1.5 km hydrothermally altered andesites are found (H 355 $\times$ to H 358 $\times$); infiltration of quartz in these rocks is a common feature. Further on in north eastern direction we pass the villages of Sidongmang and Afata; the mountains in this region chiefly consist of dark glassy pyroxene-andesites (H 358, H 359 $\times$). As we ascend to the highest summit of this region, 1354 m, small terrace-relics which consist of conglomeratic deposits with marine fossils are found at a height of 1200 m. The thickness of these deposits, which mainly consist of pebbles of glassy pyroxene-andesite and which are cemented by fine grained tuffaceous and calcerous material in which marine fossils are preserved (H 360 to H 369), does not exceed 75 metres.

From this locality to the summit, the mountains are built of obsidians and glassy andesites. Columnar joints may occasionally be observed.

Langkoeroe-Batoelolong-Koei route:

After these investigations in the surroundings of Langkoeroe our traverse through the central part of the island is resumed. We follow the way to Dalaman and from there the region between this small village and Batoelolong, situated on the south coast, is investigated, for which the horse track is used. For about 1.5 km hydrothermally altered andesites are observable; strongly bleached lavas with veins of carbonate, baryte and pyrite are rather numerous (H 371 $\times$, H 371, H 372 $\times$). When we reach the village of Koenaman, at a height of 700 m, a distinct terrace may be observed over a rather large area. This terrace is only locally covered with thin layers of raised reef limestone, but further on, in western direction, limestone is lacking and the terrace is formed by lava rocks.

Then follows a steep descent to the south coast leading over the well-known glassy pyroxene-andesites, occasionally alternating with obsidians and perlites, but for the greater part the rocks are developed as breccias and agglomerates (H 373 $\times$ to H 375 $\times$). 100 m south of Koenaman, as well as 500 m north of Batoelolong, light grey coloured amphibole-pyroxene-dacites are found in a few outcrops (H 372, H 375).

In the vicinity of Batoelolong, in the valley of a small river which debouches in the sea somewhat east of the village, a hot spring considerably raises the temperature of the riverwater.

The terraces in the surroundings of Batoelolong are not well-developed. At any rate upheaved reef limestones are lacking. Three terraces at a

height of respectively 5, 50 and 80 metres are fragmentary. They are formed by the glassy breccias and agglomerates.

From Batoelolong our way goes over the second terrace in western direction to Kiraman. No variation of lava rocks are found (H 376 $\times$, pyroxene-andesite); there are a few outcrops in vitrophyric amphibole-hypersthene-dacites (to andesites); these are light grey coloured rocks with a porphyritic habit.

Near Kiraman we leave the coast and now our way goes NW-ward to the village of Bokoeman, ascending 500 m over the glass breccias and tuffs (H 377 $\times$, H 379 $\times$) with intercalated basaltic lava flows (H 378 $\times$). The tuffs are varying in colour from white to yellowish-brown, while they are generally fine grained. On the cross-road of the way to Kalaisi strongly porphyritic andesites are encountered. Thereupon, after we have passed Bokoeman, we turn again to the south coast, to the village of Weroela. In the mountain, on the summit of which the small village is situated, glass agglomerates alternate with fine grained tuffs of a brown colour (H 380, H 381 $\times$).

We follow the coast for 2 km only and then we go straight to the North, to the village of Adiamang. We soon reach the 300 m terrace. The terrace surface dips towards the sea; it consists of tuffaceous and calcareous material in which marine fossils are found (H 384, H 390). The small village of Adiamang is also situated on the top of a hill, which mainly consists of glass breccias and agglomerates. This region is sowed with pebbles of vitrophyric amphibole-dacites (H 387 $\times$ to H 388).

Going from Adiamang in W NW direction to Bogaiboei, 400 m north from this village, we observe coarse grained tuffs and conglomerates, with an average thickness of about 75 m. These series are present over a large area (H 391, H 391 $\times$). These rocks are intercalated with enormous accumulations of glass agglomerates, sometimes with basalts (H 392 $\times$). This feature indicates a submarine character of these glass agglomerates and breccias. When we are about 1 km from Adiamang the well-developed 300 m terrace is observable in western direction. The dip sea-ward is seen very distinctly.

After crossing the S. Sahawai, at a height of 750 m, we are again amidst glass agglomerates. Bogaiboei lies now behind us and 200 m West of it vitrophyric amphibole-dacites (H 392) in a small outcrop are found, while somewhat further on vitric tuffs (H 393) and pumiceous biotite-dacites with large, clear quartz phenocrysts (H 394, H 395 $\times$) alternate with each other; both rocktypes are covered with greyish-white

tuffs (H 397), sometimes with intercalated dacitic vitrophyres, which are almost entirely devitrified and consequently of white colour (H 397 $\times$).

Then follow large exposures in pyroxene-andesites, which alternate with conglomeratic sediments, as H 391.

The village of Kasima, is built on a hill, which is composed of a 100 m thick stratum of yellow coloured tuffs (H 395). This deposit forms a steep wall, nearly vertical, in the valley of the river which is a small tributary of the S. Sahawai. The region between Kasima and Talawa consists of tuffs in thick strata, with intercalated thin lava streams. The tuffs (H 398 $\times$, H 398, H 399 $\times$) are mostly of a yellowish-brown colour, but occasionally they are white. The lavastreams consist of basic andesites to basalts (H 396 $\times$, H 396, H 399). These lavas are greyish-brown coloured; a somewhat violet hue lends these rocks a peculiar conspicuousness. Their thickness varies from 10 cm to several metres; these lavas show typical bulbous weathering phenomena, which feature has been described in basalts by several authors.

From Talawa, where our bivouac was made, we are now going in a SW direction, to Koei, which is situated on the south coast.

When we ascend about 200 m to the village of Katai, we pass a region of tuffs (H 400 $\times$ to H 401) in strata with a thickness of up to 200 metres and more. In this region, too, intercalations of lavastreams with a basic andesitic to basaltic composition, are found (H 403 $\times$, H 403). The rock-type H 403, which can be followed for a large distance, contains large, up to 2.5 cm, pyroxene crystals.

Thereupon fine crystalline lavas with andesitic composition are encountered along the way to Afakowada (900 m high). From here, gradually descending to Lelmang, we pass glass agglomerates alternating with tuffs.

When we pass the valley of the S. Koeisali, pyroxene-andesites of a structure somewhat different from the prevailing type are found (H 404, H 405 $\times$, H 405, H 1003). In an almost black glassy groundmass a large amount of cavities and large crystals of feldspar are observable.

Then we find the glass agglomerates over a large area; our way goes over steep mountains via Silalaboei to Manigiang, which is situated on the summit of a 1000 m high mountain. Columnar joints in the obsidians and glassy pyroxene-andesites are frequent.

A few hundreds of metres South from the just mentioned village, thick strata of tuffs — coarse- and fine grained strata alternating with each other — extend over a large area (H 407 $\times$). These tuffs form a flat, almost horizontal landscape over a large distance and one would be

inclined to describe this phenomenon as a terrace, but this is not certain at all. Descending to the village of Koei almost the entire mountain range with a height of 1000 m, which rises steeply from the sea, is formed by glassy agglomerates, often strongly porphyritic (H 407, H 408^x).

The surroundings of Koei:

From the surroundings of the village of Koei VERBEEK (35, p. 430) described a granodiorite, collected by natives, whilst EHRAT (11, p. 450) mentions similar rocks from the "Granitfeld Kui", but neither of these authors indicate where these rocks are found. Therefore the surroundings of this village were explored more in detail (Fig. 10).

The S. Koei was followed upstream, where glass agglomerates are very common. About 750 m from its mouth, dacitic lavas are found in a small outcrop. 500 m more to the North, solid rock exposures of quartz-andesites to dacites (H 412 to H 416) are observed.

Somewhat further on the S. Erba is reached and then in a small tributary of the S. Koei strongly altered and bleached andesites (H 410, H 411^x, H 411) are encountered.

The hills in the surrounding of these small rivers prove to consist of glass agglomerates.

The granodiorite locality could not be pointed out and as there have not been found any pebbles of these rocks in the river beds or on the coast, the occurrence of granodiorites in the neighbourhood of the village Koei should be considered as dubious. Especially the results of the explorations of EHRAT should be accepted with reservation.

Koei-Boeraga-Kikilai route:

From Koei our way now goes along the coast to the village of Boeraga. Four terraces, formed by glassy agglomerates, are visible, which are 5 m, 15 m, 50 m and about 150 m high. Raised reef limestone is absent, except on the spot where the village of Koei is built. The glassy breccias and agglomerates consist of pyroxene-andesites, often very dark coloured (H 418^x, H 419^x, H 419), but occasionally of a light grey colour (H 418). Large numbers of amphibole-hypersthene-dacites (to andesites) occur along the coast between Koei and Boeraga, so that we may assume that there are large exposures of these rocktypes in the vicinity of the coast (H 420, H 421^x, H 421).

Near the S. Bareng, the 50 m terrace is covered with reef limestone, whilst near the S. Saila very glassy andesites and obsidians with flow structure are present in large exposures.

When we reach the S. Boeraga, our way goes straight North through

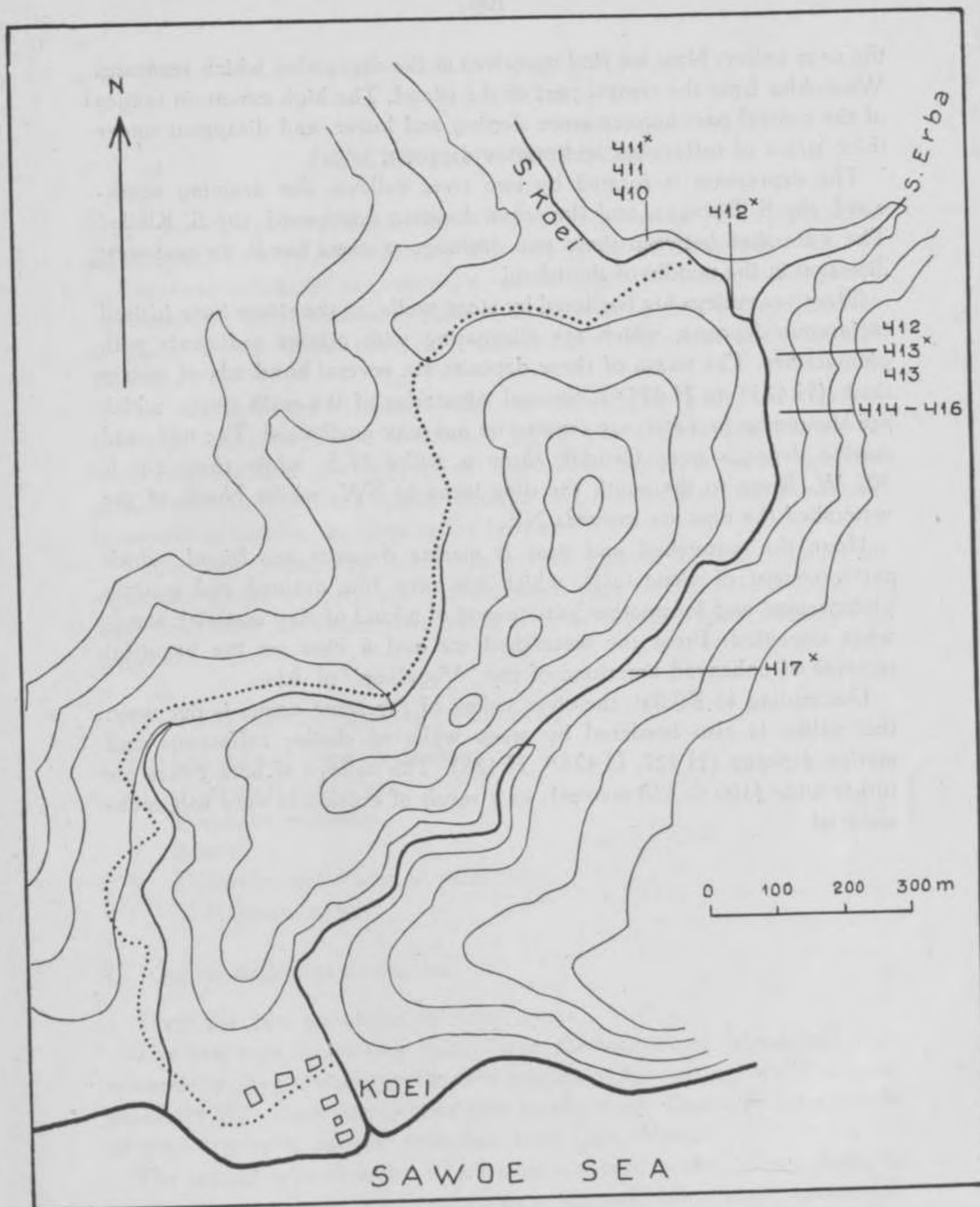


Fig. 10.

Surroundings of the village of Koei, south coast of Alor. Scale 1 : 25.000.

The interval of the isohypses is 100 m.

the river valley. Now we find ourselves in the depression which separates West-Alor from the central part of the island. The high mountain ranges of the central part become more sloping and lower, and disappear under thick strata of tuffaceous and marine deposits.

The depression is formed by two river valleys, one draining southward, the S. Boeraga, and the other draining northward, the S. Kikilai. The watershed between these two drainage systems lies in an east-west direction in the middle of the island.

The river valleys are bordered by steep walls, as the rivers have incised tuffaceous deposits, which are alternating with marine sediments with globigerines. The strata of these deposits are several hundreds of metres thick (H 423^x to H 425^x). Several tributaries of the main rivers, which are abounding in water, are crossed on our way northward. The tuff- and marine deposits near Gendok show a strike N-S, while their dip is 30° W. More to the south the dips turns to SW, whilst North of the watershed the dips are towards NE.

Upon the watershed and near it marine deposits are found, which partly consist of vitric tuffs, which are very fine grained and contain globigerines, and for another part consist of a kind of clay material, somewhat cemented. From the watershed we had a view on the beautiful terraces of upheaved limestone of the "Vogelkop" of Alor.

Descending to Kikilai, the river valley of the same name, is our way; this valley is also bordered by steep walls of similar tuffaceous and marine deposits (H 427, H 428^x, H 428). The valleys of both rivers are rather wide (100 to 150 metres), as a result of erosion in very soft rock-material.

DESCRIPTION OF ROCKS.

As has become evident from the description of the route, the investigated part of Alor consists of a few types of rocks only.

Pyroxene-andesites are strongly prevailing; they occur as glassy agglomerates and breccias. Andesites, mostly containing a large amount of glass in their bases, have been found especially south of the bay of Kebola.

The surroundings of Langkoeroe are rich in thermally and hydrothermally metamorphosed andesites, while quartz-andesites to dacites, with more or less phenocrysts of amphibole, occur in small outcrops rather scattered over the island. Basalts and gradations from pyroxene-andesites to basalts, are also rather frequent.

Tuffs also frequently occur on several places of the island, but especially in the western and southwestern part of Central-Alor. As we have seen they are often alternating with lavarocks (basic andesites to basalts)..

The rocks may be classified as follows:

1. Quartz-andesites to dacites.
2. Glass-rich andesites.
3. Pyroxene-andesites.
4. Basalts.
5. Hydrothermally altered andesites.
6. Tuffaceous rocks.

1. Quartz-andesites to dacites.

There are two somewhat different types.

The first type shows in a glassy base, phenocrysts of felspar and dark minerals, among which amphibole is generally dominating, while in some cases (H 392) large phenocrysts may be observed. This type corresponds to the vitrophyric dacites, described from East-Wetar.

The second type of rocks, which mainly occurs in the S. Koei shows in a groundmass which is almost entirely crystallized a large amount of felspar phenocrysts. The amount of dark minerals has strongly decreased with respect to the first type, whilst quartz only occurs in the groundmass.

These rocks incline to the quartz-andesites, although there is sometimes a considerable amount of alkali feldspar, in consequence of which these rocks will also be classified as dacites.

The first type: (H 335 $\times$, H 392, and the pebbles H 388 $\times$, H 389, H 420, H 421 $\times$).

Sample H 335 $\times$ is a glassy rock of somewhat porphyritic structure, while its colour is grey. Phenocrysts of feldspar and amphibole are macroscopically recognizable. The composition of the phenocrystic plagioclase feldspar is acid labradorite. Part of the individuals, the diameter of which may range up to 1.5 mm, are twinned; zonal structure is absent. Slight kaolinization is observable, while many phenocrysts enclose a large number of glassy particles. Strongly pleochroic green hornblende occurs as phenocrysts, as well as augite, but the former mineral is prevailing. The individuals of amphibole which are up to 2 mm in diameter, show a narrow opacitic border; only a few phenocrysts have entirely altered into opacite.

Some biotite, along cracks of the amphibole, is also observable. Twins of the dark minerals, except of biotite, are rather common. Some grains of magnetite of a moderate size, are associated with the amphibole.

The groundmass is rich in glass, in which a number of small laths of plagioclase occur, with a composition of oligoclase, andesine. A moderate amount of quartz in the groundmass is observable, while minute grains of magnetite and sporadically some small grains of augite also occur.

H 392 is a greyish-violet rock, with a number of phenocrysts of feldspar, quartz and dark minerals in a glassy base. The rock shows a large amount of elongated vesicles and provides it with a pumiceous habit. Phenocrysts of quartz, which are extraordinarily clear, and have a size of about 0.5 cm, are rather abundant. Part of them are somewhat corroded.

The zonally structured plagioclase feldspars have a composition of basic andesine in the cores to acid andesine in the margins. The dark minerals, which occur as phenocrysts, chiefly consist of biotite and hypersthene, while green hornblende is present in smaller amount. The biotite exhibits broad opacitic borders, some flakes are entirely resorbed. Similar features may be observed in the amphiboles. The hypersthene is fresh, without alteration.

The groundmass consists of glass, which is slightly devitrified. A few isometric grains of magnetite are present; rutile and apatite are accessories. The dusty sections of apatite are pseudopleochroic, as a result of very minute rodlike inclusions. Mineral grains of the epidote group are also

observable. This rock corresponds with a vitrophyric hypersthene-biotite-dacite.

The pebbles H 388 $\times$, H 389, H 420, H 421 $\times$. Their description may be brief, for they show striking resemblance to the vitrophyric dacites of East Wetar.

Phenocrysts of feldspar, hypersthene, amphibole and augite, and in some cases of quartz (H 388 $\times$) occur in a groundmass which is slightly crystallized and contains a moderate amount of glass. Most of the phenocrysts of the plagioclase feldspar are zonally structured. Their composition varies from medium labradorite in the core to basic andesine in the more acid margins. In H 420 the most acid margins of the feldspar phenocrysts are basic oligoclase. The phenocrysts may attain a diameter of 2.5 mm.

Among the dark minerals green hornblende is prevailing; of the pyroxenes, hypersthene is dominating over augite, which is generally present in small quantity. The pyroxenes are fresh and unaltered; hypersthene is rather strongly pleochroic from light yellow to light green rosa.

Generally the green hornblende is more or less resorbed. Broad opacitic borders, which consist of small grains of pyroxene and oxidic iron ore, are common; occasionally they are entirely resorbed; embayments, filled with groundmass compounds, due to the same resorption phenomenon, are also observable. The diameter of the phenocrystic amphibole may range up to 5 mm, whilst the sizes of the pyroxenes generally are considerably smaller. Biotite is present in a very subordinate amount. Sample H 388 $\times$ contains a few small phenocrysts of quartz, which are somewhat corroded and enclosed by a rim, built up of small grains of augite; occasionally this augite has a radial structure.

Phenocrysts of hypersthene surrounded by a rim of green hornblende may also be observed.

The groundmass, which is slightly crystallized, contains some glass. Acid plagioclase, a varying amount of quartz and some alkali feldspar are the crystallization products of the groundmass. Also some flakes of amphibole and grains of pyroxene are found; the size of the crystallization products of the groundmass varies between 0.01 and 0.15 mm, sometimes it may range up to 0.5 mm. Magnetite is present in moderate amount in all samples; sometimes it may attain a phenocrystic size.

These rocks contain several inclusions, which have a base of glass. The phenocrysts, which consist of varying amounts of feldspar, hyper-

sthene, augite and amphibole, seem to have hindered each other during crystallization.

The zonally structured plagioclase has a composition of basic bytownite in the cores to basic andesine in the more acid margins. The amphibole does not show an opacitic border. In some rocks amphibole prevails among the dark minerals, in others hypersthene, while augite is mostly present in inconsiderable quantity. All phenocrysts are of about the same size.

The second type: (H 412, H 413^x, H 414, H 416 and the pebble H 417).

These rocks are generally of a light greyish-green colour, with a porphyritic habit.

Phenocrysts of felspar and some of dark minerals occur in a groundmass, which is almost entirely crystallized. Occasionally some glass may be observed.

The plagioclase felspar is weakly zoned, and has a composition of medium labradorite, with a slight decrease of basicity in the more acid margins.

Some phenocrysts show reverse zoning, while the basic zones, with a composition, which may range up to medium bytownite, alternate with more acid ones (H 414 and H 416). Their diameter may range up to 7 mm.

Phenocrysts of dark minerals are present in very moderate amount; nearly all individuals have entirely altered, only a few small fresh amphiboles are observable. Alteration into a fibrous ferri-ferous chlorite variety and serpentinous substance is very common. The original dark minerals were for a good deal pyroxenes; their idiomorphic outlines are still found.

In samples H 412 and H 414, a few small phenocrysts of quartz are present, surrounded by a turbid zone. The groundmass of these rocks is of the same composition, though its structure may vary considerably. Besides some glass, the groundmass consists of acid plagioclase, in small laths, quartz, and alkali felspar in varying amounts. The composition of the plagioclase is somewhat varying between oligoclase-andesine and medium andesine.

In some rocks the groundmass consists chiefly of pseudo-spherulitic and spherulitic bodies of quartz and alkali felspar. Micrographic intergrowths have been found, while occasionally in the centre of these individuals a lozenge-shaped quartz grain is present. The average diameter of the groundmass is 0.05 mm; it may range up to 0.15 mm.

The sample H 417, shows in the groundmass poikilitic quartz crystals, in which small laths of acid plagioclase are embedded.

Secondary quartz sometimes fills the cavities. A colourless mineral with low refractive indices, which is almost isotropic, is present as alteration products within the phenocrystic plagioclase felspar.

2. Glass-rich andesites.

The samples H 302 and H 305 are dark bluish-black coloured rocks with a glassy base. Phenocrysts of felspar are common, while those of pyroxene are scarce. Often they are of zonal structure; twinning is common. They have a composition of medium labradorite with slightly more acid margins. In H 305 the phenocrystic plagioclase felspar, which may reach a diameter of 12 mm, is labradorite-bytownite with more acid margins of acid labradorite.

The phenocrysts of pyroxene, — only augite is present — are generally much smaller.

The groundmass is rich in glass and small laths of plagioclase, with a composition of medium andesine, while in H 302 the plagioclase is oligoclase-andesine. In this sample a distinct flow-structure is shown by parallel arrangement of the plagioclase laths. Large, elongated vesicles make this structure much more pronounced.

Small grains of oxidic iron ore are scattered through the rock.

3. Pyroxene-andesites.

Samples (H 310, H 311 $\times$, H 320, H 389, H 408, H 426, H 341 $\times$ and H 418 $\times$, H 418, H 419 $\times$, H 396 $\times$, H 396, H 399, H 307 $\times$).

There are several different types among the pyroxene-andesites.

One type, to which the samples H 418 $\times$, H 418, H 419 $\times$ belong, is strongly prevailing in the island.

Generally these rocks are nearly black, occasionally light green and always strongly porphyritic of structure. Phenocrysts of plagioclase felspar, rhombic and monoclinic pyroxene are always present. The composition of the phenocrystic plagioclase felspar is varying between medium labradorite and acid bytownite, while in consequence of the zonal structure, which may be frequently observed, the more acid margins are of acid-labradoritic composition. Reverse zoning is present and twinning according to several twinning laws is very common. Their diameter is about 5 mm.

Phenocrysts of pyroxene frequently show idiomorphic sections. Both

rhombic and monoclinic pyroxene are present, often in almost equal amounts, but their mutual proportions may differ considerably. Hypersthene often shows a rather strong pleochroism from yellowish- to light green rosa. The diameter generally is somewhat smaller than that of the plagioclase phenocrysts.

The groundmass is rich in glass, which may contain a varying quantity of small laths of plagioclase, with a composition of basic andesine, and small grains of pyroxene and oxidic iron ore.

The pyroxene of the groundmass often consists of augite only; in some samples some hypersthene is present as well.

In H 418, a large amount of microlites is present in the groundmass.

Samples H 310, H 311^x show a more crystallized habit. Their mineral composition corresponds entirely to the pyroxene-andesites.

The felspar laths of the groundmass of H 426 show a distinct parallel arrangement, so providing a flow structure around the phenocrystic plagioclase, which has a composition varying from medium bytownite to medium labradorite, in consequence of zonal structure. This rock, as well as sample H 341^x, contains besides pyroxene, green hornblende as dark constituent, partly as phenocrysts, partly as small prisms in the groundmass.

Sample H 320 shows a decrease in the dark constituents. The amount of phenocrystic plagioclase, which has a composition of labradorite-bytownite ($\pm 70\%$ An.), is strongly dominating over the quantity of pyroxene. Only a few phenocrysts of augite are present, while the groundmass contains a large amount of small grains of pyroxene.

Another type of pyroxene-andesite is exhibited by sample H 408. In a very dense, glassy groundmass, which contains numerous cavities of about 3 mm in diameter, a great number of large phenocrysts of felspar is present. The diameter of these plagioclase felspars is about 12 mm. Twinning is common, while the composition is acid bytownite. The zonal structure is very weak. The groundmass of this rock shows a peculiar feature, which has strong resemblance to the structure of the groundmass of the glass-encrusted andesites, which have been described of the island of Wetar.

The striking feature of radial arrangements of augite prisms (augite, because of its very oblique extinction) set upon arcuate stems, so providing distinct spirals (Plate XII, fig. 2), is common. Besides augite, which is strongly dominating in the glassy groundmass, some very thin laths of acid plagioclase are observable. They often show a feathery development, a feature which is also observable for the thin augite prisms.

The last group of pyroxene-andesites, which will be described here, are gradation rocks to the basalts (H 396 $\times$, H 396, H 399, H 307 $\times$). Macroscopically they differ from the normal pyroxene-andesites in their colour, which is grey-brown, often with a violet hue, so a colour which characterizes the basalts from this island. Their structure is strongly porphyritic; phenocrysts of plagioclase are frequent. The generally somewhat zonally structured individuals have a composition of acid bytownite in the cores, with acid labradorite in the more acid margins. The diameter may reach up to 7 mm. Twinning is very common. Phenocrysts of pyroxene are observable in moderate amount. Monoclinic as well as rhombic pyroxene is present, the length of which never exceed 1.2 mm.

The groundmass consists, besides a moderate amount of brownish coloured glass, of felspar and pyroxene, in almost equal amounts, with diameters of up to 0.5 mm. The plagioclase felspar of the groundmass is basic andesine, with more acid margins of acid andesine. Zonal structure is common. The pyroxene is almost entirely augite; hypersthene is rare.

Magnetite in small isometric sections (0.1—0.3 mm) is fairly abundant. Occasionally (as in sample H 307 $\times$) small grains are observable, which probably consist of iddingsitic substance, which may be considered as an alteration product of olivine. But no distinct pseudomorphs after olivine are found in these rocks, in consequence of which they have been reckoned to the pyroxene-andesites and not to the basalts.

This can also be said of the samples H 309 and H 326, which are however very dense rocks of a black colour. Most of the dark minerals have entirely altered into a chloritic mineral of light brown colour, and into carbonate. Macroscopically these rocks show hardly any porphyritic habit; under the microscope this feature is more distinct.

4. Basalts.

Macroscopically these rocks (H 335 and H 390 $\times$) are recognizable by their colour, which is always greyish-brown to red-brown, while their structure is more crystalline than that of the pyroxene-andesites.

Under the microscope their structure strongly resembles that of the last mentioned rocks. But for the presence of phenocrysts of olivine, which were absent in the pyroxene-andesites, the mineral composition of the basalts is almost equal to that of these rocks. The phenocrysts of plagioclase felspar are basic labradorite, while more acid margins of acid labradorite are frequent. Zonal structure of the plagioclase felspar is very common. The ratio between the phenocrysts of monoclinic and rhombic

pyroxene is varying. Their length, as well as that of the phenocrystic feldspar is up to 2.5 mm.

The phenocrysts of olivine, the length of which may range up to 0.3 mm, are idiomorphically developed. Part of them has entirely altered into iddingsite or a serpentinous substance. The margin of the phenocrysts sometimes consists of oxidic iron ore. The groundmass of these rocks shows striking resemblance to that of the pyroxene-andesites just described.

5. Hydrothermally altered andesites.

This group of rocks is very frequent in the region around the village of Langkoeroe. Especially there are good exposures in the upper courses of the S. Pomoto.

The hydrothermally altered andesites gradually change into normal pyroxene-andesites (H 351 $\times$ —H 353 $\times$; H 375); the colour of the former rocks generally is yellowish-brown or grey. They look rather altered.

Under the microscope they show a porphyritic habit. Phenocrysts of plagioclase feldspar and altered pyroxenes are present in an almost entirely crystallized groundmass.

The phenocrystic plagioclase feldspar, which may reach a length of 3 mm, have a zonal structure, while twinning according to the albite- and Carlsbad law is common. Their composition is medium anorthite in the core, with more acid margins, the most acid composition of which is acid labradorite. The basicity of the phenocrystic feldspar is rather strongly varying. In the less altered rocks the feldspar is often quite unchanged — occasionally slight albitization — and alteration into sericite and kaoline is observable (H 344 $\times$), although the pyroxene may have far advanced towards total replacement by minerals of the amphibole group (H 340 $\times$, H 344 $\times$, H 345 $\times$). In these rocks all pyroxenes have entirely altered. Idiomorphic boundaries show that the primary phenocrystic mineral was a pyroxene, but now it has entirely altered into a fibrous green hornblende. In some other samples the idiomorphic boundaries of the phenocrystic pyroxene have become more indefinite and rounded-off. In H 345 $\times$ a large number of vesicles is present, filled with fibrous green hornblende, while occasionally a colourless variety of the amphibole group, probably actinolite, is observable. Sometimes, however, some chloritic substance is still present, but it is not certain whether this chloritic substance must be considered as an alteration product of the amphibole or as a remnant of the filling of the cavity, which has not yet been altered into amphibole, possibly by slight thermal metamorphism. The groundmass

of these rocks, which is rich in small laths of plagioclase, with a composition of andesine, contains a considerable amount of small fibres of green hornblende. The amphibole of the groundmass may also be considered as alteration product of pyroxenes. Small isometric sections of oxidic iron ore are scattered through the rock. Other secondary constituents are minerals of the epidote group, mainly strongly pleochroic pistacite, and pyrite. In the centre of some cavities a few grains of carbonate occur amidst the fibres of amphibole.

Another group of hydrothermally altered andesites (H 341, H 342, H 345, H 348 $\times$, H 349, H 353), in which amphibole is lacking, almost entirely contains secondary minerals. Already macroscopically accumulations of chlorite, carbonate and minerals of the epidote group are distinguishable, while veins of carbonate and baryte have already been earlier reported. Microscopically all rocks have a porphyritic habit. The carbonate crystals show denticular boundaries against each other and between crossed nicols a blotchy extinction is observable. Minerals of the epidote group are occasionally frequent. They partly occur as fine divided masses, for another part, filling up cavities, they have developed as tabular crystals with a maximal diameter of 0.5 mm. Mainly strongly pleochroic pistacite is present.

The dark minerals have entirely altered into chlorite (penninite because of its very low, ultra-blue interference colours).

Samples H 348 $\times$ and H 349 contain a considerable number of phenocrysts, with an average size of 0.8 mm, which show the idiomorphic boundaries of hypersthene, whilst in some sections a distinct cleavage is visible, so that olivine is eliminated. These phenocrysts have entirely altered into a serpentinous substance of a light brown colour. Although fresh hypersthene is absent, it is very probable that we have to deal here with bastite.

In some cases the phenocrystic feldspar is still fresh. Its composition is medium labradorite, while zonal structure is very weak. But often the feldspar has altered into carbonate, kaoline, sericite and minerals of the epidote group or into chlorite. Veinlets filled with a carbonate mineral, probably dolomite, are present. Fine divided particles of oxidic iron ore are of local occurrence.

Secondary quartz is also present, but in small amounts.

6. Tuffaceous rocks.

Large accumulations of tuffs are mentioned from the island, especially in the region along the south coast, between Batoeloelong and Boeraga,

while the N-S depression from Boeraga to Kikilai, which separates the western- from the central part of Alor, consists almost entirely of these deposits.

Part of these tuffaceous rocks are alternating with Globigerina limestones and shales, while in most cases the tuffs do not contain any calcareous material. Some of the tuffs, however, contain a varying amount of Globigerinidae.

The rocks generally are fine- to medium grained, sometimes however very coarse grained. Their colour is mostly yellowish-brown to brown, in some cases almost greyish-white. The investigation of the heavy components of these tuffs indicates the volcanic origin of the rocks.

The heavy residue of all samples has been studied. In almost all samples (H 379 $\times$, H 380, H 362 $\times$, H 385 $\times$, H 381 $\times$, H 391 $\times$, H 386, H 393, H 398, H 395, H 399 $\times$, H 400, H 400 $\times$, H 401 $\times$, H 423, H 423 $\times$, H 424, H 427, H 428 $\times$, H 428, H 1001), these residues consist of a varying amount of hypersthene, augite, and oxidic iron ore. Some samples (H 425 $\times$, H 401, H 398 $\times$) contain besides these minerals, some crystals of basaltic hornblende. Only mutual variations in quantity of these minerals may be observed. In some residues some crystals of zircon are present, while in others oxidic iron ore is almost absent.

GEOLOGICAL SUMMARY.

The investigated central part of Alor consists for the greater part of effusive rocks with intercalated tuffs, limestones and marls, containing Globigerinidae. These effusive rocks show the characteristics of submarine volcanism; especially in the region near the very steep south coast huge accumulations (sometimes with a thickness of about 900 m) of volcanic breccias and agglomerates are found, with intercalated tuffs, which sometimes contain Globigerinidae. The glass breccias and agglomerates are pyroxene-andesites. These types of rocks are strongly prevailing all over the investigated area, while some basalts are also found. Quartz-andesites to dacites have been locally found, especially in the region along the south coast of the island. Hydrothermally altered andesites were found rather frequently; the surroundings of Langkoeroe consist for the greater part of this bleached, hydrothermally altered rock type.

In contrast to the north coast, the south coast only shows at a few localities living reefs. As to the upheaved reef limestones, which have a large extension in the Kebola Peninsula, as well as in the western part of Alor, these are frequent along the north coast of Central-Alor. From the investigated region along the south coast only one locality — namely near the village Koenaman — was found, where a terrace is present, which is covered with a thin stratum of reef limestone. This occurs at a height of about 700 m. The highest terrace in the regions, just mentioned, are of the same height: about 700 m above sea level.

Along the south coast many terraces are found, which are not covered by reef limestones. The highest upheaved sedimentary formation of marine origin, was found some kilometres North from the village Langkoeroe at a height of 1200 m. The sediments are conglomerates, the pebbles of which mainly consist of pyroxene-andesites, cemented by tuffaceous and strongly powdered lava rock material, which contain marine fossils. This fact points to an upheaval of the island of at least 1200 m during relative recent times, for these sedimentary deposits may be supposed to be of young-Tertiary or even younger age.

The depression which is present between the western part of Alor and its central region, is filled with limestones, marls and tuffs, containing Globigerines. These sediments show a considerable dip westward, up to

30° in the middle of the island, while to the South and to the North, the dips are about 30° SW and 25°—30° NW respectively.

The young, upheaved coral reef limestones of the Kebola Peninsula and of West Alor are mainly horizontally stratified, especially in the central parts of these areas, although near the coast these limestones exhibit slight dips seaward.

POERA BESAR.

INTRODUCTION.

The small island of Poera besar is situated in Strait Pantar, opposite to the bay of Kebola. It is almost circular and has a diameter of about 6 km. In Poera besar one day was spent. The only available informations concerning this island are two drawings by VERBEEK (35) and one sketch from KUENEN (23, p. 54), whilst also HARTMANN (16) gives a short description of it.

The island is formed by a volcano, now extinguished, 1015 m high, which, according to HARTMANN, shows a beautiful crater with a water basin, covering part of its bottom. Observations made from a ship by KUENEN induced him to conclude that there are no upheaved reef limestones on the eastern side of the island, although VERBEEK mentioned an upheaved reef at a height of about 50 m on this side of the island, which he visited. But generally geological observations made from a ship are not very accurate, and in those cases one does better not to criticize the observations of an experienced geologist. In fact, a distinct upheaved reef terrace at a varying height of 50 to 60 m above sea level is present on this side of the island. This terrace, which is rather narrow, gradually disappears in the NNE part of the island. The north coast, on which the native village of Limarahin is situated, does not show terraces.

From the eastern side of the island several rocks were collected (Fig. 11).

Two types of lava rocks are found in the investigated region:

1. Glass-rich andesites to pyroxene-andesites.
2. Basalts.

The first group of rocks has a varying amount of pyroxene, both monoclinic and rhombic pyroxene, while neither the composition of the phenocrystic plagioclase feldspar, nor the composition of the feldspar of the groundmass show important variations. Generally the composition of the phenocrystic plagioclase feldspar varies between medium labradorite and acid bytownite, while the groundmass feldspar is more acid, with a com-

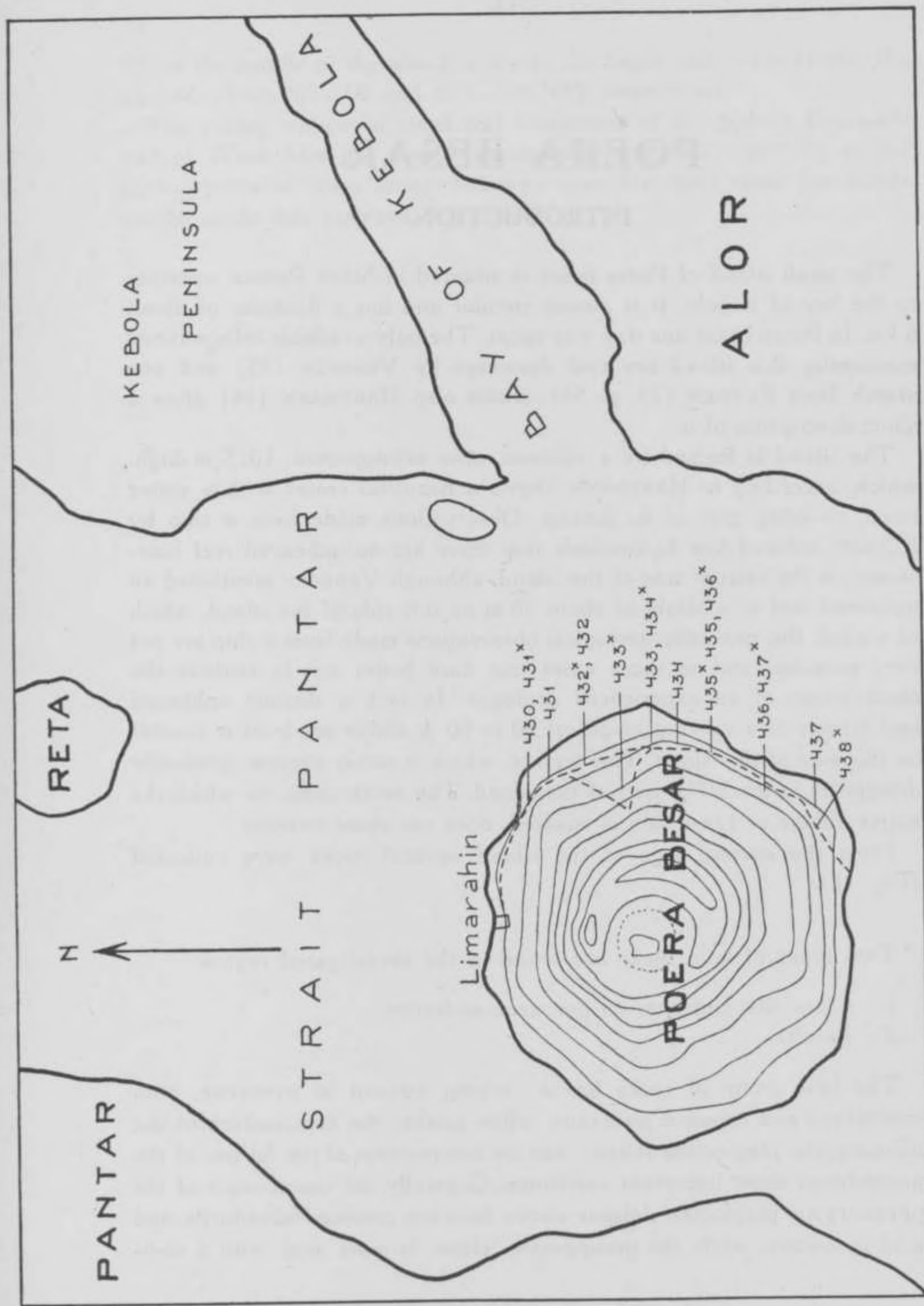


Fig. 11.
The island of Poera besar in Strait Pantar (scale 1 : 100.000).
The interval of the isohypses is 100 m.

position of andesine-labradorite. Generally the plagioclase phenocrysts of the second group, the basalts, are somewhat more basic and their basicity may range up to medium bytownite. Besides abundant pyroxene, olivine is also present. The quantity of oxidic iron ore is nearly equal in both types of lava rocks. As will be seen from the description of the rocks, they show great resemblance to certain rocks of the island of Alor.

DESCRIPTION OF ROCKS.

1. Glass-rich andesites to pyroxene-andesites (H 434, H 431, H 431 $\times$, H 433 and H 432, H 432 $\times$, H 436, H 437 $\times$).

Macroscopically the rocks of this group show slight differences in structure. Generally the glass-rich andesitic members of the group have more cavities and only show phenocrysts of felspar, while the pyroxene-andesites frequently are dense rocks, with phenocrysts of felspar and pyroxene in a glassy base. The colour of the rocks varies from greyish-blue to dark bluish-black.

Andesite. H 437 $\times$. A very dark coloured rock, with a strongly porphyritic habit. Phenocrysts of plagioclase felspar, and in considerably smaller amount of pyroxene, are present in a base, rich in glass. The felspar is a weakly zoned plagioclase, with a composition of medium labradorite, with slightly more acid margins, the basicity of which decreases to andesine-labradorite. Its diameter ranges up to 1.5 mm. Part of the pyroxene is idiomorphically developed; both hypersthene and augite occur; sometimes small glomeroporphyritic accumulations of these minerals are found. The diameter of the pyroxenes is considerably smaller than that of the phenocrystic felspar. The groundmass is rich in glass, but contains a moderate amount of small laths of acid plagioclase, which have a composition of oligoclase-andesine. The glass itself is light brown of colour. A small number of particles of oxidic iron ore is also present.

Pyroxene-andesites. H 431 $\times$, H 431. From these two samples, H 431 inclines to the rocks described as andesites. It is a dark bluish-black rock, with a large number of small cavities, a few large phenocrysts of felspar and a great amount of much smaller ones, in a glassy base, which is rather rich in very small laths of felspar and grains of pyroxene.

The few large phenocrysts of plagioclase show a distinct zonal structure. Acid and more basic zones are alternating. The composition of the core is labradorite-bytownite, while the more acid margins range up to andesine-labradorite. Some of the large phenocrysts, which may attain a length of 1.2 cm, show a spotted extinction between crossed nicols, in consequence of slight differences in composition.

The smaller phenocrysts, which have an average diameter of 1.5 mm, have a basic labradoritic composition.

A moderate amount of pyroxene, both monoclinic and rhombic pyroxene, occurs. Twinning is present, but rare.

The quantity of oxidic iron ore is considerable; some grains attain a phenocrystic size, part of them are corroded.

H 431 $\times$ is a dense rock. The amount of pyroxene has increased, strongly pleochroic hypersthene is dominating over augite. Occasionally augite surrounds the hypersthene. The plagioclase felspar is present in phenocrysts, which show a basic labradoritic composition, while their diameter is about 3 mm.

The amount of pyroxene is fairly abundant in this rock. The groundmass is glassy, with small laths of acid plagioclase and small grains of pyroxene and oxidic iron ore.

2. Basalts (H 433 $\times$, H 434 $\times$, H 435 $\times$, H 435, H 436 $\times$).

Generally the basalts of this island — as it was shown for Alor — are macroscopically recognizable by their colour which is greyish-brown with a reddish hue, while they are less porphyritic and they have a more crystalline groundmass. Under the microscope, however, the porphyritic habit is a distinct feature. Phenocrysts of plagioclase felspar, pyroxene and olivine are observable.

The phenocrysts of plagioclase are weakly zoned. Their composition varies from medium bytownite in the cores to acid labradorite in the more acid margins. The diameter may reach up to 3 mm. The phenocrysts of pyroxene, which is present as monoclinic and rhombic pyroxene, are generally somewhat smaller. Augite has grown around the hypersthene, a feature which is also very common for the pyroxenes of the basic andesites. The monoclinic variety is dominating in the rock.

Olivine is present in varying amounts. Part of the crystals are idiomorphically developed. Some of the crystals are fresh, but the greater part has strongly altered into red brown iddingsite. Iddingsite pseudomorphs after olivine are observable. They may attain a length of 1.2 mm, but generally are much smaller in size.

Magnetite is also present in considerable quantity, often it has isometric boundaries.

In H 434 $\times$ hypersthene has grown round olivine, but on the border of these two minerals, magnetite has crystallized and shows a typical structure.

The groundmass of these rocks has a varying amount of glass, which contains a large number of small laths of acid plagioclase (oligoclase-andesine), while the amount of grains of pyroxene is considerable.

LITERATURE.

1. BALSILLIE, D., The Ballantrae Igneous Complex South Ayrshire. *Geol. Mag. N.S.*, Vol. 69, p. 107—130, 1932.
2. BROUWER, H. A., Geologische onderzoeken op de Sangi-eilanden en op de eilanden Ternate en Pisang. *Jaarb. Mijnw. N. O. I., Verh. II*, p. 44—51, 1920.
3. ———, Geologische onderzoeken op het eiland Rotti. *Jaarb. Mijnw. N. O. I. Verh. III*, p. 35—106, 1920.
4. ———, Over insluitsels en cordierietgehalte van bronziet-biotiet-dacieten van het eiland Ambon. *Verh. v. h. Geol. Mijnb. Gen. voor Ned. en Kol., Geol. Serie, Dl. VIII*, 1925.
5. BROUWER, D., Bijdrage tot de Anthropologie der Alor eilanden. *Diss. Amsterdam* 1935.
6. BENSON, W. N., The geology and petrology of the Great Serpentine Belt of New South Wales. Part V. The geology of the Tamworth-district. *Proc. Linnean Soc. N. S. W.* Vol. XL, p. 540—624, 1915.
7. COQUAND, H., *Traité des roches*. Paris 1857.
8. CHUDoba, K., *Mikroskopische Charakteristik der Gesteinsbildende Mineralien*. Freiburg i. B., 1932.
9. DANA, E. S., Contributions to the petrography of the Sandwich islands. *Amer. Journ. Sci.* Vol. XXXVII (CXXXVII), p. 441—467, 1889.
10. ECKERMANN, H. VON, A contribution to the knowledge of the late sodic differentiates of basic eruptives. *Journ. of Geol.*, Vol. XLVI, p. 412—437, 1938.
11. EHRAT, H., Die Tiefengesteinen der kleinen Sunda Inseln. *N. Jahrb. für Min. Beil. Bd. 58 A*, p. 433—452, 1928.
12. ELBERT, J., Die Sunda Expedition (des Vereins für Geographie und Statistik zu Frankfurt a. Main). *Festschrift, Bd. II*, p. 211—256, 1912.
13. FREEMAN, B. C., Replacement shells around batholiths in the Waswanipi district Northwestern Quebec. *Journ. of Geol.*, Vol. XLVI, p. 681—699, 1938.
14. GAREISS, A., Ueber Pseudomorphosen nach Cordierit. *Tscherm. Min. und Petr. Mitt.*, Bd. 20, p. 1—40, 1901.
15. GILLULY, J. E., Replacement origin of the albite granite near Sparta, Oregon. *U. S. G. S. Prof. Paper 175-C.*, p. 65—81, 1933.
16. HARTMANN, M., Rapport over Alor (unpublished, in the archives of the Mining Department at Bandoeng).
17. HEERING, J., Cordieritpseudomorphosen in Sanidin-albit-rhyoliten von Tandjoeng Illipoi, Wetar (Niederl. Ost-Indien). *Proc. Kon. Acad. v. Wetenschappen, Amsterdam*. Vol. XLIV, 1941.
18. IDDINGS, J. P., Geology of the Yellowstone Park. *Monographs U. S. G. S.*, Vol. XXXII, Part II, 1899.
19. JOHANNSEN, A., A descriptive petrography of the igneous rocks. Vol. I, II, III, IV. Chicago, 1931—1938.

20. JONG, H. DE, Studien über Eruptiv- und Mischungsgesteine des Kaibobogebietes. Rutten-Hotz Geol. Petr. and Palaeont. results of Expl. in the island of Ceram. 1923. (Also published as Diss. Utrecht 1923).
21. JONG, J. D. DE, Geological investigations in West Wetar, Lirang and Solor (Eastern Lesser Soenda Islands). Diss. Amsterdam 1941.
22. KIKUCHI, Y., On pyroxene components in certain volcanic rocks from Bonin Island. Journ. Coll. Sci. Imp. Univ. Japan. Vol. III, p. 67—89, 1890.
23. KUENEN, PH. H., Geology of coral reefs. "The Snellius Expedition in the eastern part of the Neth. East-Indies 1929—1930". Vol. 5, Part II, p. 54.
24. ———, Contributions to the geology of the East Indies from the Snellius Expedition. Part I. Volcanoes. Leidsche Geol. Med. Dl. VII, p. 273—331. 1935.
25. MÖHLE, F., Beitrag zur Petrographie der Sandwich- und Samoa Inseln. N. Jahrb. für Min. Beil. Bd. XV, p. 66—104, 1902.
26. RIEDEL, J. G. F., De sluik- en kroesharige rassen tusschen Celebes en Papua. 's-Gravenhage 1886.
27. ROEVER, W. P. DE, Geological investigations in the Southwestern Moëtis region (Netherlands Timor). Geol. Exp. to the Lesser Sunda Islands under leadership of H. A. Brouwer. Vol. II, p. 101—344, Amsterdam 1940; also published as Diss. Amsterdam 1940.
28. SIMON, A., Beiträge zur Petrographie der kleinen Sunda Inseln Lombok und Wetar. Diss. Marburg 1913.
29. SIMONS, A. L., Geological investigations in NE Netherlands Timor. Geol. Exp. to the Lesser Sunda Islands under leadership of H. A. Brouwer. Vol. I, p. 111—213, Amsterdam 1940; also published as Diss. Amsterdam 1939.
30. SPURR, J. E., Classification of Igneous rocks according to composition. Amer. Geol. XXV, 1900.
31. SCHROEDER VAN DER KOLK, J. L. C., Mikroskopische Studien über Gesteine aus den Molukken. I. Gesteine von Ambon und den Uliassern. Jaarb. Mijnw. N. O. I., 24, Wetenschapp. Ged., p. 1—57, 1895.
32. TILLEY, C. E., The petrology of the granitic mass of cape Willoughby, Kangaroo Island. Part I. Trans. Roy. Soc. S. Australia, Vol. XLIII, 1919.
33. TURNER, H. W., Notice on some syenitic rocks from California. Amer. Geol. Vol. XVII, 1896.
34. VERBEEK, R. D. M., Geologische beschrijving van Ambon. Jaarb. Mijnw. N. O. I., Wetensch. Ged., 1905.
35. ———, Rapport sur les Moluques, Reconnaissances géologiques dans la partie orientale d'Archipel des Indes Orientales Néerlandaises. Jaarb. Mijnw. N. O. I., Wetensch. Ged., 1908.
36. VOORTHUYSEN, J. H. VAN, Geologische Untersuchungen im Distrikt Amfoan (Nordwest Timor). Geol. Exp. to the Lesser Sunda Islands under leadership of H. A. Brouwer. Vol. II, p. 348—367, Amsterdam 1940.
37. WEINSCHENK, E., Die gesteinsbildenden Mineralien. Freiburg i. B. 1915.
38. WICHMANN, A., Die Pseudomorphosen des Cordierits. Zeitschr. D. Geol. Gesel. Bd. 26, p. 675—701, 1874.

STELLINGEN

I.

In analogie met de voorkomens van cordieriethoudende gesteenten op de eilanden Ambon en Ceram, kan het voorkomen van cordieriet in de sandien-albiet-rhyolieten van het eiland Wetar door assimilatie van nevengesteente worden verklaard.

II.

De door GRABAU voor het Noord-Atlantische gebied opgestelde palaeogeografie van het Onder- en Midden-Cambrium, is onnauwkeurig.

(A. W. GRABAU: Palaeozoic formations in the light of the Pulsation theory. Peking 1936.)

III.

De hoge graad van metamorphose van het Zuid-oostelijke Artfjäll (Zuidelijk Zweedsch Lapland) moet ten deele worden toegeschreven aan de nabijheid van het migmatitisatiefront van Umfors.

IV.

Het gebruik van den door SARGENT ingevoerden naam „Kali-spiliet” voor geadulariseerde basalten is niet aan te bevelen.

(H. C. SARGENT: On a spilitic facies of Lower Carboniferous lava-flows in Derbyshire. Q. J. G. S. Vol. 73. 1917.)

V.

Het belangrijkste vereffeningsvlak van Zuid- en Centraal-Afrika, door MAUFE de „pré-Kalahari-peneplain” genoemd, is identiek met het Midden-Miocene vereffeningsvlak, welke door VEATCH e. a. in de Congo en Angola en door BAILEY WILLIS in het centrale meerengebied, werd vastgesteld.

(H. B. MAUFE: Some factors in the geographical evolution of Sth. Rhodesia and neighbouring countries. Sth. Afric. Geogr. Journ. XVIII, 1935.

A. C. VEATCH: Evolution of the Congo basin. Geol. Soc. of America, Memoir 3, 1935.

BAILEY WILLIS: Living Africa, New York 1930.)

THE HISTORY OF THE

... of the ...
... of the ...
... of the ...

... of the ...
... of the ...
... of the ...

... of the ...
... of the ...
... of the ...

... of the ...
... of the ...
... of the ...

... of the ...
... of the ...
... of the ...

... of the ...
... of the ...
... of the ...

... of the ...
... of the ...
... of the ...

VI.

De theorie van de gemigreerde „placer”-afzettingen als verklaring voor het ontstaan van de goudertsen van het Witwatersrand-district is te verkiezen boven de hydrothermale ontstaanswijze, zooals door GRATON e.a. wordt aangenomen.

(L. C. GRATON: Hydrothermal origin of the Rand Gold deposits. Econ. Geol. Vol. XXV, 1930.)

VII.

De Rapakivi-granieten zijn niet palingeen.

VIII.

Het begrip „meander” wordt in vele gevallen foutief gebruikt. Duidelijk onderscheid dient gemaakt te worden tusschen „kromming” en „meander”.

IX.

Zoolang omtrent het mechanisme van de migmatitisatie, granitisatie en verwante processen niet meer bekend is, verdient de terminologie van SCHEUMANN voor dergelijke processen de voorkeur boven de, door andere auteurs gegeven, omschrijvingen.

(K. H. SCHEUMANN: Metatexis und Metablastesis. Min. und Petr. Mitt. N. F. Bd. 48, 1936.

K. H. SCHEUMANN: Zur Nomenklatur migmatitischer und verwandter Gesteine. Min. und Petr. Mitt. N. F. Bd. 48, 1936.)

X.

Voor de door BACKLUND beschreven augitietische gesteenten van Nova Zembla kan, bij een frisschen toestand van het gesteente, geen avezaciet chemisme worden aangenomen.

(H. G. BACKLUND: Die Magmagesteine der Geosynklinale von Nowaja Semlia. Det Norske Videnskaps-Akademi i Oslo, 1930.)

The first part of the paper is devoted to a general discussion of the problem of the origin of life. It is shown that the problem is not only a scientific one, but also a philosophical one. The author discusses the various theories of the origin of life, and shows that the most plausible one is the theory of spontaneous generation.

The second part of the paper is devoted to a detailed discussion of the theory of spontaneous generation. It is shown that this theory is based on the fact that life is a self-organizing system, and that it is possible for such a system to arise from non-living matter.

The third part of the paper is devoted to a discussion of the evidence in favor of the theory of spontaneous generation. It is shown that there is a great deal of evidence in favor of this theory, and that it is the most plausible one.

The fourth part of the paper is devoted to a discussion of the objections to the theory of spontaneous generation. It is shown that these objections are not valid, and that the theory of spontaneous generation is still the most plausible one.

The fifth part of the paper is devoted to a discussion of the implications of the theory of spontaneous generation. It is shown that this theory has important implications for our understanding of the origin of life, and for our understanding of the nature of life itself.

The sixth part of the paper is devoted to a discussion of the history of the theory of spontaneous generation. It is shown that this theory has a long history, and that it has been the subject of much controversy.

The seventh part of the paper is devoted to a discussion of the future of the theory of spontaneous generation. It is shown that this theory is still a subject of active research, and that it is likely to remain so for some time to come.

The eighth part of the paper is devoted to a discussion of the conclusions of the paper. It is shown that the theory of spontaneous generation is the most plausible one, and that it is the most likely to be accepted in the future.

The ninth part of the paper is devoted to a discussion of the bibliography. It is shown that there is a great deal of literature on the subject of the origin of life, and that the author has consulted a wide range of sources.

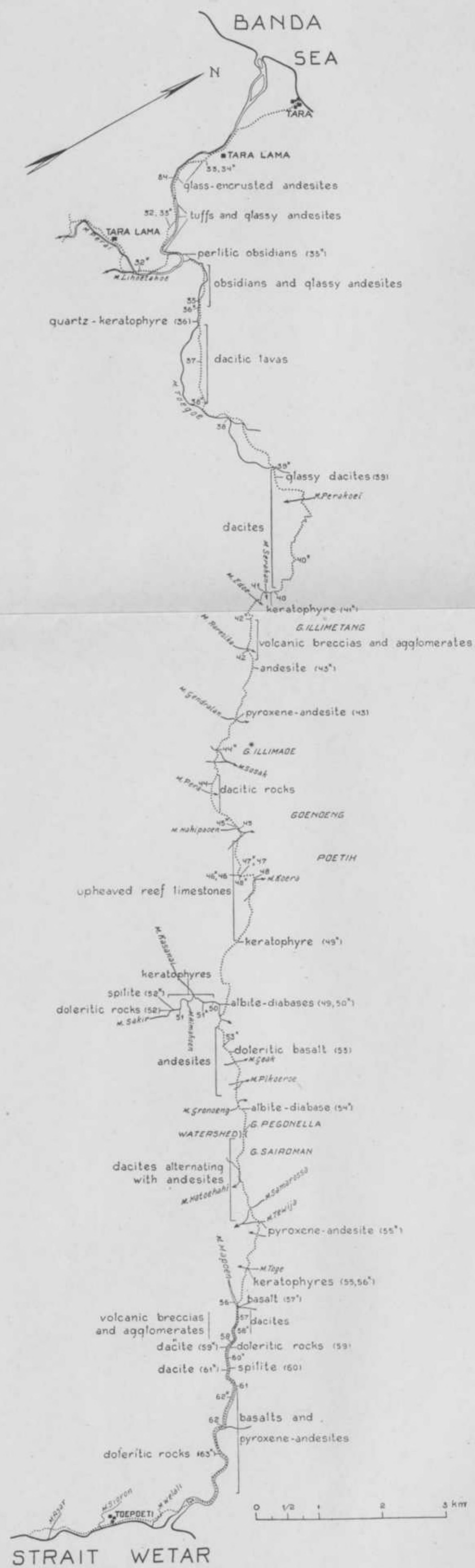
The tenth part of the paper is devoted to a discussion of the acknowledgments. It is shown that the author wishes to thank a number of people for their help and assistance in the preparation of the paper.

The eleventh part of the paper is devoted to a discussion of the index. It is shown that the index is a useful tool for finding information in the paper, and that it is well organized.



MAP II.





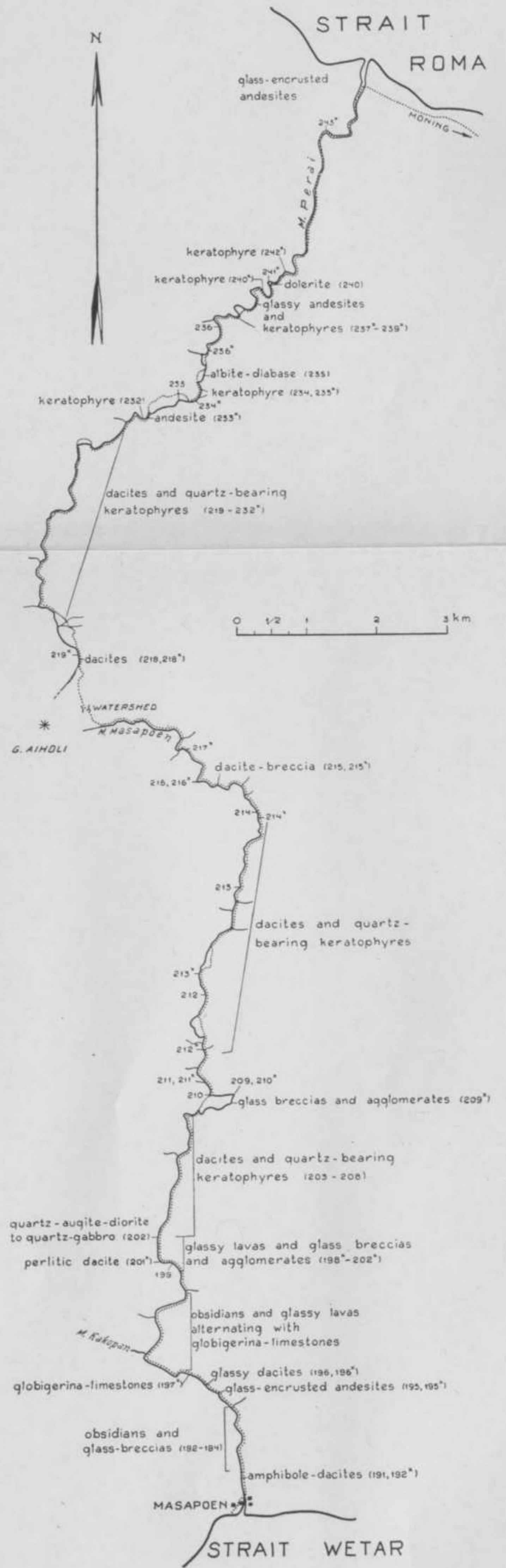
Tara-Toepoeti traverse.

Scale 1:75,000.

MAP III.



MAP III

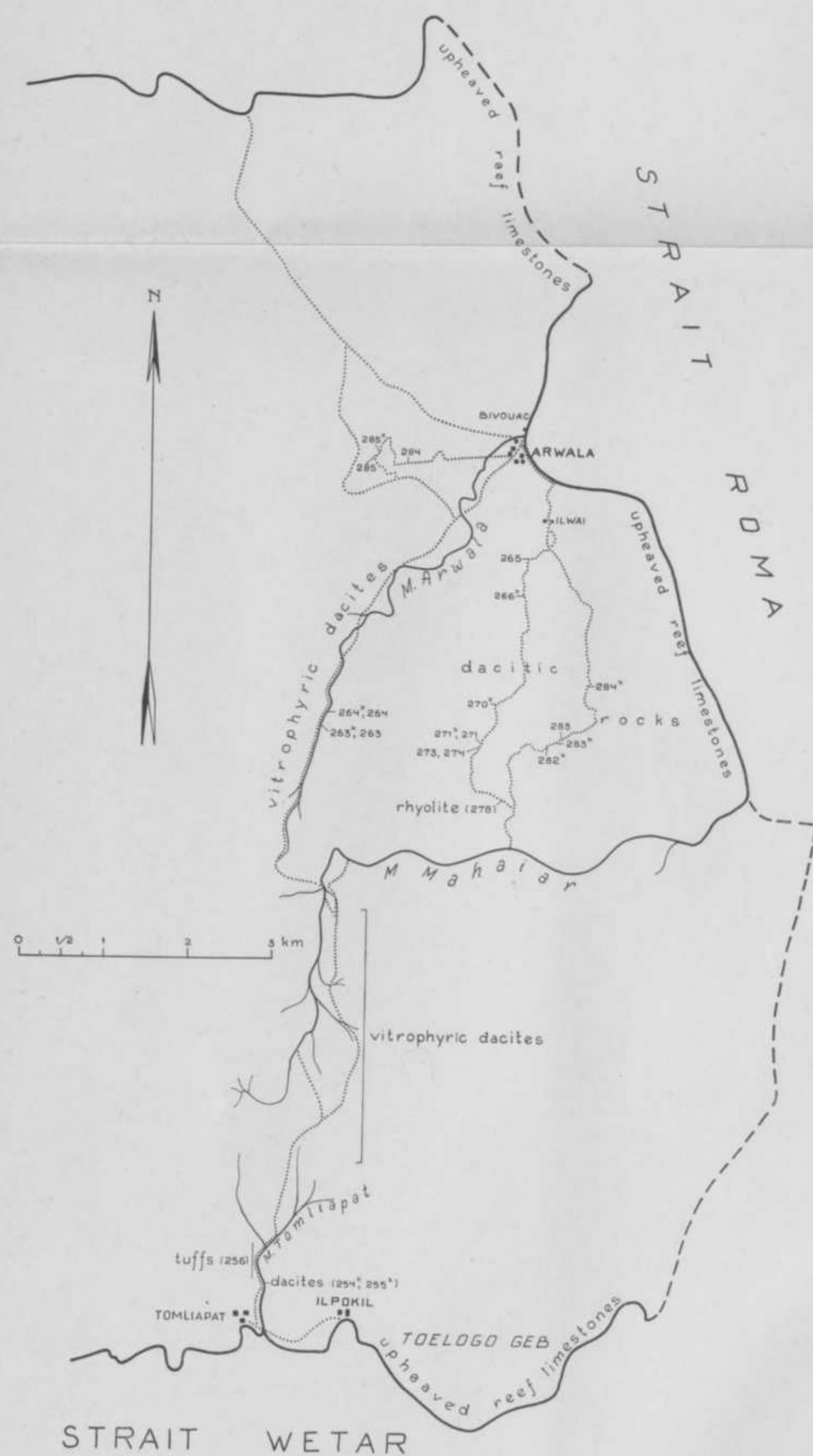


Masapoen-Moning traverse.

Scale 1:75,000.

MAP IV.





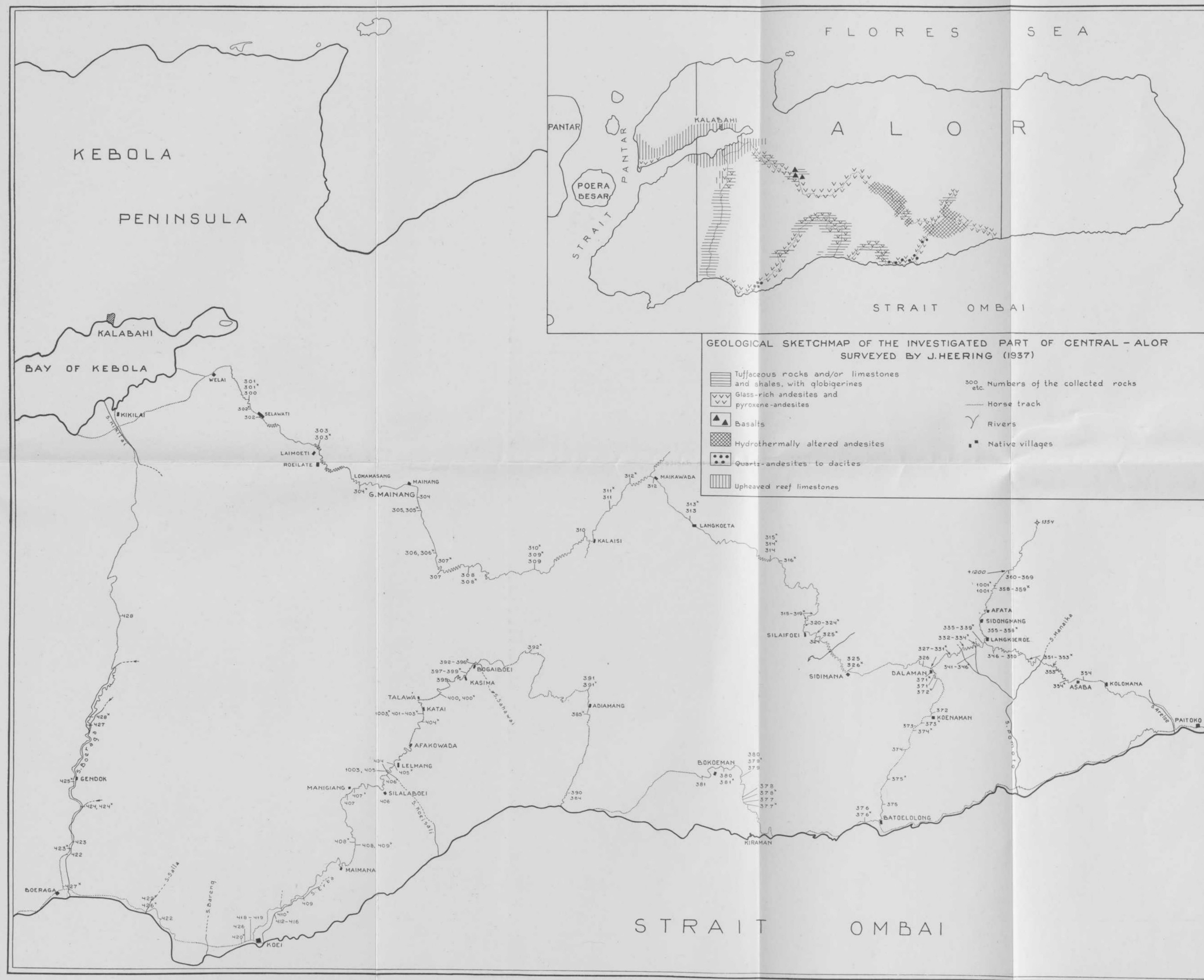
Tomliapat-Arwala traverse.

Scale 1:75,000.



The region between the lower courses of the M. Sae and M. Hoeroe.

Scale 1 : 25,000.



Scale 1:100,000.

Map of the central part of Alor (which part is indicated on the small map in the right upper corner).
Based on the topographic Map of Alor, 1932, 1:100,000.

