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Aspects of the geochemistry of Malaysian cassiterites

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Abstract: Cassiterite samples from various parts of Peninsular Malaysia have been analysed for their minor and trace element contents using U.V. Spectroscopy. The samples, numbering 114, were collected from hydrothermal, pegmatitic and pyrometasomatic deposits and represent the various kinds of Malaysian tin deposits.

Quantitative analyses show that among the minor and trace elements studied, Ta, Nb, Ti, Mn, Fe, W and Zr are constantly present. They show log-normal distribution patterns. Among these elements, Nb, Ta, Mn and Fe show certain variation with different types of tin deposits. In the pegmatitic cassiterites, their overall concentrations are highest in the columbite-tantalite-rich (Semiling) type and lowest in the columbite-tantalite-poor (Chenderiang) type. Among the hydrothermal cassiterites, the greisen type veins shows the highest concentration, followed by the quartz-wolframite vein, quartz-tourmaline vein, quartz-chlorite vein and finally the sulphide-rich vein. The few pyrometasomatic cassiterite samples analysed show very little concentration of these elements.

An examination of their geographical distribution pattern shows that cassiterites rich in Nb. Ta, Mn and Zr are mainly found in the Western Tin Belt while the W-rich cassiterites are found in the Eastern Tin Belt.

The results of qualitative analyses show that besides the seven elements mentioned, Ga, Sc, Bi, Mo, Ag and Sb are also detected in trace amounts. These elements however do not show clear relationships with the various tin deposits.

INTRODUCTION

Cassiterite in its pure form, contains very little of minor and trace elements. However, studies by previous workers (Venugopal 1952, Dudykina 1959, Steveson and Taylor 1973) showed that this mineral could incorporate considerable amounts of other elements, such as Nb, Ta, Zr, Fe, Ti, W, In, Sc, Pb and Cu. The amounts of these elements are related to the types of depositional environments. Nb, Ta and Zr are generally found highest in the pegmatitic and greisen cassiterites and lowest in the sulphide-rich vein type.

With this background information in mind, it was decided to carry out a study of the minor and trace element contents in the Malaysian cassiterites. This study would be particularly useful since the majority of the Malaysian tin-fields are alluvial in nature and in most cases the nature of occurrence of primary cassiterites could not be observed. Information on their minor and trace element contents would give indications on the nature of the primary deposits.

ANALYTICAL METHODS

Samples used were of two types; fresh cassiterites taken from primary deposits and loose alluvial grains obtained either as mine concentrates or panned from the streams. Because of the minute nature of impurities in the form of mineral inclusions or alteration products, the cassiterites were carefully cleaned by crushing in a steel mortar, sieved using a -18 mesh screen, leached with a dilute mixture of HCl and HNO_3, oven dried and finally hand-picked under a binocular microscope. For spectrographic analyses, the cleaned cassiterite grains were ground to form a smooth powder in an agate mortar.

Analyses were performed using a Hilger large quartz and prism U.V. spectrograph. The spectrums were recorded on an Ilford N50 plate at 2750 Å–4700 Å wavelength. Measurement of the line intensities were made using an Allied Research Laboratory Microphotometer, the details of which have been described in Hassan (1982). In order to establish the reproducibility of the method used, a cassiterite sample was analysed eleven times throughout the length of the analyses. The mean, standard deviation and coefficient of variation of the repeated analyses are given in Table 1 below.

Table 1

MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION OF REPEATED ANALYSES ON A CASSITERITE SAMPLE

Element	Mean	Standard deviation	Coefficient of variation
Ti	1437	121	8
Mn	128	120	15
Fe	301	25	8
Nb	525	115	22
Ta	605	64	11
W	158	21	13
Zr	212	51	24
V	36	4	11
Pb	53	13	25

ASPECTS OF GEOCHEMISTRY OF MALAYSIAN CASSITERITES

STATISTICS OF DISTRIBUTIONS OF MINOR AND TRACE ELEMENTS IN MALAYSIAN CASSITERITES

The frequency distribution histograms of minor and trace elements in the Malaysian cassiterites drawn from the present study are given in Fig. 1. In addition, the distributions have been plotted on log-cumulative frequency as well as arithmetic-cumulative frequency diagrams in an attempt to see whether the distributions are normal or log-normal, and these are given in Figs. 2a-2h.

Examination of the frequency histograms shows that all the eight elements, Ti, Mn, Fe, Nb, Ta, W, Zr, and V have positively skewed distributions. Among them, Ta, Nb and Mn have strong positive skew whilst Fe, Zr, W, V and Ti are moderately skewed.

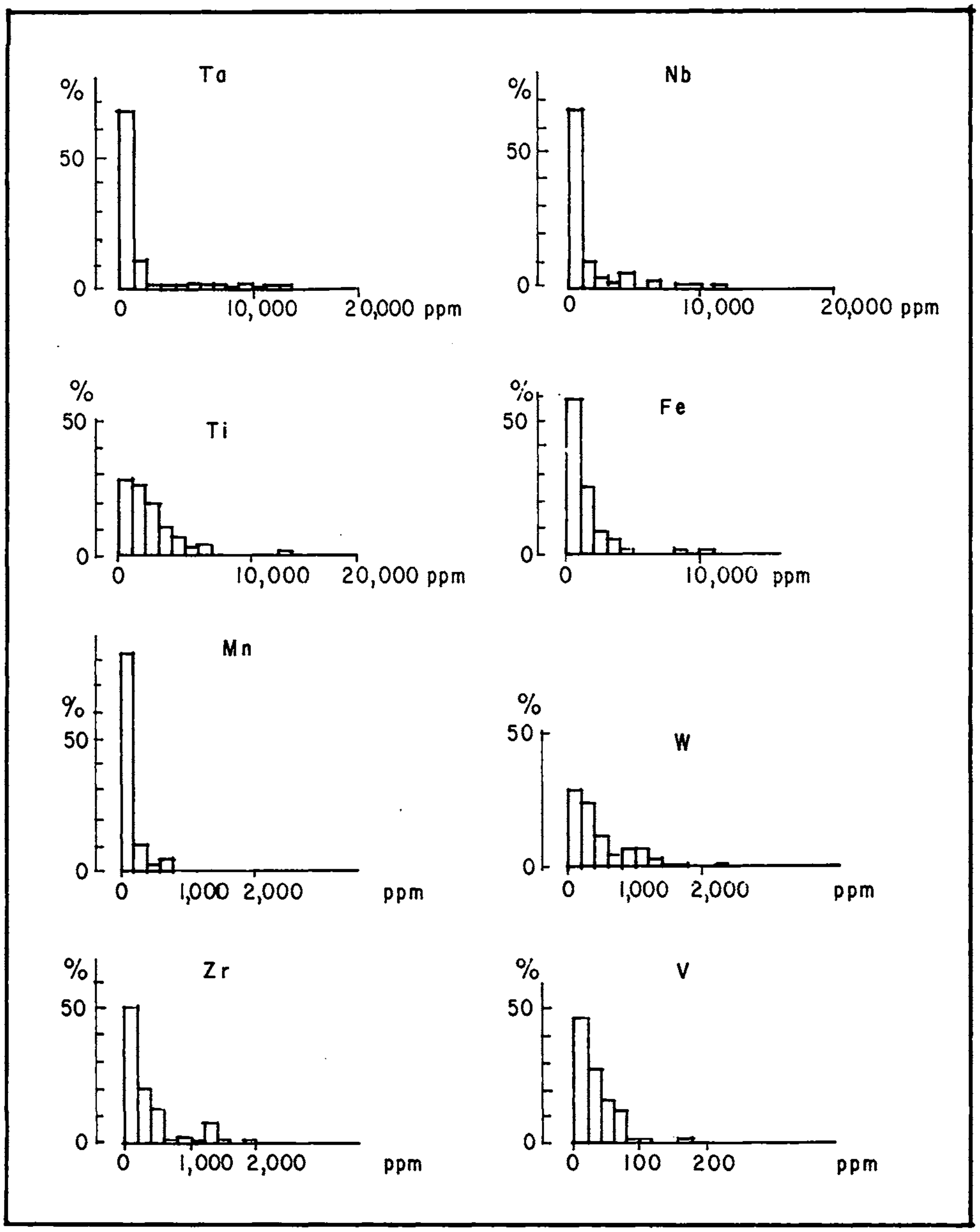

Fig. 1. Frequency distribution histograms of 8 minor and trace elements in Malaysian cassiterites.

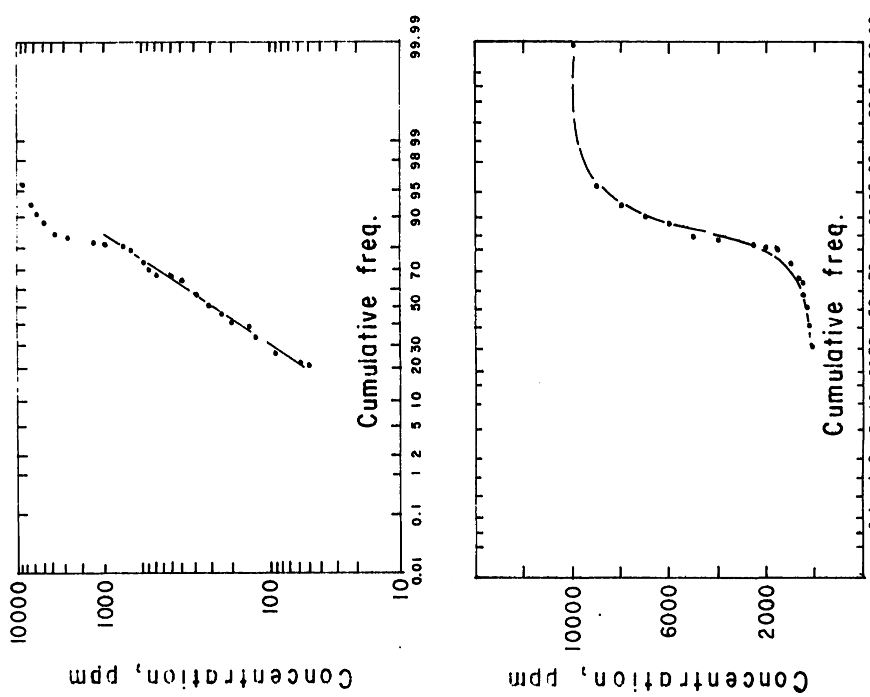

Fig. 2a. Cumulative frequency distributions of Ta

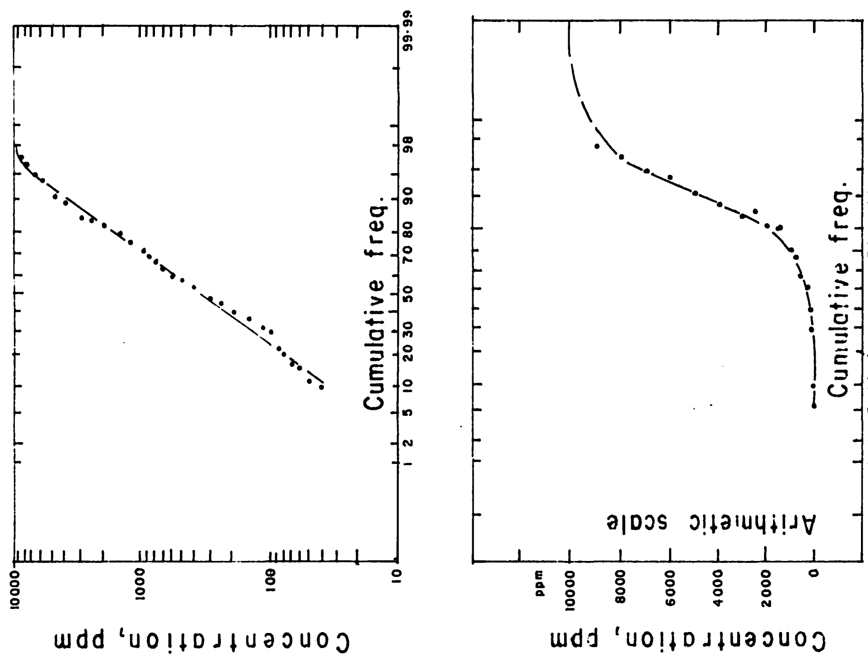

Fig. 2b. Cumulative frequency distributions of Nb

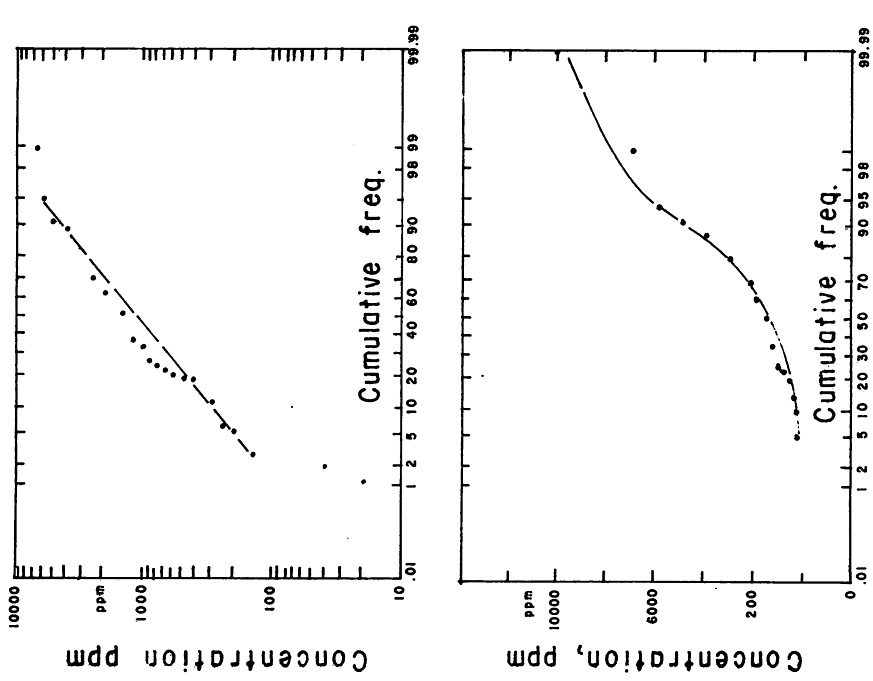

Fig. 2c. Cumulative frequency distributions of Ti

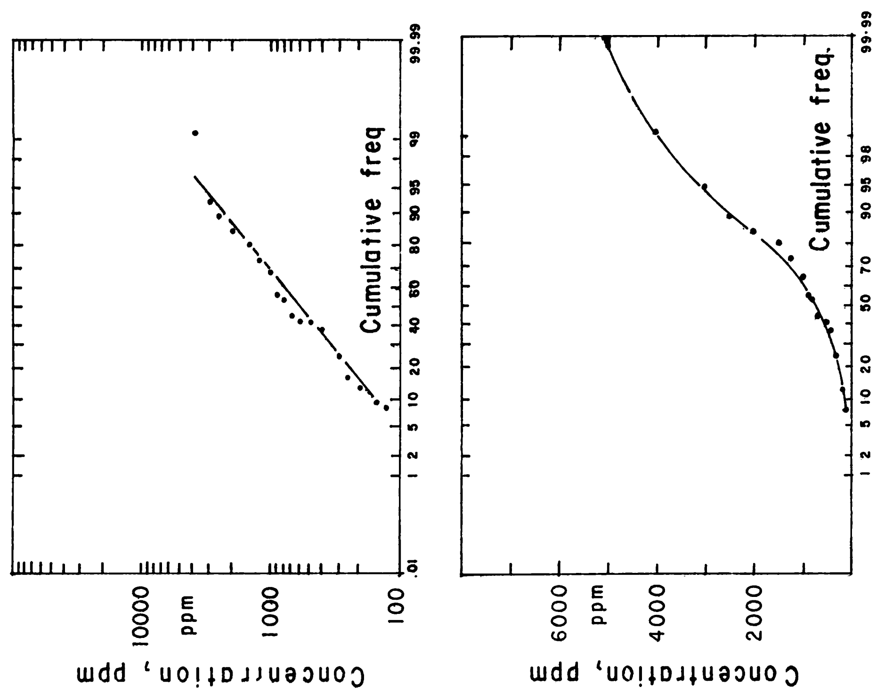

Fig. 2d. Cumulative frequency distributions of Fe

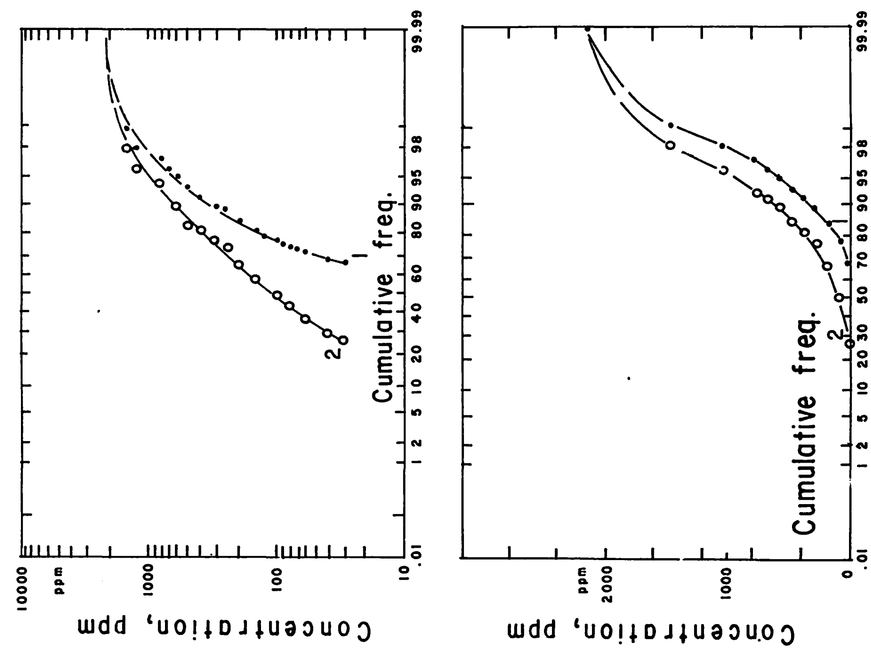

Fig. 2e. Cumulative frequency distributions of Mn

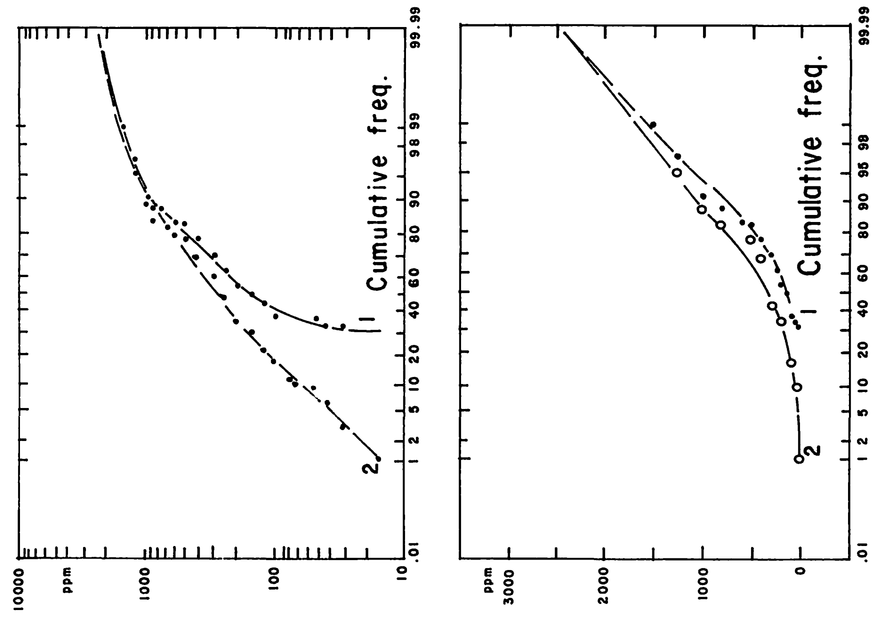

Fig. 2f. Cumulative frequency distributions of Zr

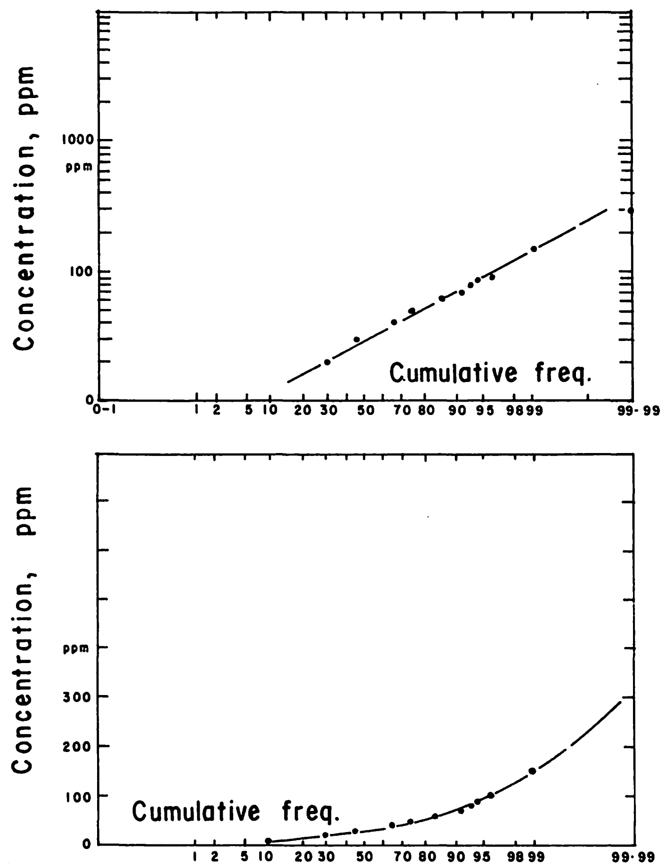

Fig. 2g. Cumulative frequency distributions of V

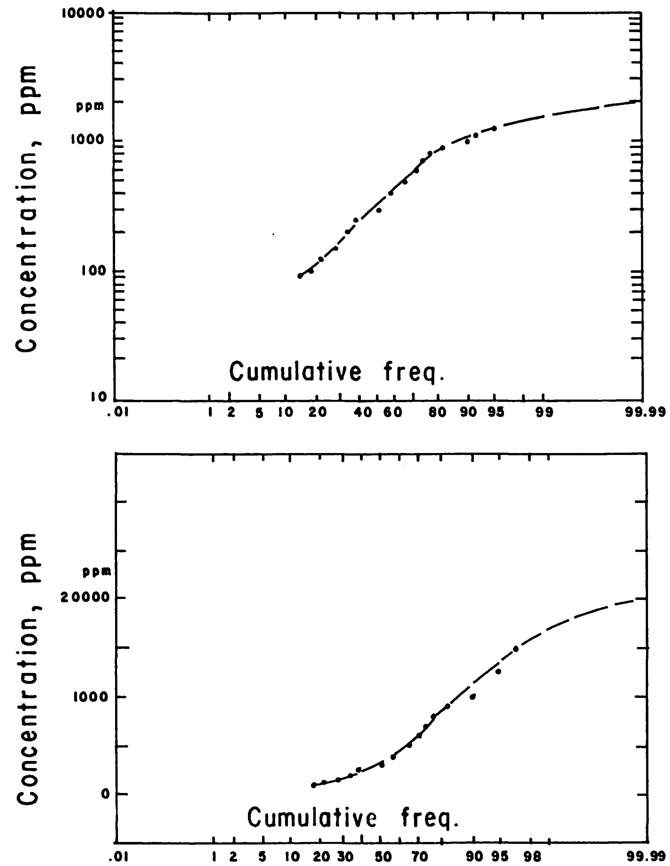

Fig. 2h. Cumulative frequency distributions of W

In both types of the cumulative-frequency distribution diagrams (Figs 2a-2h), it is observed that there is no true case of a log-normally distributed population amongst the eight elements, since in all of them, no perfect straight line is observed. These diagrams however show that Ta, Nb, Ti, Fe, V and to a certain extent, Mn, Zr, and W, have distributions which can be approximated to straight lines over large parts of their curves. By this approximation, the elements have distributions closer to log-normal rather than normal.

Further examination of the diagrams indicates that there are many minor undulations in the log-normal distribution curves of these elements. These undulations are most probably due to multipopulation nature of the distributions. Such a distribution is also seen in the frequency distribution diagrams (Fig. 1) of elements such as Ta, Nb, Zr, and W.

Thus log-normal distributions seem more common among the minor and trace elements in the cassiterites, because the majority of the specimens have low concentrations of these elements and the anomalously high ones are few. However, application of normal statistical methods to these distributions may only be valid to a limited extent. The overall distribution pattern of each element may be resolved into separate, smaller populations which individually may approach closer to the normal instead of log-normal distribution. On these normally distributed populations, ordinary statistical parameters, such as arithmetic mean and standard deviation, which are not applicable to log-normal distributions, may be applied. Clearly the risk of errors involved in the assumption of normality, even for the individually resolved population are different for each element.

MINOR AND TRACE ELEMENT CONTENTS IN CASSITERITES OF DIFFERENT CLASSES OF TIN DEPOSITS

In order to find relationship between the minor and trace element contents in the cassiterite and the types of depositional environment, the cassiterites have been arbitrarily grouped into the following classes based on the mineralogical content of associated minerals in the veins:

1. pegmatitic
2. hydrothermal
   a. greisenised vein
   b. quartz-wolframite ± tourmaline, sulphide
   c. quartz-tourmaline ± wolframite, sulphide
   d. quartz-chlorite ± tourmaline, sulphide
   e. sulphide-rich vein, lode or pipe
3. pyrometasomatic

The ranges and arithmetic means of 10 minor and trace elements in the Malaysian cassiterites, consisting of 19 pegmatitic, 36 hydrothermal and 3 pyrometasomatic cassiterites are summarised in Fig. 3. In addition, elements determined qualitatively are given in Table 2.

TABLE 2

QUALITATIVE CONTENTS OF TRACE ELEMENTS IN CASSITERITES
OF DIFFERENT CLASSES OF TIN DEPOSIT

Number	Field number	Mg	Ga	Sc	Bi	Al	Mo	Cu	Ag	Zn	Sb	Cd
1 Pegmatitic cassiterites												
1	K10.3	+				+	+	++		+		+
2	K11	+	+			++	+	+		++	+	++
3	K121	+				+	+	+		+		+
4	K122	+				+	+	+				+
5	K1·34	++				+		++		+	+	
6	B66	+				++	+	+		+		++
7	B67	+	+			++	+	+		++		++
8	B129	+				+	+	+		+	+	++
9	K55	+				+	+	+		+		++
10	K99	+	+	+		+	+	+	+	+	+	++
11	K130	++	+	+		++	+	+		+		
12	B114	+	+	+		++	+	+		++	+	++
13	B127	+	+	+		++	+	+		++	+	++
14	B137	+	+	+		++	++	++		+	+	+++
15	B46	++	+	++		++	+	+		++		++
16	B48	+		++		++	+	+		++		+
17	B49	+	+	++		++	+	+		++		++
18	B50	+		++		++		+		++		++
19	B51	+	+	+		++	+			++		+++
2 Hydrothermal Cassiterites												
20	B19	+				++		+		++		++
21	B27	+				++		+		++		++
22	K61	+	+			+		+				
23	K30	++		+		+		+		+		++
24	K100	+		+		+		+		+		+
25	B103	+		+		++				++		
26	K2	++	+			++		+		++		
27	K20	++				++		+		+		
28	K21	+	+		+	+		++	+	+		
29	B40	+				+		+		++	+	+
30	K71	+		+		+		+		+		
31	K67	+				+		++	+	+		
32	B115	+	+	+		++	+	+		++	+	++
33	B117	+		+	+	++		+	+	++		++
34	K135	+				++		+		++		+
35	B68	+				+		+				
36	B69	+				++		+		++		
37	B78	+	+			+		+		++		
38	B93	+	+	+	+	++		+		+		
39	B95	+		+	++	++		+	+			
40	B135	++				++		+		++		
41	K87	+			+	+		+	++	+		
42	K88	+		+		+		+		+	+	
43	K105	+				+		++	+	+		
44	K106	+				+			+			

TABLE 2 (contd.)

Number	Field number	Mg	Ga	Sc	Bi	Al	Mo	Cu	Ag	Zn	Sb	Cd
45	K107	++				++		++	+			
46	B105	+				++		+		++		
47	B112	++				++		+		++		
48	K103	++	+			+		++	+	+		
49	K125	++				++		+				
50	K131	+++				+		+				
51	B12	+	++		+	++		++				
52	B133	++				++		+			+	
53	B134	++	+			++		+		++	+	
54	B136	++		+		++		++		+	+	+
3 Pyrometasomatic cassiterites												
55	K104	++	+			++		++		+		
56	K120	+				+		+		+		
57	K128	+				+		+				

Note

Relative concentrations
+ low
++ medium
+++ high.

1. **Pegmatitic cassiterites**
   Nos. 1–8, Columbite-tantalite-rich pegmatite, Semiling
   Nos. 9–14, Columbite-tantalite-rich pegmatite, Bakri
   Nos. 15–19, Columbite-tantalite-poor pegmatite, Chenderiang

2. **Hydrothermal cassiterites**
   Nos. 20–25, Greisenised veins, mixed localities.
   Nos. 26–33, Quartz-wolframite ± tourmaline, sulphides, mixed localities.
   Nos. 34–40, Quartz-tourmaline ± wolframite, sulphides, mixed localities.
   Nos. 41–47, Quartz-chlorites ± sulphides, mixed localities.
   Nos. 48–54, Quartz-sulphides, mixed localities.

3. **Pyrometasomatic cassiterites**
   No. 55–57, mixed localities.

It is evident from Fig. 3 that differences in concentration of minor and trace elements exist among the cassiterites of different classes. These differences are strongly shown by Ti, Mn, Fe, Nb, Ta, Zr and W while V, Pb and In show only marginal difference. The differences are also noticeable from the elements determined qualitatively.

a. Pegmatitic cassiterites

Cassiterites from this class are noted for their contrastingly high contents of Ti, Nb, Ta, Fe, Zr and Mn (mean values of 3900, 6800, 6800, 3700, 1100 and 490 ppm, respectively) and low W contents (mean value of 180 ppm). The high values of minor

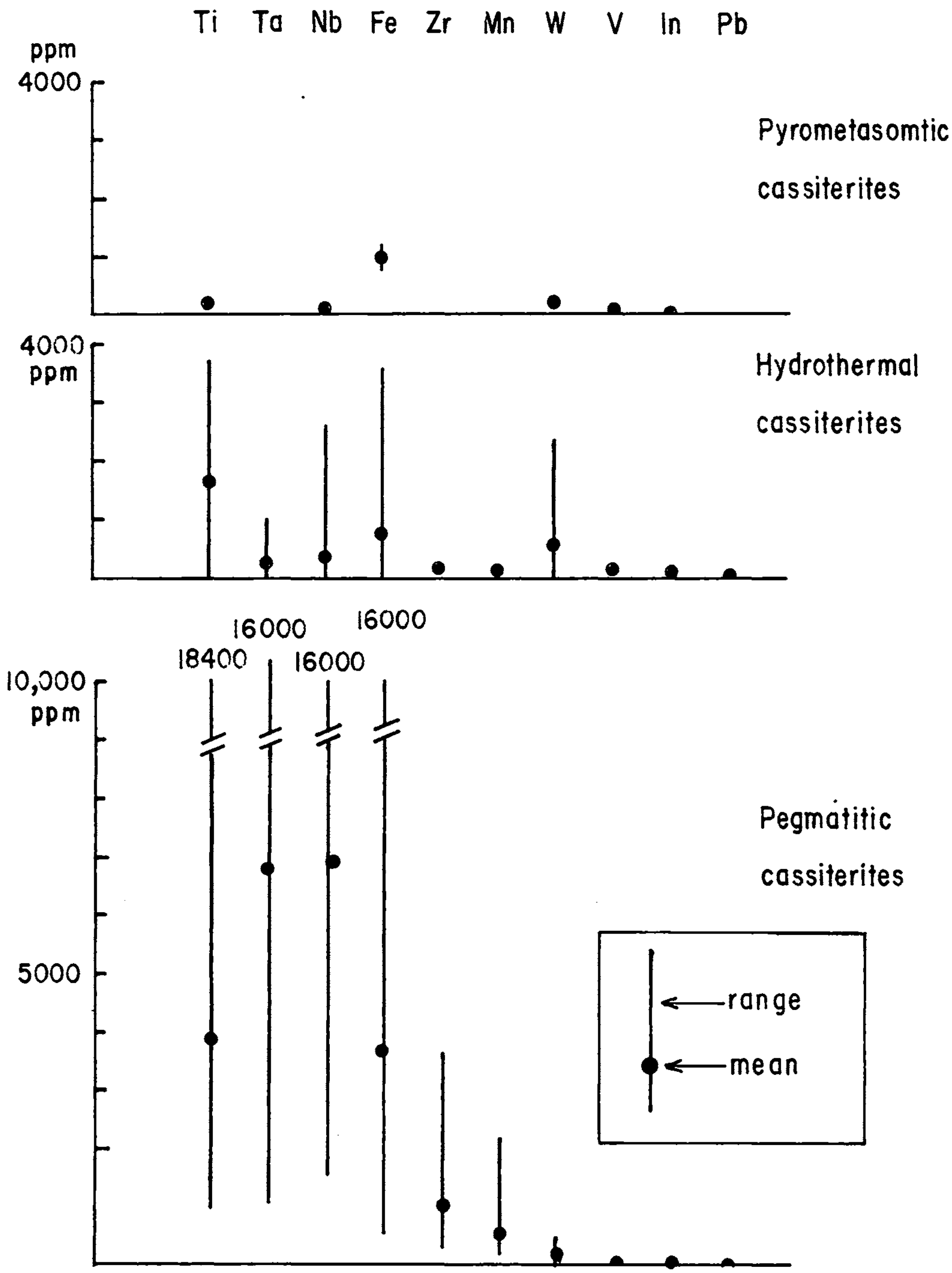

Fig. 3. Contents of minor and trace elements in pyrometasomatic, hydrothermal and pegmatitic cassiterites.

and trace elements in these cassiterites are comparable to those reported by earlier workers (Venugopal, 1952; Steveson and Taylor, 1973).

From qualitative determinations (Table 2), pegmatitic cassiterites apparently incorporated a large number of minor and trace elements, some of which are not detected in cassiterites of other classes. Mo for instance, is detected only in pegmatitic cassiterite, and Cd, Sc and Ga are more common in pegmatitic cassiterite than elsewhere.

The pegmatitic cassiterites can be further sub-divided into two sub-classes, based on their mineralogical contents: i) Semiling-Bakri type rich in columbite-tantalite. The Chenderiang cassiterites have significantly lower amounts of minor and trace elements than those of the Semiling-Bakri types. (Fig. 4). Ta, Nb, Fe, Zr and Mn contents in the Chenderiang types are two to five times lower than those in the Semiling-Bakri types. However, W shows an opposite trend; its content is four times higher in the Chenderiang pegmatitic cassiterite compared to those in the Semiling-Bakri type.

Qualitative determinations (Table 2) also show minor differences between the two types of pegmatitic cassiterites; Sb is common in the Semiling-Bakri cassiterites but is absent in the Chenderiang type.

b. Hydrothermal vein cassiterites

Cassiterites of this class have contents of Ti, Fe, Nb, Ta and Zr (mean values of 1500, 960, 230, and 110 ppm, respectively) of at least three times lower than those of the pegmatitic cassiterites, and W content of at least twice higher. Qualitative determinations show that Mo is absent, Pb is rare while V, Ga, Sc, Cd, In and Sb are fairly common.

The hydrothermal cassiterites have been further divided into 5 sub-classes, based on the mineral contents of the veins (Fig. 5). Among these sub-classes, the greisenised vein and wolframite-bearing vein types have high Ti, Fe, Nb, Ta and Zr contents, while the sulphide-rich type contains lower amounts of minor and trace elements in their cassiterites. Among the elements, Nb, Ta, and to a certain extent, Zr, show gradual decrease in contents. The Mn content in hydrothermal cassiterites is very low and in most cases, is below the limit of detection.

Ti and Fe, which are generally high in greisen, wolframite-bearing and chlorite-bearing veins, and low in the sulphide-rich and tourmaline-bearing veins, do not show variation similar to those of Ta, Nb and Zr.

W is concentrated in cassiterites of chlorite-bearing veins. The presence of W in the veins apparently has no effect on the W content of the cassiterites, as cassiterites from wolframite-bearing veins have much lower W.

c. Pyrometasomatic cassiterites

Tin deposits of the pyrometasomatic class are not common and in the present study, only three cassiterites specimens from this type were available for analysis.

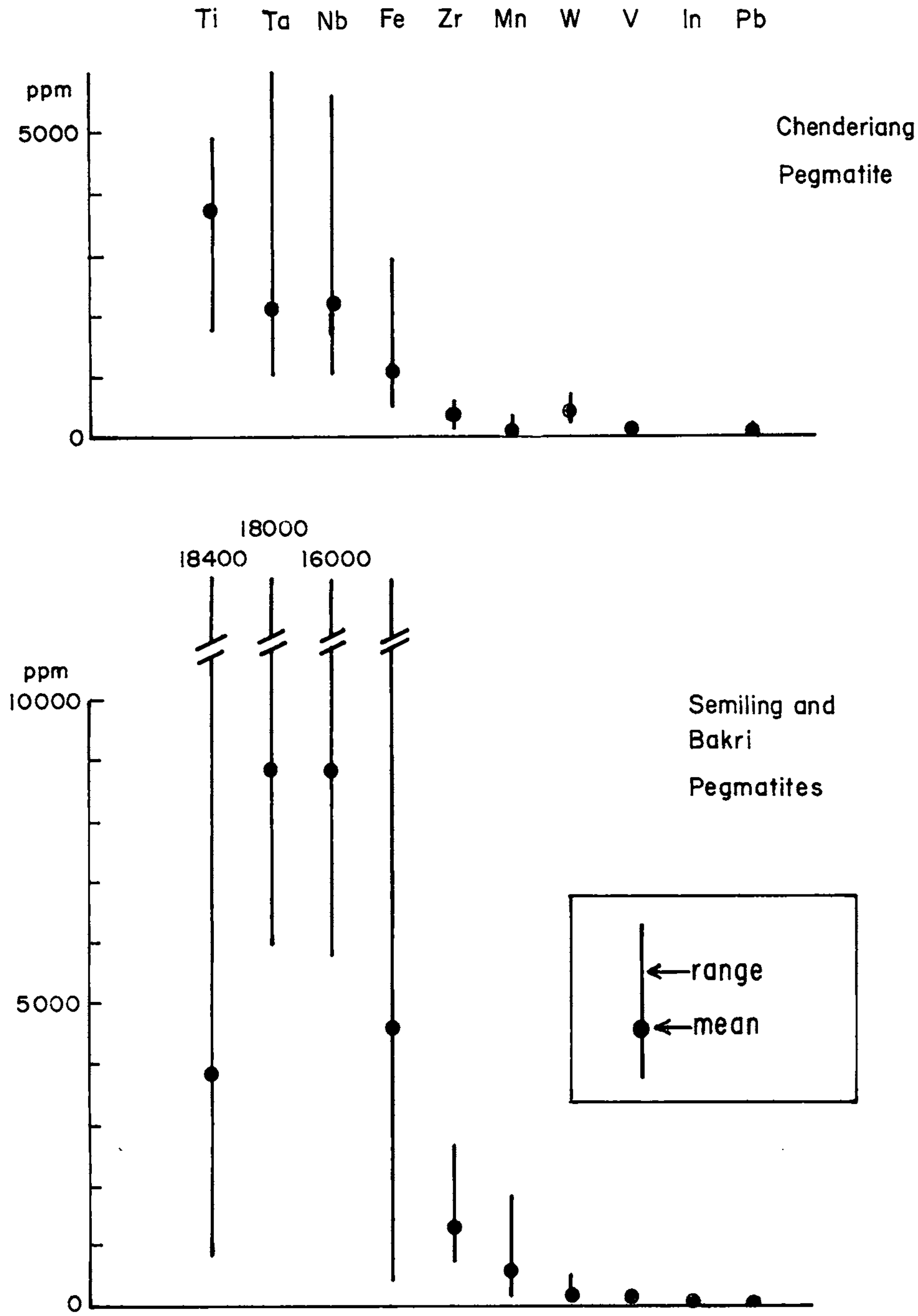

Fig. 4. Contents of minor and trace elements in Chenderiang and Semiling—Bakri pegmatitic cassiterites.

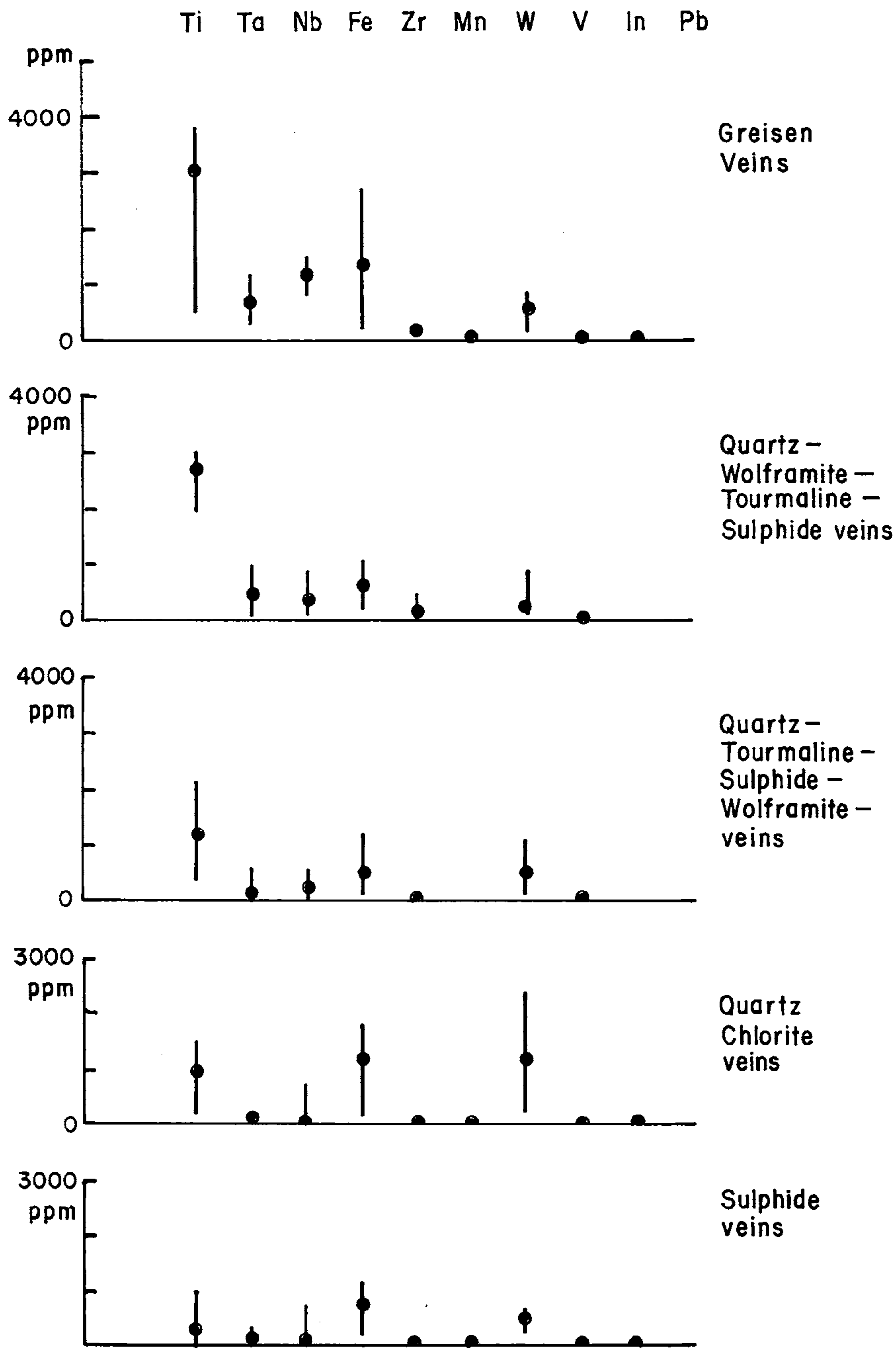

Fig. 5. Contents of minor and trace elements in different types of hydrothermal cassiterites.

From the thre analyses, it is observed that Nb, Ta, Mn and Zr concentrations in pyrometasomatic cassiterites are low (Nb-50 ppm while Ta, Mn and Zr were not detected), while qualitative determinations show that only V, besides the ubiquitous Mg, Al and Cu are present. These analyses indicate the pyrometasomatic cassiterite is not easily distinguishable from hydrothermal cassiterities.

Taking the cassiterites as a whole, it is seen that minor and trace element contents show characteristic distribution patterns. Fe, Ti, Ta, Nb, Mn and Zr tend to be concentrated in pegmatitic cassiterites and are very much lower in other classes. In the hydrothermal class, cassiterites from greisenised veins and wolframite-bearing veins have comparable high minor and trace element contents, whilst these are low in the cassiterites of the sulphide-rich veins and pipes.

The enrichment of minor and trace elements is clearly-related to the temperature-pressure conditions of the environment of deposition; the high temperature-pressure conditions of the pegmatitic tin deposits are conducive to the incorporation of minor and trace elements into their cassiterites, and in low temperature-pressure conditions, in the sulphide-rich veins and pipes, cassiterites are relatively free of minor and trace elements.

Fe, and Ti show less sensitivity than Nb, Ta, Mn and Zr to the temperature-pressure conditions. For instance, the mean Fe content in the sulphide-rich cassiterites is higher than those in the tourmaline-bearing vein cassiterites. Ti, which is generally high in pegmatitic cassiterites, may show low values, though the cassiterite contains high Ta, Nb, Mn and Zr.

COMPARISON OF MINOR AND TRACE ELEMENTS IN CASSITERITES OF VARIOUS TIN-FIELDS IN PENINSULAR MALAYSIA

It is evident from the previous section that minor and trace elements in the cassiterites of various classes of tin deposits show systematic variations, and Ta, Nb, Mn, Zr, and W were found to be the most diagnostic.

In the first part of this section, the minor and trace element contents of the cassiterites of the Western Tin Belt are compared to those of the Eastern Tin Belt. Such comparison is relevant since the granites in the two tin belts from which the tin deposits are generally to be genetically related, are shown to be geochemically and tectonically different from each other (Bignell, 1972; Hutchison, 1977; Yeap, 1980). In the second part of the section, the major differences in the minor and trace elements contents of the cassiterites of various tin-fields are discussed.

i. Comparison of minor and trace elements contents in cassiterites from Western and Eastern Tin Belts of Peninsular Malaysia.

The ranges and arithmetic means of minor and trace elements in cassiterites of Western and Eastern Tin Belts are given in Table 3. From the columns of arithmetic mean values, and taking into consideration the ranges and the number of samples in the groups, it is evident that real differences exist between the minor and trace element content of the cassiterites of the two belts. Comparing the mean values of minor and

TABLE 3

COMPARISON OF TRACE ELEMENT CONTENTS IN CASSITERITES FROM WESTERN AND EASTERN TIN BELTS OF PENINSULAR MALAYSIA

Elements	a) All Western Tin Belt cassiterites				b) Non-pegmatitic Western Tin Belt cassiterites				c) All Eastern Tin Belt cassiterites			
	No. of samples n_1	No. of samples n_2	Range ppm	Arithmetic means	No. of samples n_1	No. of samples n_2	Range ppm	Arithmetic means	No. of samples n_1	No. of samples n_2	Range ppm	Arithmetic means
Ti	2	83	100–12400	2800	-	65	100–7500	2600	1	26	100–4400	1500
Mn	39	46	30– 2200	310	43	22	30– 700	200	27	-	below detect.	limit
Fe	-	85	1– 4400	1000	-	65	1–3000	640	2	25	1–4000	1900
Nb	4	81	30–12000	1800	2	63	30–4600	910	2	25	30– 950	240
Ta	16	69	100–12000	2400	15	50	100–5100	830	9	18	100– 500	200
W	8	77	100– 1800	420	-	65	100–1800	440	1	26	100–2400	1100
Zr	17	68	30– 2600	530	20	45	30–1300	350	16	11	30– 320	200
V	28	57	10– 170	40	18	47	10– 170	40	5	22	10– 65	55
In	73	12	30– 100	55	56	9	30– 100	45	24	3	30– 45	40
Pb	67	18	30– 60	35	55	10	30– 60	40	22	50	30– 130	160

n_1—number of samples with element content below limit of detection
n_2—number of samples with element content within limit of detection

trace elements of all the Western Belt cassiterites, with those of the Eastern Belt cassiterites (Table 3), it is observed that Nb, Ta, Mn and Zr are mainly concentrated in the Western Belt cassiterites, while W shows the reverse trend.

It was observed earlier that Nb, Ta, Mn, Zr and W are sensitive to temperature-pressure conditions of deposition of cassiterites. Nb, Ta, Mn and Zr are highest in pegmatitic cassiterites which are formed under higher temperature-pressure conditions, while W is lowest in pegmatitic cassiterites. Hence, the relatively high concentrations of Nb, Ta, Mn and Zr in the Western Belt cassiterites suggest that these cassiterites were deposited in relatively higher temperature-pressure environment, possibly due to deeper emplacement, compared to the Eastern Belt cassiterites.

The mean values of minor and trace elements in non-pegmatitic cassiterites of the Western Tin Belt, when compared with those of the Eastern Tin Belt, show that Nb, Ta, Mn and Zr values are higher in the former. This suggests that in the Western Belt relatively high minor and trace element contents are found not only in pegmatitic cassiterites but are also in hydrothermal vein cassiterites.

ii. Comparison of minor and trace elements in cassiterites of various tin-fields of Peninsular Malaysia.

The spatial distributions of five elements Ta, Nb, Mn, Zr and W in the cassiterites from various tin-fields of Peninsular Malaysia are shown in Fig. 6a-6f, and a summary of the concentrations is given in Table 4.

Tantalum

It is observed from Fig. 6b that cassiterites with high Ta contents (> 1000 ppm) are confined to the Western Belt, while those in the Eastern Belt are generally below 1000 ppm. Among the tin-fields in the Western Belt, Bakri has the highest mean value (9400 ppm, No. 17, Table 4), followed by Semiling (8500 ppm, No. 3 of Table 4) and Chenderiang (1200 ppm, No. 9, Table 4). Mean Ta values in cassiterite concentrates of unknown origin from Selim, Kelian-Kalumpang and Sintok (Fig. 6b) based on 2 to 3 analyses of each also indicate high values comparable to those of Chenderiang, but others form Segari and Selama, though having high values, may not be reliable as each of them is only based on a single analysis.

In the Kinta Valley, the northwestern part has low Ta contents (below 100 ppm) but these increase slightly along the eastern part (mean of 300 ppm) and towards the south.

Cassiterites from Kuala Lumpur tin-field are also characterised by low Ta. Those from the northern part of the field have a mean value of 400 ppm (No. 14 (a), Table 4). Hutchison (1978) reported isolated areas with high Ta values in the Kuala Lumpur cassiterite concentrates. In the present study, the cassiterite from Yew Hing Mine, on Ulu Langat road was found to contain 1000 ppm Ta.

In the Eastern Tin Belt, where Ta content in the cassiterites is generally low, the highest mean value is 360 ppm from Gambang.

TABLE 4

ARITHMETIC MEANS OF 5 MINOR AND TRACE ELEMENTS IN CASSITERITES FROM THE VARIOUS TINFIELDS OF PENINSULAR MALAYSIA (PPM)

Elements	Number	1	2	3	4	5	6	7	8(a)	8(b)	8(c)	9	10	11	12	13
	No. of analyses	3	2	8	1	2	1	2	6	2	2	5	5	3	3	3
Mn		490	n.d	950	100	250	30	n.d.	n.d.	n.d	n.d	100	60	90	450	n.d
Nb		2400	400	7000	1100	2900	2600	60	90	70	440	1400	1800	2200	3900	390
Ta		1000	500	8500	1400	3700	1200	100	n.d	100	430	1200	880	1400	4000	470
W		180	220	170	400	100	400	610	480	670	140	420	1000	360	410	280
Zr		310	160	1200	400	1100	500	n.d	n.d	n.d	100	400	430	580	1100	240

n.d. = not detected

Number	Locality	Number	Locality
1	Sintok	8(a)	North West Kinta Valley
2	Baling	8(b)	North East Kinta Valley
3	Semiling	8(c)	Southern Kinta Valley
4	Selama	9	Chenderiang
5	Taiping	10	Tapah—Bidor
6	Segari	11	Selim
7	Klian Intan	12	Kelian—Kalumpang
8	Kinta Valley	13	Serendah—Ulu Yam

TABLE 4 (contd.)

Elements	Number	14(a)	14(b)	14(c)	14(d)	14(e)	15	16	17	18	19	20	21	22	23	24	25
	No. of analyses	6	9	3	9	1	2	3	6	2	2	2	4	4	9	1	1
Mn		30	n.d	n.d	n.d	90	n.d	140	210	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Nb		380	390	500	270	1500	250	930	5100	260	260	140	680	50	100	50	40
Ta		400	240	200	100	1000	270	980	9400	n.d	300	140	360	100	100	n.d	n.d
W		250	600	200	570	210	690	80	n.d	190	1100	2000	950	1500	1100	1100	1500
Zr		200	60	30	40	290	240	310	1200	n.d	170	n.d	180	n.d	40	n.d	n.d

n.d. = not detected

Number	Locality	Number	Locality
14	Kuala Lumpur	18	Pelepah Kanan
	(a) Kuala Lumpur north	19	Jemaluang
	(b) Puchong—Sg. Way—Subang	20	Bukit Payong
	(c) Ampang—Kapong Pandan	21	Gambang
	(d) Sungei Besi—Salak South	22	Sungei Lembing
	(e) Cheras—Ponsoon Road	23	Bandi
15	Bentong—Karak	24	Bukit Tulis, Paka
16	Titi	25	Bukit Besi
17	Bakri		

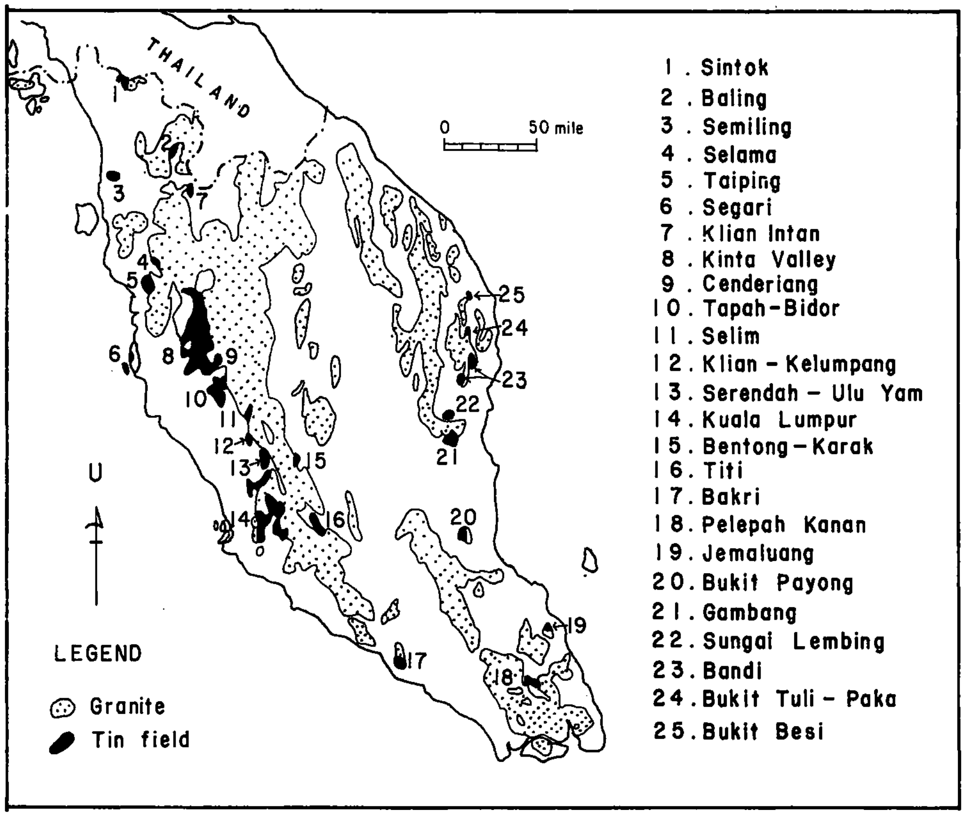

Fig. 6a. Distribution of Tinfields in Peninsular Malaysia

Niobium

Niobium shows a systematic relationship to Ta; thus areas with high Ta content in their cassiterites coincide with those of high Ta content (Fig. 6c). Cassiterites of unknown origin from Taiping, Selim, Kelian-Kalumpang and Sintok, observed previously to contain high Ta, are also found to have high Nb.

Manganese

Manganese also follows a similar pattern f distribution to that of Ta and Nb, with high values in the Western Belt approximately coinciding with those of Ta and Nb (Fig. 6d). Kinta Valley evidently has very low Mn (mostly below the limit of detection) and in the Kuala Lumpur tin-field, Mn values are barely above the detection limit. In the Eastern Belt, Mn values are generally below detection limit.

Zircon

Zircon also shows an approximately similar pattern of distribution to that of Ta,

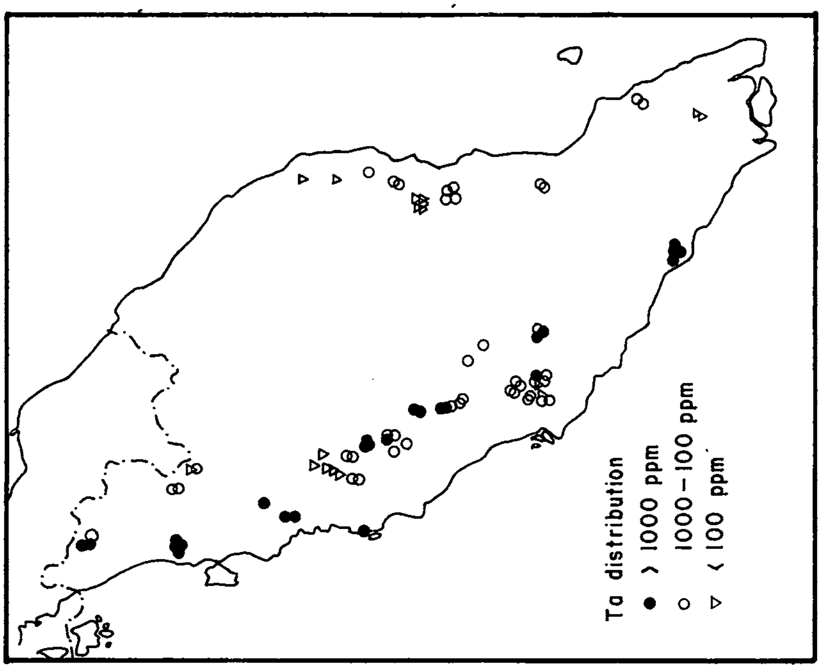

Fig. 6b. Ta distribution

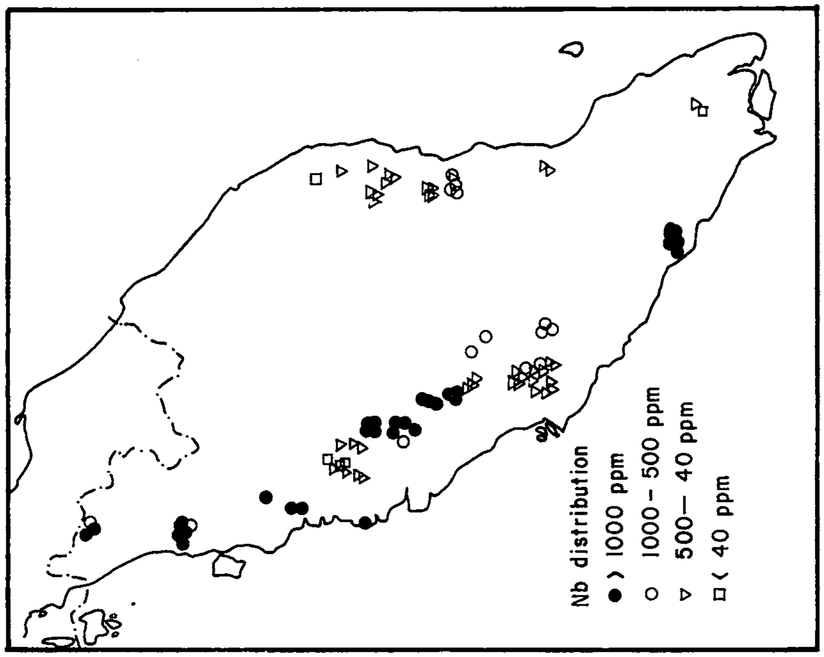

Fig. 6c. Nb distribution

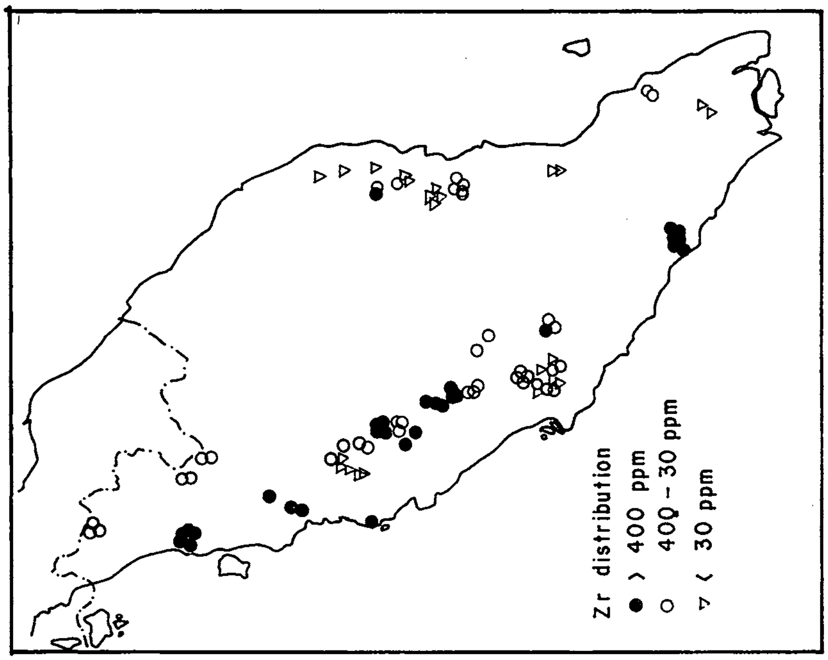

Fig. 6e. Zr distribution

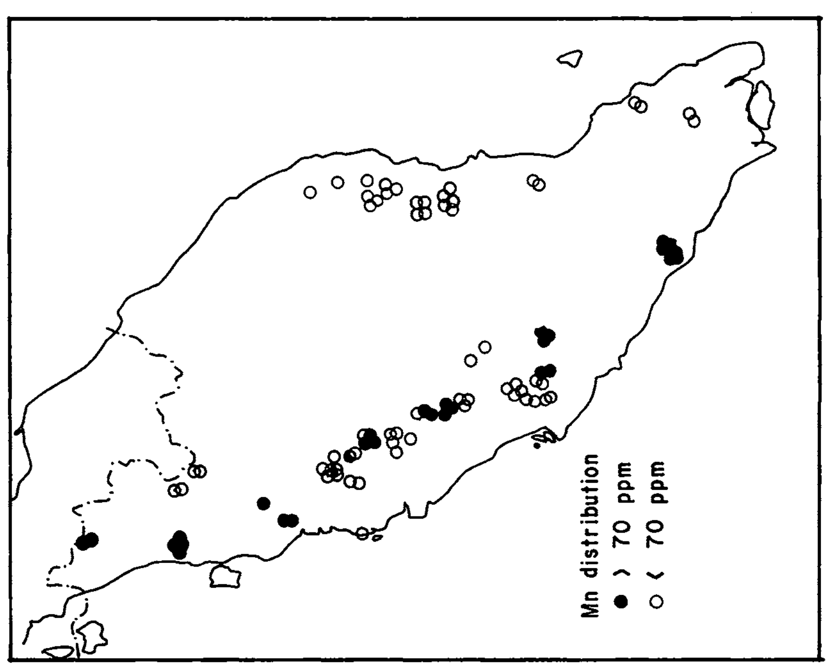

Fig. 6d. Mn distribution

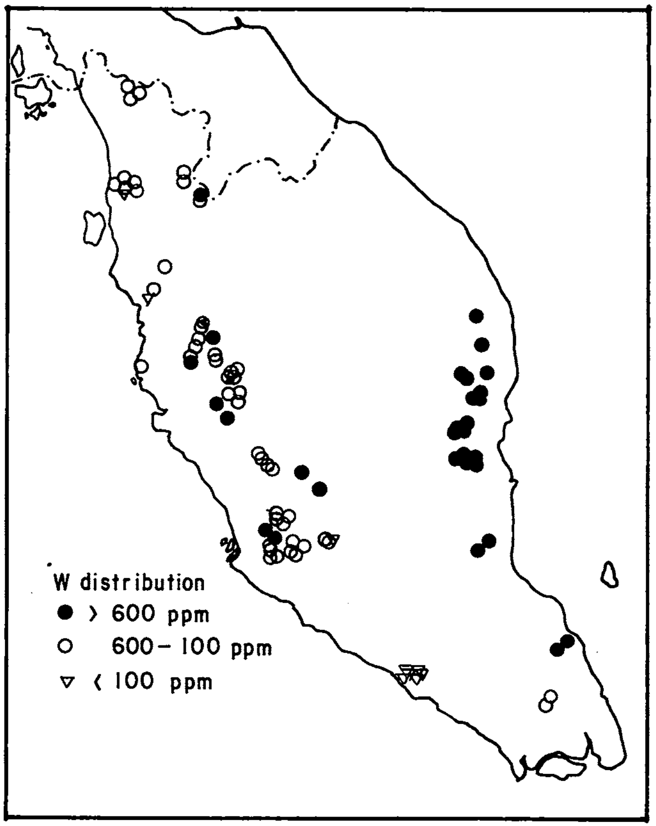

Fig. 6f. W distribution

Nb and Mn (Fig. 6e), with peak values in the Semiling and Bakri cassiterites and low values from Kuala Lumpur, Kinta Valley and the Eastern Belt.

Tungsten

In contrast to Ta, Nb, Mn and Zr, W shows a different pattern of distribution; an antipathetic variation compared to the other elements. Hence in the deposits that are high in Ta, Nb, Mn and Zr, W is low, and vice versa. W is not detected in any of the specimens from Bakri, is low in Semiling, and in other Western Belt areas where Ta and Nb values decrease, W tends to increase. In the Eastern Belt, where Ta and Nb are low, W is generally high (Fig 6f).

From the geographical distributions of Ta, Nb, Mn, Zr and W, it is observed that tin-fields of Selama, Taiping, Tapah, Bidor, Selim, Klian-Kelumpang and Titi have Ta, Nb, Mn and Zr contents in their cassiterites similar to that of Chenderiang. This implies that in those areas, pegmatites similar to those of Chenderiang, with relatively poor columbite-tantalite content, may be found.

NATURE OF OCCURRENCE OF THE ELEMENTS IN THE CASSITERITES

Ta, Nb, Mn and Zr

Data from U.V. spectrosocpic analysis of the cassiterites indicate concentrations of Ta, Nb, and Zr are generally in sympathetic relationship. A high concentration of Ta in a cassiterite is usually accompanied by high concentrations of Nb, Mn and Zr, and vice versa.

Microprobe examinations (Hassan 1982) revealed that Ta, Nb and Mn occur in 4 forms:

a. as solid solution in cassiterites

b. as exsolution bodies of columbite, tantalite and tapiolite

c. as included columbite-tantalite

d. as Nb-Ta rutile

Although Zr was not determined by the microprobe, its sympathetic behaviour towards Ta, Nb and Mn is apparent from the spectroscopic analysis. The fact that it is reported as a common element in most columbite-tantalites (Fadipe 1980) also suggests that part of the Zr is present in the columbite-tantalite bodies.

The exsolved and included bodies of columbite-tantalite are common in the highly magnetic pegmatitic cassiterites. It is rare in the non-pegmatitic greisen and other vein cassiterites. Hence, it may be inferred that while anomalous concentrations of Ta, Nb, Mn and Zr in the pegmatitic cassiterites are due to the columbite-tantalite bodies, in the non-pegmatitic cassiterities, these elements psrobably occur in solid-solution.

Titanium

It was revealed by microprobe analysis (Hassan 1982) that Ti in the cassiterites was present in the following forms:

a. as Nb-Ta rutile and ordinary rutile

b. as ilmenite

c. as solid solution

Rutile grains in the cassiterites are thought to be undigested inclusions (Leube and Stumpl, 1963). Ilmenite, from its intimate relationship with the exsolved columbite-tantalite, may have exsolved from the cassiterite. The presence of rutile inclusions that have no genetic relationship must have accounted for the erratically high Ti contents in the cassiterites.

Iron

Fe in the cassiterites has been shown to exist in 5 forms in the cassiterites:

a. as solid solution with the cassiterites

b. as included magnetite

c. as part of the columbite-tantalite and tapiolite bodies

d. as ilmenite

e. as Nb-Ta rutile

In the highly magnetic pegmatitic cassiterites, all the forms of iron present were observed, but in the non-pegmatitic cassiterites exsolution and inclusion bodies were rarely observed and iron mainly occurred in solid solution.

Like Ti, Fe distribution is erratic, and this behaviour may be due to two reasons:

a. presence of included magnetites, especially in the deposits associated with iron ore

b. presence of high Fe in solid solution, exemplified by 'ferromagnetic' cassiterites, and these cassiterites are not specifically related to any one kind of tin deposit.

Tungsten

W is present in the cassiterite in two forms, viz., as solid solution and as mineral inclusions. It has been concluded (Hassan 1982) that W is present in solid solution in the cassiterites, because, from microprobe analysis most of the clean, inclusion free cassiterites contain small amounts of W. Presence of W as mineral inclusion in the cassiterites has been reported by other workers (Moore and Howie 1979).

CONCLUSIONS

The following conclusions are derived from the present work:

1. Statistical distributions of minor and trace elements in the Malaysian cassiterites are lognormal and positively skewed, with only a small fraction of the samples having high concentrations of the elements. These came from pegmatitic cassiterites of Bakri and Semiling.

2. Contents of minor and trace elements in Malaysian cassiterites agree with the findings of previous workers. Very high values of the elements Nb, Ta, Fe, Ti, W, Zr and Mn were found in pegmatitic cassiterites. In hydrothermal cassiterites, the elements are highest in the greisenised veins and decreased towards the wolframite vein, tourmaline vein, chlorite vein and finally the sulphide vein.

3. Pyrometasomatic cassiterites are rather low in the trace and minor elements but they could not be differentiated from the chloritic or sulphidic vein cassiterites.

4. Cassiterites from the Western Belt tin-fields are generally higher in Nb, Ta, Mn and Zr contents, whereas the Eastern Belt cassiterites are generally richer in W. This difference may reflect the overall difference in geochemistry of the source material and the tectonic environment of emplacement of the ore deposits in the two belts.

5. In comparing the minor and trace element contents in the alluvial cassiterites of uncertain origin, there are indications that the tin-fields of Selama, Taiping, Tapah, Bidor, Slim River, Klian-Kelumpang and Titi are similar to the tinfield in which the Chenderiang pegmatites have been found.

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REFERENCES

BIGNELL, J.D., 1972. *The geochronology of the Malayan Granites.* Unpubl. D. Phil. thesis, Univ. of Oxford, 323 p.

DUDYKINA, A.S., 1959. Paragenetic association of trace elements in cassiterites of various genetic type of tin deposits. *Trudy. Inst. Geol. rudn., Mestorozh.,* 28, 111–121. English Abst. in Chem. Abst., 15, 1961–1962, 105.

FADIPE, A.A., 1980. *The geochemical and mineralogical aspects of Niobium-Tantalum mineralization in African pegmatites.* Unpubl. Ph. D. thesis, Univ. of Leeds.

HASSAN, W.F.T., 1982. *Aspects of geochemistry and mineralogy of tin and associated minerals in the Malaysian tin-fields.* Unpubl. Ph. D. thesis, Univ. of Leeds.

HUTCHISON, C.S. 1977. Granite emplacement and tectonic subdivisions of Peninsular Malaysia. *Bull. Geol. Soc. M'sia,* 9, 187–207.

HUTCHISON, C.S., 1978. The impurities of S.E. Asian tin-ore concentrates. *Geol. Soc. M'sia Newsletter,* 4, 39–43.

LEUBE, A. and STUMPFL, E.F., 1963. The Rooiberg and Leeuwport tin mines, Transvaal, S. Africa. *Econ. Geol.,* 58, 391–418.

MOORE, F., and HOWIE, R.A., 1979. Geochemistry of Some Cornubian cassiterites. *Miner. Deposita* 14, 103–107.

STEVESON, B.G., and TAYLOR, R.G., 1973. The trace element content of some cassiterites from Eastern Australia. *Proc. Roy. Soc. Queensland,* 84, 43–54.

VENUGOPAL, K., 1952. *Trace elements in cassiterites and stannites.* Unpubl. Ph. D. thesis, Royal School of Mines, London.

YEAP, C.H., 1980. *A comparative study of Peninsular Malaysia granites with special reference to tin mineralisation.* Unpubl. Ph. D. thesis, Univ. of Malaya. 395 p.

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