

*Citation:*

H.A. Brouwer, On the granitic area of Rokan (Middle Sumatra) and on contact-phenomena in the surrounding schists, in:

KNAW, Proceedings, 17 III, 1914-1915, Amsterdam, 1915, pp. 1190-1202

$$\frac{2ap}{c} \sin \frac{\varphi}{2} = 2\pi Q$$

is put for shortness.

Thus we get the dark rings:

$$M^2 \left( 1 + \frac{\sin 2\pi Q}{2\pi Q} \right)$$

which were mentioned in § 1<sup>1)</sup>.

*Determination of the mean value II.*

The distances from Rontgen tube to molecule, and from molecule to photographic plate being enormously large in comparison with the distance  $AB=a$ , we could act up to now as if we had to deal with an interference problem of FRAUENHOFER. If for the determination of the mean value II the molecule is made to occupy all situations in the irradiated space, these molecule displacements are practically still infinitesimal compared with the distance from Rontgen tube, but not compared with the distance from molecule to plate. In connection with this in the slight displacements of the molecule *parallel* to the photographic plate the dark rings move over an equally large distance. In displacement *normal* to the plate a slight enlargement or diminution of the rings occurs. We see that this brings about a slight fading of the rings.

**Geology.** — “*On the granitic area of Rokan (Middle-Sumatra) and on contact-phenomena in the surrounding schists.* By Dr. H. A. BROUWER. (Communicated by Prof. G. A. F. MOLENGRAAFF).

(Communicated in the meeting of June 27, 1914).

Between Rokan and Loeboek Bandhara the Rokan Kiri cuts a granitic mass of about  $4\frac{1}{2}$  km. in width, which on its northwestern and southeastern sides is adjoined by tertiary sandstones and conglomerates, which however, along a portion of the south west limit, are separated from the granite by a narrow strip of schists.

During the exploration of this area some facts were collected concerning the various facies of the granites and the contactphenomena in the surrounding schists. The schists dip towards the granitic mass

<sup>1)</sup> The factor  $M^2$  varies of course also with  $\varphi$ ; perhaps in the same way as  $\cos^2 \varphi$ . In § 1 we have however disregarded this variation for the present to get a first survey.

the strike chiefly being W.N.W. to N.N.W., and the dip alternating between north east and south west; the sandstones and conglomerates which unconformably overlies the schists and the granite, and are far younger, dip away from the granite-mass on both sides.

In his description of a portion of the Western Coast of Sumatra

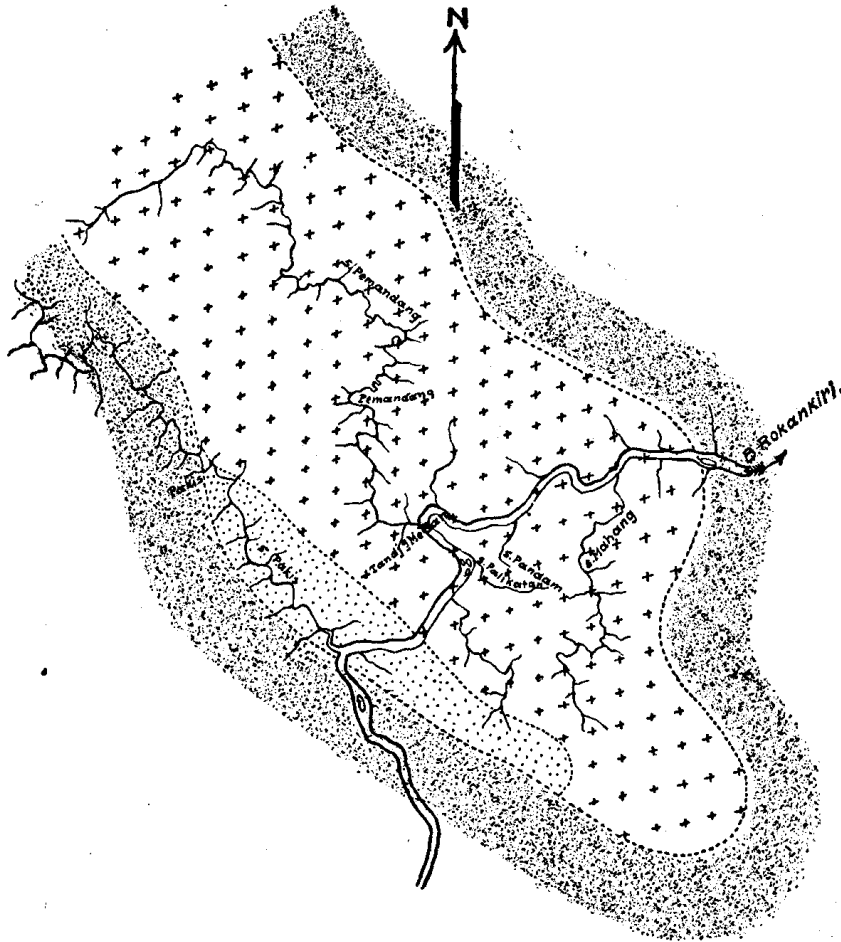


Fig. 1. Map of the granitic mass of the Rokan-county (after the map in the "Jaarboek van het Mijnuwezen in Nederlandsch Indië" for 1902, made under the supervision of the engineer E. A. NEEB). Scale 1 to 100.000.

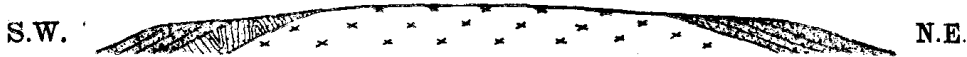
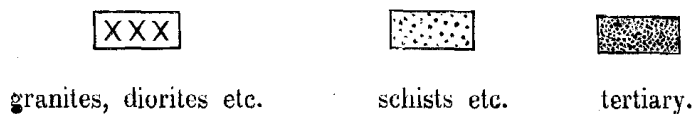


Fig. 2. Intersection over the middle of fig. 1.



VERBEEK<sup>1)</sup> describes numerous quartz diorites, which probably form irregular patches in the granites and some veins of quartz diorite in granite. In the granitic area of the Rokan county granitic veins occur in quartz-dioritic rocks and thus a part of the granites must be younger than the quartz diorites.

#### FACIES OF THE GRANITES.

The rocks of the granitic area which were examined contain two-mica granites, biotite granites and their transitions into quartz-diorites. The quartz-diorites examined are rich in biotite and contain a green amphibole in small quantities.

Porphyritic rocks with very large feldsparphenocrists are very numerous, just as in the Malakka granites. Often the phenocrists show a more or less distinct parallel arrangement, and the porphyritic rocks sometimes occur in alternating layers with the normal ones. Rocks with gneissoid structure also occur.

Pegmatitic facies are very numerous. Along both borders of the Rokan Kiri and in the numerous side-rivers of the Rokan Kiri running through the granitic area, their outcrops are repeatedly visible as more or less irregularly defined masses or as veins running regularly for some distance; as a rule, these rocks are rich in tourmaline. In the rocks Batoe Kandik projecting on the right side of the Rokan Kiri pegmatites are found containing very much biotite, their crystals measuring sometimes several cm<sup>3</sup>, and for the rest consisting chiefly of feldspar, quartz and tourmaline. Dykes of quartz tourmaline rocks free from feldspar also occur here; the rock which intersects these pegmatites is a medium grained granite without phenocrists. The rock which protrudes at the mouth of the Sei Mahang in the middle of the Rokan Kiri shows a great variety of rocks. Along with medium-grained granites one finds here very many pegmatitic segregations which for the greater part consist of feldspar, quartz, tourmaline with dark or light-coloured mica, whereas patches with the structure of graphic granite protrude as knobs from the surrounding rock.

Dykes which are more acid and contain fewer dark minerals than the rocks they intersect were found in several places. To quote one instance dykes of light-coloured biotite granite on various points cut through quartzdiorites on both borders of the Rokan Kiri.

<sup>1)</sup> R. D. M. VERBEEK, Topographische en geologische beschrijving van een gedeelte van Sumatra's Westkust, 1883, p. 220.

*Biotitic granites.*

A biotitic granite of the right border of the Rokan Kiri near Tanah Dingin contains besides orthoclase some microcline and very little acid plagioclase. Quartz is found in large quantities and shows the aggregate polarisation or undular extinction commonly occurring in the granite quartzes of strongly folded regions. Muscovite only occurs in very small quantity in this rock; ore and apatite are both present. The two last mentioned minerals are often intergrown with biotite.

Similar biotite granites have been collected on the left border of the Rokan Kiri, in the sharp bend downstream from Tandjong Medan. Granophyric intergrowths of quartz and feldspar were found here in small quantities.

According to ABENDANON, green augite occurs in granites rich in biotite from the upper part of the S<sup>c</sup> Pemandang. (Cf. "Jaarboek van het Mijnwezen" for 1902, p. 138.)

*Two-mica-granites.*

The medium-grained rocks in which the numerous pegmatites of the Batoe Kandik occur, belong to this group. They are poor in dark constituents and consist chiefly of orthoclase, some microcline and acid plagioclase and quartz. Brown as well as green biotite occur, often intergrown in one crystal and in alternating layers. Small quartz crystals are sometimes poikilitically enclosed by the feldspars; the feldspars are slightly sericitized. In these rocks again, the quartz shows aggregate polarisation and undular extinction. Ore and apatite occur in very small quantities only.

In the medium-grained rocks with the numerous pegmatites from the cliffs near the mouth of the S<sup>c</sup> Mahang the percentage of plagioclase has increased, whereas muscovite is found in smaller quantities than biotite. Besides orthoclase some microcline is found. The plagioclase has almost the constitution of oligoclase-albite, the quartz shows aggregate polarisation, small rounded crystals of quartz are sometimes poikilitically enclosed by the feldspars. Some of the feldspars are feebly sericitized, whereas larger muscovite crystals more or less in parallel position one to the other are sometimes enclosed.

Medium-grained granites very poor in mica minerals protrude as rocks in the bed of the Rokan Kiri near Tandjong Medan.

*Quartzdiorites.*

These rocks contain less quartz and generally more biotite than the granites described above.

From the first rocks in situ on the left bank of the Rokan Kiri, in the sharp bend downstream of Tandjong Medan, and from the rocks projecting there from the right bank specimens of dioritic rocks were collected consisting chiefly of plagioclase with quartz and biotite, the further constituents being amphibole, titanite, apatite, some chlorite and very little ore.

The plagioclase has almost the same composition as andesine, some more acidic mixtures (oligoclase-andesine) also occurring, and a feebly zonal structure with repeated alternations of zones more acidic and more basic being rather common. Exceptionally the plagioclase was found to be partly surrounded by a narrow margin of granophyric texture in which the feldspar is not polysynthetically twinned. In slides of the symmetrical zone of the plagioclase this last feldspar shows a straight extinction, this fact pointing to orthoclase. The quartz shows aggregate polarisation, the lamellae of the plagioclases being bent. The biotite with very small axial angle is as a rule fresh, exceptionally some alteration into chlorite occurs. Green amphibole is found in small quantity, titanite occurs in grains and in more or less rounded crystals, and, as well as the apatite, is often enclosed by biotite. On the other hand small biotite crystals in places are enclosed by a large crystal of titanite.

*Granitic dykes in the diorites.*

At a distance of about 2 m. from each other on the left bank of the Rokan Kiri in the sharp bend down Tandjong Medan two dykes were found cutting the quartz diorites. These medium to fine-grained rocks, light coloured, consist largely of orthoclase (and microcline) and quartz. Acid plagioclases are found in small quantity, the further constituents being: biotite, apatite, and some green chlorite. Ore is almost totally absent. The chlorite is sometimes found alternating in layers with biotite in the flakes of the latter mineral. An intergrowth of kalifeldspar with quartz is remarkable in which numerous small rounded or almost idiomorphic crystals of quartz enclosed by the feldspar extinguish at the same time.

Granophyric intergrowths, in which the quartz is irregularly shaped, also occur in small quantities.

One of the granitic dykes in the quartz diorites on the other bank of the Rokan Kiri consists entirely of a mixture of quartz and feldspar, some traces only of biotite and chlorite occurring.

*Gneissoid granites.*

In a left branch of the Pakis river, near the kampong Pakis,

porphyritic rocks were found showing a distinct parallel structure and containing only few dark constituents. They are poor in plagioclase, microcline occurring in varying quantity with orthoclase. The feldspars only occur as phenocrists, as a rule rounded and showing more or less irregular contours; they show traces of sericitization and sometimes enclose rather large crystals of colourless mica. The biotite sometimes contains ore in numerous disseminated minute crystals and often it is partly chloritized.

Pyrite occurs in rather numerous small crystals in some of these rocks. Feldspar and quartz are sometimes granophyrically intergrown. The crystals of the groundmass are often found enclosed by the phenocrists of feldspar and the matrix sometimes penetrates into the phenocrists. The often occurring irregular extinctions of the quartzes point to pressure after the crystallization of the rocks.

#### *Pegmatites.*

Some provisional facts will be given here on the constitution of the very numerous pegmatites. The pegmatites rich in biotite, from the Batoe Kandik, consist chiefly of plagioclase, orthoclase, quartz with undular extinction and biotite, tourmaline and colourless mica also occurring. The plagioclase has almost the constitution of oligoclase, whereas more acid mixtures approaching to oligoclase-albite, also occur. As a rule, the tourmaline shows absorption colours of brownish hue, more bluish colours sometimes being found round the brown colours as a bordering zone of varying breadth and occasionally missing; no sharp distinction exists between these varieties.

A dyke of a width of about 2 metres with N. N. W. strike, consisting of pegmatite containing tourmaline and occasionally much biotite, in which numerous small crystals of reddish brown garnet are macroscopically visible, over a short distance appears outcropping in small rocks, which, the level of the water being low, are visible on the left bank of the Rokan Kiri near Tandjong Medan. They are rich in acid plagioclase, orthoclase and quartz. Several of the plagioclases proved on examination to be acid oligoclase-albite, more basic mixtures, however, also occurring. The feldspars sometimes are to some extent sericitized. The crystals of the garnet are idiomorphous and microscopically colourless. The tourmaline is usually not idiomorphous in the prismatic zone, the brown colour of the crystals is often less deep in the central parties than in the bordering zone, more blue colours moreover occurring in the central parts. Finally, the occurrence of zircon in small idiomorphous crystals with pyramidal limit outlines must be mentioned.

In the small rocky isle near the mouth of the Sei Mahang, pegmatites with much dark or light coloured mica are almost similarly constituted as the surrounding granites; the feldspar crystals measuring up to ten decimeters, found at the same place, which are beautifully graphic-granitically intergrown with quartz, have been mentioned above.

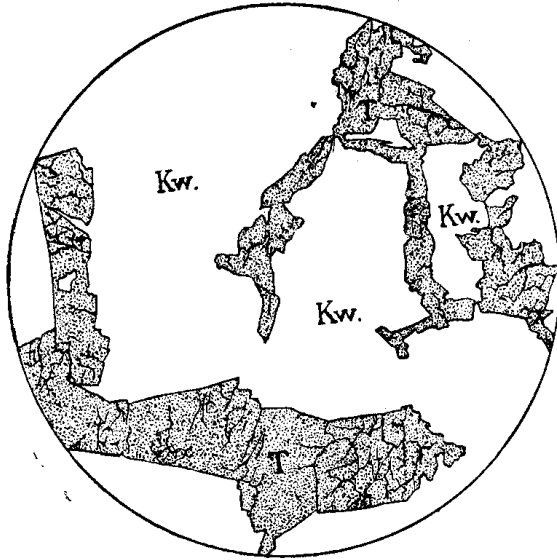


Fig. 3. Concretion of one quartz and one tourmaline crystal.

T = tourmaline. Qu. = quartz.

consequently belong to the same crystal. The tourmaline chiefly shows brown absorption colours, more bluish colours sometimes occurring in the bordering zones; a blue tourmaline is occasionally crystallized in small crystals at the periphery of the brown crystals. In these pegmatites as yet no tin-ore was found; about the same thing is reported by TOBLER<sup>1)</sup> from the granites of the mountains of Doeablas in Djambi, which as well as the granite of the Rokan-county are closely related to the tin-granites of Banka and Malakka. Numerous pneumatolytic veins consisting of quartz and tourmaline are found there.

#### THE SURROUNDING SCHISTS.

The schists which separate the granites along a portion of their southwestern limit from the tertiary sandstones and conglomerates, are laid bare by denudation in several places on both borders of the Rokan Kiri, and they can be excellently observed on the banks of the Sei Pakis, which crosses the whole length of the strip of schists northwest of the Rokan Kiri.

<sup>1)</sup> A. TOBLER. Voorloopige mededeeling over de geologie der Residentie Djambi. Jaarb. v. h. Mijnwezen in Ned. Oost-Indië, 1910; Verhandelingen, p. 20.



So far as they do not show any traces — or to a slight degree only — of contact metamorphism, they are of small-mineralogical importance; the contact-rocks only will be mentioned underneath.

Many of the rocks contain calcite in varying quantity, and the series of rocks examined includes various gradations between limestone, sericite schist, and chert or quartzitic schist free from calcite and sericite. Limestones are e.g. exposed for a great distance in the S<sup>ri</sup> Mangis, a small right branch of the S<sup>ri</sup> Pakis, about halfway between the kampong Pakis and the Rokan Kiri. Those are partly white semi-crystalline limestones, partly they are very dark coloured or rich in strongly pigmented veins. Farther upstream in the river Mangis these rocks are covered by the tertiary sandstones and conglomerates.

Transitions of these rocks into phyllites rich in calcite by intermediance of rocks with little quartz and sericite in a calcitic matrix are found; whereas by an increase of the percentage of quartz and mica, transitions into the calcium-phyllites are formed. Calcium-phyllites with sericite schists are e.g. exposed in the banks of the S<sup>ri</sup> Pakis near its mouth, and higher upstream in the river similar rocks alternating with rocks richer in calcite and with limestones are repeatedly exposed. The sericite schists are sometimes macroscopically dense rocks, sometimes they are crystalline and strongly schistose. The latter often contain tourmaline, whereas also varieties rich in pyrite are found.

The tourmaline is often more or less idiomorphous in the prismatic zone, sometimes the crystals being divided into various irregular, simultaneously extinguishing parts, separated by the quartz-sericite-mixture.

The quartz shows aggregate polarisation and undular extinction, kataclastic structures often occurring.

Fine-granular and strongly schistose two-mica-schists containing much mica which are found in the left bank of the S<sup>ri</sup> Pakis, contain some tourmaline and pyrite, and moreover in lenticular portions which are poor in mica or free from mica some feldspar was found in small quantity between the quartz crystals. This fact in connection with the high percentage of biotite and with the facts to be mentioned underneath, renders it probable that these rocks have already to a certain degree been affected by contact-metamorphism.

Finally the occurrence of brecciated rocks may be mentioned containing fragments of sericite schists cemented by a fine aggregate of quartz grains. In these sericite schists black layers strongly pigmented alternate with those containing little pigment.

## CONTACT-PHENOMENA.

Although in consequence of the fact that little rock in situ is exposed, not a continuous section is found from the granite area into not contact-metamorphic rocks, the character of the metamorphism may sufficiently be determined from the facts collected.

Between the kampong Pakis and the northwestern side of the strip of schists, in the middle of the river, two little rocks arise, consisting partly of granite, partly of contact-metamorphic rocks. At the same place, in the right bank of the river, granitic rocks of distinctly parallel structure are exposed.

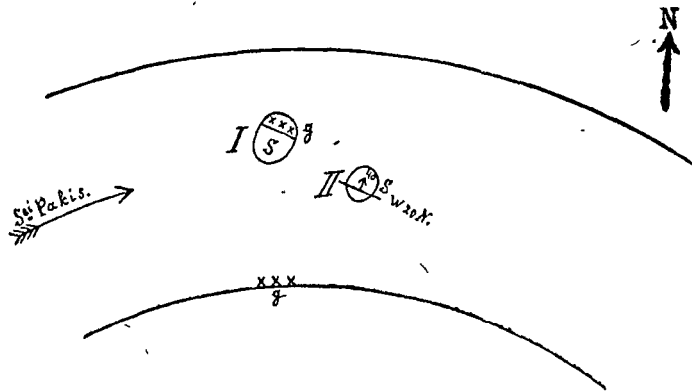


Fig. 4. Contact of granite and schists a short distance upstream from kampong Pakis.

(g = granite. S = hornfels etc. cut by apophyses of granite.)

The northern portion of the small rock I is composed of granitic rocks, the southern portion as well as the rock II consisting chiefly of hornfels with intercalated apophyses of igneous origin. The granites are dark coloured; they contain much biotite and show distinctly parallel structure. The rocks are altered into a hard, fine crystalline grayish-black hornfels, showing the original schistosity of the unaltered sediments. Very thin layers of granitic material can be distinguished even macroscopically.

Microscopically the hornfels and the intercalated granitic bands do not show sharp lines of demarcation.

The granite from the northern portion of rock I consists of orthoclase, plagioclase, quartz, biotite, some ore, zircon and apatite. The feldspars form larger crystals, enclosed by a finer quartzose crystalline mixture containing feldspar and other minerals. The rocks therefore show a more or less distinct porphyritic structure with a subordinate groundmass. The plagioclases belong to the andesine

group; in some slides, a.o. from the extreme northern end of rock I they show a zonar structure with a bordering zone of great acidity. Sometimes the crystals have been broken and the different fragments have been shifted with respect to each other, and later a greenish mica substance has been deposited in the cracks. The flakes of biotite also are often bent and show strongly undular extinctions; the quartz, found in great quantity in the groundmass, shows a strong aggregate polarisation. The cliff on the right bank of the Sei Pakis near the rocky islands, contains rather large plagioclase and orthoclase crystals in the quartzose mixture of quartz, feldspar and biotite. Various plagioclases were determined to be andesine, they often show a zonar structure with more acidic bordering zone. Along the circumference of the feldspar crystals a granophyric texture is found in places. The rock contains rather much calcite, and also some crystals of zircon.

The contact-metamorphic sediments alternate with numerous layers of granitic rocks, several similar layers — sometimes macroscopically, sometimes only microscopically observable, — also occurring in the hornfels. Thus it is a case of injection of granite in the schists, whereas between the stratified granitic apophyses the schist moreover has been feldspathised independently of the development of the feldspars in the granite.

Granitic apophyses in the island II principally consist of orthoclase and of, sometimes zonar, plagioclase, quartz and biotite. The feldspars occur as crystals of good size, more or less rounded and sometimes strongly sericitized, enclosed by a fine-grained granular mixture of quartz and biotite with well marked strongly schistose structure.

The quartz shows a strong aggregate-polarisation. Further these apophyses contain rather much brown or greenish brown tourmaline, some pyrite and a few small crystals of zircon<sup>1)</sup>, which sometimes show rounded forms, sometimes are idiomorph, with pyramidal limitation. The hornfels differs from the granite of the apophyses with regard to the size of grains and the mutual relation of constituting minerals. They are very schistose, rich in biotite, often contain tourmaline too, and show a more or less distinct porphyritic structure caused by the large size of several of the feldspar crystals. The feldspars are free from inclusions, or they include a few quartz crystals and flakes of biotite only. In some metamorphic rocks apatite is found in numerous crystals.

<sup>1)</sup> These crystals are colourless and often show pyramidal limitation. In basal intersections we sometimes meet with distinct cleavage lines according to (110). As yet no cassiterite has been demonstrated to be present in these rocks.

Very schistose hornfels in the same island the layers of which dip away beneath the rocks mentioned above consist almost entirely of feldspathised schists with intercalated layers of granitic material which are very thin and partly can only be observed under the microscope. In this hornfels too, larger feldspars contrast with the fine crystalline quartz-biotite-mixture surrounding the feldspars. Here also, inclusions of quartz and biotite occur in small number in some feldspars, sometimes being arranged in the direction of schistosity. Exceptionally and in a small number, these inclusions also occur in a hornfels near the contact with the granites in the little island I, and here too a more or less distinct arrangement parallel to the schistplanes of the rock can be observed; however, for the greater part the feldspars are totally free from inclusions. Moreover, this rock is much coarser crystalline than those mentioned above. Some larger feldsparcrystals occur in the finer crystalline mixture. The structure of the hornfels is very much like that of the adjoining granite rocks and no sharp line of demarcation exists between the two kinds of rocks.

Further away from the contact, metamorphic rocks were collected in which much muscovite is present along with biotite.

In the southern part of the island II, similar granitic rocks as in the northern part of the island I occur; here the feldspars are very strongly sericitized and the rock contains much secondary calcite; numerous pyritecrystals also occur. Adjoining these granites, but dipping away from the granite with strike W. 20 N. and dip 40° N.E. dense cherts and sericite-schists occur, which on microscopical examination prove to consist of a very fine-grained mixture of quartz-crystals and aggregates of small quartz-grains. In the quartz-mixture sericite occurs in varying quantity, along with sericite, chlorite, iron-ore and some apatite occur. These rocks show no traces of contactmetamorphism.

Rather well crystallized muscovite schists in the banks of the S<sup>t</sup> Pakis have been mentioned above.

Not far downstream from the kaupong Pakis rocks resembling hornfels are found, in which much muscovite occurs along with biotite; in some of them traces of feldspathisation were observed. However, many of the rocks examined are free from feldspar; they contain a few larger quartz crystals with undular extinction, or aggregates of quartz-grains in a finer-crystalline mass chiefly consisting of quartz with biotite and muscovite.

Tourmaline crystals of idiomorphic or almost idiomorphic limitation are sometimes rather numerous. a blue core is sometimes rather

sharply separated from a brown bordering zone. Finally, small crystals of apatite and fine ore-particles occur in these rocks. In the left branch of the S<sup>ri</sup> Pakis near the kampong Pakis, the first solid rocks found in situ are granites with a parallel-structure often apparent. It is highly probable that in the part not exposed between the granites and the S<sup>ri</sup> Pakis, the zone of the feldspar hornfels and granite apophyses occurs, which farther up the river is exposed. The granites at the contact contain much biotite, the increase of the percentage of biotite being a common phenomenon of endomorph contact-metamorphism. This fact may here account for the high percentage of mica, although elsewhere in the granitic area, rocks containing much biotite also occur.

VERBEEK <sup>1)</sup> describes dark gray, sometimes black hornfels containing feldspar, from Panoesian near the river Sinamar in the Ngalau-Sariboe mountains. The percentage of feldspar (chiefly plagioclase) is only contained in the contact-rocks just touching the granite, as soon as we get away from the granite more than 2 or 3 m., the percentage of feldspar diminishes and soon totally disappears. Apparently we have to do here with contact-phenomena equivalent to those mentioned above.

Putting together the data obtained in several localities, the following statement may be given on the nature of the contact-metamorphism.

1. At the contact of the granites a narrow zone of the surrounding schists has been feldspathised. The contact rocks almost graduate into gneisses, and the sharp contrast between igneous rock and sediment has disappeared. Granite apophyses occur in alternating layers with the schists. Farther away from the contact this feldspathisation is entirely missing.

2. In the hornfels the original stratification of the rocks has been conserved.

3. Biotite is the mica found in the feldspathised hornfels near the contact with the granite, muscovite appearing in the contact metamorphosed rocks farther away from the contact.

4. The zone of the contact rocks with Al-silicates (andalusite etc.) is missing, the zone of the mica schists succeeding the feldspathised zone<sup>2)</sup>.

5. Tourmaline is a common mineral in the contact-metamorphic rocks.

<sup>1)</sup> R. D. M. VERBEEK, loc. cit. p. 179.

<sup>2)</sup> "Knotenglimmerschiefer" and "Knotenthonschiefer" were not met with, but the author considers undecided whether they are entirely missing or not.

6. The often appearing porphyritic structure with rounded edges, of the apparent feldspar phenocrists of the granites, and the highly undular extinctions and aggregate-polarisations of the quartz in the granites and hornrocks point to strong pressure in the rocks after they had been solidified.

This metamorphism thus shows an entirely different character from that of the classic contact-zones of the type Steiger Schiefer (ROSENBUSCH), where the sediments furnish the mineral constituents, the eruptive rocks heat and pressure, molecular interchanging only taking place in the contact-zone. It is much like the metamorphism described by MICHEL LÉVY for the Plateau Central, by BARROIS for Brittany, and by LACROIX for the Pyrenees. The feldspathisation of the schists without connection with the stratified granite apophyses, and the manifold occurrence of tourmaline, point to the influence of mineralisators and to a supply of constituents of the granitic magma in the contact-zone.

The numerous pegmatites mentioned above tend to prove that mineralisators have been present in the granitic magma in large quantities. The presence of feldspars and tourmaline as well in the pegmatites as in the contact-metamorphic rocks, illustrates the pneumatolytic character of the contact-metamorphism.

---

E R R A T A.

In the Proceedings of the Meeting of September 26, 1914.

p. 507 in the table: in the column headed  $10^5 \Delta R$  for 237 read 244.  
the numbers of the column headed  $R-1$  are to be provided with the sign —.

---

April 23, 1915.