a rough and cindery appearance. The resemblance between the slag heap of an ironwork and the natural lava is very striking. Indeed, to stand on a lava-flow with the eyes shut by the side of a steam blow-hole and with the smell of the molten metal in the nostrils, it does not require a great exercise of the imagination to transplant oneself from the volcanoes of the South Sea Islands to the ironworks in the Black Country of Great Britain. Travelling over the rugged, cindery flows was attended with difficulty and danger, and the jagged edges made progress slow.

A strange phenomenon was witnessed in one of the volcanoes. After belching molten metal for two weeks, its activity gradually subsided, and apparently, from out the same vent, torrents of ice-cold water began to flow. The same phenomenon was witnessed by an old French settler in a volcanic outburst twenty years previously. From the other volcanoes abundant streams of moderately cold water gushed out and occasioned no surprise, but ice-cold water and molten metal from the same fountain seemed strange and incongruous. The floods of ice-cold water followed the same course as the lava-flow, covering the lava with a thick layer of silt and ash. A good path was formed, rendering this lava track the easiest of all the streams to traverse. Following its course it is possible to trace the lava from the sea to its place of origin at the edge of the ash plain.

The phenomena presented by the Ambrym eruptions would seem to indicate that water played as important a part in fissure eruptions, where intermittent explosions of steam were absent, as in the violent eruptions from a crater cone where explosions of steam were present. Eight lava streams were formed during the eruption; some of them had their source in overflows of lava from crater vents amid paroxysmal explosions of steam, others welled out of the earth like a fountain without the formation of crater cones and without explosions of steam. But the presence of water was as marked in the one case as in the other. In the fissure eruption which took place near the village of Meltungan streams of lava literally gushed out of the fissures without intermittent explosions of steam. These fissures were characterized by an entire absence of volcanic cones and extruded a continuous stream of molten lava which flowed for miles until it reached the sea. The lavas from these flows were impregnated with as much aqueous vapour as the lavas from crater eruptions. From other islands, 15 to 20 miles away, these lava streams could be traced by the columns of steam which rose from the cooling metal.[1]

IV.—The Pahang Volcanic Series.

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(WITH A MAP, PLATE XXX.)

(*Concluded from the October Number, p. 462.*)

Description of Tuffs and Breccias of the Pahang Volcanic Series.

By far the greater part of the volcanic rocks of Malaya consists of fragmental deposits, which at first sight seem to be andesite-tuffs and andesite-breccias, for most of them contain abundant

[1] Dr. Gregory's description of the Ambrym eruptions will appear in the December Number.

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fragments of andesitic lava. However, the majority also contain numerous fragments of quartz, some of which occur as isolated angular grains in the cement, others embedded in a very fine-grained siliceous rock, and sometimes showing rounded outlines and even bays, invaded by the siliceous aggregate. Tuffs which occur in certain localities, e.g. at Kuala Tekal, Tembeling, and Sibah near Kuala Lipis on the Pahang railway, contain the usual fragments of andesite-lava, with numerous fragments of quartz like those just described, and in addition fragments of rhyolite-lava or quartz-porphyry. It is probable that the great majority of the Pahang Volcanic Series of tuffs are formed of an admixture of andesitic, rhyolitic, and sedimentary material.

The first type to be described is an andesite-rhyolite-breccia[1] from the Benta–Kuantan road, at the 47th mile from Benta. There is no hand-specimen of this rock in the collection, but judging from the slide (Pl. XXIX,[2] Fig. 4) it is a dark-green rock, fairly fine-grained, with occasional red spots, made up of abundant fragments of andesite-lava and quartz, with occasional crystals of felspar and fragments of quartzite, set in a cement of quartz and calcite. In addition there are numerous pieces of altered rock, consisting of a fine-grained siliceous aggregate with large included quartz grains, and in one case enclosing a rectangular pseudomorph of magnetite, probably after felspar. Also there are some fragments of a highly altered rock, composed of a rather coarser quartz mosaic, with a little black iron-ore evenly distributed throughout the mass, and comparatively large irregular flakes of white mica.

The andesite-lava fragments are made up of felspar laths, usually untwinned and with a low extinction angle, set in a dark-green isotropic material which often includes large grains of magnetite. There is a greater quantity of glass in these lava fragments than in any of the andesite-lavas which have been noticed in situ. The felspar laths are bent, suggesting that the andesite fragments were hot plastic masses when they were detached from the parent body. Some of the lava fragments contain numerous cavities filled with a green chloritic mineral which is arranged in radiating fibres.

The quartz grains vary considerably in size and appearance, some being angular while others are rounded and have a corroded appearance. The quartzite fragments are stained red with hæmatite, and magnetite and hæmatite are widespread, both in the lava fragments and in the cement. The few felspar crystals which are contained in the tuff are usually broken, and in composition correspond to oligoclase-andesine.

Breccias similar to this occur outside Pahang in the south of Negri Sembilan *[3] and north of Johore *, but the rhyolite admixture cannot here be recognized definitely, and the numerous angular

[1] Described by Mr. Scrivenor in *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 43, No. 1851, pl. xi.

[2] Plate XXIX of rock-sections, also explanation, appeared with the earlier part of this paper in the October Number, facing p. 462.

[3] An asterisk marks the names of all those places in Malaya mentioned in the text which are outside the area shown on the accompanying Map, Plate XXX.

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quartz grains may be shattered fragments from the volcanic neck. They are probably not a sandy admixture brought down by streams, for the fragmental volcanic rocks of this district are interstratified with a series of shales which were at one time calcareous, and from which sandy beds are typically absent.

A volcanic breccia was found occurring as boulders at Kuala Seli* in Selangor at the 13½ mile from Kuala Lumpur on the road to Ginting Bidei (not shown on map), and reference has already been made to the rock as perhaps revealing the age of the purple quartz-porphyry which is found as boulders on the Main Range between Kuala Lumpur and Bentong.

It is green in colour and is made up of angular fragments of the following rocks; quartz-porphyry something like that occurring in situ at Jeram Gading* and as boulders in this district and on Ginting Sempak*, quartzite, and small rounded pieces of a homogeneous fine-grained siliceous rock like those which occur in the felspathic grits that are so often associated with cherts. They may be of sedimentary origin or they may be devitrified lava. There are pseudomorphs of epidote and an opaque dust which have a wavy outline, and in form resemble the altered biotite crystals in the Ginting Sempak quartz-porphyry. In addition grains of quartz make up a considerable part of the rock, some of them angular, others having a rounded corroded appearance, and broken crystals of orthoclase and oligoclase-andesine felspar are also common. There is very little fine-grained material, but amongst it can be noticed some grains of secondary epidote.

About half a mile west of Tembeling a deposit of andesite-rhyolite-breccia is exposed in the railway-cutting which is probably near a volcanic neck, for it is a coarse-grained red rock, the fragments being often more than an inch across, and consisting of quartzite, limestone, lava (both andesite and rhyolite), and crystals of felspar, quartz, and occasionally augite, the cement being quartz-aggregate, calcite, and iron-ores.

The andesite-lava fragments are well preserved, and belong to the type with a ground-mass of very small microliths of felspar enclosing well-shaped augites partly altered to chlorite, calcite and magnetite, and biotite crystals which have been bleached and have sometimes been entirely obliterated by secondary iron-ores. The rhyolite fragments are much more altered, the ground-mass now consisting of a secondary aggregate of quartz in which round bodies which were originally spherulites can occasionally be distinguished under crossed nicols. The shape of the lava fragments is very irregular, but there is no sign of a rapidly cooled margin. These lava fragments are distinct in character from the deposits of boulders in tuff which will be described later, the principal point of difference being that they are not water-worn.

Another slightly different type exposed in the railway-cuttings near Kuala Tekal may be described as an andesite-rhyolite-tuff, and in the hand-specimen it is a dark-green rock containing small black lava fragments, and crystals of felspar, quartz, and biotite, varying up to ½ cm. across.

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Under the microscope the lava fragments are seen to be of two varieties, one made up entirely of felspar laths with trachytic structure, the other being very fine-grained and containing spherulites. The felspar crystals also are of two varieties—oligoclase-andesine and orthoclase. There is a good deal of dark-green chloritic material spread throughout the rock.

A similar rock at Sibah near Kuala Lipis contains a good deal of secondary epidote and mica, some of which has been formed by the alteration of augite crystals. No augite is left unaltered, but the sharply defined octagonal outline of the pseudomorphs suggests that augite was the original mineral.

Andesite tuffs without considerable admixture of more acid material are rare, but a specimen of greenstone with abundant epidote collected on the Benta–Kuantan road near the main Gondwana outcrop east of the Pahang River is more basic than those hitherto described, and contains little, if any, rhyolite material. The fragments of andesite-lava contain small augites as granules interstitial to the felspar laths. Crystals of oligoclase-andesine and augite are common, and there are a few fragments of quartz which are penetrated by epidote, and which when viewed between crossed nicols look like fragments of granophyre in which the felspar has been replaced by epidote. Fragments of an altered shaly sedimentary rock occur, and so do occasional rounded grains of corundum. Magnetite is very abundant in this rock, most of it being secondary.

Besides the above types, consisting in the main of fragments with very little fine-grained matrix, there is the compact type of tuff, in which the bulk of the rock is made up of a very fine-grained material, now of a siliceous nature.

Such deposits can only be determined as volcanic when a considerable number of the larger fragments are of felspar or, as only rarely happens, when fragments of lava can be recognized; in fact, there is an insensible gradation into a sedimentary grit. Probably many rhyolite tuffs are of this nature, and cannot be distinguished from felspathic grits. Then, again, other rocks very much resemble rhyolite tuffs, but they cannot be distinguished from partly altered rhyolite-lava flows unless some field evidence is forthcoming.

Deposits of Boulders in Tuff.

A most remarkable deposit is found in Pahang associated with tuffs and breccias similar to those already described. It consists of rounded masses of lava, tuff, acid intrusive rocks, or sedimentary rocks embedded in a fragmental matrix, the masses being very different from bombs and lapilli which are usually associated with tuffs. In several of the known exposures the boulder-in-tuff deposit passes into the usual tuff without boulders or pebbles.

Their characteristics are summed up as follows:—

1. They vary in size from a pea to over a yard across (at Kuala Tekal).

2. They are water-worn, show no sign of vesicular structure, and have not a glassy margin.

3. They are sometimes arranged in definite strata where they occur as pebbles of small size, e.g. at Tanjong Lindong.

4. In composition they coincide with the Pahang Volcanic Series rocks found in situ, including andesite-lava, rhyolite-lava, andesite-rhyolite tuffs and breccias, quartz-porphyry, and granophyre. No dolerite boulders have yet been found in these deposits. In addition to these volcanic rocks, one boulder of reticulating quartz veins was found in the Kuala Tekal section, and at Batu Redap many of the pebbles consist of a rock which should be described as a slightly felspathic grit—though it may be a fine-grained rhyolite-tuff. There is no distinction between the mode of occurrence of the sedimentary rock and the vein-quartz as boulders in the tuff, and the much more numerous boulders of igneous rocks.

The table on p. 508 gives the different localities in which the boulder deposits are found and the nature of the boulders.

Some of the boulders in tuff at Pulau Guai (see Map, Plate XXX) are of a rhyolite with numerous dark angular shale-inclusions, some of which contain crystals of chiastolite. This rock contains a good deal of calcite mixed with it.

It is very like a rhyolite-lava with shale-inclusions which occurs in situ at Pulau Chengai. Unfortunately, in the field the Pulau Chengai rock was mistaken for a conglomerate belonging to the Gondwana series, and certain other exposures near here which were named as coarse-grained quartzites may be really this same rhyolite-lava with inclusions of shale, so nothing can be said with certainty as to whether the boulder deposits of Pulau Chengai occur near the boundary of the Gondwanas and Raubs. This cannot be taken as evidence, but it will be seen from the third column of the following table that there is evidence to show that the boulder deposits occur always at a boundary of an outcrop of Gondwana rocks with Raub rocks.

The tentative theory as to their origin,[1] put forward by Mr. Scrivenor, the Government Geologist, was "that they were derived from already consolidated sheets of lava and ash, and masses of igneous rock consolidated below the surface, and that they became rounded by attrition in some way we cannot explain before they were shot up into the sea and fell back on ash being deposited on the sea-bottom".

Owing to the infrequency of exposures the field relationships of the deposit are very little known, but, in the nine districts where the deposit has been examined, the small amount of evidence that can be collected indicates that the deposit lies at the junction of Raub and Gondwana rocks. It is probable that there was an important unconformity between the Raub Series and the deposition of the Gondwana rocks, and evidence for this is afforded by the occurrence of pebbles of veined chert and Pahang Volcanic Series rocks in the Gondwana conglomerates. It seems likely that the pebbles were derived from cherts and Pahang Volcanic Series rocks of Raub age, and the fact that sufficient time elapsed after the formation of the

[1] *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 47.

No.	Locality.	Nature of Boulders.	Remarks as to Associated Rocks, etc.
1.	Near Kuala Tekai, Tembeling River.	Tuffs andesite. Quartz-porphyry (?).	Country rock is Gondwana quartzites, etc., yet the boulder deposits contain much calcite.
2.	Pulau Guai (Pahang River).	Rhyolite - andesite - tuff. Rhyolite-lava, andesite - lava. Quartz - porphyry and porphyrite.	Up-stream from here the nearest sedimentary rock in situ is Gondwana quartzite 1½ miles away.
3.	114½ mile, railway.	Much weathered, no specimens collected.	Quartzite near 115th mile. Exposures too much weathered at and near 114½ mile to say whether Raubs or Gondwanas.
4.	Tanjong Lindong to Pulau Prias (Pahang River).	Rhyolite, andesite, and perhaps quartz-porphyry.	An outcrop of Gondwana quartzite occurs near Bulau Prias.
5.	105th mile, railway.	Andesite, trachyte, rhyolite or quartz-porphyry, granophyre.	At boundary of Gondwanas and Raubs. Granophyre is in situ in Raub Series rocks within 3 miles of this place.
6.	Kuala Jeransong to Lubok Plang (Pahang River).	Rhyolite and perhaps quartz-porphyry.	Chert is interstratified with the tuffs at Lubok Plang, also rhyolite-lava flows. The surrounding country rocks are Raubs.
7.	Batu Redap (Pahang River).	Felspathic grits, perhaps volcanic.	The railway is within a mile or so and core-boulders of quartzite are lying on limestone, so there may be a junction of Gondwanas and Raubs near here.
8.	Pulau Chengai (Chengali), Pahang River.	Rhyolite and perhaps rhyolite-tuff.	Probably near boundary of Gondwana and Raub rocks.
9.	Kuala Tekal, 87th mile, railway.	Rhyolite quartz-porphyry, and porphyrite.	Cuttings too much weathered to determine whether the sedimentary rocks belong to the Raub Series or whether they are Gondwanas.

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Raub cherts for them to undergo veining before being eroded shows that the unconformity was an important one. This theory was explained in full in 1911 by Mr. Scrivenor,[1] but at that time it was thought that the chert beds formed a single separate series between the Raub and Gondwana rocks, whereas it is now known that many of the chert beds of the Peninsula are interstratified with Gondwana quartzites.

If the deposits of boulders and pebbles in tuff occur at the boundary of Raub and Gondwana rocks, it is fairly clear that they were formed during the period between them, i.e. in the period of terrestrial conditions.

Mr. Scrivenor said in 1911, that they bear resemblance to the "ashy conglomerate" of the Mendips, described by Professor S. H. Reynolds,[2] but added that after examining Mr. Scrivenor's photograph of the Pulau Guai beds (plate ix, Ulu Pahang memoir) Professor Reynolds thought that the two deposits do not agree. The bedding observed in the Pahang deposits is a point of difference from the Mendip "ashy conglomerate". Professor Reynolds gives four possibilities as to the nature and origin of the Mendip deposit, and one of them, slightly amended, is now suggested as accounting for the Pahang deposit.

The deposit of boulders and pebbles in tuff was laid down during the latter part of the unconformity which followed the Raub period, and during the subsidence when the Gondwana rocks were formed. The line from Kuala Tekai on the River Tembeling to Kuala Tekal on the River Pahang marks the position of the coastline during a pause in the depression, in which beach deposits were formed in sheltered parts of the coastline, and were mixed with volcanic ash which all this time was being deposited on the sea-floor by active volcanoes. Sufficient time must have elapsed between the beginning of the terrestrial conditions and the end of the period of formation of the beach-deposit to allow for the denudation of the considerable thickness of sedimentary rocks which must have covered the quartz-porphyry, granophyre, and other intrusions, for boulders of these intrusive rocks are common in the beach-deposit.

This theory explains the heterogeneous nature of the boulders and pebbles and their well-rounded appearance. It also explains the bedded nature of the deposit and its association at Lubok Plang with a band of chert, for it has been suggested before that chert can be formed in shallow water if the growth of Radiolaria is favoured by abundant silicates being supplied to the sea-water[3] by gases from

[1] *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 56.

[2] Quart. Journ. Geol. Soc., vol. lxiii, p. 227.

[3] J. B. Scrivenor, "Radiolarian-bearing Rocks in the East Indies": GEOL. MAG., Dec. V, Vol. IX, No. VI, June, 1912, pp. 241–8. Mr. Scrivenor discusses the origin of the Peninsula chert, and points out that in Kedah the chert is not associated with volcanic rocks. He suggests that large quantities of silica in solution, supplied by tropical weathering of siliceous rocks, may have promoted, or helped to promote, the abundant growth of Radiolaria in shallow seas.

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volcanic effusions.[1] The absence of any great quantity of sedimentary material can readily be understood, as also the fact that the boulder-in-tuff deposit often passes into a tuff devoid of pebbly material.

The theory that the boulders were deposited in water near a shore-line helps to explain a peculiar circumstance noticed with regard to the tuffs near Pulau Guai. There is a series ef exposures of granophyre over a distance of 4 miles to the north of Pulau Guai, one occurring only about a hundred yards up-stream from the first boulder deposit, and all the tuffs between Pulau Guai and Kuala Tembeling contain fragments of granophyre, whilst of the many specimens of tuffs examined from Pulau Guai only one contained what might be regarded as a fragment of granophyre. At the 102nd mile on the railway there is an intrusion of granophyre, while 3 miles further north is a boulder deposit in tuff. One of the boulders consists of granophyre, and fragments of granophyre occur in the tuff at the 105th mile and in tuffs between there and the intrusion.

The granophyre was exposed by the action of denudation during the period of unconformity, and fragments of it were carried down by stream action and deposited with tuffs which were being formed by active volcanoes at the time. Evidently the shore-line moved from west to east or a little north of west to a little south of east, and this explains the change from tuffs with granophyre fragments to tuffs without granophyre fragments when going down-stream at Pulau Guai, for as soon as the outcrop of granophyre became submerged below low-tide mark it would no longer be subject to denudation.

It was hoped to include in this paper a comparison of the Pahang Volcanic Series with the older volcanic rocks of the Malay Archipelago, as described in various Dutch and German publications, but the process of translation has proved so laborious and slow that it has not been possible to compare them with the volcanic rocks of any other districts but the Goemaigebergte of South Sumatra, which are described by Dr. Emil Gutzwiller in *Mijnwezen*, 1912, *Verhandelingen*.

Comparison of the Pahang Volcanic Series with the Permo-Carboniferous Volcanic Rocks of the Goemaigebergte, South Sumatra.

There are no older acid intrusive rocks in Sumatra which correspond to the quartz-porphyries and granophyres of Pahang, nor are there any rhyolitic lavas or trachytes.

Dolerites.

Those rocks of the Goemaigebergte which typically have an ophitic structure are divided by Dr. Emil Gutzwiller into two groups, the diabase-porphyrites and the diabases; the former group containing no olivine or diallage, while the second group usually contain one or other of them.

Very few specimens of dolerite of the period of the Pahang Volcanic Series have been collected in Pahang, so a detailed comparison

[1] E. E. L. Dixon, Quart. Journ. Geol. Soc., vol. lxvii, pp. 511–31, 1911.

of the specimens in the two countries would be without value, but one difference is sufficiently clear, namely that the felspar of the Pahang Volcanic Series dolerites is very much more acid in character, varying, in the five or six specimens examined, from oligoclase with an extinction angle of 12° to andesine. As already mentioned in the detailed description of the Pahang Volcanic Series dolerites, one of them contains quartz which is probably original. The alteration of the augite in both series results either in the formation of chlorite or of an amphibole. None of the dolerites collected from the Pahang Volcanic Series contain either diallage or olivine.

Andesites.

Dr. Emil Gutzwiller follows the custom of the Continental petrologists in using the name *porphyrite* for the older andesitic lavas.

Judging by the descriptions of the ten Goemaigebergte porphyrites given in *Mijnwezen*, 1912, the most obvious difference is in colour, for none of the porphyrites of South Sumatra have the red-brown colour which is so typical of many of the Pahang Volcanic Series andesites. A more important difference is in the composition of the felspar, for only two specimens out of the ten contain oligoclase-andesine, the remainder having felspars varying from andesine-labradorite (three specimens), through labradorite (two specimens), to bytownite (two specimens) and anorthite (one specimen), whereas the felspar of the Pahang Volcanic Series andesites on the other hand is never more basic than andesine.

The mode of alteration of the felspars in both the Pahang Volcanic Series and the Sumatran andesites is occasionally the same, then resulting in both cases in the formation of chlorite, but usually there is a considerable difference in the products of alteration of the two series, which is to be expected after considering that, apart from occasional specimens, the composition of the felspars in the two series is so widely different. In many of the Pahang Volcanic Series rocks the alteration product is a brown, opaque, extremely fine-grained material, which is probably kaolin, often associated with tiny flakes of secondary mica, not a common mode of alteration for the felspar of the Sumatran rocks. On the other hand, the felspar of the Sumatran rocks is often altered with the separation of epidote and calcite (saussurite). The oligoclase-andesine felspar of one of the Tembeling andesites contains a good deal of epidote, but in most of the Pahang Volcanic Series rocks the epidote which they contain has not been formed from the felspar. These rocks usually contain calcite, sometimes formed by alteration of the felspar, but often simply added to the rock by infiltration from neighbouring calcareous sediments.

The porphyrites of South Sumatra are divided petrologically into two groups, the labradorite-porphyrites and the augite-porphyrites, the first group containing no phenocrysts of pyroxene, but in some cases (Nos. 7, 8, and 9 Gloegoer) chlorite aggregates occur which are undoubtedly secondary after amphibole or pyroxene. In some of these, augite grains occur unaltered in the groundmass. A similar

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division of the Pahang Volcanic Series andesites into those with and those without augite could be made, but, as already mentioned, it is quite possible that all the andesites originally contained augite, which in some cases has been weathered to chlorite. The shape of the chlorite aggregates in some of the lavas confirms this idea, but in others chlorite occurs only as irregular areas in the groundmass, and there is no confirmatory evidence as to its origin.

Titanite is an alteration product common in the Sumatran rocks, whereas it was seen in only one of andesites of Pahang; some of the Sumatran augite-porphyrites are uralitized, and titanite occurs as a secondary product formed during this change. Another point of difference is that some of the Pahang Volcanic Series andesites contain olivine, whereas none occurs in the Sumatran porphyrites.

Apart from the differences mentioned above, the andesites of the two series bear a certain resemblance one to the other. Both are practically always holocrystalline with plagioclase felspar making up the greater part of the rocks as phenocrysts and groundmass, the latter containing little or no glassy base. Apatite is widespread in small quantities in all the Pahang Volcanic Series and Sumatran andesites, and a colourless augite with its alteration products are also widely distributed. Rhombic pyroxene is always absent.

Serpentine.

Serpentine and peridotites are found in many of the islands of the Dutch East Indies, including Java, Borneo, the Moluccas, and the west coast of Sumatra. Dr. Verbeek writes a description of all these occurrences in *Mijnwezen, Wetenschappelijk gedeelte*, 1905, and from this it appears that the serpentine in all these places was derived from olivine. Most of the serpentine outcrops in the Peninsula show no traces of the original rock, but occasionally, as in Negri Sembilan, remnants of amphibole suggest that the serpentine owes its origin to that mineral. An outcrop in the Perak River, however, resembles serpentine of the islands of the Archipelago in containing remnants of olivine.

Tuffs and Breccias.

They differ in much the same way as do the Sumatran lavas from the Pahang Volcanic Series lavas. The andesitic constituents are similar, except in the composition of the felspars, but no simultaneous effusion of rhyolite material took place in Sumatra, and so the Sumatran fragmental rocks differ from those of Malaya in that the tuffs are of an unmixed andesitic composition. The same difference applies to the breccias of the two areas. There is nothing similar to the remarkable deposits of boulders in tuff in the Sumatran area.

The age of the Sumatran volcanic rocks is given by Verbeek[1] as youngest Palæozoic, while Volz[2] gives them a pre-Triassic

[1] R. D. M. Verbeek, "Top. En. geol. beschrijving van een gedeelte van Sumatra's West Kust": Batavia Landsdrukkerij, 1883, p. 270.

[2] W. Volz, "Zur Geologie von Sumatra": Geol. und paläontol. Abhandlungen herausgegeben von E. Koken, Neue Folge, Bd. vi, Hft. ii, pp. 87 ff., Jena, 1904.

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age, and on account of this Dr. Aug. Tobler, in his description of the volcanic rocks of South Sumatra in *Mijnwezen*, 1912, assigns them to the Permo-Carboniferous period. Thus, in age the Sumatran and Malayan volcanic rocks correspond, for the latter are extensively interstratified with Raub rocks, and certain fossils from limestone beds belonging to the Raub Series give it a Permo-Carboniferous age.

Volz says that the volcanic rocks of South Sumatra do not persist so late as the Triassic period, and this is a point of difference from the Malayan rocks, for the latter were being deposited during and probably later than the period of formation of the Lower Gondwana beds of Pahang, which are correlated with the uppermost Trias.

The Tertiary volcanic rocks of the Goemaigebergte seem, from Dr. Gutzwiller's descriptions, to contain no epidote, and this agrees with the rocks of the Malay Peninsula, where rocks younger than the Mesozoic granite contain no epidote. It will be remembered that some specimens of the dark-purple quartz-porphyry of Selangor contain epidote, and that this is taken as evidence of the pre-Granitic age of the intrusion.

Conclusions.

It is not possible to define the limits of the volcanic period with any certainty. The majority of the tuffs and lavas are interstratified with Raub shales, and fossil evidence proves that some of them are of Permian age. The field evidence suggests that the Raub shales are contemporaneous with the Raub limestones, and the latter contain fossils of Upper Carboniferous Limestone (*Visean* age), but no volcanic rocks have yet been seen that were underlain and overlain by Raub limestones. A boulder-in-tuff deposit was seen in contact with a vertical face of limestone in the river bank a few hundred yards down-stream from Lubok Plang, but according to the theory that the boulders are a beach-deposit it is certain that the deposit is lying unconformably against the limestone. So we have proof that there was volcanic activity during the Permian period (late Raub), and there is no proof that it started so early as the Carboniferous period.

It is possible that volcanic activity continued during the period of dry land which prevailed through the greater part of the Triassic and perhaps during a part of the Permian period, and we know that tuffs were being deposited at the coming on of the Gondwana shallow-water conditions, when the beach-deposit was formed.

Tuffs and lavas were extruded during the deposition of the earliest Gondwana rocks in the north and south zone now marked by the Pahang and Tembeling Rivers and probably also further to the east, though this last point has not been investigated. No cases of Pahang Volcanic Series intrusions penetrating Gondwana rocks have been noticed, though there are several doubtful cases; for instance, the granophyre north of Pulau Guai and the quartz-porphyry at Jeram Gading*. However, if the beach-deposit of boulders in tuff was formed immediately before the earliest Gondwana rocks of the locality it is clear that the granophyre was intruded and laid bare before this date, for granophyre boulders are included in the deposit.

Rhyolite-lavas were extruded during the Raub period, and apparently eruptions of acid rocks and andesites occurred alternately. There is no evidence that rhyolites were extruded as lavas later than the Raub period, but eruptions of andesitic composition took place during the formation of both the Raub and Gondwana rocks, and as the eruptions were in full activity during the formation of the earliest Gondwana beds it is possible that they persisted through the period of dry land.

All the Raub volcanic rocks that have been examined were evidently deposited under the sea, and such was the case too with the Gondwana volcanic rocks, though in the latter case it is quite probable that for some time the volcanic vents continued to be above sea-level. Radiolarian cherts are associated with Pahang Volcanic Series rocks at Lubok Plang and on the Main Range in Lower Selangor*, and it is possible that the silica in the sea-water necessary for the building up of Radiolarian tests was supplied by pneumatolytic emanations from these eruptions. However, no proof of extensive albitization of the Pahang Volcanic Series rocks is available, and this is a serious drawback to the theory that the two rocks are related in origin.

The only intrusion of dolerite that was seen on the Pahang Railway was in a weathered railway cutting near the boundary of Gondwanas and Raubs, and it was uncertain whether or not it penetrated Gondwana rocks. There is no proof whether the dolerite is of Raub or Gondwana age. The absence of dolerite boulders from the beach-deposit can be explained by the scarcity of the dolerite outcrops, and does not prove anything about the age of the intrusions.

NOTICES OF MEMOIRS.

I.—Swiney Lectures on Geology.[1]

A course of twelve lectures[2] on "The Mineral Resources of the British Empire" will be delivered by Dr. John S. Flett, F.R.S., at the Royal Society of Arts, 18 and 19 John Street, Adelphi, W.C.

Syllabus.

Lecture I. Tuesday, November 13. Introductory.—The mineral industries in peace and war. Relation of mineral production to Colonial development. Distribution of minerals of economic value in the British Empire. Trade between Britain and Colonies in minerals, metals, etc., in normal times. Effect of war on mineral production and distribution in the Empire. Statistics of British Imperial production. Resources of the Empire in minerals.

[1] With the sanction of the Trustees of the British Museum (Natural History).

[2] The lectures will be given on Tuesdays, Thursdays, and Fridays at 5.30 p.m., beginning Tuesday, November 13, and ending Friday, December 7, 1917. To be illustrated by lantern slides. Admission free.

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