NOTES ON PROSPECTING
FOR
TIN-ORE
IN THE
FEDERATED MALAY STATES.

J. B. SCRIVENOR,
Geologist to the Federated Malay States Government.

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- **Figure I.**—Section showing the Structure of the Kinta Valley before the Formation of the Limestone Hills.
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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.

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 themselves 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, 1906, by H. Kynaston, E. T. Mello, 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