SCRIVENOR

NOTES ON PROSPECTING

FOR

TIN-ORE

IN THE

FEDERATED MALAY STATES.

J. B. SCRIVENOR,

Geologist to the Federated Malay States Government.

KUALA LUMPUR:

PRINTED AT THE F.M.S. GOVERNMENT PRESS.

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INTRODUCTION.

The following notes on prospecting for tin-ore in the Federated Malay States have been prompted partly by what is now obvious to all of us, the approaching exhaustion of easily won ore near the surface in localities where transport is cheap, and partly by the fact that certain prospecting operations undertaken in the last two or three years have been so misapplied, owing to lack of appreciation of the structure of the ground being dealt with, as to result in nothing but a waste of capital and an unfortunate impression on the part of those who undertook the work that the country is no good.

My own practical experience of prospecting is not large, and I am aware that in addressing these lines to the mining community I am attempting to advise many whose practical experience has been spread over a greater number of years than my own; but I trust that it will be recognised that my object is not to criticise, but to turn to account opportunities of comparing one mining district with another, and one mine with another, together with a certain amount of special knowledge, in an endeavour to save useless expenditure and in showing to some extent how much value should be placed on the results obtained when prospecting ground for tin-ore. Mistakes have doubtless been made here in the valuation of mining properties, as they have been made in every country possessed of considerable mineral wealth. In this country some such mistakes have resulted from unlooked for peculiarities in the structure of the ground or from the fact that some tin deposits upset calculations by behaving in a manner different from tin deposits elsewhere. In a well-known work* the following passage occurs: "Miners with fixed ideas resulting from observations made in a limited area are consequently liable to make serious mistakes when they attempt to apply their experience in distant and totally new localities." The liability, as I have reason to know, is not confined to miners; but whether a man be miner or geologist, in a new country he has nothing to guide him but previous experience, and rightly or wrongly, capital is not kept idle, nor are miners required to wait, while scientists make a protracted and careful examination of the ground to be mined in order to guard against mistakes. We still learn by experience and comfort ourselves with the reflection that he who makes no mistakes makes nothing.

These notes, which do not pretend to be a complete treatment of the subject, are written solely for the mining community in this country, and therefore I have refrained from taking up space with a description of the properties by which

* "A Treatise on Ore Deposits," Phillips and Louis, pp. 93, 94.

tin-ore may be recognised. I do not mean that there is nothing to be said on the subject worthy of attention: on the contrary tin-ore sometimes occurs in extraordinary forms that escape recognition even here, and may escape recognition when there is no apparent reason for such elusiveness. The subject is one, however, that should be treated at length in order to be of real use and to meet every case that has come under notice, and these pages do not seem to be the place for such an attempt. If I may utter a word of warning, however, let no one think he "knows tin," a phrase that one hears occasionally among miners, because it is a matter of general experience that however simple the subject may appear, study of it shows that more remains to be learned. Cassiterite, as a mineral species, does not attract the mineralogist by any characteristics of especial crystallographic or chemical interest, but a long experience of the mineral as an ore has taught me that if anyone supposes he has come to an end of serviceable knowledge concerning it, he is likely to find he is wrong.

In the last section of this paper, on the valuation of prospecting samples, it will perhaps appear to some that I advocate a method that errs on the side of unnecessary accuracy. There is, of course, a limit in treating samples from prospecting work beyond which it is unnecessary to go for practical purposes. For instance, it would be unreasonable to insist on results being worked out to three places of decimals, or even two, in the majority of cases. But has anything occurred in this country to show that prospecting in the past has been unnecessarily accurate? I was frankly told on one occasion that my method of preparing samples is not "practical," but I defend it on the ground that the most practical prospecting is the most accurate prospecting, within the limits indicated above, and that where thousands of pounds sterling may be involved, it is wrong to refuse to avail oneself of simple means that will eliminate some, at any rate, of the errors that vitiate what my critic meant by "practical" work. No sane man will claim that prospecting work, however elaborate, will give an exact figure for the value of the ground. It is an approximation only, but we should try to get as near the exact figure as may be by searching for all possible sources of error and correcting them if we can.

I have quoted passages in this paper from Phillips and Louis' "Treatise on Ore Deposits," and would recommend all who are interested in mining and prospecting to read that or some other such work in order that they may appreciate better than they could from anything I might write here, how important a knowledge of the structure of the ground one deals with is to those who prospect or work it. It is not suggested that every miner should be on familiar terms with the legion of rock species for which recognition has been claimed by various authors during past years, that he should be able to assign to a bed its correct age by means of the fossils it contains, or walk with ease among the signs and symbols of a text-book of mineralogy. What is claimed is that every miner should take advantage of such knowledge as has been obtained by trained men in order to save money by raising prospecting above the level of pure luck and numbers, which have been the basis of most prospecting successes in the world, although accompanied by what we hear little about, disappointment to many, wasted capital, and severe privations.

I know, too, that the recognition of certain minerals in small grains, such as one gets in prospecting samples, is a very different matter from identifying good laboratory specimens of the same mineral when taking a course of mineralogy. A concentrate from tin-bearing ground frequently contains mixtures of heavy minerals, and it would be absurd to expect every miner to be able to give an accurate analysis of such mixtures, or even to invest in a petrological microscope as an aid to prospecting, since such work requires careful training and long practice before confidence can be felt in results. But it is open to any miner or prospector in the Federated Malay States to send concentrates or other mineral samples to my office to be dealt with as quickly as other work permits, while such specimens as cannot be dealt with satisfactorily here are forwarded to the Director of the Imperial Institute in London, whose staff supplies analyses of the highest order and also advises as to the treatment and disposal of minerals of economic value.

I.

PROSPECTING DETRITAL DEPOSITS IN THE GRANITE HILLS.

We all know that nature abhors a vacuum. It might be added that next to a vacuum nature abhors a definition; and this is no less apparent when any detailed classification of tin-ore deposits is attempted than in other branches of scientific research. We may talk glibly about "alluvial" and "lode" tin-ore, but since alluvium means in the strict sense of the term the *débris* of rocks sorted out into gravel, sand, and clay, by river action, and "lode" tin-ore should be confined to ore that occurs in veins, it will be found that such a broad division does not include by any means all the types of deposits that are known to us. Some division, however, is necessary, for the sake of clearness, and I have therefore adopted one that is at the same time comprehensive and easily understood. Under detrital deposits I include all immediate sources of tin-ore where the cassiterite has been deposited mechanically after removal from the position it originally occupied when it first came into being as crystallized tin-dioxide, or where it can only be said to have been moved from its original position without subsequent deposition, as in the case of soil deposits on the sides of hills, where movement is effected by soil-creep; while under non-detrital deposits I include all deposits in which the tin-ore still occupies the same position in which it was originally precipitated by chemical action.

Since all tin-ore, as far as is known, has been derived ultimately from granitic magmas—that is masses of molten material that solidified as granite and allied rocks—I propose to deal first with the detrital deposits that are found resting on the parent rock in the granite hills.

Although a large output of ore is derived from these deposits, they are little known owing to their distance from settlements and the consequent difficulty of transport. They flourish most at the present time in Ulu Pahang and Ulu Selangor, and those whose business it is to visit them know too well that they extend from the lowest valleys near the granite margin up to the high divide where Chinese miners sometimes have to pay as much as $6 per pikul transport to the nearest town.

The ore won is mostly from the beds of streams and the alluvium fringing the steep sides of the valleys. Valleys such as these are generally full of huge boulders of granite that appear to be water-worn, but that are really hard "core-boulders" of granite that have resisted weathering. The richest detrital ore is generally found under these boulders owing to their having acted as natural riffles, and a common sight in the granite hills is two or three Chinese coolies burrowing under vast masses of granite for pay-dirt, taking great risks of letting down upon themselves tons of rock which are sometimes "supported" by a few sticks of soft timber.

What guide is there to payable tin-deposits in the granite hills? They are not confined to any particular zone and therefore the field for search is a large one.

The best guide is the presence of pebbles of tourmaline-bearing rocks in river beds. These may have travelled some distance down-stream, and if a river containing them be followed up, and if it be found that higher up-stream the large boulders of granite containing prominent white porphyritic crystals of felspar become fewer, giving place to finer grained granitic rocks containing tourmaline, and veined with quartz, felspar, tourmaline and white mica, then a search should certainly be made for tin-ore. The presence of tourmaline in quantity, however, in any granite stream is sufficient reason for a search for ore, but where collections of boulders such as those indicated are found, the richest tin-ore deposits may be expected.

If on the sides of a valley or in a stream-bed large quantities of quartz are found, they probably indicate the presence of a vein, and search should be made down-stream for detrital ore from the outcrop of the vein. Pure quartz alone, however, without tourmaline or white mica, may lead to nothing of value. Indications may be found also of complex veins containing iron-oxides and perhaps some metallic sulphides. These justify a similar search down-stream.

The presence of topaz-bearing rocks is also a good guide to tin-ore, but unfortunately topaz is a difficult mineral to detect when in small grains, being very like quartz in appearance (in mining and prospecting operations its presence is generally unnoticed until an attempt is made to separate it from the tin-ore).

Again, if the soil in a granite valley is white and clayey, or if the stream is found to be flowing over white clay with grains of quartz, and perhaps tourmaline also, tin-ore may be expected, the white clay being kaolin, a mineral whose formation was connected with the formation of tin-ore; and if it is found that the white clay is traversed by veins of quartz, quartz and tourmaline, quartz and white mica, or quartz, tourmaline and white mica, the chances of finding payable deposits of tin-ore are increased. Crystals of cassiterite may be found in the veins themsleves or in the clay (*vide* section II).

Owing to the concentrating action of rivers and the natural riffles afforded by the big core-boulders, the richest detrital deposits may be expected, generally speaking, in the alluvium; but detrital tin-ore is also found in the soil of the steep sides of the granite valleys, where it results from the disintegration of non-detrital deposits, some amount of movement from its original position having been effected by soil-creep, that is, the gradual movement of the soil towards the bottom of the valleys. Since the alluvium was in all probability immediately derived from such tin-bearing soil as the streams carved out their beds, when tin-bearing alluvium is found, the sides of the valley should be prospected also.

When a tin-bearing valley has been found, the next step is to consider how to arrive at the value of the ground. In exceptional cases, such as where an alluvial flat is formed at the junction of two streams, or where a diminution in the grade of a stream has brought about the same result, a reliable figure may be obtained by pitting (boring would almost certainly be too much impeded by boulders). Close pitting or trenching on the sides of the valley also would give an idea of the amount of tin-ore in the soil, but as the ore is likely to be very patchy, a considerable error could be avoided only by going to great expense. The ore in the boulder-laden alluvium at the bottom of the valleys is always patchy, and the fact that the richest patches are generally covered by huge masses of solid rock makes systematic prospecting impossible. In fact, when once it has been ascertained that tin-ore is present in quantities that are likely to be payable, the best method of getting further information is to flood the valley with Chinese coolies working on tribute. Circumstances might permit bringing water from a distance by means of a ditch to enable the tributers to sluice down the hill sides, and after a few months' work the lessee should be able to judge whether it would pay him to substitute a small hydraulic plant for his tributers. An objection to putting tributers on to such land is that they "pick out the eyes" of a tin-bearing valley, and leave the poorer ground. This may be so, but without their aid it would be difficult in this country to prove that a large number of "eyes" exist. I do not think that anyone who knows much about the Chinese mining cooly would expect good results from men working a granite valley on day-wages, if he ever obtained the men on such terms.

II.

PROSPECTING NON-DETRITAL TIN DEPOSITS IN THE GRANITE HILLS.

Underlying the tin-bearing soil on the sides of the granite valleys, and underneath the alluvium, the work of tribute coolies or individual miners has sometimes disclosed the source of the detrital ore by uncovering various non-detrital deposits that have themselves yielded large quantities of ore. These are, fine grained granitic rocks with tin-ore disseminated through the mass and also occurring in a number of small veins of pockets; larger quartz veins with bunches of ore in big crystals; lenticles and veins of rock consisting of quartz, tourmaline and cassiterite; rocks containing tin-ore, tourmaline and topaz; and sometimes tin-bearing veins traversing porphyritic granite.

For the most part these non-detrital deposits are so soft owing to weathering, and another more obscure cause, that the work on the alluvium or soil above is carried on down into the non-detrital deposits without any break. The value of tribute work in uncovering these deposits cannot be gainsaid, but prospecting such deposits by means of tribute labour is hard to defend. An alluvial or soil deposit is essentially a surface deposit that extends to a limited and easily determined depth, whereas it cannot be stated that one of these non-detrital deposits will certainly end at a given depth. Some of the small veins and masses of ore, it is true, are soon exhausted, but they are generally contained in a rock that is itself tin-bearing, and that may extend a long way down into the granite mass, traversed by more small veins and containing similar bunches of ore. The problem is to find out to what depth it will prove payable to work such rocks, and as there is no reason to suppose that in the course of a descent into such ground rich and poor material will not alternate, it is not to be expected that tribute labourers will prospect it thoroughly, since when they are faced by a mass of ground that does not pay them to work, they suspend operations instead of carrying on a search for more payable ore beyond the poor ground. An example of the drawbacks of such work occurred not long ago. A pipe of ore in granite was discovered and given to tributers to prospect. These men worked steadily at the pipe, taking out every bit of ore and roughly dressing it as long as it paid them to do so. At last there came a day when the ore diminished in value and work did not yield a profit.

The tributers stopped and the pipe was regarded as of no further use, although there was still ore in the face, and no reason to suppose that it was hopeless to look for payable ore beyond.

It would, of course, be wrong to advise miners to spend large sums in such a proceeding as excavating absolutely barren rock in the hopes of finding ore somewhere ahead of him, but as long as there is not a marked change from rocks such as one usually finds associated with tin-ore to hard porphyritic granite, and as long as there is tin-ore, whether in payable quantities or not, in the working face, it is only taking the ordinary risks that cannot be eliminated from prospecting and mining operations to go ahead as far as one's available capital allows in an attempt to find better ore.

I shall deal with the subject of prospecting non-detrital deposits more fully in a later section, but would add here with regard to the finding of non-detrital deposits in the granite hills that it must be admitted that without the aid of tribute work on detrital deposits the prospector's task is one that looks well nigh hopeless. Imagine a prospector from Australia or South Africa suddenly landed on a block of one thousand acres of virgin jungle on the slopes of a granite mountain with instructions to find how much tin-ore it contained. Unless a stream were in sight, perhaps not a vestige of hard rock would be visible. Nothing but trees and more trees, undergrowth and more undergrowth, on a floor of dead vegetation and sodden soil. Nothing even suggestive of mineral wealth; no rocks to show him whether he will be likely to find tin-ore or not.

That speculation is no better a producer of tin-ore than prophecy is very true, and I realise as clearly as anyone that ultimately the prospector and miner prove the wealth of a mining field, but it is perhaps a legitimate digression to suggest that it would be very remarkable if the enormous area of granite that we have here, and in which we have already found tin-ore widely distributed, failed to yield many more non-detrital deposits than we know of at present. I would recommend in this connection anyone interested in the subject to read "The Geology of the Waterberg Tin-Fields" (Memoir No. 4 of the Transvaal Geological Survey, 1909, by H. Kynaston, E. T. Mellor, and V. P. Swinborne), a volume that will give a very clear idea of non-detrital deposits of tin-ore found in South Africa, and the possibilities of similar deposits elsewhere.

III.

PROSPECTING ALONG GRANITE MARGINS.

Experience in other countries has shown that the greatest number of tin-deposits are found near the junction of the parent granite with the rocks into which it has been intruded, both in the former and in the latter, and on the whole the evidence in this country does not point to any marked exception to the rule. At first sight, however, the fact that so many workings are located high up in the granite hills, almost equi-distant from either margin, with miles of granite on either side, seems to constitute a formidable objection to accepting as a general rule the statement that tin deposits are mostly confined to the neighbourhood of granite junctions with the older rocks, but there is some reason to suppose that the present form of the main granite range of the Peninsula is not very different from the original form of the mass of granite that solidified deep in the earth's crust. Denudation has removed most of the altered rocks that then rested on the top of the solidified igneous rock, but has not eaten far down into the igneous rock itself, so that we may be justified in regarding the whole superficial area of the main granite range and other granite ranges as being approximately the outer limit of the original granite mass, in addition to the actual junction exposed on the flanks of the mountains.

We will consider here, however, only the actual junction that we can see between the granite and the older rocks on the flanks of the big hills, the contacts which many look upon as the most hopeful places for discoveries of rich ore.

This belief is well founded, but the main point that I would make in this section is that one cannot expect the whole line of contact or its neighbourhood to be stanniferous. A prospector works along the edge of a certain outcrop of granite and finds nothing worth working. He may conclude that the theory of a granite contact being a good place to look for tin-ore is incorrect, and one cannot help sympathising with his bad fortune. But the theory is not to blame; the prospector has been handicapped in not being able, owing to the force of circumstances, to extend his operation over a sufficient length of the contact. Indeed, if we consider the matter from another point of view, how fortunate it is that the available tin in a mass of molten granite has not been evenly distributed over the whole superficial area of the solid rock. Had that been the case the demand for tin would have to be perhaps even greater than for gold or platinum to make it worth winning.

Tin deposits cannot reasonably be expected along the whole of a granite margin. Is there any guide to those portions of the margin that are stanniferous?

There are two possibilities: the occurrence of minerals that generally accompany tin guiding one to the ore itself, and the possibility of some particular rock having favoured the precipitation of tin-dioxide in quantity more than other rocks along the margin.

As in the case of tin deposits in the granite hills, the occurrence of tourmaline is an invaluable guide, whether it be in the granite mass or in the altered older rocks. It will be found generally as large and easily recognisable crystals in the granite, but in the altered sedimentary rocks it will rarely form good crystals and in consequence it will be hard to detect. The commonest form in which it occurs is as tourmaline schist, a rock that looks rather like chocolate when slightly weathered, and when fresh is fairly hard with a peculiar lustre due to light being reflected from thousands of microscopic prisms of brown tourmaline. The presence of this rock on the border of the granite is very promising and search should be made in all streams draining the country where it occurs for tin-ore.

Abundant quartz near the granite margin may mean the presence of a vein carrying tin, but unless traces of tourmaline, white mica, or metallic sulphides can be seen in the quartz, it may fail to lead to anything of value. A feature of veins containing tin-ore in the altered rocks beyond the granite margin is that they rarely carry much quartz.

In some countries abundant iron oxides in rocks such as we get here adjoining the granite would be a hopeful sign of the presence of a non-detrital ore-deposit, but here iron-stone ("laterite") is formed so abundantly in weathered schists, shales, and sandy rocks, and the limestone so frequently contains in its rough crannies and caves masses of deep red ferruginous earth, both of which have no immediate connection with the tin deposits as far as their formation is concerned, that they alone cannot be taken as a guide. If, however, on breaking open a hard mass of brown iron-stone, a core of bright metallic iron sulphide is found, then the iron-stone may be taken as indicating the presence of a non-detrital deposit in the vicinity, and search should be made for tin-ore, since the sulphide shows that the whole of the oxide, probably, has been derived from sulphide forming part of a lode or mass of ore.

Topaz is not very likely to occur in the altered rocks, but may occur abundantly in the granite near the margin, and is a guide to tin-ore.

It is important to note that tourmaline is very rare in non-detrital deposits contained in limestone, but that on the other hand pale green or colourless fluor-spar is common. Sulphides of iron, copper, and arsenic are always abundant, and stibnite sometimes occurs with tin-ore in limestone, so that if any of these minerals are found in limestone at the contact with the granite, they probably indicate a deposit of tin-ore.

With regard to the question of one rock along the granite margin favouring the deposition of cassiterite more than another, there is little to be said. I have seen evidence of tin-ore having been formed in greater quantity in sandy than in finer grained rocks, and although I cannot say that this should be regarded as the rule, I would be inclined to pay more attention to an outcrop of sandy rocks abutting on granite than on shales or slates

I have just mentioned certain minerals that may act as guides to tin-deposits in limestone, but the junction of the limestone with the granite is remarkable in almost every case that I have seen in being clean and in the limestone containing no ore deposits of importance. Sometimes indeed the limestone at the junction appears not to differ at all from the limestone far away from the granite margin, and it would be difficult, as far as my experience goes, to find a less promising rock adjoining the granite than the crystalline limestone. The same does not apply, however, to the granite margin at its junction with the limestone, nor, of course, does it apply to detrital deposits lying in cavities formed in the limestone by solution: the statement refers solely to non-detrital deposits.

A possible objection to the limestone being regarded as unlikely ground for tin-deposits is that two of the most famous mines in the country are situated on or near the junction of limestone with granite—namely, Tronoh and Sungei Besi; but as far as I know at present in neither case has the output of ore come from the limestone itself, nor have I ever seen any ore actually in the limestone at either mine. We know, however, that tin-ore does occur in limestone, generally in pipes or very small veins, and although those found up till now have been a considerable distance from the granite junction as seen on the surface, there is good reason to believe that they are connected with granite in depth, and therefore we must own that similar deposits may be found at the junction seen on the surface of the ground. But pipes and veins sufficiently attractive to encourage exploitation have proved to be rare, and their existence does not affect the general statement that limestone adjoining a granite margin is not good ground for prospecting for non-detrital deposits. How different is the case with detrital deposits will be seen in the next section.

IV.

PROSPECTING ALLUVIAL FLATS AND ALLUVIUM IN THE LIMESTONE HILLS.

In a typical alluvial deposit nature has greatly assisted the miner in two ways: first by oxidizing the metallic sulphides and again by a distinct sorting of the material into gravel, sand, and clay. The former facilitates the concentration of the ore; the latter results in the deposits being more "regular" than other deposits; so that when there is no doubt that the prospector is dealing with a real alluvial deposit formed by a river in its valley, and when bores have been put down to bed-rock at intervals in a geometric pattern, showing an approximately constant thickness of tin-bearing ground, then it may be assumed that there is a bed of pay-dirt waiting to be worked of the same extent as the area over which the bores have been distributed.

Now as these notes do not pretend to be exhaustive, and in fact could not be so, seeing that as yet our knowledge of the structure of the country is only just commencing to crystallize, I propose to limit the remarks on alluvial flats to a brief discussion of that familiar term *kong*. Moreover, elaborate notes on the prospecting of alluvial flats might now be considered somewhat late.

At first sight it would appear that there are no difficulties hidden by this word, and that "*sampai kong*" is a phrase that admits of no misapplication. Nevertheless it is well known to some that in actual practice *kong* does not mean bed-rock so much as an arbitrary downward limit to the pay-dirt fixed by uncritical but pious opinion, although the Chinese use of the term is certainly more dignified than the analogous "*sampai dada*" of the Malay gold-digger in Pahang, who is very prone to cry "*sudah sampai dada*" when working for someone else if the particular pit he is engaged on becomes too deep or too wet for his comfort.

What the real significance of *kong* may be to a Chinese miner I do not profess to know. It has, however, been taken by white miners to be the equivalent of "bed-rock," which suggests some hard rock on which the alluvial deposits lie. If bed-rock were always hard in this country, the problem of determining whether one had arrived there or not would be simple, but not only is it difficult sometimes to decide when the bottom of the alluvium has been reached, but sometimes one's preconceived notions are upset by finding that there is more than one bed of pay-dirt. Some suggestions therefore of how various bed-rocks in this country may be recognized will perhaps prove of value. It is assumed that either bores or pits are used for prospecting.

Limestone.—This is usually easily recognised, but sometimes, when much weathered, it looks rather like finely granular quartz. If after heating fragments in dilute hydrochloric acid no gas is given off, then the rock is likely to be quartz. If the rock only effervesces in dilute hydrochloric acid when heated, it probably contains a lot of magnesium (magnesium limestone) or iron (chalybite). It is not uncommon to find a cap of iron-stone and manganese oxides immediately above the limestone.

It should be borne very carefully in mind that where limestone forms the bed-rock to alluvial deposits they may prove to be much disturbed from their original position by reason of the gradual and irregular solution of the limestone underneath.

Shales, Slates and Schists.—These will be soft for a few inches or perhaps feet under the lowest bed of alluvium and it is possible that hand-boring tools may be driven some distance down into them to no purpose before hard rock is struck. The *débris* from the bores, however, will always contain fragments showing the original structure of the rocks and there should be no difficulty in determining whether the last bed of alluvium has been passed.

Quartzite and Sandstone.—The same applies to these rocks as to the last mentioned. Angular pieces of stone that have resisted weathering are sure to be found with the *débris*.

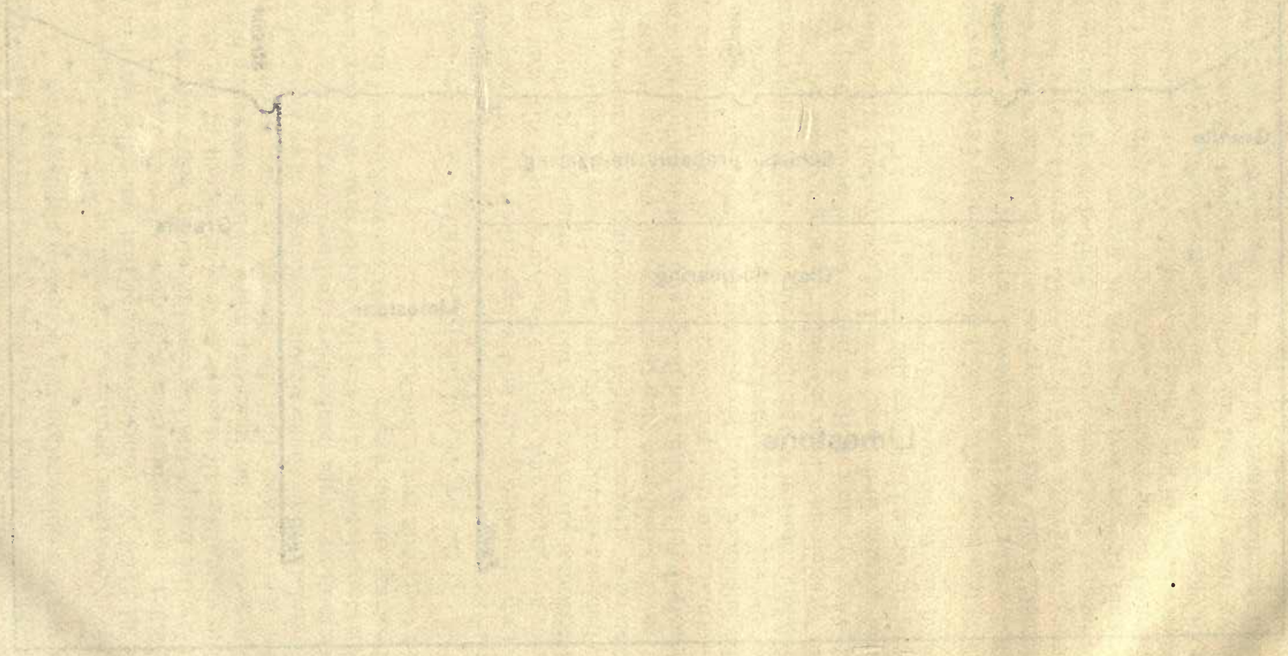
Granite and Allied Rocks.—Many alluvial deposits are on a granitic bed-rock, and owing to the extraordinary manner in which granitic rocks weather in this country it is often very hard to tell if one has passed out of alluvium or not. In some cases so great is the resemblance between a weathered granitic rock and a detrital bed that the only satisfactory test is the presence or absence of veins. In granite, however soft it may be from weathering, one nearly always finds distinct veins of quartz, etc. In recent alluvium veins never occur. When boring one may penetrate a long way into decomposed granite without knowing it, but as there are good chances of the rock being stanniferous, it is not altogether lost labour; but if for any reason it is found necessary to determine accurately when granite is entered, the only sure way would appear to be to prospect by means of pits, which would enable the prospector to see any veins in section.

Some of the early literature dealing with our tin deposits leaves the idea that the *kong* is generally a mass of kaolin (*e.g.*, Phillips and Louis' "Ore Deposits," pp. 599, 600). This, of course, was a generalisation founded on insufficient observation, but kaolin undoubtedly does occur as bed-rock and should form an exception to what has been said above about a bed-rock of granite or allied rocks, since the extreme fineness and the whiteness of the clayey mass render it easily recognisable. Kaolin is frequently stanniferous and therefore bores or pits should be pushed on through it until hard rock is reached.

Bed-Rock of Stiff Clay.—In addition to the rocks mentioned above it will be found in some parts of the country that below the pay-dirt stiff clay is encountered. There will be more to say of this in the next section; here it will suffice to remark that although the clay may be barren immediately under the pay-dirt, bores should be pushed on through it until they can go no farther, which will probably be due to limestone being encountered.

Alluvium in the Limestone Hills.

The origin of our limestone hills is a matter that has given much food for thought and called forth some original ideas. I do not propose to give my own views on the subject in detail here, and must therefore hope to be pardoned for appearing dogmatic. The best known limestone hills are those in the Kinta Valley, and if anyone will look carefully at their sides he will see near the base of many cliffs numerous clearly marked horizontal grooves. These get fainter higher up the cliff owing to their



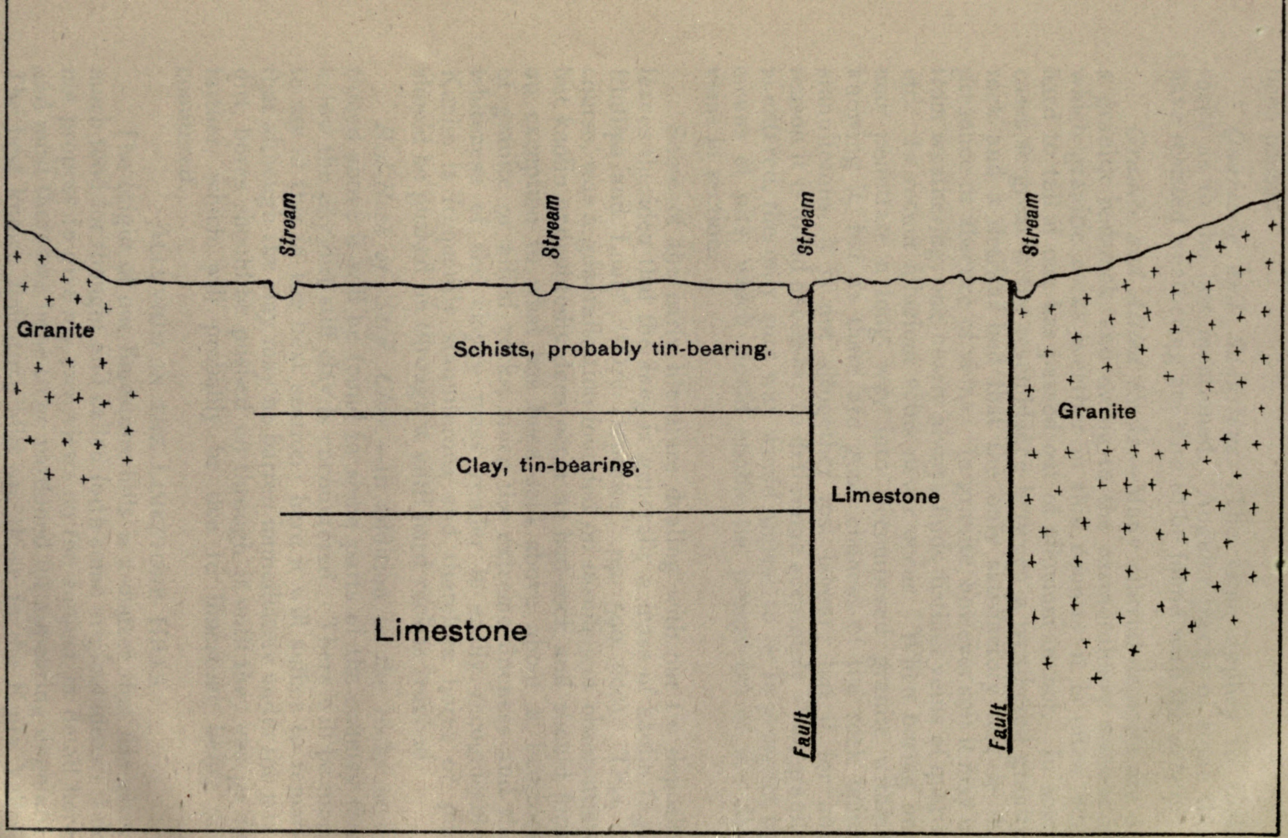


Figure 1. Section looking North showing the Structure of the Kinta

having been formed long before those lower down and a consequent longer exposure to weathering and the formation of secondary calcium carbonate, agencies that have led to their complete obliteration at a height of about 80 feet.

Now these grooves were cut in the limestone by running water and are conclusive proof that once the level of the Kinta Valley was higher than it is now. It was once, I believe, level with the top of the highest limestone hills, and the structure of the valley was then more or less as shown in Figure 1. It will be seen that the limestone mass which now forms hills stood up in the earth's crust as though it was intended to be the foundation of some titanic building. The vertical faces, due to faulting, were flanked by tin-bearing granite on the east and by stanniferous clays and by schists that may also have been tin-bearing, on the west. The relative thickness of clay and schists at that time is not known.

As the streams of the Kinta Valley cut down into their beds and meandered over the plains they formed, keeping to the more easily denuded clays and schists, they would from time to time run alongside and eat into the limestone walls, thus making the horizontal grooves. At the same time solution by surface water would be acting on the limestone, honeycombing it with caves, and the streams would be flowing over tin-bearing ground. Gravel, sand, and silt, therefore, all carrying tin-ore, would be washed during times of flood, and perhaps when the streams were normal, into the caves and crevices of the limestone and would be left there while the stream sank lower and lower. In course of time the first formed cave deposits would become disturbed by further solution of the limestone and their arrangement in layers of gravel, sand, etc., would in some cases be largely upset. Moreover, most of the deposits would become deeply stained by iron oxides and some would be converted into a hard mass by calcite formed between the grains, so that the tin-ore could not be won unless the stone were crushed in a battery.

If anyone will consider the sequence of events as given above and will accept the statements without requiring all the evidence, which, I may say, is based on well-known natural processes, and does not invoke the aid of pre-Huttonian theories, he will see that wherever limestone hills are flanked by tin-bearing beds they should be searched from top to bottom for old alluvial deposits formed as the streams carved out their valleys, but I cannot say that I know of any guide to such deposits in the hills themselves. Old channels by which masses of alluvium were washed in may have been blocked up by recent deposits of carbonate of lime, and the alluvium itself may have been moved from its first position owing to solution of the limestone. Reason tells us that valuable deposits may occur on the very summits of the limestone hills, but there is no short road to finding them : diligent search or good fortune alone can succeed.

V.

PROSPECTING DETRITAL DEPOSITS BELOW THE RECENT ALLUVIUM.

For the most part detrital deposits, or, as they are sometimes called, placers, are of recent origin—that is to say, although they may be thousands of years old, they belong to the same period of earth history as that in which we live. There are, however, certain older detrital deposits that have been preserved from a former geological period, such as the deep leads of Australia, from which ore can be won, and in this country there are certain stanniferous clayey beds, sometimes with included boulders, that are not only older than and distinct from the recent detrital deposits, but are older than the tin-bearing granite so familiar in our hills. As yet very little is known of the extent of these old detrital deposits, but they may be expected to occur immediately above limestone, and they may be separated from recent deposits above by schists or sandy beds. The clays referred to in the last section as being a possible *kong* are these clays.

The problem is the prospecting of beds of clay containing tin-ore, lying on a limestone bed-rock and maybe covered by younger rocks themselves probably stanniferous. First let me indicate some of the peculiarities of these beds, both inherent and due to the nature of the bed-rock, in order that the difficulties likely to be met with may be appreciated.

In an alluvial deposit the sorting action of running water has resulted in the formation of strata of pay-dirt of approximately even value, and if two bores, put down a chain apart on the same stratum, both show five katis per cubic yard as the value of the ground, it is a reasonable deduction that the portion of the bed lying between the two bores carries five katis per cubic yard also. Experience of the old clay detrital beds shows that in their case such a deduction would be entirely unwarranted, because the mode of formation of these beds was such that little or no sorting action took place; and although in the locality where they are best known so far—Gopeng—every sample taken yields some tin-ore, sometimes, it is true, no more than a trace, the cassiterite is so irregularly distributed throughout the mass that a large error may creep into prospecting work by bores unless a great number are put down. As an instance of this I may mention one particular case where a mine manager had put down numerous bores and obtained poor results. The mine was working, however, and in course of time the ground prospected was cut away and washed. It gave quite a good return, the explanation undoubtedly being that the body of the clay contained a very small amount of ore, but also held small patches of rich ground that had all been missed in the bores. The actual result in this case was probably gratifying to the manager, but it might

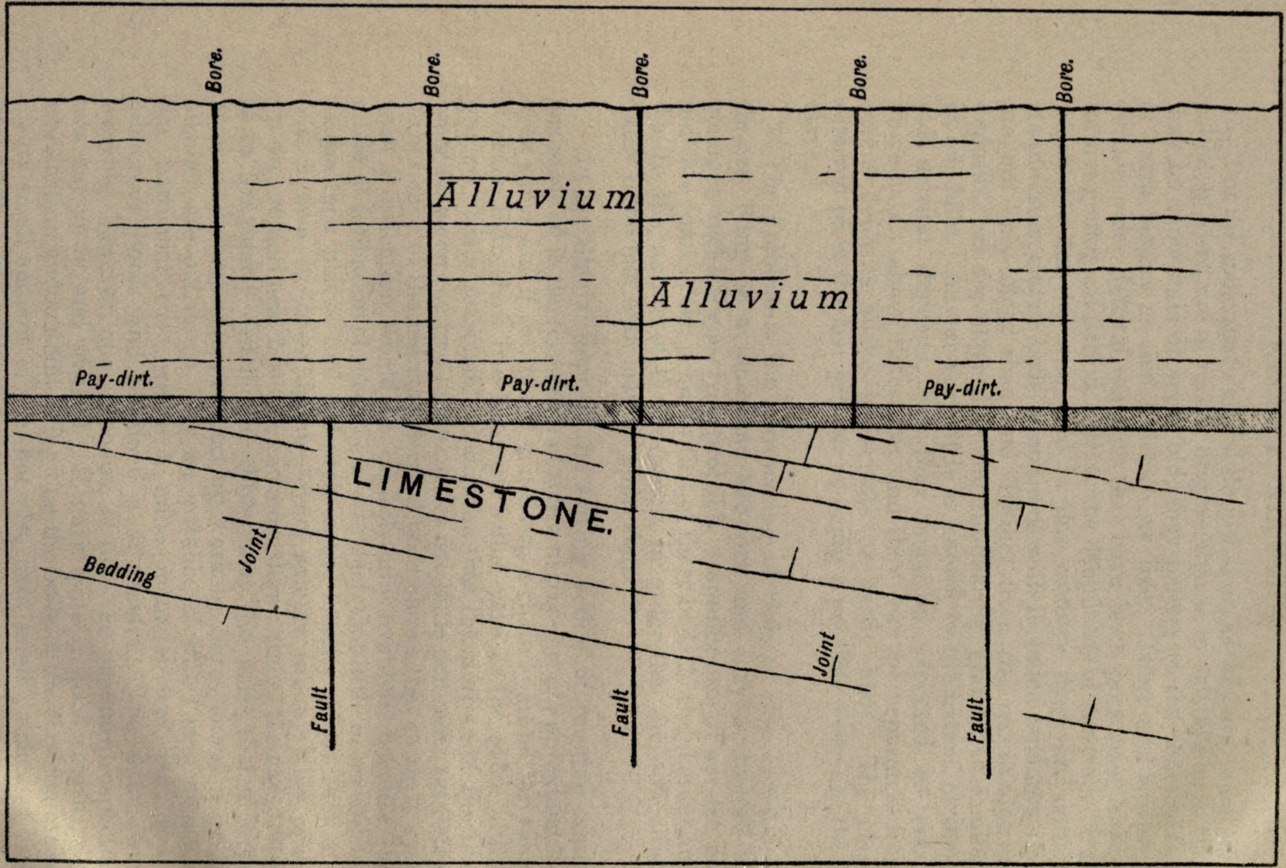


Figure 2. Section shewing Alluvial Beds with Pay-dirt at the Base lying on Limestone.

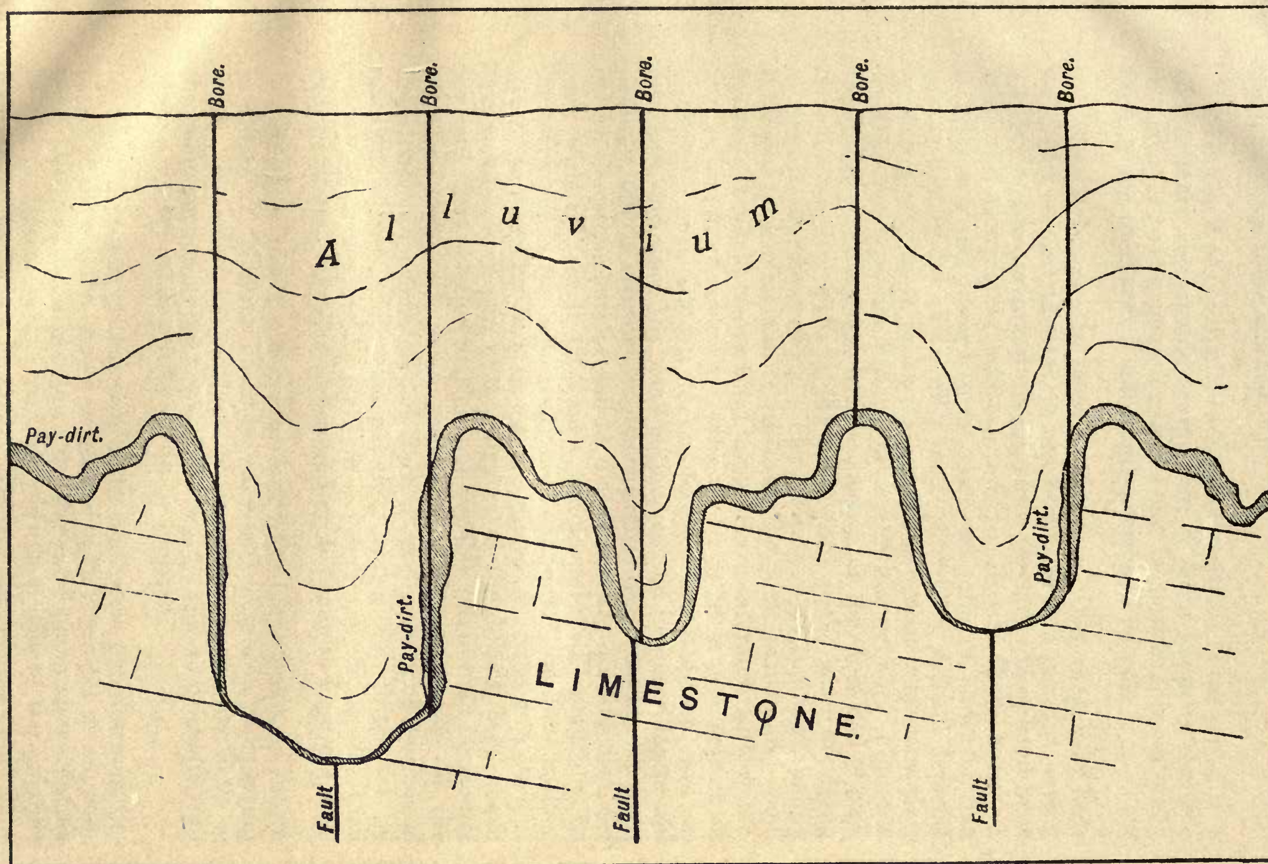


Figure 3. Section shewing the same Beds as in Figure 2 after the Limestone bedrock has been attacked by Water.

happen in another case that the bores all passed through rich patches, so that considerable disappointment would be felt when the land came to be worked.

This lack of continuity in the rich portions of the pay-dirt is all the more remarkable seeing that it often happens that the thickness of good ground found in a bore is considerable, naturally leading one to expect a still larger horizontal extent.

Now it is open to question whether, when these clay beds were first formed, there were any bodies of rich pay-dirt having a considerable horizontal extent, since the latter may have been deposited as irregular masses. I have tried to show, however, in Figures 2 and 3 how natural processes going on under our feet quietly day by day can modify the regularity of detrital deposits in such a way as to make the results of boring very deceptive, whether the pay-dirt has lateral extension or not. Figure 2 shows beds of alluvium, with a continuous four-foot bed of pay-dirt carrying five katis to the cubic yard at the base, overlying a smooth limestone floor. The limestone is dipping slightly from the horizontal and is traversed by joint planes and small faults. The beds above the limestone are saturated with water, and as limestone is slowly soluble in water (it is not soluble in absolutely pure water), the surface of the bed-rock will be attacked, and since the small fissures caused by joints, faults and bedding, offer a channel for water percolating from above, parts of the limestone surface will be dissolved away quicker than the rest, with the result that cups and troughs will gradually be hollowed out in the solid rock, and in time the limestone surface will be as irregular as is shown in Figure 3. Now it is obvious that when a large part of the support of the detrital beds above is removed by solution they cannot possibly retain their horizontal position: they sink down with the altering contours of the limestone and ultimately all trace of their previous horizontal position is lost, while the pay-dirt, drawn out somewhat by having to accommodate itself to a larger superficial area than before, presents the sharply curved profile seen in Figure 3.

Suppose that a prospector bored the karang as it is shown in Figure 2. Nothing could be more satisfactory in prospecting work. He would get four feet of pay-dirt carrying five katis to the cubic yard in every bore, and would be able to calculate with some accuracy what profits would be realised.

Let us suppose that five bores had been put down in the plane of the section shown in Figure 2, and now let us suppose that bores had been put down on the same spots after solution of the limestone surface had altered the profile of the pay-dirt stratum to that seen in Figure 3. Three of these bores would show about 20, 20 and 16 feet, respectively, of pay-dirt carrying five katis to the cubic yard, one would strike a thin bed of pay-dirt, say one foot thick, where the bed had been most drawn out, under a great thickness of overburden, and the fifth would show four feet of pay-dirt at a moderate depth.

What would be the prospector's report on the property?

This hypothetical case shows how far a prospector could go astray with a single continuous bed of pay-dirt lying immediately on the bed-rock. How much greater would be the difficulties if instead of a simple layer of pay-dirt there were above the limestone a thick mass of clay with irregularly shaped bodies of pay-dirt sporadically distributed in it. As the clay fell into the cavities formed by solution, the ore-bodies would be drawn out into long vertical or inclined streaks. They would not necessarily be next the limestone: the base of the clay might be quite barren. Bores put down in such ground would show the most erratic results. One rich bore might be surrounded by bores that yielded no tin-ore at all. Bores passing along vertical streaks of ore would produce the impression that a bed of pay-dirt of great thickness had been found. Bores put down a few feet away from these vertical streaks might show nothing but worthless ground. It is but too well-known that land such as I attempt to describe has been opened up with great expectations, destined to be dispelled, and although it is only human nature to find fault with the prospecting in such cases, it is difficult to see how it is possible under the circumstances to blame anyone. Consider that hitherto the prospector had been accustomed to valuing orderly alluvial deposits by a simple calculation that had always proved approximately correct. He takes the same tools a little deeper, and not unnaturally applies the same calculations, with the result that he proves to be entirely wrong. The prospector only has his own and other people's experience to guide him; and until certain mines were opened up in the Federated Malay States, no one, as far as I am aware, had had experience of a horizontal bed of pay-dirt being suddenly replaced, in ground that might excusably be taken to be a continuation of the alluvium, by vertical strips of the same ore.

Seeing that it is probable that the future output will depend largely on clays such as these, the valuation of the ground is a matter of great importance; but it must be apparent that an approximately accurate figure can only be obtained by very close boring, which means a large outlay, but would be decidedly better than opening a mine and having to revalue it afterwards.

Another peculiarity of these old detrital beds is that in some places they have acquired a second supply of tin-ore from the younger granite, resulting in very rich ground. The original supply is detrital and was produced mechanically; the later supply is non-detrital and was produced chemically. Little is known about such occurrences as yet, but they are of course more likely to be found near the junction of the clay beds with the granite and in the vicinity of veins from the granite. There is some reason to suppose that the colour of the clays may prove a guide to such deposits, since in the neighbourhood of veins and at the granite junction they are generally stained a deep red, so that one would be tempted to explore more thoroughly where deep red clays reached the surface than elsewhere.

VI.

PROSPECTING VEINS AND PIPES.

The ease with which the detrital tin-ore in the Federated Malay States has been won and the small outlay of capital formerly necessary for opening a profitable mine, have had a marked effect on the attitude of the mining community towards prospecting and developing "lode" tin. That veins and pipes exist, the latter in the limestone and the granite, the former in limestone, granite, and the old sedimentary rocks, is known; but while opportunities present themselves for obtaining quick returns from more easily worked deposits it is not to be expected that capital will be employed to face the risks of "lode" mining, nor is it likely that everyone engaged in the industry appreciates fully the great difference there is between the exploiting of an alluvial deposit and the prospecting and development of a vein.

It is not intended in the present section to attempt any discussion on how a lode should be developed, that being entirely a miner's work, but recent events in more than one locality have shown that a few words on the preliminary stages of prospecting will not be out of place.

The great point to be borne in mind when attacking a lode is that prospecting methods applicable to detrital deposits are not, generally speaking, applicable to lodes, and it should also be remembered that unless there are surface indications to start on, or some very good reason for expecting a lode in depth where there are no surface indications (I do not attempt to define what such reasons might be), making holes in the ground in search of lodes is very much like looking for a needle in a bundle of hay, with the important difference that you have no guarantee that the needle is there at all.

The first asset a prospector should acquire before attempting to prospect a lode is some knowledge of the constitution of lodes, and particularly of the distribution of ore in a lode. If this knowledge has been obtained he will certainly prospect his particular vein by sinking a shaft and driving levels along it, thus preparing the way for systematic development. But the man who only knows the ways of certain detrital deposits will assuredly object to the expense of sinking and driving, and will perhaps argue that drilling holes from the surface through the lode will answer just as well. As hand-boring tools with auger and sand-pump would be unable to do the work in most cases, he uses the best instrument for the purpose, a diamond drill; but as he objects to the expense of sinking and driving he will limit himself to a machine giving a small core, at the most two inches in diameter.

On the one side the prospector has his drill and an outcrop as assets; on the other side are several items to be taken into consideration as liabilities.

He will not realise that the outcrop of a lode is generally richer than the stone underground.

In the most regular lodes the ore occurs in "shoots" that are mostly inclined away from the vertical. Our prospector does not know whether the ore under him occurs in a shoot or not and if he did know he would still be ignorant of the direction it took.

Lodes are not continuous sheets of homogeneous ore. To quote Phillips and Louis again (p. 93): "In a vast majority of cases the more metalliferous parts of a lode, or those which yield the ore sought in an approximately marketable state, constitute but a comparitively small proportion of the whole, and but few metalliferous veins are sufficiently rich throughout their extent to pay for the removal of the whole of the veinstone." Moreover, sometimes it is difficult enough to follow a lode in a level measuring six feet by four, on account of its pinching out for a greater or less distance and then opening out into an ore-body again. The prospector can only make small holes in the rocks a little over two inches in diameter and he will hope to determine by their help whether the vein is worth mining or not. Let us suppose that the outcrop is running north and south and that work on the surface has shown the lode to be dipping east. The drill is installed on the east side of the outcrop and the operations commence, the prospector calculating from the degree of dip to strike the lode at sixty feet. At sixty feet the 2-inch core shows no ore, no quartz, indeed nothing remarkable. The drill is pushed on, but still nothing is found, and the prospector concludes that the lode has pinched out altogether, although what has really happened is that the drill has passed through a barren spot in a vein that would perhaps prove payable when worked. On the other hand, the drill might pass through a particularly rich spot, and bring up a core consisting of nothing but tin-ore, which would make the lode appear a great deal more valuable than was really the case. The cores from the small drill-holes would almost certainly prove to be misleading as regards the value of the vein.

Another thing that the prospector would be unlikely to learn from his drill would be whether the lode were faulted or not, but given an unfaulted lode and a distinct shoot of ore, I trust the above will suffice to show that a prospector operating from the surface with a diamond drill cannot expect reliable information.

There are some cases, however, in which a drill would prove very useful—namely, in ground traversed by a number of small veins close together. Very little reliance could be placed on the values obtained from the cores, but the utility would lie in proving the extent of the veins.

A pipe in limestone or granite, giving a small surface only to work on, and being probably irregular both in shape and course, is extremely hard to prospect by any method; in fact the only thing to do is to follow the ore wherever it goes, which will generally mean that the pipe is worked out as it is followed up, a proceeding that hardly fits in with ordinary ideas of prospecting. Real prospecting, however, will be accomplished by not throwing up the work when the ore becomes unpayable and in pushing forward steadily as long as there is ore in the face, or rocks or minerals, such as sulphides and fluor-spar in limestone, and tourmaline in granite, that indicate a possibility of more tin-ore existing beyond.

The same thing applies to veins—namely, the necessity of persevering although the ore visible at the moment may not be payable, and even though the vein may disappear. Phillips and Louis say on this subject (p. 107): "Statements relative to the entire disappearance of lodes in depth must therefore be received with caution, since, had the work been continued, the vein would have probably have again been found and have again become productive."

VII.

VALUATION OF PROSPECTING SAMPLES.

Prospecting Records.

Leaving out of consideration beds of alluvial tin-ore in open valleys, where some regularity of value may be expected, but which have been worked over already in the better known parts of these States, the initial source of error in calculating the amount of ore in a given piece of land is that the pay-dirt is not evenly distributed. This source of error, given efficient work, is doubtless the most serious of all, and can only be counteracted by close boring, but enough has been said to show how careful one should be in drawing conclusions from the distribution of ore as it appears in the bores and I would pass on to other sources of error that admit of easier correction, especially the treatment of the samples after they have been taken from the bores.

In all prospecting work aiming at an approach to accuracy the ground taken from the bore is measured, the usual system of measurement being to pack it into a box of known cubic capacity. Boxes of various dimensions are used, and until lately they were all, I believe, "dry boxes," but last year it was suggested by Mr. L. G. Attenborough, manager of the Bruseh Hydraulic Tin Mines, that the unavoidable error due to the practical impossibility of packing the earth into a dry box so tightly as to occupy the same space that it occupied before being disturbed by the boring tools, could to a large extent be obviated by using a "displacement box" in which packing the earth would be unnecessary. The principle of this box is delightfully simple and has the great advantage of almost completely eliminating the human element. Suppose that it is required to measure one-quarter of a cubic foot of ground. A box is constructed whose internal dimensions give a cubic capacity of double the amount of earth required—*i.e.*, one-half a cubic foot. The box is then placed on a level piece of ground near the bore-hole and filled half-full with water. The material to be sampled is then dropped into the box until the water rises level with the rim, when there will be in the box exactly one-quarter of a cubic foot of earth *plus* the amount of moisture it contained when taken from the bore.

It has been objected that when boring in sandy ground the amount of moisture that percolates into a bore hole would make the ground sampled wetter than it would be in a working face, and that therefore the results obtained by a displacement box would be subjected to a considerable error. There are two replies to this: the same objection affects dry boxes; and it can be partially counteracted by straining the sand in a cloth before measuring it. It must be admitted, however, that the difference between the moisture in the box and the amount of moisture that would be found in a working face is a source of error even with a displacement box, but that need not prevent one from accepting the displacement box as bringing one nearer to accuracy than any dry box.

The question of the measurement of earth in the loose so as to enable a valuation figure to be given for the same ground before it was cut was attacked in 1910 by Mr. D. H. Bannerman, the author of a detailed paper on the subject read before the Perak Chamber of Mines, and I have had the advantage of discussing with Mr. Bannerman the difficulties and sources of error met with in boring. The difficulties of measuring sandy ground that rises in the pipes are admitted by all, but taking a core out of stiff clay with an auger looks a simple affair. On comparing notes, however, it was found that there was room for error even in the recognition of what belonged to the core and what did not. The actual example that gave rise to misgivings was as follows: In certain bores in stiff clay I was employing a 5-inch hand boring set, and measured my samples as one-sixth of a cubic foot each. The clay-auger cut approximately one-sixth of a cubic foot every two feet that it cut in depth. Now it is commonly supposed that the diameter of the core in a case like this would be determined by the inside diameter of the pipe, and two feet of 5-inch pipe have a cubic capacity of 471.24 cubic inches, whereas one-sixth of a cubic foot is 288 cubic inches. What becomes of the balance of 183.24 cubic inches? To me it seems that the solution is that the auger and not the pipe determines the diameter of the core, and that as the former must have free play inside the latter, the internal diameter of the auger is considerably less than five inches. Suppose it is four inches: two feet of 4-inch pipe is 301.58 cubic inches: one-sixth of a cubic foot is 288 cubic foot, nearly the same figure. Mr. Bannerman thought that the balance of 183.24 cubic inches is accounted for by the bottom pipe compressing and pushing outwards the clay as it progresses, thus diminishing the volume that remains to be taken up through the pipe. I found that if I let the auger go ahead of the pipes and pushed the latter down periodically there was always an accumulation of clay like that already cut to be cleaned out before the auger could be dropped to the same depth that it had reached before. This clay was not washed, and so I obtained, to the best of my belief, a clean core whose diameter was determined by the internal diameter of the auger, and the danger of sampling the same ground twice over was escaped.

The particular source of error that I would call attention to, however, is in concentrating and cleaning the measured sample before weighing and calculating the value per cubic yard. The method adopted by myself to reduce this error as much as possible is as follows:

The kapala in charge of the bore is allowed to partly wash the sample, but never to wash it clean. How far he should be permitted to go is a matter for individual judgment.

The partially cleaned sample is then dried and put in a conveniently shaped bowl and a heavy liquid called bromoform * is poured in. Bromoform when pure has specific gravity of about 2.85, and it follows therefore that quartz and felspar will float in it, but before pouring off the liquid with the floating quartz, etc., it should be well stirred to prevent any fine-grained tin-ore being held up by surface tension. After rinsing out the bowl with more bromoform until all the quartz, etc., left adhering to the sides as the liquid was poured out is got rid of, there will be a concentrate at the bottom of the bowl of tin-ore mixed with heavy minerals, some of which are sure to be magnetic.

As bromoform will not mix with water this concentrate is washed with methylated spirit and then dried. It is next brought under an ordinary magnet to remove magnetite if present, and then under a small electro-magnet that removes all the commonly occurring magnetic impurities such as ilmenite, monazite, tourmaline, and iron oxides or carbonate.† When this treatment is completed there will remain a concentrate of

* Messrs. J. J. Griffin and Sons, of Kingsway, London, advertise bromoform at 7*s.* 9*d.* per pound.

† I obtained a very handy little electro-magnet from Fuess, Steglitz, Berlin, at a cost of about £6. The current is supplied by Hellersen dry-cells, six of which give a very powerful magnetic field.

cassiterite that may be pure, and can therefore be weighed as tin-ore without further precautions, but that will probably contain some non-magnetic impurities—zircon, topaz, and perhaps corundum. Supposing that zircon alone is present, it may be found possible in rare cases to separate it by shaking the sample over a 90-mesh sieve without loss of tin-ore, since zircon generally occurs in very fine grains and the tin-ore may all be too coarse to pass through a 90-mesh sieve. The same does not apply to topaz and corundum, however, and in the majority of cases the best procedure is to weigh the sample and then assay it for the percentage of tin. A wet assay will give the most accurate result, but a cyanide pot-assay, if not kept in the furnace too long or too strongly heated, will not introduce an appreciable error.

It may be that metallic sulphides are present in the concentrate. These can be broken down by heating with nitric acid, and the sulphur separated can generally be washed off. If any difficulty is experienced in doing this owing to the abundance of sulphur, the concentrate should be boiled in aqua regia or ignited.

No attempt should be made to separate the zircon, topaz, or corundum from the cassiterite by washing with water, as that is certain to result in a loss of tin-ore. The value of the assay is this. It will in nearly every case be possible to judge to what assay value it will be possible to concentrate the ore in bulk, either by trial of a small portion of the ground or by watching similar ore being concentrated. Say that it is expected that an assay value of 74 per cent. can be reached and that weighed samples assay 68 per cent., it is easy to calculate what would be the value per cubic yard at the higher assay value.

Possibly the purchase and use of bromoform and an electro-magnet may be held to be fatal objections to this method. Then I would suggest the following procedure to guard against a large error. Having taken over the partly washed samples from the kapala, dry them and separate them by means of sieves into as many grades as may appear necessary, and then wash each grade separately. This will facilitate the cleansing of the sample without serious loss of tin-ore.

It will very probably be objected that the bromoform-magnetic method errs in that it aims at extracting the uttermost particle of ore from the sample, whereas the miner wants to know what he will be able to save in practice. Here a fundamental principle is called in question on which it is impossible to speak too plainly. The object of sampling is to find out as nearly as possible the actual tin-ore contents in the ground on the assumption that the miner will endeavour to work up his percentage extraction as near 100 per cent. as possible. No one would expect an extraction of 100 per cent. to be reached, but few people expect a miner to advertise the fact that his sampling shows an apparent extraction of more than 100 per cent.

It may also be objected that there are sample washers in the country so skilful that these elaborate precautions are unnecessary. Being doubtful on the point myself I once prepared some samples with known weights of tin-ore, made easy or difficult to deal with by the omission or addition of other heavy minerals, and asked an old Malay lady at Gopeng to wash them up for a consideration. She had been recommended as a lady of very long experience at the work (15 years if I remember rightly) and great skill, but with the easy samples she gave me too high a result and with the difficult samples she went hopelessly adrift. Her treatment of a mixture of cassiterite and topaz was particularly instructive, because topaz is a constant impurity in a large part of the Gopeng mining-field, and although this lady failed to get a clean separation in a small sample, in bulk treatment all the topaz goes away into the *amang*. This is an example of what I believe to be a general rule—namely, that in bulk treatment impurities can be eliminated, accompanied by some tin-ore, by washing with water, without any bad effect to the miner; but that in sampling, a non-magnetic impurity like topaz cannot be washed off by water without a serious loss of tin-ore that will upset the prospector's results, the moral being that the separation should not be attempted when dealing with samples and that the error due to its presence should be corrected by assay.

Another point that should be remembered is that any error that enters into sampling ground carrying tin-ore is multiplied before the final result is arrived at. It is not uncommon for samples to be taken measuring only one-eighth of a cubic foot. Whatever error the concentrate from this sample carries will, on the calculation to cubic yardage being made, be multiplied by 216.

In conclusion I would appeal to prospectors to remember posterity in recording their results. A scientist, trained to note every detail, because he is taught that they may prove useful someday, perhaps sees things in a different light: perhaps he views posterity in a different light. Nevertheless it is hoped that it is not useless to suggest that results that may be unattractive to one individual or one company, may prove attractive to another individual, another company, or posterity, and that even negative results should be recorded to save posterity the expense of prospecting the ground again. At the time of writing I am engaged on an attempt to discover what amount of prospecting has been done in Kinta, and with a few exceptions, no details can be obtained at all, because they were not recorded. A leaseholder says he put down so many pits or bores and that there was not enough tin to make working the land profitable. He very rarely knows anything about the value per cubic yard. Records of prospecting should contain the following information: the date of boring, the relative position of the bores, the depth of the bores, the value, however small it may be, of each sample in katis per cubic yard shown at its proper depth, the nature of the bed-rock, the nature of the ground bored, the nature and size of the tools used, and the name of the kapala in charge. Useful additional information would be the grade of the ore determined by standard sieves, and the nature of the heavy impurities. The samples should always be assayed unless it is obvious that no heavy impurities are present.

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