

Prospect over and around a strange hill

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"He must have the greatest skill in his work, that he may know first of all what mountain or hill, what valley or plain, can be prospected most profitably, or what he should leave alone".

Agricola: De Re Metallica

Abstract: It is pointed out that a *strange* hill and its immediate surroundings should always be regarded as a target for prospectors. Strangely, this fact has generally not been emphasised by 20th century writers of books, etc., on mineral exploration and the geology of ore-deposits.

For the purpose of this paper a hill is regarded as strange if one or more of the following criteria apply to it:-

- (i) it dominates a comparatively flat terrain;
- (ii) it differs significantly in shape from its neighbours;
- (iii) it has an unusual geologic setting;
- (iv) it stands out from the general terrain because of its plan-shape;
- (v) it possesses an anomalous ornamentation;
- (vi) it possesses anomalous geochemical and/or geophysical characteristics. (These are not discussed in the text.)

Finally, it is suggested that a law should be established that for the sake of brevity should read *"If you know of a strange hill prospect there"*.

INTRODUCTION

For the purpose of this paper a strange hill is defined as one that dominates an otherwise flat terrain or which is morphologically or otherwise markedly different from neighbouring hills. Whether a given feature should be termed a ridge, or mountain, rather than a hill is, for present purposes, of little consequence.

Recognition of the presence of a strange hill is of importance to those searching for ore-deposits because such deposits, primary and/or secondary ones (placers) are often associated with such a body. The reason for writing this is to

high-light this relationship which, in spite of its importance, has been given scant attention by those who have written text-books and papers on the fundamentals of economic geology and mineral exploration. However, at the outset it must be stressed that many major deposits, particularly of the bedded type, are *not*, associated with strange hills, and that throughout geological time strange hills associated with mineral deposits have, on occasion, been eliminated by natural processes. In addition, changes in land/sea relationships have resulted in some strange hills, associated with mineralisation, being completely submerged. A probable example occurs off the east coast of Belitung. There a crudely circular granitoid mass (originally a strange hill?) was ringed around by stanniferous-rich sediments. It is also important to note that some, probably many, strange hills, such as Ayres Rock, in the centre of Australia, lack associated ore-deposits.

Essentially as a result of my particularly geologic interests and experiences many of the strange hills mentioned in this paper are crudely circular in plan. This is because many owe their origin to the intrusion of granitic cusps and/or to the presence of ring structures such as are revealed, for example, during the destruction of many varieties of volcanic cone. However, strange hills with associated ore deposits are not invariably circular in plan. The granitoid Carn Brea ridge of West Cornwall (Fig.1) which is capped by a few greisen-bordered veins containing cassiterite, wolframite, etc., and which is flanked by major tin-bearing lodes, is a good example of a strange hill that departs from the circular plan. For the present purpose, the Great Dyke of Zimbabwe, containing viable stratiform chromite deposits, may be thought of as strange maxi-hill. It is locally 3 miles wide and extends virtually from the northern to the southern boundary of the country. It is a feature that is readily seen on satellite images, in part because its sparse cover of vegetation is in marked contrast to that of the fringing seasonal swamps (dambos) and basement rocks. Now, on aerial photographs the presence of the dyke is further advertised by the lines of white waste rock that border the exploited chromite bands and which strike about parallel to the dyke's long axis.

Although a strange hill may have no *known* ore-deposits associated with it, such a feature and its immediate environs should never be neglected by the prospector. Indeed, had the Finns appreciated the significance of a strange hill their country's major ore-deposit might have been discovered earlier and as a result of much less exploratory work. Briefly, the history of its discovery was as follows:— In 1907-8, during the excavation of a canal, a large, cupriferous glacial erratic was encountered. After prolonged search a boulder train of similar material was established which originated in the vicinity of what others had termed the '*strange hill*'. This hill, which coincided with a large magnetic anomaly, was subsequently drilled and a large copper-bearing ore-body was delineated. This was named the Outokumpo (Finnish for '*strange hill*') ore-body,

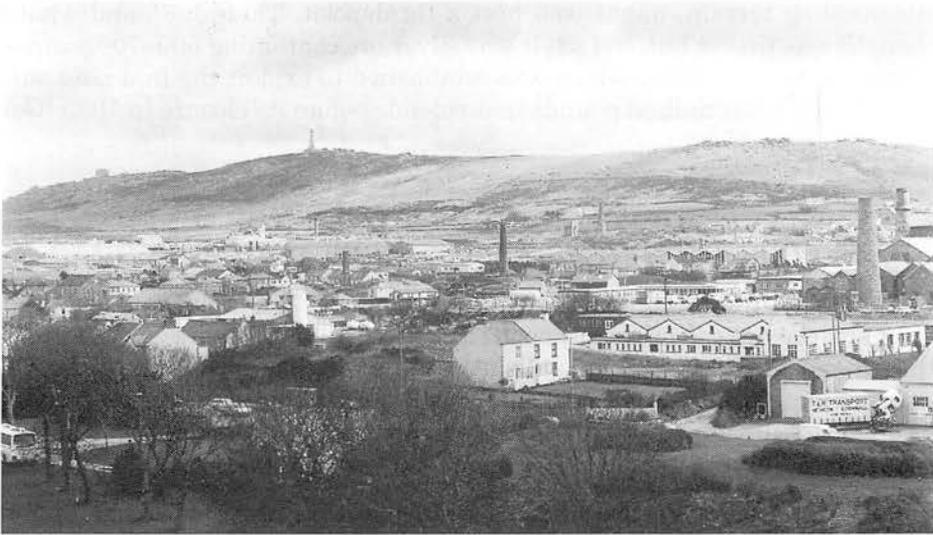


Figure 1 : Carn Brea (Camborne/Redruth mine-field , Cornwall, U.K.) — An elongate granitoid hill surmounted by a few, parallel, poor, greisen bordered veins containing cassiterite, wolframite and arsenopyrite and situated near the monument. Most of the foreground consists of metasediments and minor metabasites which pre-date the granitoid. Porphyry dykes and lodes containing tin and copper ore, of major economic importance, strike parallel to the long axis of the hill. The sites of some of the mines that exploited the lodes are indicated by the tall chimney stacks.

and it “*was to become the foundation for the development of Finland’s largest mining and metallurgical company*” (Anon., 1985, p.439).

During recent years the major Serra Pelada gold deposit was discovered in Brazil. Perhaps this deposit would have been found earlier had it been appreciated that strange hills should be prospected. The following quotation from an anonymous writer [1986 (Feb. 16), p.34] make the point:—*“It wasn’t a mountain in the first place, more of a hill. But in the thick of the Amazon jungle such a rounded hump of rock devoid of greenery stands out and they called it Serra Pelada, the Naked Mountain. Six years ago the Naked Mountain stood on the banks of the River Paraubepas, notable only for its baldness, until the day early in 1980 when gold by the handful was discovered, trapped in the clay and rock”*. Probably this ‘*mountain*’ was bald because it possessed a gossan cap.

The discovery of the silver-rich deposit at Broken Hill, New South Wales, is a beautiful example of how the examination of a strange hills can yield great dividends. Charlie Rasp, a boundary rider who had acquired a little geological knowledge having read a book, costing a shilling, on the subject, concluded that the jagged feature, know as Broken Hill, which stood about 120 feet above the

surrounding terrain, might well host a tin deposit. There he found what he thought was tin ore but, in fact, it was silver ore containing 600–700 ounces of silver per ton. The mine which was established to exploit the find paid out in excess of thirteen million pounds in dividends before its closure in 1939 (Gaman, 1988, pp.35-36.).

WHAT FROM THE POINT OF VIEW OF THE MINERAL EXPLORATIONIST, CHARACTERISES A STRANGE HILL?

Before stating what characterises a strange hill it is relevant to note that some such bodies can be readily spotted from the ground, others only easily from the air. Some can best be established by the study of aerial photographs or satellite images. Others, which I shall not discuss in this note, are only revealed as strange hills after the area has been subjected to ground and /or airborne geophysical surveys and/or to geochemical investigations.

A given hill may be classified as strange if it possesses one or more of the following characteristics:—

1. *The hill dominates a comparatively flat terrain*

Examples:- Gunung Jerai (Kedah Peak), Malaysia. This feature dominates the skyline north of Penang and contains iron and tin deposits.

St. Agnes, Cornwall, U.K. A hill arising out of a Pliocene marine platform. It consists of metapelites and possesses a granitoid core. It is bordered by rich tin lodes (Figs. 2A and 2B)

St. Michael's Mount, Cornwall. A prominent granitoid mass partly cloaked by hornfels and containing a swarm of greisen-bordered, cassiterite- and wolframite-bearing veins. When the tide is high this strange hill becomes an island (Figs. 3A and 3B).

The "*hill of copper*" at Akjoujt, Mauritania, which dominates a desert plain.

Khas Thap Khwai, c. 20 km north of the Thai city of Lop Buri. An isolated hill that contains the largest known iron deposit in Thailand. This contact metamorphic deposit "*was found when the highway cut through a colluvial blanket of hematite rubble that forms an apron on the.....slope of an isolated hill..... which rises about 50 metres above the surrounding plain*" (Brown *et al.*, 1951, pp. 76-77.)

2. *The hill differs significantly in shape from its neighbours.*

Examples :- On the west coast of Peninsular Thailand, not far to the south of Phangnga, one hill, immediately behind a coastal village, when viewed from offshore, is seen to possess a distinctly different shape from that of its neighbours, which are limestone. This strange hill is composed of an igneous (probably



Figure 2A : A photograph of St. Agnes Beacon (Cornwall, U.K.). This isolated hill, on the skyline is about 11 km to the NNE of the point from which the photograph was taken. It consists, essentially of metapelites intruded by a buried granitoid cusp. A part of the latter, which has been exposed in a quarry, is greisenised and contains some cassiterite and sulphides. The hill is fringed by a number of rich tin (cassiterite) and copper lodes which supported an important hard-rock mining industry.

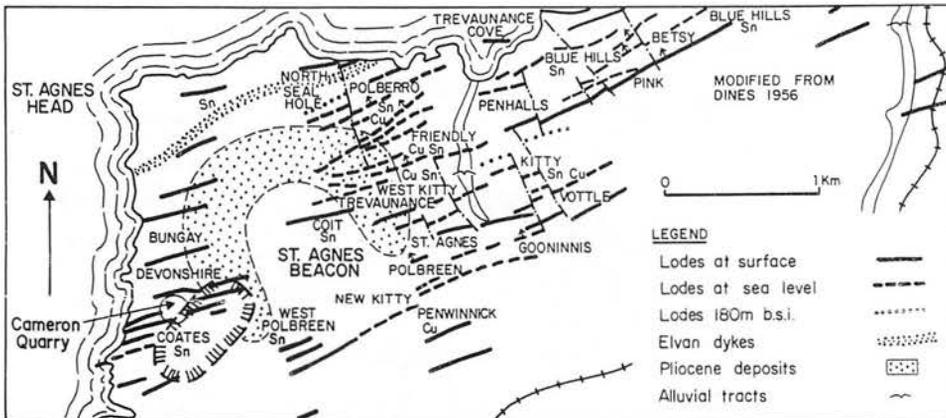


Figure 2B : This map of the St. Agnes Beacon mining field shows the distribution of the major lodes around the 'strange' hill which was an island in Pliocene(?) times and is now largely surrounded by 'fossil' beach deposits. The flat land surrounding the hill is a marine (Pliocene?) platform.



Figure 3A : A photograph of St. Michael's Mount (Cornwall, U.K.) At low-tide this feature is a part of the mainland, at high-tide it is an island. It consists, essentially, of a prominent granitoid cusp, that is cloaked on the landward side by metapelites which are locally clothed by trees.

The white granitic arcuate fringe of the island, in the foreground of the photograph, comprises a 10 ft (c. 3 m) platform on which a closely sheeted system of greisen - bordered veins containing cassiterite and wolframite occurs.

The possibility that major lodes might exist beneath the sea in the general vicinity of St. Michael's Mount has not been adequately investigated.

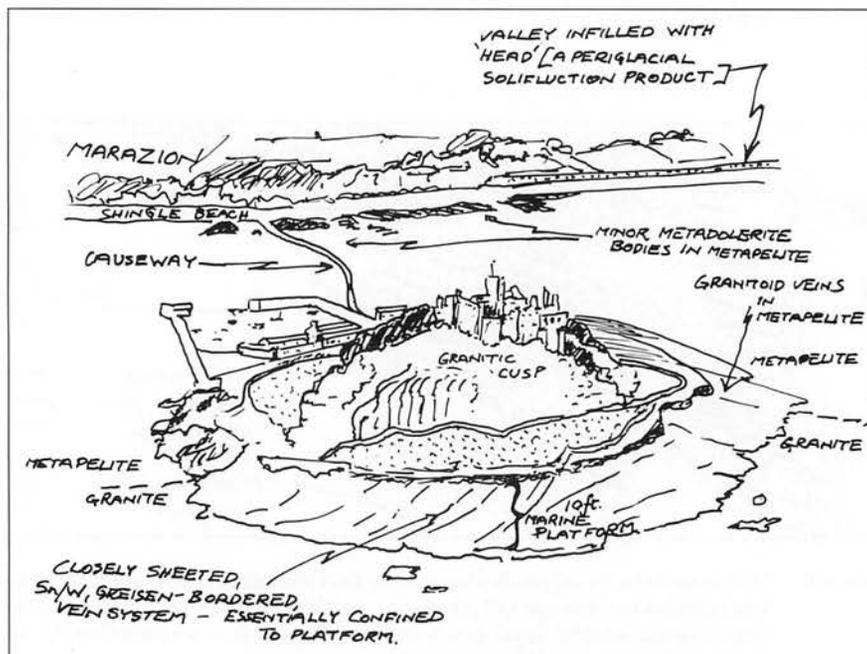


Figure 3B : A sketch of the seaward side of St. Michael's Mount showing the major geologic features.

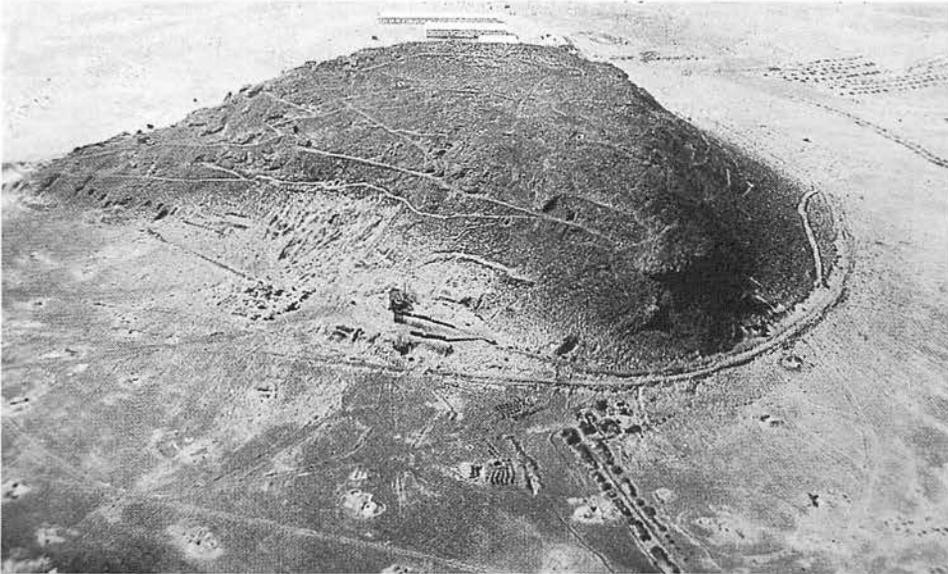


Figure 4: Aerial photograph of the copper-rich hill at Akjoujt, Mauritania, which is one of a pair of strange hills that are prominent in the desert landscape.

granitoid) rock and limestone and at the contact subeconomic Cu/Fe skarns occur. There is also a marked change in the vegetation as the contact is crossed and this is clearly seen from the sea. In 1956 the above facts enabled me to locate, without difficulty, the source of a specimen of skarn ore that had been brought to me sometime earlier by a local person who was not prepared to divulge from where it had been collected.

Morro do Potosi, Rondonia, Brazil was conical in shape and in respect of shape it differed not only from neighbouring hills but also from any hill that I saw in the Rondonian tin province. This strange hill consisted essentially of stanniferous exogreisen capped by an inverted conical hydrothermal breccia which contained an abundance of cassiterite and topaz and a little wolframite (Figs. 5A and 5B).

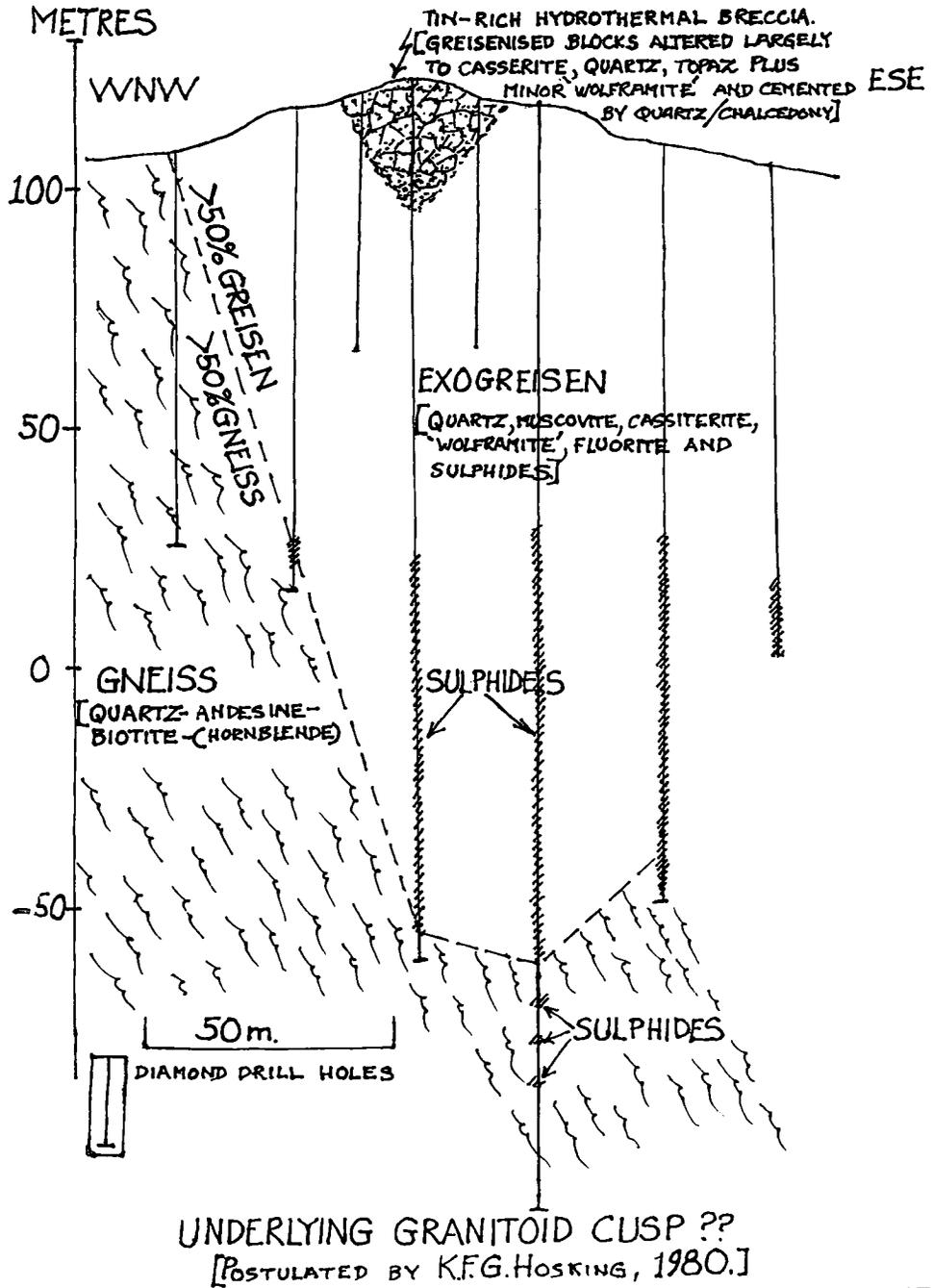
The known tin deposits of Rondonia are confined to three belts that together form a crudely-shaped letter Y. Morro do Potasi was at the triple junction and so, perhaps, where one would be most likely to find a strange hill.

[Morro do Potosi was the most important known hard-rock tin deposit in Rondonia. As a result of mining the hill no longer exists!]

The W/Mo/Sn porphyry deposit at Mount Pleasant, New Brunswick, Canada, which is hosted by volcanics, is one of a string of satellite igneous bodies that fringe a granitoid batholith. All but the Mt. Pleasant satellite are granitoids. The



Figure 5A: A photograph of tin-rich hill known as Morro Potosi in the tin-field of Rondonia, Brazil. In recent years this hill has been completely eliminated during the recovery of the cassiterite that it contained. The hill was a strange feature in the Rondonian environment and it occurred at the hub of the tin-bearing areas.



MORRO POTOSI

[LONGITUDINAL SECTION ALONG LINE 26]

Figure 5B: A longitudinal section of Morro Potosi, after a section provided by the mining company, and based essentially on surface mapping and the results of diamond drilling.

Mount Pleasant feature differs in shape from its satellite associates. From some situations miles away it dominates the skyline and invites prospection. However, its likely potential was only realised after the region had been geochemically surveyed.

3. *The hill has an unusual geologic setting.*

Examples:- Morro do Potosi, mentioned earlier, is a good example. Tronoh, Perak, Malaysia — Somewhat to the west of the site that was occupied by the office of the Tronoh (tin-dredging) Company there is an isolated hill situated across the N – S contact of the limestone and non-calcareous sedimentary rocks. It has a granitoid core and was the focus of strong primary tin mineralisation. Denudation eliminated most of the primary deposits and this led to extremely rich concentrations of cassiterite in local placers. These were initially exploited by underground and opencast means and were the foundation of the Tronoh Company's long prosperity.

4. *The hill stands out from the general terrain because of its plan-shape.*

The most obvious members of this group are those dominated by circular features. They are represented by some of the volcanic deposits of Bolivia with which are associated important deposits of tin and other metals. The carbonatites, such as the Palaborwa example of South Africa, and the anorogenic granites with which tin deposits are associated in Rondonia, Brazil, and in Nigeria are further members of this group. I know of an African carbonatite that was discovered by a geologist when, as a passenger travelling in a commercial aeroplane, he was casually looking at the ground from one of the plane's windows. The remarkable clarity which some of the Rondonian 'ring granites' appear on aerial photographs is apparent from figure 2, p. 391, of Kloosterman's paper (1968).

Sometimes radial and/or concentric dykes and/or lodes may further emphasise the anomalous nature of circular hills.

Now it is not irrelevant to remind the reader that the Tertiary ring dykes of the West of Scotland are not associated with any mineral deposits of economic importance, as far as I am aware. A reminder that strange hills do not always have ore deposits associated with them.

5. *The hill possesses anomalous ornamentation of which the following are examples:-*

(i) Lineament patterns:- The Tunku Mahkota's tungsten mine in Pahang, Malaysia, was developed in a prominent hill which consists of a granitoid cusp overlain by metasediments. Analysis of an aerial photograph showed that the hill possessed a considerably more complex lineament pattern than the rocks of the immediately neighbouring terrain (see Hosking, 1973, fig. 11, 28).

(ii) Drainage patterns:- Perhaps twenty years ago a hill known as Hill 717, on the property of Pahang Consolidated Company Limited, Malaysia, was selected for examination because it, unlike its neighbours, possessed a distinct radial drainage pattern. This pattern suggested that underlying the exposed metasediments there might be a granitoid cusp with which tin mineralisation might be associated. I believe that such exploratory work as was done indicated that the hill was, indeed, mineralised but that it was not worth exploiting.

(iii) Vegetation patterns:- A hill may be well vegetated but the plant cover may be distinctly different from that of the neighbouring hills or the general terrain. The Thai hill, on the west coast of Peninsular Thailand, noted earlier, is a good example of such a phenomenon. Other hills may be strange because they, unlike the neighbouring terrain, possess little or no vegetation cover. Serra Pelada, noted earlier, is an example of such a hill. The hill, Mae Sot, in northwest Thailand, is another example. Mae Sot is rich in the zinc minerals smithsonite, hemimorphite and hydrozincite. Because of the high concentration of zinc in the superficial parts of the hill only very specialised plants can grow there and these are most in evidence on the lower slopes. In marked contrast, the ground immediately adjacent to the hill is well-wooded (Fig. 6).

(iv) Supergene mineral patterns:- Supergene processes may so modify the superficial parts of a mineralised hill that it assumes a quality of strangeness and so stands out when observed from the air and perhaps, also, when seen from the ground. Usually the 'strange' quality is due to the development of a gozzan cap of a distinctive colour. In addition, the cap is commonly readily apparent because it supports little or no vegetation. Serra Pelada, noted earlier, is a good example. The Ok Tedi copper/gold porphyry, in Papua New Guinea, is another. There the primary ore is capped by a gold-rich gozzan. In an air-photograph, in colour, the gozzan zone is reddish-brown, in marked contrast to the greens of the densely wooded area that surrounds it.

Sometimes products of supergene processes other than 'normal' gozzan, may give a mineralised hill an unusual appearance. Years ago, Professor Petersen, of the University of Lima, Peru, showed me some photographs, in colour, of a Peruvian hill that appeared to have patches of bright green encrusting plants on it. In fact, these coloured areas were stains due to secondary copper species and the hill contained a porphyry copper deposit which up to that time had not been exploited because of its proximity to the frontier.

CONCLUSION

Hopefully this paper will convince the reader, if he or she were not already convinced, that no mineral explorationist can afford to neglect a strange hill. Indeed, a law might be established with advantage which in order that it might be easily remembered might be stated thus:- *If you know of a strange hill prospect there.*



Figure 6 : A photograph, looking SSW, of the Pa-Daeng zinc deposit, Mae Sod District, Tak Province, North Thailand. The zinc deposit is confined to the treeless hill, surmounted by a wat, in the background of the photograph. The local high concentrations of zinc in the soil of the hill in question have prevented the growth of trees: only plants that are lovers of zinc or can withstand high concentrations of the element are found there.

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