disturbing the texture of the replaced rock except in the most extreme instances.

6. *Augitite*.—The pebble of igneous rock in Professor Pirsson's collection is a dark, fresh, vesicular lava, with phenocrysts of a shining black pyroxene. In thin section it shows numerous small phenocrysts of purplish augite and brown 'basaltic' hornblende in a groundmass consisting mainly of augite microlites, with subordinate euhedral magnetite and a colourless glassy base. The augite phenocrysts are usually purplish in colour, but frequently become green towards the interior of the crystals. They are zoned in colour bands, differing slightly in optical properties, and enclose magnetite crystals, especially near their margins. The hornblendes are also euhedral, but are indented by the augites wherever they come into contact. They have a strong pleochroism in shades of brown. The augite microlites of the groundmass are almost colourless, and are embedded in a clear glassy substance of refractive index lower than that of Canada balsam. The rock is entirely felspar-free, and may be regarded as an augitite with hornblende. It is quite fresh and of recent appearance. It is a type of lava which is usually associated with series of alkaline character.

Conclusions.—The study of this collection unfortunately throws very little new light on the moot question of the tectonic relations of South Georgia. The igneous rocks described are probably part of Heim's 'altvulcanischer' area of the south-east end of South Georgia,¹ and belong with the calcic end of the igneous series rather than with the alkalic; but rocks of a distinctively Andean type are still to be discovered. The pebble of augitite found by R. W. Chappell and received through Professor Pirsson is certainly of alkalic type, but on account of its mode of occurrence and isolated character no weight can be attached to it. Hence the question as to whether South Georgia belongs to Suess' "Southern Antilles" and is situated on a great loop connecting the Patagonian Andes with the mountains of Graham Land, or whether it is a remnant of an old sunken continental land, still remains open so far as the petrographic evidence goes.² The members of the Weddell Sea party of Sir E. Shackleton's Transantarctic Expedition spent some time on South Georgia on their outward journey, and it is possible that their geologists found opportunity to collect data sufficient to solve this problem.

III.—PNEUMATOLYTIC ALTERATION OF A VERY FINE-GRAINED GRANITIC ROCK FROM NEGRI SEMBILAN, FEDERATED MALAY STATES.³

By E. S. WILLBOURN, B.A., Assistant Geologist, F.M.S.

ABOUT one mile to the north of the railway station at Ayer Kuning, in the south of Negri Sembilan, one of the Federated Malay States bordering on Johore and Malacca, is a low but conspicuous range of hills covered with long grass. The highest of the

¹ Fr. Heim, *Zeitschr. Ges. Erdkunde*, Berlin, April, 1913.

² Tyrrell, *Trans. Roy. Soc. Edinburgh*, vol. 1, pt. iv, p. 832, 1915.

³ Communicated with the permission of the Government Geologist, F.M.S.

hills, on which is a beacon used by the Trigonometrical Survey, stands about 300 feet above the level of the surrounding country. The general trend of the hill range is in a direction of S. 60° W. to N. 60° E., and there are several hills which branch from the main axis, usually more or less at right angles to it. The eastern half of the range over a distance of about half a mile only need be considered, as there are no rock exposures on the western half.

The framework of the hills is seen to be made up of a white, fine-grained rock, containing small iron-stained cavities, which in its usual weathered state very much resembles a fine sandstone. Examination under the microscope shows it to be a very fine-grained igneous rock, consisting essentially of quartz and mica, sometimes with feldspar, and nearly always with abundant blue tourmaline. In one or two places hard fragments of silicified shale were found lying on the hills, and one exposure showed patches of shales included in the white rock. It is doubtful whether these are shales of the Raub Series, which have become non-calcareous through the ordinary processes of weathering, or whether they belong to the younger Gondwana Series, consisting of shales interbedded with quartzites and sandstones. The boundary-line between outcrops of the two series lies in the locality, but its exact position cannot be traced. From the evidence of the dislocation of occasional quartz veins which penetrate the white rock, it is seen to have undergone faulting, and this is confirmed by microscopical examination of the shales. However, the amount of throw of the largest fault observed is only a few inches.

A large outcrop of granite is situated to the south-west, about two miles from the Trigonometrical Survey beacon.

In a hand-specimen the hard unweathered rock is seen to be very fine-grained. It is homogeneous in appearance, except that it contains dark-blue bodies, usually not bigger than a pea, sporadically scattered throughout the rock. They look very much like blots of blue-black ink on white blotting-paper. Under the microscope the rock is seen to consist for the main part of quartz and muscovite. The quartz occurs as irregular grains of a uniform small size, one separated from another by an aggregate of still finer grain, consisting of quartz and muscovite. There are a few flakes of yellowish mica of considerably larger size which contain tiny inclusions. Some specimens of the rock seem to contain no feldspar at all. An attempt was made to separate feldspar from a crushed sample of the rock by using a solution of mercury potassium iodide of a density such that orthoclase would float and quartz would sink. Some specimens proved to contain no feldspar at all, others contained a small quantity of orthoclase.

With still other specimens there is no need at all to use a heavy liquid in order to determine the presence of feldspar, for small phenocrysts can be seen under the microscope. These can just be distinguished in the hand-specimen. They are of quartz, orthoclase, and plagioclase with extinction angle corresponding to oligoclase. The rest of the rock is made up of a mosaic of quartz and feldspar with occasional flakes of yellowish mica, which contains inclusions.

The quartz grains in the quartz-feldspar mosaic are of the same size as those in the quartz-mica rock. The flakes of mica in the former

rock appear to be identical with the few larger flakes of mica in the quartz-mica rock.

The dark-blue bodies mentioned above consist of quartz and blue tourmaline. The quartz occurs as irregular grains of the same size as those in the white quartz-felspar or quartz-mica rock which encloses the bodies.

The tourmaline occasionally shows crystal outline, then occurring as tiny prisms, but usually it occurs as shapeless grains, one of which may enclose two or three of the quartz grains. The dividing line between the quartz tourmaline bodies and the surrounding white rock is very irregular, particularly in the quartz-felspar rock. The tourmaline seems to be replacing muscovite in the quartz-muscovite rock, and felspar in the quartz-felspar rock. The difference in the appearance of the quartz-tourmaline bodies is very striking in hand-specimens of the two rocks, for the bodies in the quartz-muscovite rock appear to have a sharp outline, and their shape is roughly spherical. They weather out in a conspicuous fashion, and in places can be found lying about on the rock surface. The bodies in the quartz-felspar rock have an irregular branching outline.

Sometimes the bodies are more or less regularly distributed throughout the mass of the white rock (quartz-muscovite or quartz-felspar), but in some exposures there is an arrangement along definite parallel planes. One specimen of quartz-mica rock collected from the east end of the hill range shows a large number of the bodies partially amalgamated to form a plate, so that a cross section has the appearance of a string of beads. Under the microscope these bodies are seen to have the same structure as those already described, and the plate, although not unlike a vein, is seen to be very different from certain true quartz-tourmaline veins which were observed in several parts of the hills, penetrating the quartz-muscovite rock. These veins are minute with a thickness of only about $\frac{1}{8}$ to $\frac{1}{16}$ of an inch. They consist of long prisms of blue tourmaline set in a mosaic of clear quartz. The veins are of a very much coarser grain than the parent rock. They have sharply defined walls. Sometimes a prism of tourmaline was observed not to end abruptly at the wall of the vein, but to penetrate for a short distance into the quartz-mica rock. As soon as it left the vein, however, it lost its sharp crystal outline and enclosed the quartz grains of the quartz-mica rock, taking the place of the interstitial flakes of muscovite.

In exposures immediately east and west of the beacon hill, the tourmaline bodies are very small in size, being no bigger than a pin's head. More often than not they are arranged along definite planes, otherwise there is no distinction between them and the larger bodies.

Two small exposures on opposite sides of the beacon hill show a rock of a slightly coarser grain than that already described. Moreover, no tourmaline can be seen in the hand-specimen. Under the microscope it is seen to be porphyritic, the phenocrysts being bleached biotite and quartz with the irregular outline characteristic of the corroded quartz phenocrysts in porphyritic rocks. In addition there are areas of secondary mica whose form suggests that they are altered felspar phenocrysts. The biotite contains needles of rutile associated

with iron-ores and sometimes forming a sagenite web. It is practically uniaxial. The ground-mass consists of quartz and secondary mica. A slide cut from one specimen showed a wavy line, like a crack penetrating the rock, along which occurs some fine-grained opaque material and, at one point, a large grain of blue tourmaline. A specimen of this rock was crushed in order to examine the heavy minerals. Much zircon in small perfect crystals is present and also several grains of blue tourmaline.

This rock resembles an igneous rock which outcrops at the old disused gold-mine of Bukit Chindras, which is situated along the direction of the Ayer Kuning hill range (namely about N. 60° E.), and is between one and two miles distant from it.

The gold-bearing quartz veins strike in a direction approximately north and south. Mr. Scrivenor, the Government Geologist, visited the mine in 1904, shortly after it had been shut down, and he then noted (Preliminary Report on the Gold Mines of F.M.S., Kuala Lumpur, May, 1904) that the country rock is "bleached shale . . . together with a small quantity of a pale green rock which was not seen *in situ*, composed of fine flakes of colourless and pale green muscovite, quartz grains, iron ores, and small prisms of rutile".

The rock can now be seen forming an outcrop on the hillside 70 yards long in a direction about N.W. by S.E. and about 20 yards wide. It is much weathered, but slides cut for microscopic investigation showed phenocrysts of bleached biotite, containing needle-shaped inclusions of rutile associated with iron-ores, with large corroded quartz phenocrysts, and areas of regular form filled with an aggregate of secondary muscovite which may represent feldspar phenocrysts. The remainder of the rock consists of an irregular mass of secondary quartz and mica. The rock shows evidence of having undergone strong shearing, and thin quartz veins penetrating the rock have also been subjected to strain. It contains a certain amount of iron pyrites, is plentifully stained with iron, and has numerous cavities.

The rocks described above bear a strong resemblance to the beresites of the Urals described by G. Rose.¹ He describes them as vein rocks which outcrop in talc and chlorite schists, themselves traversed by the gold-bearing quartz veins. Beresite is a very uniformly grained rock, nearly always decomposed and impregnated with iron pyrites. It is made up of orthoclase, plagioclase, quartz, and primary mica, and these are altered to secondary mica and quartz, according to another writer, Arzruni. Some varieties resemble sericite schists, others resemble micaceous sandstones. Original rutile is present as aggregates and as inclusions in quartz. Rosenbusch² and also Zirkel³ quote Helmhacker, who wrote a later description. He says that beresite is a quartz porphyry, poor in quartz, in which the feldspars vary in amount, and may disappear altogether on account of their alteration to muscovite and quartz.

¹ Zirkel, *Petrographie*, vol. ii, p. 41, 1894.

² H. Rosenbusch, *Mikroskopische Physiographie, II Massige Gesteine*, p. 462, 1896.

³ Zirkel, *Petrographie*, vol. iii, p. 793, 1894.

As mentioned above, the quartz-muscovite rock of Chindras is traversed by gold-bearing quartz veins, and this is another point of resemblance with beresite. The Malay headman at Ayer Kuning informed the writer that his father had got a small quantity of gold many years ago by washing the soil of the Ayer Kuning hill range, but not sufficient to encourage him to go on with the work.

The elvans of Cornwall resemble these rocks to a certain extent, but differ in that they frequently contain brown primary tourmaline and also they are coarser in grain. Regarding the alteration of elvans, Dr. Flett¹ says: "abundance of fine muscovite in the ground mass of an elvan is probably a certain indication of pneumatolytic action, as muscovite is very rarely a primary ingredient of these rocks." The formation of greisen in the elvans of Cornwall has often been accompanied by the formation of tinstone. The nearest locality to Ayer Kuning in which cassiterite is found in any quantity is at the contact of granite with sandy shales, four or five miles to the west.

The Ayer Kuning and Chindras rocks differ from ordinary greisens in two respects. Greisens are rocks consisting of quartz and white mica, usually with tourmaline and topaz as accessories. The Ayer Kuning rock contains no topaz, and the Chindras rock in addition contains no tourmaline. Also the Ayer Kuning rock differs from other described greisens in its very fine grain. The felspathic portions of it may be described as a very fine-grained granite porphyry.²

The Grainsgill greisen³ is another rock formed probably in a similar way by the alteration of felspar to white mica, and it also is like the Ayer Kuning rocks in that it is deficient in topaz and tinstone, but the latter differ in their very much finer grain.

It seems clear from the specimens examined that all of the Ayer Kuning and Chindras rock was felspathic in the first place, and that in the greater part of it the felspar has subsequently been altered to white mica. This is suggested by the similar texture of the felspathic and non-felspathic rocks, although there is one difference, namely, the lack of phenocrysts in the fine-grained quartz-muscovite rock. However, the coarser quartz-muscovite rock of the beacon hill and of Bukit Chindras contains phenocrysts. The field evidence leaves no doubt that the two rocks are part of the same intrusive mass, for specimens of both the felspathic rock and the quartz-muscovite rock were collected from the same exposure.

There is good reason to believe that the quartz-tourmaline bodies are secondary structures, and not products of consolidation. Their grain is uniformly like that of the surrounding white rock, and the tourmaline, which is always the blue variety, is in the same relation to the quartz as is the secondary mica-quartz aggregate in that it is

¹ Mem. Geol. Survey, Land's End District, p. 65, 1907.

² As the ground-mass is not cryptocrystalline but a fine-textured crystalline aggregate of quartz and felspar, the best term is either granite porphyry or microgranite, and granite porphyry is the better of these, because of the phenocrysts.

³ Q.J.G.S., vol. li, p. 142, 1895.

essentially interstitial. In the quartz-tourmaline veins which are described above the tourmaline is idiomorphic and the quartz is interstitial, but, as has been pointed out before, when one of the long prisms of tourmaline penetrates into the country rock, although the crystalline continuity is preserved, in that the crystal extinguishes as a whole, yet that portion of it in the quartz-mica rock now encloses the quartz grains, so behaving like the tourmaline in the quartz-tourmaline bodies. The arrangement of the bodies along parallel planes could be explained as a flow-structure, but none of the phenocrysts show signs of similar orientation: so it seems to be reasonable to take it as further evidence pointing to the secondary nature of the bodies, and that where this arrangement along parallel planes exists it is due to former planes of weakness in the rock which afforded easy access to mineralizing vapours. The single grain of tourmaline observed in the coarser quartz-muscovite rock exposed on the beacon hill lay in a crack and appeared to have had a secondary origin.

Conclusion.

There is little doubt but that the rock is the result of the greisenization of a very fine-grained granitic rock, some of which has been less altered and can still be recognized as a granite porphyry. The rock, however, was not all porphyritic, and the greater part of it might have been an aplite. Perhaps the alteration of the felspar to tourmaline and the alteration to secondary mica took place in distinct operations. Some specimens of the felspathic rock appear to contain no secondary muscovite at all, yet a considerable quantity of the felspar has been altered to tourmaline. Again, as described above, some of the rock contains practically no tourmaline, and the felspar seems to be completely altered to muscovite. There is an indication that the process of tourmalinization was the later of the two. It has been noted that the quartz-tourmaline bodies in the quartz-felspar rock are much less definite in outline than those in the matrix of quartz and muscovite. The only difference in the two rocks is that one contains much felspar and little muscovite, while the other contains much muscovite and little felspar. Presumably this difference was responsible for the difference in the quartz-tourmaline bodies, and so it must have existed before the tourmalinization occurred.

The origin of the Ayer Kuning rocks and that of the Russian beresites seems to have been very similar. Beresite is a quartz porphyry in which the felspars have been altered to secondary mica and quartz. The Ayer Kuning rock is the result of a similar alteration of a very fine-grained granite porphyry which passes into an aplite without phenocrysts. The Chindras rock contains little or no tourmaline, but in Ayer Kuning rocks the blue tourmaline is a characteristic feature. A point of difference between these rocks and beresite is that the latter is rather poor in quartz owing to the small amount in the original quartz porphyry. The Ayer Kuning granite porphyry appears to have been of normal composition.