Geol. Soc. Malaysia, Bulletin 6, July 1973; pp. 297–308.

The Primary Tin Mineralisation Patterns of West Malaysia

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"A mighty maze! but not without a plan."

(Alexander Pope)

Abstract: In this paper the more obvious features of the primary tin mineralisation pattern of West Malaysia are noted. Then the various major types of primary deposit, which are the dominant units of the pattern, are broadly described, and their distribution, particularly with respect to the granitic masses, is considered. The distribution of certain varieties of cassiterite and of other tin-bearing species is also commented on. A tentative history of development of the pattern is presented and mention is made of the tin-barren/tin-product granite question in the light of this hypothesis.

INTRODUCTION

The distribution of tin deposits (primary and secondary) shown in Figure 1 indicates quite clearly that they are spatially closely related to the exposed granites, and two major tin belts are apparent, the one associated with the Main Range and the other with the east coast granites. For the most part the deposits are situated along the flanks of the major acid intrusives: well inside the granite contacts they are sparce and small. Along the granite/invaded-rock contacts, the deposits in question are apparently erratically distributed, and in the case of the Main Range, tin mineralisation is much more strongly developed along its western flank than along its eastern one. In the Eastern Belt the primary deposits of Pahang Consolidated Mine are, economically speaking, vastly more important than any others known there.

THE NATURE OF THE PRIMARY TIN DEPOSITS (THE MAJOR UNITS OF THE PATTERN): THEIR DISTRIBUTION

For the purpose of this paper the primary tin deposits in question have been classified as indicated in Table 1, and a few brief details of the nature and distribution of the groups and sub-groups, which are pertinent to the topic under review, are given below:

(i) *Stanniferous pegmatites and aplites*

Stanniferous pegmatites with niobium/tantalum species (and other exotic ones such as gahnite and cheralite) appear to be confined to Kedah Peak (Kedah) and Bakri (Johore) where they are associated with intrusives, perhaps of Carboniferous Age. (Bignell. Personal communication.) Stanniferous pegmatites/aplites, lacking niobium/tantalum species, are associated with the Main Range granites, from which quite a considerable number of Upper Triassic radiogenic ages have been obtained, but from which, also, a few Carboniferous and Upper Cretaceous ages have been recorded.

Whilst the cassiterites in the niobium/tantalum pegmatites may be syngenetic with respect to the host (they are squat bipyramidal, strongly pleochroic, and highly tantaliferous and/or niobiferous), the cassiterites of the Main Range pegmatite/aplite bodies (which are not very common nor very important, economically speaking) may well be epigenetic with respect to the host, in common with the sulphides which, not infrequently, accompany them.

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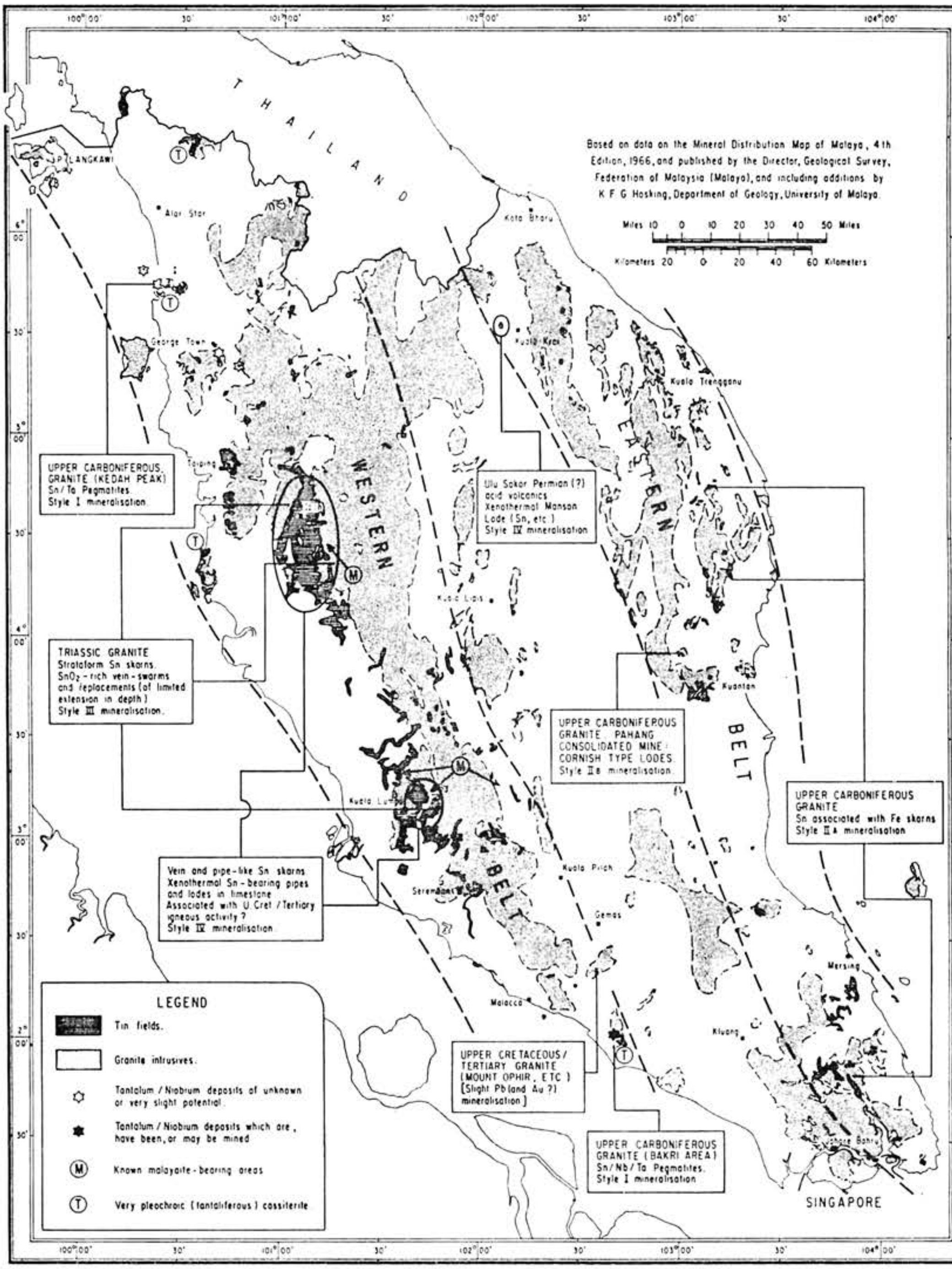


Fig. 1. The Distribution of Tin & Tantalum/Niobium Deposits in West Malaysia.

TABLE I

A CLASSIFICATION OF THE PRIMARY TIN DEPOSITS OF WEST MALAYSIA
(Hosking, 1971)

TYPES OF DEPOSIT	SUB-GROUPS	EXAMPLES AND NOTES
1. PEGMATITES	(i) Stanniferous, with Nb/Ta species.	Bakri (Johore); Kedah Peak (Kedah)—Possibly syngenetic cassiterite (i.e., with respect to the pegmatite).
	† (ii) Stanniferous, but lacking Nb/Ta species.	*Bujang Melaka (Perak)*; Gunong Baku (Perak); Fook Wan Foh Kongsi, Chenderiang (Perak)—Probably epigenetic cassiterite (i.e., with respect to the pegmatite).
2. APLITES	† ———————	Gunong Bakau (Pahang)—Possibly syngenetic cassiterite (i.e., with respect to the aplite).
3. PYROMETASOMATIC (i.e., those deposits with a gangue of skarn species.)	(i) Malayaite only tin species present.	Rawang (Selangor); Kanching Mine, Templar Park (Selangor).
	(ii) Andradite only known tin-bearing species present.	Langkawi Islands.
	†(iii) Malayaite+cassiterite, etc.	Sungei Gow (Pahang); Chenderiang (Perak).
	*(iv) Skarn species+cassiterite.	*Beatrice Pipe (Perak)*.
	* (v) Skarn species+magnetite and cassiterite, etc.	*Bukit Besi (Trengganu)*; Machan Satahun (Trengganu); Pelepah Kanan (Johore) (in part). — cassiterite (and magnetite) probably hydrothermal.
4. HYDROTHERMAL	(i) Mineralogically and structurally simple veins.	
	(a) A few, greisen bordered, in granite.	Lumut (Perak).
	*(b) Many, in granite.	*Kledang Range (Perak)*—streaky bacon ore.
	*(c) Vein swarms in non-calcareous metasediments.	*Chin Chin Mine (Malacca)*; *Rahman Hydraulic Mine (Perak)*—Overlying granite cusp(?); Tronoh (Perak)—overlying and flanking granite cusp; Bundi Mine (Trengganu).
	(ii) Massive replacement bodies.	
	*(a) In granite.	*Sungei Besi Mine (Selangor)*.
	*(b) Pipes in limestone.	*Lahat Pipe (Perak)*.
	(iii) Lodes, mineralogically simple to moderately complex; structurally moderately to very complex.	
	*(a) Lodes of limited extension down dip.	*Menglembu Lodes (Kledang Range, Perak)*.
	‡(b) Cornish-type lodes—marked extension down dip.	*Lodes of Pahang Consolidated Mine (Pahang)*.
	(iv) *Xenothermal types*	
	(i) Veins in limestone.	Exposed in several open-cast 'alluvial' mines near Kampong Pandan and Ampang (Selangor) and in the Ban Hin Lee Mine, Kepong (Selangor).
	† (ii) Pipes in limestone.	Sin Woh Leong Kongsi, Simpang Ampat, Menglembu (Perak).
	(iii) Lodes in geologically varied environments.	Manson Lode (Kelantan); Tekka Lodes (Perak).

KEY:—
- † One or more deposits within the Sub-group have been worked for cassiterite.
- * The Sub-groups in which, economically speaking, the more important deposits occur.
- ‡ The Sub-group in which, economically speaking, the most important deposit occurs.

NOTES:—
1. Particularly important (economically speaking) named deposits are in italics.
2. For further data concerning the named deposits see HOSKING, K.F.G. (1971), "The primary mineral deposits of West Malaysia". Chapt. 11 of "Geology of the Malay Peninsula" eds. Gobbett, D.J.; Hutchison, C.S. (In the press. To be published by John Wiley —Interscience, New York.)
3. There is no reason for believing that West Malaysia contains tin deposits that can be classed as magmatic disseminations, that is, if the pegmatites and aplites are disregarded. Syngenetic cassiterite *may* occur in the major granitic masses, but if this is so, then the mineral is never present in more than trace amounts.
4. In all the types of deposit noted above, examples displaying telescoping occur. Primary zoning within individual ore-bodies is virtually absent. The lodes of Pahang Consolidated Mine are the only ones known to the compiler of this table that display this characteristic, and then only to a very slight degree.

(ii) *Pyrometasomatic deposits*

The tin in West Malaysian stanniferous skarns may be solely present as an accessory component in such silicates as andradite and vesuvianite, or largely as malayaite, or as malayaite plus cassiterite, or as cassiterite. Such deposits are confined to the western half of Malaysia. Locally, in the Eastern Belt, cassiterite may be closely associated with ferruginous skarns, in which the magnetite may be somewhat stanniferous.

In these skarns, or pyrometasomatic deposits, the cassiterite is, beyond reasonable doubt, of hydrothermal origin. Locally it may be, in part, derived from malayaite, but commonly it simply represents the direct product of hydrothermal mineralisation which occurred in a calc-silicate hornfels environment. In the Western Belt, strataform, vein-like and pipe-like stanniferous skarns exist, but in the Eastern Belt only the first mentioned type is to be found.

(iii) *Hydrothermal deposits*

Those deposits may be divided into xenothermal ones and others.

The others display wide morphological differences and vary greatly in mineralogical and structural complexity. In the Western Belt isolated veins and lodes, and swarms of these bodies are common and occur particularly in rocks other than the limestones. In the Western Belt, also, stanniferous hydrothermal pipes occur locally in the granite and limestone of the Kinta field. Particularly in the Selangor field stanniferous veins and carbona-type bodies have been impounded in the granite by the limestone.

All these hydrothermal bodies appear to have limited extension in depth and strike and none of them show any evidence of primary zoning.

While in the East Coast Belt stanniferous vein/lode swarms occur whose characteristics are similar to those noted above, structurally complex lodes, of considerable strike extent, are also present which may contain economically important quantities of cassiterite over dip lengths of up to 2,000 feet. The most notable examples of these, which are very similar to the Cornish lodes, are found in the Pahang Consolidated Mine area, but also in the Bundi Mine poor cassiterite-bearing veins occupy a belt about 1,300 feet from top to bottom outside, but parallel to, the granite contact.

The Eastern Belt deposits, in common with those of the Western Belt, display virtually no primary zoning, although possibly the upper horizons of the Pahang Consolidated lodes are the most cupriferous.

It is important to note that at least the granites of the northern half of the Eastern Belt appear to be dominantly of Upper Carboniferous age, unlike those of the Western Belt which would seem to be dominantly of Triassic age.

Xenothermal deposits (Fig. 2) which are highly telescoped and contain a considerable variety of minerals, varying from early cassiterite to late antimony and mercury species, reach their maximum development in the Western Belt in the Kinta and Selangor fields. There they are largely confined to the limestones and usually occur as veins or pipes. Some of these bodies contain calcsilicates and so can be classified as pyrometasomatic, but to do so really tends to obscure their more important characteristics.

In the Eastern Belt only one stanniferous xenothermal deposit is known. It occurs at Ulu Sokor, Kelantan, and is possibly of Permian age. In this, so called, Manson Lode, cassiterite is associated with a wide variety of sulphides including stannite, pyrrhotite, sphalerite, galena and cinnabar.

Some of the major differences between the tin and associated mineralisation of the eastern and western halves of West Malaysia are shown in Table 2. In this same table a few other geologic differences between these two halves, which are relevant to the subject under review, are also included.

Table 2. A Comparison of The Ages of The Granites and The Tin Mineralisation of The Western Belt of West Malaysia with those of The Eastern one (K.F.G. Hosking, 1972)

WESTERN BELT		EASTERN BELT
FAR WEST ZONE	MAIN RANGE ZONE	
Upper Carboniferous granite present.	Dominantly Upper Triassic granite, but some Upper Carboniferous and Upper Cretaceous granite present.	Dominantly Upper Carboniferous granite, at least in northern half.
Nb/Ta-Sn pegmatites.	Sn pegmatites/aplites.	No Sn pegmatites.
Sn-skarns very rare. (Sn-andradite skarns at Langkawi).	Sn-skarns, sometimes with malayaite: not rare.	Sn-Fe skarns present. Malayaite absent. SnO_2 wholly hydrothermal.
	Strataform, pipe-like, and vein-like skarns known.	Strataform skarns only recorded.
Hypothermal stanniferous veins/lodes, singly or in swarms, with limited dip extension, sparsely distributed. Generally rather poor.	Many rich stanniferous veins/lodes, and occasionally pipes, singly or in swarms, but generally, at least, with very limited dip extension.	Hydrothermal stanniferous veins/lodes, singly or in swarms, *with limited dip extension*, fairly sparsely distributed within the Belt.
No primary stanniferous bodies with considerable dip extension known.	No primary stanniferous bodies with considerable dip extension known, but some pipes in the limestone *may* possess this characteristic.	Stanniferous lodes, with considerable dip extension, and of major importance, occur at Pahang Consolidated Mine, and *may* be present elsewhere in the Belt.
No xenothermal tin deposits recorded.	Many xenothermal tin deposits (veins and pipes, and generally in the limestone) known, particularly in the Kinta and Selangor fields.	Only one xenothermal tin deposit known and it is the Manson deposit, Kelantan.
Zone in which the most strongly pleochroic cassiterites, and those highest in Ta and/or (?) Nb occur.	Zone in which cassiterites occur which vary from strongly pleochroic to non-pleochroic.	Zone in which the cassiterite is generally weakly pleochroic or non-pleochroic.
Tetra-stannite only recorded at Langkawi.	Tetra-stannite occurs in several areas, also cuprostannite and other tin-bearing sulphides in the Selangor field.	Tetra-stannite only recorded in the Manson deposit.

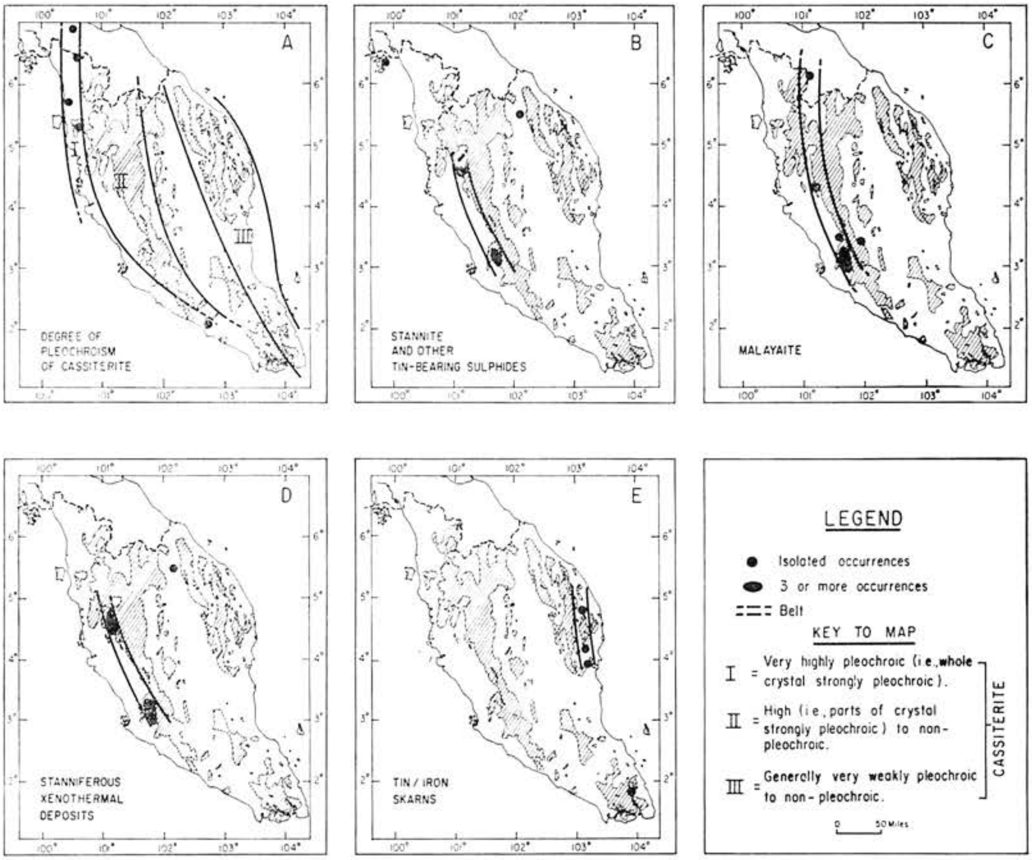


Fig. 2. Distribution Patterns of the Tin Species and of Certain Types of Primary Stanniferous Deposit of West Malaysia.

DISTRIBUTION PATTERNS OF CERTAIN VARIETIES OF CASSITERITE AND OF OTHER TIN-BEARING SPECIES

Passing reference has already been made to the distribution of certain varieties of cassiterite and of some other tin-bearing species. Some further brief remarks on this topic are justified as the distribution patterns of the minerals in question further emphasise the differences between the tin mineralisation of the Eastern and Western Belts and the strong tendency both for similar tin minerals and similar tin deposits to be broadly aligned parallel to the axial trend of the country.

Reference has already been made to the fact that the intensely pleochroic cassiterites, that is, those whose complete crystals show an intense deep-red/pale-brownish pleochroism, and have a high Ta and/or (?) Nb content, are confined to the Western Belt. In fact, such cassiterites are confined to the line Dindings/Kedah Peak/Bukit Kachi and to the Bakri District of Johore (Fig. 2a). The cassiterites in primary deposits bordering and immediately to the west of the Main Range, vary from being strongly pleochroic (that is, certain zones of the crystals show the intense colour changes noted above) to non-pleochroic. The cassiterites of the Eastern Belt, apart from that at Chendrong, are very weakly pleochroic, or non-pleochroic. The Chendrong cassiterite, which possesses some crystal zones which are strongly pleochroic, is associated with wolframite and scheelite, and the distinctive character of the ore makes one wonder if it is not, perhaps, of a distinctly different age, (perhaps Triassic), from that of its stanniferous neighbours.

The known malayaite occurrences, all of which are confined to the Western Belt, also show a crudely north-south alignment, as, with two exceptions, do all the known tin-bearing sulphide ones. The exceptions are the Pulau Langkawi occurrence and the Manson Lode of the East Coast. The presence of stannite in the latter serves to further emphasise the unique character of this stanniferous body as far as the East Coast tin deposits are concerned (Fig. 2b). The tin-bearing sulphides encountered are dominantly tetra-stannites, but in the Kuala Lumpur area, cuprostannite occurs, and probably teallite and possibly franckeite.

THE HISTORY OF DEVELOPMENT OF THE PRIMARY TIN PATTERN

From the foregoing it is clear that in part the style of tin mineralisation of the Eastern Belt is quite unlike any of the different styles found in the Western Belt. In particular, in the Western Belt, it is relevant to note the niobium/tantalum/tin pegmatites locally 'fringing" the west coast, the xenothermal deposits which occur immediately to the west of the Main Range, particularly in the Kinta and Selangor fields, and the malayaite occurrences (Fig. 2c). For reasons which will be apparent later, it is again important to note that members of the stanniferous pyrometasomatic group of the Western Belt may be subdivided into those that are strataform and those that are vein-like or pipe-like.

Without considering radiogenic ages it would seem reasonable to suggest that the markedly different styles of tin mineralisation encountered in West Malaysia might be, in part, because they are genetically related to granitic bodies which were emplaced at distinctly different geologic times. In any event, it would seem fundamentally unreasonable to think that all the granites of Malaysia are virtually of the same age. Furthermore, the quite well developed metamorphic aureoles associated with the granites of the Eastern Belt indicate that the latter were emplaced at higher horizons than the distinctly mesozone Main Range and adjacent granites.

In the Western Belt the need to postulate at least two phases of tin mineralisation of distinctly different ages cannot be avoided. This is primarily so because, on the one hand, the pure limestone has impounded tin deposits in the granite, and on the other, this same limestone contains stanniferous skarn and xenothermal fault-controlled veins and pipes. The pure limestone would be expected to deform rather than to fracture were it deeply buried in the mesozone and heated by an invading granitic magma, It would be expected to behave as a brittle body and fracture readily were it lightly loaded. Thus it is clear why tin mineralisation genetically related to the mesozone granite was confined to the latter when the igneous body was in contact with pure limestone. Of course, non-calcareous metasediments, and skarns developed from beds of impure limestone, being brittle, were probably both capable, at this stage, of being sites of tin deposition.

When, as a result of prolonged denudation, these pure limestones were brought near the surface and subjected to renewed acid igneous activity, they fractured readily, thus enabling, in the first instance, vein-like and pipe-like skarns to develop in them and then stanniferous xenothermal bodies. In due course deposits other than stanniferous ones developed in them: amongst these may be cited the metasomatic scheelite/fluorite deposit of Kramat Pulai (Perak), which was emplaced in limestone beneath two plunging anticlines of schist. In this latter case it is important to note that it was the limestone rather than the schist and the adjacent skarn beds that was strongly fractured.

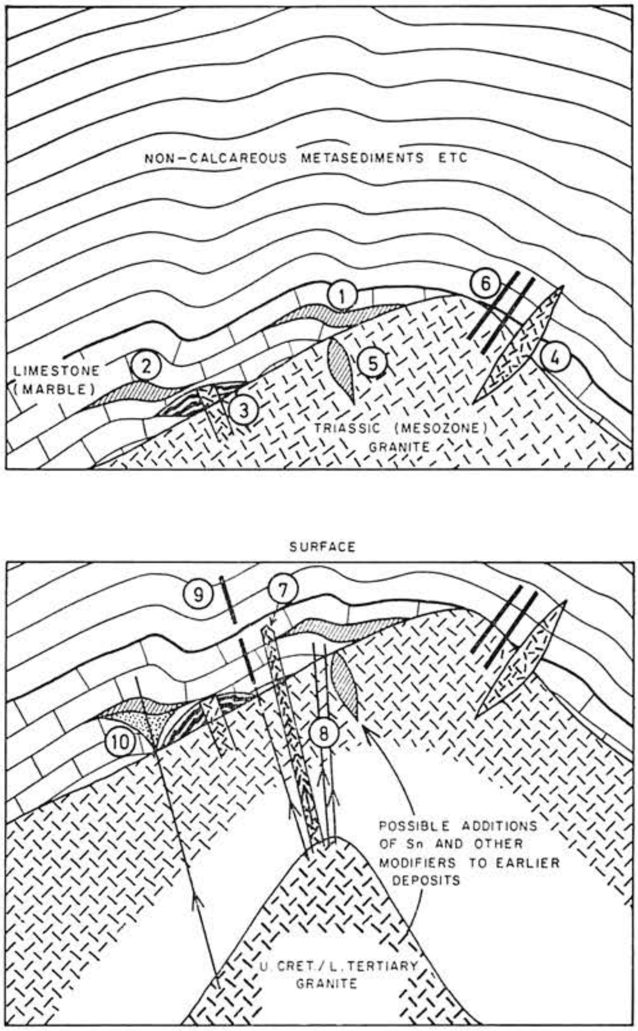
Radiogenic ages of the granites of the Western Belt give support to this hypothesis in that whilst, as noted earlier, most of the Main Range and adjacent granites would appear to be mesozonal and largely Triassic in age, a few isolated, small and probably high level granites, of which Mount Ophir (Johore) is the most well known, have been dated as Upper Cretaceous. (Bignell. Personal communication.) Figure 3 is an attempt to express the above hypothesis pictorially.

Bearing in mind, in addition to the above, that a number of the east coast granites have yielded Upper Carboniferous ages, as indeed, have some of the granitic rocks from the tin/niobium/tantalum areas of Kedah Peak and Bakri, on the west coast, it is instructive to attempt now a complete synthesis of the history of the tin pattern in the light of Bilibin's (1968) views concerning the sequence of events occurring in mobile belts. This approach seems a valid one, because, although a mobile belt was, for Bilibin, a deforming geosyncline, it is now likely that he was, in fact, studying active belts associated with subducting plates.

According to Bilibin (1968) meaningful primary tin deposits are first formed in what he terms the middle stages of development of a folded zone, that is, when the 'geosyncline' is being converted into a folded belt and when syntectonic granitic batholiths are emplaced. The tin deposits, which are generally believed to be genetically related to these granites, are largely pegmatites, often containing tantalite/columbite in association with the cassiterite, and/or hydrothermal veins and lodes of varying structural and mineralogical complexity. During the late stage of development of the folded zones, tin-sulphide deposits, often associated with acid-intermediate volcanics, may also develop. Such tin deposits are usually xenothermal in character. Still later, deposits of various kinds, but including those of antimony, gold, copper, lead, mercury, fluorite, witherite and barite may develop in association with minor intrusives and effusives of widely varying composition. Finally, there is an outpouring of basaltic magma.

It may be tentatively concluded that in West Malaysia synorogenic granites which reached fairly high levels, were emplaced in Upper Carboniferous times. Present evidence suggests that these attained their maximum development in the Eastern Belt, although there is evidence that they were also developed in the Western Belt where they might, in the Main Range area, have been largely obliterated by later granites. It is suggested that genetically related to these granites are the so-called tin-iron skarns, some tin/tungsten vein swarms, and the Pahang Consolidated lodes of the East Belt, and the tin/niobium/ tantalum pegmatites of Bakri and Kedah Peak on the west coast. The xenothermal Manson Lode was formed subsequently, perhaps in Permian times.

The sequence of events postulated by Bilibin was then arrested and commenced once more from the beginning. Renewed acid igneous actively, which was at a maximum along the line of the present Main Range and immediately to the west of it,



1. STRATAFORM SKARN
2. FOLDED BED OF NON-CALCAREOUS SEDIMENT OR METASEDIMENT
3. PEGMATITE IN PART IN A SKARN HOST
4. PEGMATITE IN GRANITE / NON-CALCAREOUS HOST ROCKS
5. TIN OREBODY IMPOUNDED BENEATH LIMESTONE
6. TIN-BEARING LODES/VEINS IN GRANITE / NON-CALCAREOUS HOST ROCKS
7. PEGMATITE IN GRANITE / LIMESTONE HOST ROCKS
8. TIN-BEARING LODES / VEINS IN GRANITE, ETC.
9. XENOTHERMAL TIN-BEARING DEPOSIT IN LIMESTONE, POSSIBLY ASSOCIATED WITH VEIN- OR PIPE-LIKE SKARNS
10. METASOMATIC TUNGSTEN-BEARING DEPOSIT IMPOUNDED IN LIMESTONE BY A METASEDIMENTARY FOLDED BED

Fig. 3. The Postulated Major Results, in West Malaysia, of Superimposing Mineralisation due to a High-Level Granitic Invasion on that due to Granite Emplaced in the Mesozone.

resulted in the emplacement, in the mesozone, in Triassic times, of most of the Main Range granite together with that of the Kledang and associated ranges in Perak, and the Damansara mass in Selangor. Associated with this phase of igneous activity was the development of pegmatites, aplites, perhaps containing some syngenetic cassiterite, skarns, in part stanniferous, and undoubted hydrothermal deposits of widely varying structural and mineralogical complexity. During the development of the last-mentioned deposits some of the pegmatites, aplites and skarns became the sites of deposition of cassiterite. Where this granite was in contact with pure limestone tin deposits tended to be impounded within the granite. Some hydrothermal tin deposits in the Eastern Belt, which are not xenothermal in character, and which occur in a post-Carboniferous environment, as, for example, that at Bukit Payong (Pahang), may be genetically related to Triassic igneous activity.

Post-orogenic acid igneous activity in Upper Cretaceous times, which led to the emplacement of Mount Ophir and certain neighbouring granitic bosses, is thought to have extended northwards, on either side of the Main Range, and to be responsible, notably for the xenothermal tin deposits of Selangor and Perak but possibly also the scheelite deposit of Kramat Pulai (noted earlier) together with the gold, stibnite and cinnabar bordering both sides of the Main Range.

At a still later stage, galena, bornite, chalcopyrite, fluorite, strontium and barium species and zeolites were deposited in the Segamat basalt which rests unconformably on Triassic sediments. Finally there was an outpouring of barren basalt in the Kuantan area of the Eastern Belt and its K/Ar radiogenic age is 1.8 m.y. (Bignell. Personal communication.)

It is of considerable interest to note that the above hypothesis, which is little different from that proposed by the writer a few years ago (Hosking, 1969), fits very well into Hutchison's (1972) interpretation of the general geologic evolution of West Malaysia in terms of plate tectonics. Broadly speaking, Hutchison associates the development of the Carboniferous granites with a subduction zone about parallel to the long axis of the country but to the east of it. The Triassic granite he ascribes to igneous activity related to a later developed subduction zone also parallel to the long axis of West Malaysia but considerably to the west of the country. He thinks that deformation of the wedge between the opposed subduction zones initiated the Upper Cretaceous igneous activity noted above, and also that it was responsible for the development of the granites of the Natuna Islands with which a little tin mineralisation is associated.

SOME IMPLICATIONS OF THIS FOREGOING HYPOTHESIS

If it is accepted that in West Malaysia there were three important widely separated periods of major tin deposition and a fourth which was responsible for the Manson deposit, but which may have been comparatively unimportant, then the following interesting possibilities become apparent:

i. In a given field, tin deposits of widely different ages may occur.
ii. An early tin deposit may be modified in a number of ways during later periods of mineralisation and so may eventually contain cassiterites of two or three widely different ages.
iii. A tin deposit occurring in an outcropping granite may be genetically related to a much later granite that does not outcrop.
iv. The marked concentration of tin deposits on the west side of the Main Range, particularly in the Kinta and Selangor fields, and the comparative paucity

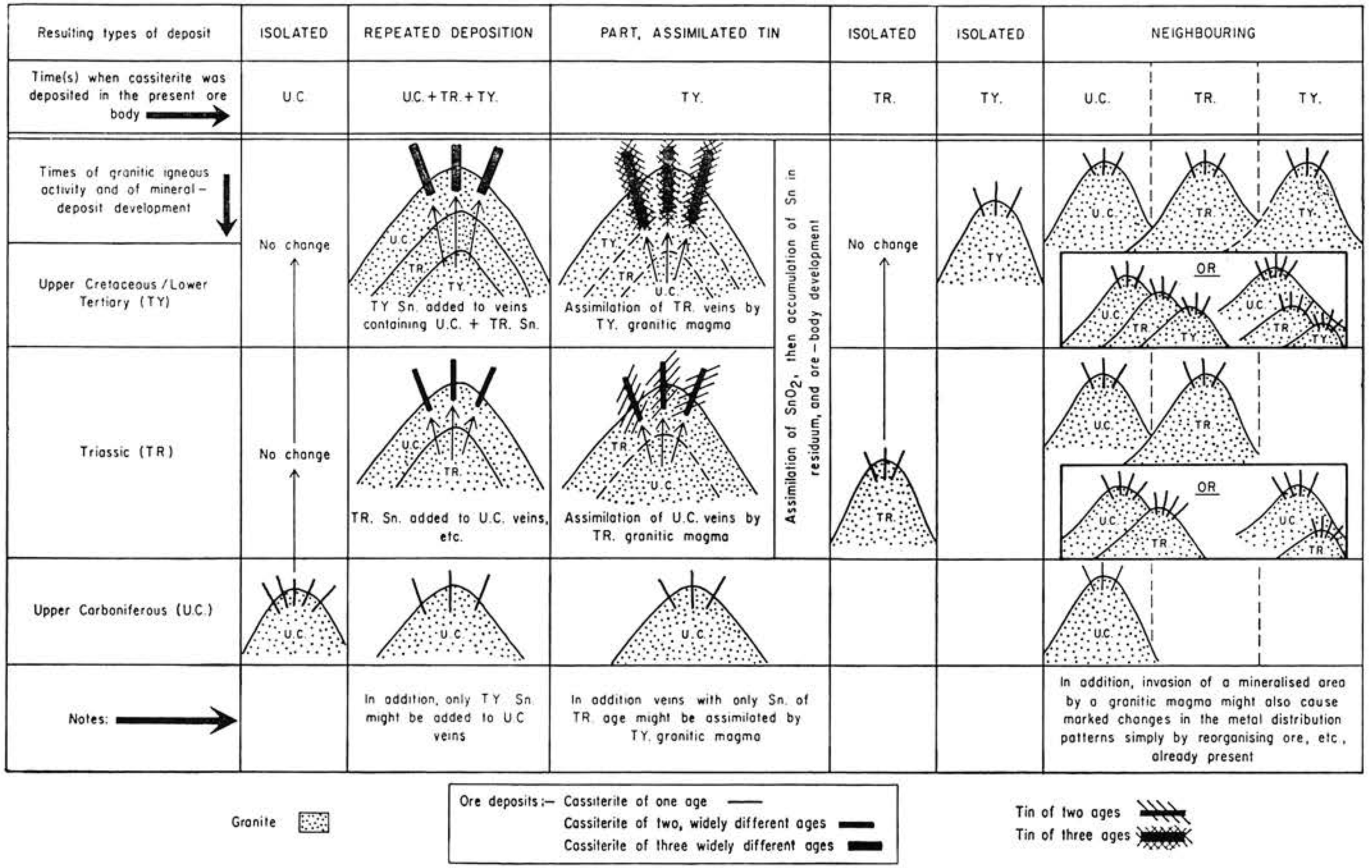


Fig. 4. Some variations in the Genesis of Pneumatolytic(?) / Hydrothermal Tin deposits in the Western Mineralised Belt of West Malaysia, which might have occurred as a result of the three major granitic invasions, each with its Associated Phase of Mineralisation, that are believed to have taken place there.

of tin deposits on the east side of the Range, might be because deposition of much of the tin was associated with Upper Cretaceous igneous activity which was largely concentrated to the west of the Main Range.

Some further possible results of granitic intrusions and associated tin mineralisations of distinctly different ages which might be found in West Malaysia are shown on Figure 4.

CONCLUSION

In conclusion it seems likely that the tin in the primary deposits of West Malaysia is that which has been abstracted on a number of occasions since the Carboniferous from the crust. No recycling has occurred since the Carboniferous, but early-deposited tin may well have been assimilated by later granites and, in due course, redeposited in ore-bodies. Finally, the complex granite/tin mineralisation picture drawn in this paper must surely indicate that the tin barren/tin productive problem is a far more complex one than most writers on the subject would have one believe, and it suggests that if hard-rock geochemical methods are to be used in West Malaysia and similar metallogenetic provinces during the search for primary tin deposits, only those aimed at locating epigenetic anomalous envelopes should be employed.

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