REPORT ON THE GEOLOGY AND PHYSICAL GEOGRAPHY OF THE STATE OF PERAK.

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Geology.

The Geology of the State of Perak may be briefly described as consisting of :—

1. An immense granite formation passing into schists and slates of very early or ancient geological age.

2. Of a formation of paleozoic slates and clays, forming outliers or detached portions showing that it has been subject to great denudation. It is nearly always decomposed into blue mottled clays, red sandy clays, or highly variegated contorted clays commonly called Laterite. It forms small hills, or lies along the base of the ranges or in the valleys and on plains. It is not now of great thickness but has evidently once covered the whole granite formation.

3. Limestone in detached outliers or isolated hills of precipitous character showing much denudation. It is stratified or crystalline. There are no traces of fossils, or at least none have been yet found. I think, however, that it is probably of paleozoic age. From its wide extension throughout Perak where it crops out in so many places, I should say that it once covered the whole of the granite and paleozoic clays.

4. Drifts and alluvium derived from ancient streams and river beds, formed of material from all the preceding deposits.

In these drifts there are deposits of tin which occur in a manner very similar to the alluvial gold in Australia, that is to say, in "leads" which are the ancient river beds of the country.

Tin also occurs in caves in the limestone and at the junction of the paleozoic clays with the granite. In the former case the ore has been drifted into its present position. In the latter it does not occur abundantly.

5. Above these alluvial deposits there is the usual surface soil, supporting for the most part a dense vegetation.

Physical Geography.

The mountain system of the State of Perak, consists of detached groups of mountains which cover the west side of this part of the Peninsula, with an almost continuous range close to the sea of the Straits of Malacca.

The groups of mountains form parallel chains 20 or 30 miles long and with a direction a little oblique to the true meridional line. Sometimes they are wholly detached groups so as to allow rivers from the eastward to pass between them. Such for instance is seen in the ranges between the rivers Kinta and Perak. This group of mountains declines to the north, so as to allow the Plus River to join the Perak, and to the south the Kinta joins the Perak.

The Islands off the Coast, such as the Dindings, Pula Penang, and those off State Keddah (Pulo Leddas, P. Lankawi, Buton, &c.), are probably portions of similar groups. They usually run in sharp parallel ridges variously modified by oblique spurs which sometimes connect the main chains. These junctions form watersheds which throw off small streams to the north-east and south-west.

The following are the principal groups of mountains known to me, proceeding from south to north.

Dindings.

Off the Coast in front of the Dindings River (Lat. about 4° 12′ N.), there is a series of islands of moderate elevation, though one peak in Pulo Pankore may be 800 feet high. All these islands are granitic, with tin and a little fine scaly gold (so it is said.) These

are densely clothed with jungle and have fringing reefs of coral. I have visited three or four of these islands, and they are all of the same character.

On the main land there is a cluster of hills called the false Dindings, from the fact, that at a short distance they look like islands. They give rise to small rivers such the Dindings River and its tributaries. This cluster is also granitic, and tin occurs on the alluvial beds derived from it.

Gunong Bubu.

North-east of this group, but quite detached from it, is a series of parallel mountain ridges with a uniform N.N.E. trend. These ridges are eight or nine in number. The central one is the highest, culminating in Mount Bubu, a fine peak of about 5600 feet in elevation. All the ridges are granitic with occasional patches of metamorphic schists, all more or less rich in tin, though there are but few mines in this group. A remarkable character in these mountains is that all the ridges are extremely steep and frequently interrupted by granite precipices of 1000 feet or more. Gunong Bubu is only accessible in one or two places, the summit being surrounded by escarpments of rocks of great height.

Rivers Kangsa and Kenas.

Many small streams join the Perak River from this range. The Rivers Kenas and Kangsa both flow into the Perak from the slopes of this group, the Kenas in a south-east and the Kangsa in a north-east direction. In an ascent made by me to the summit of Mount Bubu, I was able to explore some of the sources of these rivers, which afford a home to many a Rhinoceros, but few other animals except monkeys (Hylobates, Semnopithecus and Macacus.) The rivers descend many hundred feet in a series of cascades, giving rise to some of the finest scenery in the Malay Peninsula.

Gapis Pass.

North of Mount Bubu this group of ridges falls away abruptly, leaving a narrow pass (Gapis Pass) between them and the west

group. This pass is about 400 feet above the level of the sea, and therefore too elevated to permit of any river outlet.

Mount Pondok.

In Gapis Pass, or rather at the eastern end of it, there is an isolated hill of highly crystalline limestone. It is an outlier of the great paleozoic limestone formation already referred to. Mount Pondok is about 4000 feet high and quite precipitous. Its junction with the granite or paleozoic clays is not visible. Its bright blue and red precipices, crowned by dark green jungle, makes it a singular and beautiful object, though there are many similar to it, in the State of Perak and elsewhere in the Peninsula.

Mount Ijau.

North of Gapis another group of ranges succeeds, culminating in Mount Ijau. This cluster of ridges appears to be nearly of the same dimensions as the Mount Bubu group, but not so high by 1000 feet or so. I estimate that each group is from 20 to 25 miles long and 14 to 16 miles broad, covering an area of about 400 square miles. This, however, is only a rough estimate formed from views obtained from the summits of Group Bubu. I have not been able to examine closely the termination of Mount Ijau group to the north. From the sea and from the Perak River one can perceive a distinct pass like that of Gapis. It is probably about the same height and does not form the outlet of any river from the eastern side of the range.

Kurau Group.

North of Gunong Ijau is another group which I don't know how to distinguish, except that it forms the watershed of the Kurau River. Its highest point is said to be a mountain also called Ijau. If it be the peak which seems the highest point in the range, it does not appear from a distance to be so high as Mount Ijau to the south.

Mount Iuas.

Mount Iuas, as understood by the Malays of Selama, is the highest point of another detached group north of the Krian and Selama Rivers. At a few miles distance from the foot of this range it seemed somewhat over 4000 feet high, and the highest point of an isolated group of ridges.

Keddah Peak.

North of Iuas in the State of Keddah, there is, close to the sea a detached group of mountains, round the southern base of which the Keddah River flows. Keddah Peak is the highest summit and probably over 4000 feet above the sea.

Other Groups.

In the north of Perak near Patani there are other groups of mountains, notably the Gunong Kendrong Group, which is quite detached from any other hills.

Perak River.

The whole of these groups are sufficientiy connected to prevent any drainage from the central range from flowing directly to the West Coast of the Peninsula. Thus the Perak River which has its source in the Keddah and Patani Mountains flows to the southward in a winding course of over 200 miles. It has many tributaries the most important of which are the Plus and Kinta.

Plus River.

The Plus River has its sources in the high mountain group east of Mount Iuas and in the main range. It flows round the southern end of the Bukit Panjang Range and then joins the Perak.

Kinta Ranges.

South of this junction of the Plus is a group of mountains, called by some the Kinta Ranges. This group is about 25 miles long. It is quite detached from all the others having a generally north and

south direction, but sending off spurs, north-east from the eastern side, and south-west from the western. As in all these groups of mountains the spurs on the eastern side are not numerous. The group is entirely granitic but on its lower slopes has extensive deposits of limestone. This belongs to the formation already referred to. Above and below the limestone strata drift tin is worked; below, that is to say, the horizon of the limestone. I am not aware of any instance where the calcareous strata have been bored through.

For about 25 miles this range separates the valley of the Perak River from that of the Kinta, which flows on its western base. The highest peaks rise to about 3750 feet above the sea and give rise to small streams which all flow into the Perak. There is a remarkable uniformity in three or four of the highest summits which are about the centre of the chain. They are all within a few feet of the same height. From these mountains the range falls away gradually to the south. It sends off two considerable spurs to the south-west. Where it ceases the River Kinta joins the Perak.

Kinta Valley.

The valley of the Kinta River is about as wide as that of the Perak. Both rivers flow on the eastern sides of their respective valleys. The eastern tributaries are many and important. On the sides, limestone, granite, and schistose slates crop out. To the eastward there are many detached hills of limestone, fronting the main central chain. They form very characteristic features in the landscape from their precipitous outline and brilliantly coloured escarpments of blue, green and bright red rock. They are also distinguished by a different vegetation.

Perak Valley.

The valley of the Perak River is bounded on the west by the groups of mountains already described. I have previously observed that the stream flows on the eastern side of the valley. This is owing to the many spurs and outliers on the eastern slopes of Mount Bubu and the Ijau Ranges. It would seem as if there

had been much less denudation on the eastern than on the western side of the range. This may be owing to the prevailing rains falling more abundantly on the western than on the eastern sides of the mountains.

As a consequence of this, the tin workings appear to be (with no exception known to me) on the western slopes of the ranges, where the waste and wash have been probably greater.

Batu Kurau.

Between Mount Bubu Group, Mount Ijau Group and the sea, there are no hills except small outliers, mostly of paleozoic clay. These have evidently, at one time, been united to the ranges. North of the Larut River there is an isolated limestone mountain near the Kurau River called Batu Kurau. It is similar to Mount Pondok in the Gapis Pass. It is quite unconnected with the main range, and rises out of the plain between the spurs which form the valley of the Kurau River. There is also a small detached range dividing the valley of the Krian River from that of the Kurau.

Main Range.

The geology of the main range is apparently like the rest of the country, namely granite, slates, and limestone, with traces of basaltic rocks. The general structure of the range can best be studied from some of the mountains to the Westward. It forms a most imposing boundary to the whole of the western horizon. In the most northerly portion visible there is a mountain of rounded outline which appears to be very lofty. This range then declines to the southward with a somewhat serrated outline, with an average height of over 3000 feet. At a point near the latitude of the centre of the Kinta range the chain rises, and in the distance is seen a peak which is probably over 8000 feet high. This hill may be the one named the Sugar-Loaf Hill by some. The Malay name is a subject of uncertainty. It is the most distant mountain of its particular group and is a conspicuous object of conical outline. South and west of this the chain rises into a grand cluster of peaks, the highest of which is over 8000

feet at a rough estimate. I think this mountain is the one known as Gunong Robinson. From it the range declines, but is still a bold series of picturesque peaks, many of which must be over 6000 feet high. Other higher points are said to be occasionally visible in the south-east. It is possible that geologically the main range is younger than the groups already referred to.

IDEAL SECTION.

The following is a description of a section through the State from east to west, in about the latitude of Thaiping.

Proceeding westward from the Straits of Malacca we meet :—

1. Alluvial mangrove flats.

2. Light quaternary drifts with much vegetable matter, granite, sand and gravel, lying upon stream tin.

3. Clays and partly decomposed schists and slates, sandstones, red, yellow, blue and grey, commonly called Laterite, from the brick red colour of some portions. This is a paleozoic stratified rock, resembling in lithological character the Ordovecian or Cambrian deposits of other countries. There are no fossils, and as lithological character is by no means a certain clue, though it has a considerable value in these older rocks, it will be understood that I only provisionally refer the rocks in question to any horizon, especially to the Ordovecian which in Australia and other countries are so rich in minerals.

4. Granite rocks of the first range which I shall here distinguish as the Thaiping Range.

5. Alluvial of the valley of the Perak River, consisting of drift from the spurs of the granite mountains, and including stream tin in the valleys formed by these spurs. It is uncertain if the Cambrian deposits re-appear in this valley, but here we meet with—

6. Detached outliers of a highly crystalline limestone with almost perpendicular dip.

7. A second granite range which I distingush as the Kinta Range dividing the valley of the Perak River from that of the Kinta.

8. Alluvium of the Kinta Valley.

9. A low limestone range of crystalline limestone in which a dip and strike may be observed.

10. Alluvial valley.

11. Central granite chain.

I shall now proceed to consider the geology of these eleven formations.

1. *Alluvial Mangrove Flats.*—These are a series of mud islands and flats from two to three miles in width, fringing the whole of the coast line. The vegetation is principally made up of Rhizophoræ. There can be no doubt that such islands and flats are the usual deposits from lands on which great erosion is going on, from numerous and large rivers and an abundant rainfall. They point very clearly also to an absence of any upheaval along the coast line. Like the eastward of Australia in its northern and central portions the waste from the land is gradually extending the limits of the shore and filling up the sea. Such a process has been going on for a very long geological period in the Straits of Malacca. Both the coasts of Sumatra and Malaysia prove this as well as the shallowness of the Strait and the numerous mud banks occurring in it. The rich vegetable mould in this formation is entirely due to the mangrove forests, valuable as timber for fuel and making a very graceful and luxuriant fringe to the shores. I intend subsequently to make a report on the general aspect of the vegetation of the mangrove flats. It is extremely probable that here they cover tin deposits, but the great depth and the water must render them inaccessible.

1. *Quaternary Drifts.*—Probably most of the surface drifts in this State are quaternary, but I restrict the term now to those drifts, which form the alluvial plain between the Mangrove and the Thaiping Range. These range between 10 and 30 feet deep and have all been deposited by the various small streams which now run across the plain. These have been larger and smaller, fewer or more numerous by turns in the history of the filling up of the level. The channels have also shifted to an almost inconceivable extent according as the levels were altered by the deposition of

drift. This is composed of clays, fine sand, fine or coarse gravel which is large near the hills, and finally tin sand, which rests upon blue, white or red clays. The sand is quartzose, angular, composed of transported grains, evidently sifted by water and not abraded. It is transparent, showing much color under the polariscope. The pebbles in the gravel are rounded granite, with black mica, schorl, and grains of tin.

There are also rounded fragments of quartz of various colours, generally opaque white, but also red, brown, rose coloured, and violet. The two latter tints are due to fluor spar. The whole of the deposits have been derived from the granite and the tin has sunk to the lowest level by the force of gravitation. The drifts are sometimes full of stumps of trees and large stems of fallen timber. There are also the remains of jungle swamps which have given rise to deposits of black and brown humus full of roots, stumps, trees, leaves, &c. This deposit loses half its weight on drying, and the remainder burns leaving half its weight of ash. Remains of boats, paddles and fragments of pottery have occasionally been found in the drift. Except when covered with vegetable remains it is of a light colour and gives rise to a poor soil, covered with Calang *(Imperata arundinacea)* or jungle.

3. *Paleozoic Clays.*—These generally form the bottom on which the tin sand rests. They are much decomposed, yet preserve the marks of former stratification. They have been contorted and metamorphosed, sometimes resembling Gneiss. There are cross veins of white quartz and felspar in certain portions, showing metamorphism. Brick red and yellow sandstone bands are frequently intercalated. The common result of decomposition on this rock caused by water containing carbonic acid is to change it into red brick earth, which goes by the name of "Laterite." The use of this term throughout the peninsula is inconvenient and should be discontinued because it groups under one name several formations. Any rocks, such as trap, granite, and gneiss, may decompose into a red earth through the influence of water straining through vegetable matter and containing carbonic acid. A very small quantity of iron being thus converted into peroxide

will stain a large mass of earth. As a rule the laterites of the drift are derived from the paleozoic clays but they are sometimes due to the surface decomposition of granite. In one instance in the Kinta Valley this red deposit is caused by the erosion of a basaltic dyke of a recent tertiary age.

An important question arises in connection with these paleozoic clays which are found to contain on the surface a little tin combined with rounded grains of iron. The question is how far they may have been the original matrix of the tin sand. If we regard the granite as only a more highly metamorphosed portion of these rocks they may be considered as stanniferous. My opinion is that they are an upper formation lying on the granite, and contain a little tin.

A more important question is whether the clays derived from this rock may always be considered as a true "bottom." For stream tin I should say decidedly yes. There can be no tertiary drift between this formation and the granite. But I am not so sure that in these loose clays stream tin may not sink to a certain depth and be found a little below the first level. At the junction of the paleozoic clay with the granite it is consistent with experience to expect to find granular tin in small pockets or veins. These deposits would be local. It is an open question whether they would repay a search for them. The paleozoic clay is only a few feet in thickness and rests directly upon the granite, so there would be no great expense in testing the question. In looking for a second bottom for stream tin, as the ore would have to sink through soft sandstone or into very loose clay, any search beyond a few feet would be useless.

Granite Rocks.

The whole of the Thaiping Range and a good deal of the rock underlying the stream tin is a coarse blueish or grey granite, containing but little mica, large crystals of orthoclase felspar, with schorl, cassiterite, tungstates of iron (wolfram), fluor spar, manganese, and titaniferous iron imbedded in a quartzose paste. It is clearly a metamorphic rock, as many portions are still schistose,

and the marks of former stratification can be traced in the granite. There are occasional bands or veins of quartz and felspar, but no true metalliferous vein has as yet been discovered.

The stream tin which has been found so abundantly at the foot of some portions of this range has been derived from the granite, in which it was scattered or disseminated in small crystals. Probably the tin was nearly confined to the upper part of the granite, especially at its junction with the paleozoic rock. Liberated in the gradual weathering of the stone it has been swept down into the valleys and flats by the almost continuous rainfall. The gravitation of the particles has performed the necesssary sifting. As the tin is found in the lowest strata it may owe this position to three causes. 1. Gravitation facilitated by the repeated washing and sifting to which stream beds are subject, and the heaviness of tin ore. 2. A greater richness in the upper granite at its junction with the paleozoic clays. 3. Stream tin gradually sinking through the strata.

Tin ore is not universally scattered through the matrix of the granite in its upper portions, but it must be so to a very large extent, considering the wide spread character of stream tin deposits in Perak. It may be regarded as a very good indication of the existence of stream tin where there is evidence of another formation, such as the Ordovecian clays or the limestone. In cases where the overlying formation has been denuded away the red clay is a good indication. My reason for this opinion is that all metalliferous formations are richest at the junction of a different deposit. Thus when the upper formation has been denuded away the upper portion of the granite has been very rich in tin. All my experience in Australia has forced these conclusions upon me.

It should also be borne in mind that the gradual wearing away and denudation of the granite has reduced the slope of the mountain at the foot and gradually converted it into a plain. But time was when the upturned paleozoic rock presented steep and jagged edges to the sides of the hills. These acted as ripple tables in which the tin was caught and accumulated. It was not until the drift had silted up within reach of these rocks and reduced all to a plain that light sands would accumulate upon them.

Instances of this are common at Assam Kumbang, where the surface soil is level, but underneath this the paleozoic clays are found to be very uneven and lying in ridges on the summits of which there is no tin but with very rich deposits in the valleys between.

Thaiping Range.

The range that bounds the plain from the coast has this peculiarity, that it sends out at right angles a number of long undulating spurs, gradually decreasing in height and becoming a series of small detached hills. The spurs end sometimes abruptly, and sometimes run out into the plains for four or five miles. They give rise to a series of long narrow valleys. Near Thaiping the spurs and the valleys are shorter. Round the sudden termination of the spur on which the Government quarry is situated, is the rich tin field of Assam Kumbang. It is curious to remark how the tin mines curve round the base of the hill, and also to what a distance they extend from it. The Residency Hill is a detached portion of one of the many short spurs abutting from the main range. There is evidence that they are or they were covered with outliers of the paleozoic rock, and to this I attribute the richness of the tin fields around Thaiping.

5. *Valley of the Perak River.*—Jungle and alluvium prevent any close examination of the geology of this portion of the section. There are detached outliers of the limestone formation and in the valleys near them I should look for rich tin deposits. At Salak, about four miles from Enggor there is a fine valley with tin in it derived from the spur of the range. In this case there are schists and hard slates in the bed of the river where the stream tin is found.

Kinta Range.

This is another granite mountain chain which is detached from the main axis and trending south. Its exact height is not well known. Those portions which I have seen were overlaid by limestone strata, crystalline but with a clear easterly dip of about 17 degrees. This rock bore a strong resemblance to the Devonian limestones of North-eastern Australia. These are also crystalline

but on being treated with acids they manifest organisms, such as Stenophora, Favosites and fragments of Brachiopoda. Here I could discover nothing of the kind. Sections showed the usual striated crystalline structure of calcite but no trace of any fossil. I cannot conceive that such large masses of limestone should be entirely destitute of organic tissue of some kind and I am not without hopes that under favourable circumstanees they will yet be found.

I look upon the limestone formation as probably younger than the paleozoic clays but I have seen no section which establishes this beyond question. Apparently the limestone lies directly on the granite and so do the paleozoic clays. But the limestones are on a higher level and show generally a slighter dip. Looking at the physical geography of the river valleys, which in section show granite, paleozoic clays and schists, and then more towards the centre limestone ranges, the inference is that the limestones lie above the clays. Lithological character may also be appealed to. There is very little difference between the Silurian rocks all over the world and even such local characters as the Oolitic of Europe possesses are found to have perfect representatives in the Oolitic of Australia. According to this the limestone may be estimated as Devonian or Lower Carboniferous.

8. *Alluvium of the Kinta Valley.*—This overlies the limestone but not to such an extent as to prevent outcrops. There are also outcrops of granite and in one place a small patch of highly inclined schists and slates. In a journey I made up the Kampar River, which is a tributary of the Kinta, and flows by the side of a small elevation or table land of limestone and granite, I noticed the same sections but more limestone rock. The whole of the alluvium of these rivers, inasmuch as it is derived from the junction of the granite with the two other formations, I regard as probably rich in stream tin. The Malays have tested it to a trifling extent and always with success.

9. *Limestone Range.*—This forms a series of irregular hills lying like a rampart at a short distance from the main central range. Its appearance from any elevation to the westward is very peculiar. It forms a series of detached almost conical hills

seldom above 1500 feet high and presenting precipitous sides of greyish or blueish rock very beautifully variegated with stalactites and various infiltrations of iron oxides. The vegetation on these rocks is to some extent different from that of the granite, and no doubt where it has been examined by the Rev. B. Scortechini, will show most interesting and new features.

It is quite evident that this limestone has been subject to enormous denudation and of a very rapid kind. Like all similar rocks the hills are full of caves situate on the face of the cliffs, inaccessible without appliances. In these caves tin sand is found, evidently derived from the granite. Some of this tin drift with granite detritus occurs in caves several hundred feet above the present level of the plains whence any stream could affect them, and three or four miles from the nearest granite rocks. This will give an idea of the extent to which erosion has worn away these rocks. I shall have occasion subsequently to describe some of the mines worked in these caves.

From near Pappan, and again from the hill on which the residence of Mr. de la Croix is built at Lahat, excellent views may be obtained of this singular range. Its irregular outline and the white faces of its cliffs make it a conspicuous feature, especially as the cliffs and the dense dark green vegetation with which they are always surrounded give strong contrasts of colour.

10. *Alluvial Valley.*—The width of the valley between the limestone hills and the main range is not great, but varies from one to ten miles. It is broken up by many ridges of both limestone and granite amid which flow rivulets and small rivers. In some of these smaller valleys tin is worked and in all it may be expected.

11. *Central Granite Chain.*—The few opportunities I have had of examing spurs of this range convinces me that it differs in no essential particular from the Thaiping Range. It is granitic and rises into greater elevations. Some of its summits are supposed to be between 8000 and 9000 feet above the sea. Seen from a distance the highest peaks have a grand and picturesque aspect. As far as the country is known this range is believed to be the main axis of elevation. All the other granite ranges are detached

from it to the north, so that in reality they are diverging groups distinct from it, and terminating to the southwards. It is owing to these isolated groups that the Malayan Peninsula widens out to so great an extent about the centre of the State of Perak. Looking at the extent to which denudation has taken place, we have clear evidence that the central range has been much higher than it is now, but its reduction has been by erosion, not by subsidence. Much of this has been carried to the sea as sediment, and some spread in the valleys. The upheaval of these large mountain systems is too much involved in obscurity to render any speculations on the subject of use in estimating the physical geology of the country. It may, however, be fairly assumed that the granite was at one time overlaid completely by the paleozoic formation, and probably by the limestone. The upheaval dates subsequently to the deposition of the latter. The granite has broken through both formations, depositing them, and it may be other newer strata on each side of the chain. Erosion through the countless ages has left us the rocks as they stand at present.

The granite being a metamorphic rock was probably at one time stratified and was one of the earliest formations, either Lower Cambrian, or Laurentian. This accords with what is universally observed in connection with tin deposits which are always found in the most ancient rocks. The metamorphism must date subsequently to the deposition of the paleozoic clays and may even have been subsequent to the deposition of the limestone. The breaking through of the granite chain may have been much later. The chronology of the operations thus revealed may be stated thus: 1. The tin was originally disseminated in finely divided masses in the paleozoic strata, of whatever age they were. 2. It was subsequently segregated and brought to the surface of the overlying rocks. 3. It was brought within the influence of erosion by the upheaval of the granitic chain. 4. Denudation distributed it as stream tin in the valleys and alluvium.

There is one more geological question that may here be touched upon. It is generally recognised in the present day that in granite we have one of the results of volcanic action presented to us. It

supposed to be more the deep-seated portions of the fusion which at the earth's surface produces basalts, lavas, and scoriæ. That this is very near the truth may be seen from certain sections in Northern Europe whose upper portions have all the characters of volcanic products but gradually merge into granite in the lower sections. Hydrothermal action consequent upon pressure is the assigned cause of all the phenomena, but this is of no moment in our present inquiry. We may therefore conclude that there have been volcanic products in connection with this range, which have now disappeared or nearly disappeared.

It must be borne in mind however, that these cannot be looked for under the recent form of the volcanic series. Local metamorphism has changed them. According to the researches of Phillips and others, basalts, dolerites, &c., would be changed into diorite, diabase, and other rocks, in which augite disappears, and hornblende takes its place. Time and that constant interchange of particles which takes place in even the most solid rocks would effect these changes.

Furthermore, even if there had been no erosion, we could not expect to find these metamorphosed volcanic products widely distributed. Probably they are only connected with those outlets where the pressure was less, the gases and steam were able to expand, and the chemical influence of oxidation felt.

But nearly all of these products belonging as they did to the upper portion of the granite have been swept away by erosion. Yet not quite all. In the section of the Kuala Kangsa pass at about 14 miles from Thaiping, there is a wide dyke which is trappean. It has been much metamorphosed, and at present has considerable resemblance to a porphyritic rock. I have not examined sections as yet, and therefore cannot give any further information as to its character. This is the only dyke or rock of a trappean character which I have seen in connection with the granite, nor would this have been visible but for the cutting connected with the road through the Pass at Gapis.

It should be mentioned here that one of the greatest difficulties experienced in exploring the geology of this country is the absence

of any sections. The only roads are those made by the Government during the last six years. On none of these are there any extensive cuttings. On the rivers it is extremely rare to see a section of rock exposed ; in fact, I only know of two instances, amongst all the rivers I have visited. The rest of the country is jungle where outcrops of rock are covered with dense vegetation.

Near Pappan, in the Kinta District, on the road between Batu Gadja and Pappan, there is a small cutting through a recent volcanic rock. It is basaltic, and the appearance is very like the doleritic lavas of Australia. A small section showed crystals of Augite in a glassy paste with abundance of microliths and magnetite. In the drifts about this neighbourhood I found many rounded waterworn pebbles of basalt, the vesicles of which are either filled with zeolites or lined with chalcedony. I believe this is the first discovery of recent volcanic rock in this portion of the Malay Peninsula, and of course there must be more than this example. It is most interesting as showing the former connection of this land with the great volcanic belt which runs through Sumatra, Java, and the islands to the eastward. Whatever connection there was has now completely died out nor does it appear probable that its manifestation has in any important degree modified the physical geography of the Peninsula.

The Tin Mines.

I shall now proceed to give an account of the various tin mines I have visited throughout the State.

Thaiping.

The mines of Thaiping are stream tin deposits underlying drifts derived from the Larut River and some small tributaries. They are situated at the ends of some small spurs running westward from the Thaiping granite range. They also run up the valleys between these spurs as far as the base of the range. The geology of these spurs is granite, covered with a red earth which is seen from other sections to be derived from the paleozoic clays already referred to. In a few instances these clays remain as outliers

with well defined stratification. Towards the gaol and at the foot of the quarry hill the paleozoic formation may be seen, with much contorted bedding, and ribbon like structure, forming bands of red, yellow, and white. It is evident that the present river valleys have all been cut through this rock on to the granite and that the materials forming the drift have been derived from both. I consider that the paleozoic clays play a most important part in connection with the tin deposits, according to what has already been said. The rich tin sand has its matrix in the granite, but more abundantly at its junction with the paleozoic clays than elsewhere.

All the tin workings at Thaiping are in drift, and therefore in what has at one time or another been a portion of a river valley. The depth of the drift is never more than 30 feet and sometimes much less. Near the range it is less and the gravel coarser, often mingled with boulders of granite of a ton or so in weight. The tin sand is also coarse. The general run of the sections is :— 1. Alluvium of yellow clay. 2. Sand of yellow colour with occasional drift wood of large size. 3. Blue and yellow clays with infiltrations of much bright red oxide of iron. 4. Coarse waterworn gravel composed of granite and various coloured quartz and felspars. 5. Tin sand, in clay or sand or pipeclay. The tin is fine in quality. The crystals usually not much abraded and seldom much larger than two millimetres in diameter. In speaking of tin ore or tin, tin sand, cassiterite or oxide of tin (Sn O2) is meant, that is to say, pure metallic tin 78·62 and oxygen 21 38. It occurs in short prisms with four or eight sided pyramidal summits or complicated by twin crystals. Generally however it is so abraded and broken as to leave scarcely any trace of crystallization. It is blackish like graphite, sometimes reddish brown or ruby red, often transparent but rarely colourless. Its fracture is hackly and its lustre vitreous. In many specimens of fine tin from Thaiping small broken prisms of transparent olive green are not uncommon. In this there appears to me to be a distinct difference between the tin ores of Perak and those of Australia, especially those of Victoria. The latter contain a much larger proportion of hyacinth-red crystals. Samples from the above named countries

could easily be distinguished by those who have had a little experience in tin ores.

Without entering into detail I may refer generally to all the mines about Thaiping as affording instances of the origin of the stream tin deposits. The Residency of Thaiping is built on a small isolated hill, capped with red clay, about 100 feet or so above the plain. Very rich mines were formerly worked at the foot of it. There are other hillocks of the same kind at the base of which tin is now worked, and there are others further out in the plain where the yellow clays give a fair indication that tin deposits may be looked for at a moderate depth.

Five samples of pure tin ore carefully picked and separated from impurity gave the following results for Specific Gravity.

Sample 1.	Thaiping	6·78
2.	Thaiping	6·80
3.	Klian Pow	6·77
4.	Kamunting	6·80
5.	Assam Kumbang...	6·78

Most of the specimens are hard enough to scratch glass.

It is remarked that the stream tin of Australia is rich in sapphires and other gems. In Perak there appear to be none.

Assam Kumbang.

Due north of the town of Thaiping, a spur from the range extends, and round the foot of this in a direction N.N.W. from the town are the mines of Assam Kumbang. They commence about a mile from the town, and continue round the foot of the mountain for three or four miles. These mines are mainly distinguished for the great distance they extend from the range. It will be understood from the conditions under which stream tin accumulates, that it cannot be looked for far from the influence of rapid streams, or from where rapid streams have formerly been. At

the mines referred to, the spur of the range is very steep, and the wash from it may on that account have been carried out much further. As a matter of course, the further from the hills, the finer the tin, as only small particles of the ore can be carried any distance by water. Two miles seems to be about the limit to which the very fine particles of tin have been carried into the plains by floods.

These mines seem to confirm the view that the rich tin deposits have been formed by the wearing down of the paleozoic clays at their junction with the granite. There is less oxide of iron and coloured clays in these mines than in those at Thaiping. White porcelain clays and sands are the rule. In many places however, the drift lies upon the softened and almost disintegrated paleozoic clays, showing that they still lie at the foot of the hills, and must have been very much worn away in the wash and denudation that have laid the granite bare.

Kamunting.

These mines are at the foot of the range about three miles north of Thaiping. The drift lies upon the paleozoic clays in some mines and in others upon the granite. They are all very close to the base of the mountain from which they have been derived. It appeared to me as if the deposits could be shown to follow the course of more than one ancient stream bed. Both here and at Assam Kumbang, there are deposits of vegetable matter some eight to fourteen feet thick. Large trees and stumps with logs are found, the stumps and roots being often in the position in which they grew. This shows that the locality has been alternately the bed of a stream and the site of a forest, probably when the stream took a different course and left the banks and bed free to receive a forest vegetation.

Another peculiar circumstance connected with the clays in these localities is the water standing in any of the old workings becomes a beautiful pale blue colour. Neither by microscopic examination nor chemical tests was I able to find any satisfactory

reason for this. The water is quite colourless in small quantities. I am inclined to think it is due to a hydrated silicate of alumina (Halloysite) derived from the clays, but it may be also a minute diatom (Tryblionella?) which is sparingly found in the water. *See Note.*

The tin in all these mines is abundant, rather coarse, and often in two strata of a foot or more in thickness. It is generally in the lowest portion of the drift, covered with coarse water-worn sands and gravel, fine yellow and white sands and vegetable matter in regular strata.

Salak.

This mine is situated in a valley formed by granitic spurs from the range on the eastern side of the Perak River. It is about four miles east of Enggor, a village on the river about five miles north of Kuala Kangsa. The workings are in a small river valley which at the time of my visit (February 6th, 1884) was nearly dry. All the workings were in alluvial drift with coarse gravel, but with much fine sand above. In the bed of the river there were outcrops of very hard stratified quartzite forming bars across the stream. These have acted as "ripples" and consequently much drift tin was accumulated on the upper sides of them. I was told that there were indications of a tin vein here but I saw none. The whole of this valley must be rich in tin, but it is only worked to a small extent as yet, by Chinese. The tin is excellent, with grains of a large size. I saw some crystals half an inch in diameter with little signs of abrasion.

Note.—The action of water holding carbonic acid in solution (derived from the vegetation) accounts for most of the changes in the clays and sands of these localities. The orthoclase felspar containing potash becomes easily soluble in carbonized waters. Thus the potash becomes carbonate of potash and the silica of the felspar is set free, partly in solution, and partly as siliceous sand. Nearly all the water in these pools gives a slightly alkaline reaction. I need hardly say that carbonate of potash is a very soluble salt and easily carried away by running water. Soda felspars are not so common in the granite here, but if present a similar process of solution goes on, only that the product is carbonate of soda.

Pappan.

This is a stream tin deposit in the valley of the Kinta. The limestone formation crops out at a short distance, and in fact flanks the whole of the range, but does not here rise into such a high series of hills as on the eastern side of the valley. The Pappan mines are in river drift composed of sand with granite gravel. This is much mixed with occasional waterworn fragments of basalt three inches or so in diameter. The vesicles of this rock are filled with infiltrations of lime and chalcedony. The drift varies very much in thickness. In some parts of the flats near the Shanghai Company's works it is scarcely 20 feet, while further up the valley it increases enormously. In some old Malay workings on the hill at the back of the village the deposit of drift is between 60 and 70 feet. This is scarcely a quarter of a mile up the valley. The drift here is very fine grained and has hardened into an almost compact sandstone. Much of it is stained a deep red especially where the water from the surface has free access to it.

The old workings are abandoned and now form a large square waterhole nearly 30 feet deep, surrounded by picturesque cliffs of compact yellow, white, and red drift. The water in the mine is, like nearly all the deep mining waters in this country, of a clear light blue of a beautiful tint, quite different from that of sea-water.

There must be two or three strata of tin sand in this locality. On the path by the side of the workings a small but very rich seam crops out. I washed a small sample and found an unusual amount of tin in coarse grains. This was being worked by a native chief, but only on the surface, with the help of a few Malays.

The accumulation of so much drift above the tin in which no metal is found would seem to point out that the granite in its lower portions is barren of ore. In shallow drifts the river gravels have most probably been turned over by the water again again, and so in this manner the tin sand sifted out and gradually settled at the bottom. Or in very thin layers of sand permeated by water, tin may easily sink through to the clay. Such large accumulations of sand as we have in the case of Pappan, if they have slowly been

gathered by the weathering of granite, have probably not been sifted by water, and ought to contain all that the granite contained. The absence of tin ore in this drift is therefore significant. There may however, have been a large river here, and this may have been a sandbank. The present aspect of the valley is against such a supposition, but as denudation is evident to the extent of a thousand feet and more in the limestones on the other side of the Kinta valley, equal erosion may be supposed to have taken place here. I am, however, inclined to think that the rich tin deposits were found on the upper part of the granite at its junction with the limestone or the paleozoic clays already referred to.

Altogether, I consider the Pappan district as very rich in stream tin and offering most favourable prospects when properly mined.

Poussin.

About two miles from Pappan on the road between that village and Batu Gadja there is a small mining community of Malays. They work upon a low ridge on which white limestone crops out. It is crystalline, but retains its marks of stratification which dips about 17° east. The rock is very much eroded, and cut into pinnacles, and sharp angles of fantastic appearance. Much of the stone is covered with clay and light soil. This the Malays remove by cutting narrow trenches, never more than ten feet deep. In the crevices and amid the pinnacles of the limestone thus uncovered, they find tin sand. It must be abundant and of great richness, for though the methods of mining are so rude, and confined to mere narrow pockets, and though the ore is smelted in a small charcoal furnace with a piston bellows, yet they manage to make a good deal of money out of these mines.

Amid the gravel above the limestone were many rounded and angular fragments of the basalt already referred to. It appeared to me as if the clay and gravel were derived from granite and that there were marks of river action.

Between these mines and Pappan there is the small outcrop of basaltic rock already referred to. The cutting has only revealed

a very small portion of the decomposed surface, so that it cannot as yet be said whether this is a dyke or a more extensive outpouring of trap.

Lahat.

Separated from the valley of Pappan by a low granite spur from the main range is the valley of Lahat, a stream tin deposit taken up by the Company, of which Mons. J. Errington de la Croix, is the manager. It is as usual a stream tin deposit, but is not yet uncovered sufficiently to enable one to pronounce upon its richness. The drift appeared to be of moderate depth and mostly of fine sand and clay, with a good deal of vegetable deposit. The drift has been formed by the river Kinta which winds around this spur. I could see no outcrop of any rock except granite, but the limestone is all through the adjacent valley.

Mons. de la Croix has cleared the timber from a portion of the side of the valley. This has given him a beautiful site for his residence and the houses of his assistants at a height of 170 feet above the river. The view from this is very extensive. The Kinta ranges appear of moderate height to the westward. To the east were high ranges of mountains from 5000 to 8000 feet, fronted by limestone cliffs and hills, some about 1200 feet in elevation. These are thickly wooded, and all around the plains was dense jungle.

Goping.

This is an extensive valley of stream tin deposits about 10 miles from Lahat. The mines lie on the eastern side of the Kinta and on the eastern side of the limestone range, in a valley formed by spurs from the main range. It is said that the stream tin has been nearly worked out. The mines are few in number and apparently have been inefficiently worked. From the habit the Chinese have of throwing the stripping or spoil heaps in all directions, it is very probable that much ground is covered which has never been worked at all. It seems to me very improbable that such a large valley can have been completely tested, much less exhausted.

Tecca.

Between Lahat and Goping there is a small mining village at the foot of a spur from the main range and close to limestone rocks. I did not examine the workings here which are small. There are also other small tin workings ot the base of the limestone hills. But it appears to me that all the valleys at the junction of the limestone ought to be rich in tin. The indications are exactly the same as those of the rich mines mentioned already.

Kampar River.

Along this river Malays have worked for tin successfully in the sand-banks left dry by the stream. Or they have turned the course of the river and found abundance of tin sand in its former bed. All along the course of this stream there are outcrops of both limestone and granite, showing every favourable indication at the junction of the two deposits.

Kuala Diepang.

About four miles from the junction of the Diepang with the Kampar River, the new Government road passes close to the limestone range. Here Malays and Chinese are working for stream tin in the limestone caves which are found at various levels above the river valley. Payable tin has been taken out of mines 1000 feet above the valley. The tin is in fine earth of dark brown colour, mingled with glossy rounded pea iron ore. It is very unlike the tin drift of the valleys but the difference is due to its mode of preservation. Much of the earth is a kind of guano, chiefly derived from the decomposed excrement of bats and birds. The remainder is probably derived from decomposed granite materials of which the siliceous particles still remain.

If as I suppose this tin sand is derived from the granite it affords evidence of the great erosion to which the limestone has been subjected. We must suppose that the limestone strata where the caves are now where once the bottom of a valley connected with

the granite, the nearest portions of which are three or four miles away. Limestones are however so easily dissolved by water containing carbonic acid that there is nothing astonishing in this denudation. The highest point at which the tin is found is said to be 1000 feet above the present level of the valley. This I did not see. The Malays and Chinese were working in caves 300 or 400 feet up the face of the cliff. The ore was sent down in baskets running on wire.

Dindings.

At the Island of Pulo Pankore, one of the Dindings Group a small quantity of tin sand is obtained by washing the sand in the valleys. The island is entirely of granite with much red clay on some small hills. I did not see any other indications of the paleozoic formation. There are no regular mines. The tin sand is washed from the surface by a few Malays, and smelted in a small charcoal furnace of the rudest construction. The Datu of the locality said that gold was also found in the sand but could not show me any specimens. He brought me however, to a narrow valley about two miles north of the landing place. The spot pointed out was in the bed of a small stream full of large boulders. We washed several panfuls of sand but without seeing a trace of the precious metal. Nevertheless, the Datu insisted that if we would only get some of the sand from under the very large boulders we should find plenty of gold, but as no one had ever done so, this was merely his opinion. It would take a good deal of dynamite to remove even the smallest of the rocks.

It is very possible that minute scaly gold may be found in connexion with the granite. It is so found at Batang Padang at no great distance to the south-east. It may be also mentioned that the first discovery of tin sand in Australia was made in connexion with gold in the drifts of the Oven's River. Gold in granite is however, rare in Australia, but it is not uncommon, and even rich deposits have been found at the junction of granite with lower paleozoic slates and schists. I believe that at some former time small quantities of gold have been found at Pulo Pankore.

Selama.

These mines are situated near the Krian River, which forms the boundary between Keddah and the State of Perak at the Kuala Selama. They are very rich in drift or stream tin derived from the decomposition of the paleozoic clays at their junction with the granite. Close to the village of Selama there is an outcrop of paleozoic rock. It is highly ferruginous sandstone, the external appearance which at the outcrop has been much modified by the action of water. The sandstone is a brown mottled with red, and those various colours which mark the presence of ferric oxide. The outcrop forms a regular ledge, and appears like a dyke about 15 feet above the ground. It is possible that there is a vein or lode near it though I saw none. The tin found at the surface in the mud of a swamp at the foot of the outcrop is very rich. The Malays easily gather small quantities of good ore without digging at all, in fact most of the families in the village contribute in this way to their own support.

The workings in the neighbourhood appear to have been conducted on no plan. No one with sufficient capital to drain the mine effectually appears to have worked a claim. The mines are a series of small holdings, and the ground has been turned over in a wasteful manner. The consequences are that the spoil heaps are an obstacle to any working with small capital, and the mines are almost abandoned. Yet it appears to me to be a singularly rich deposit of tin, and only wants the employment of capital to render it as flourishing as any in Perak. A large extent of clear ground which must contain tin, and in many places has been proved to contain tin, is quite unworked.

CONCLUSION.

From what has been said in the preceding report it appears that we may form the following conclusions.

1. That stream tin deposits are the only ones worked hitherto in the State of Perak.

2. These are drift formations derived from the weathering and wearing down by water of the granite and other overlying strata on the neighbouring hills.

3. They have accumulated very slowly in the beds of ancient or existing streams.

4. It is probable that the tin has been mostly derived from the wearing down of the paleozoic clays and granite at their point of junction.

5. Tin must therefore be sought for only at the base of hills in ancient drift beds. Generally also the western slopes are the richest.

6. Red and yellow clays, or better still an outcrop of slates at the foot of a range are favourable indications.

7. True tin lodes or mineral veins have only been found in the northern part of the State, and these have not been worked.

I may state further that the general impression left on my mind is that only a small portion of the tin deposits of Perak has yet been worked. The similarity of the formations throughout the State gives good ground for believing that tin may be expected on the western bases of all the mountain groups I have referred to. I cannot speak so certainly as to the main range, which geologically may be more modern and belong to an entirely different mountain system.