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Niobium-Tantalum minerals from Peninsular Malaysia

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Abstract: Niobium-Tantalum minerals found in concentrates and heavy minerals from Peninsular Malaysia have been studied, and their mode of occurrences described. Chemical compositions were determined mainly by Electron-probe microanalysis, but X-ray fluorescence method has also been applied. From the study, columbite-tantalite, Nb- Ta- rutile, wodginite and fersmite have been recognised. Their geographical distribution and geochemical compositions were delineated.

INTRODUCTION

Nb-Ta minerals, predominantly grouped under columbite, have been important as a by-product of tin-mining operations from certain parts of Peninsular Malaysia. Its production has been recorded as early as 1950. Available statistics indicated that the annual production for the peninsula in 1950 was 8 tons, reaching maximum production period in the middle fifties with 1956 production at 276 tons. Columbite production in the peninsular has however declined since and the total annual production has seldom exceeded 90 tons.

METHODS OF ANALYSIS

This study is based mainly on Nb-Ta- bearing minerals found in the heavy mineral fractions of alluvial deposits, obtained either as mine concentrates or panned stream sediments. Cleaning of the mineral samples were made by leaching the grains in aqua-regia over a water-bath for at least two hours, drying them in an oven and for maximum purity the grains were hand-picked under a binocular-microscope.

The analyses were mainly made using a JOEL JXA-50A wave-length dispersive Electron-probe Microanalyser, based on widely accepted procedures (e.g. Sweatman and Long, 1969; Wright, 1973). ZAF data correction was made on-line using a modified version of FRAME (Yakowitz, *et al.*, 1973). Supplementary bulk analyses were made using XRF technique, using Phillips pw 1400 fully automatic machine, based on XRF method for Nb-Ta minerals used by Kallman (1964) and Eddy *et al.* (1974).

The Nb-Ta-bearing minerals

In the present study, the following Nb-Ta-bearing minerals have been recognised:
1. Columbite-tantalite
2. Nb-Ta rutile
3. Nb-Ta minerals in cassiterites

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4. Wodginite
5. Tapiolite
6. Fersmite

Fergusonite, a rare-earth-bearing niobate, has also been observed but it was not analysed due to certain limitation of the Electron-probe.

Columbite-tantalites (Fe, Mn) (Nb, Ta)$_2$O$_6$

This is the commonest and most widespread group of Nb-Ta minerals found in granite pegmatites and as accessory in certain alkali granitic rocks. In Peninsular Malaysia, significant Columbite-tantalite occurrences are confined mainly in two areas; Semiling in Kedah and Bakri in Johor. Here it is found in association with cassiterite, gahnite, green monazite, garnet and other usual minerals in granitic pegmatites of probably Upper Carboniferous age. Mineralised pegmatites from other parts of the peninsula are not known to have similar Columbite-tantalite mineralisation. Chenderiang area near Kinta Valley, generally known for its cassiterite-topaz-bearing pegmatites, has only traces of columbite-tantalite from one of the mines. In other parts of the peninsula, this mineral is rare and only traces of it were observed from certain localities, e.g. Kuala Dipang, Taiping, and Kuala Lumpur. It is particularly rare in the East Coast Tin Belt as not a single grain of it has been observed in the samples collected.

Columbite-tantalite samples from Bakri, Semiling, Kinta Valley and Kuala Lumpur areas have been analysed using an electron micro probe, the result of which is given in Table 1.

The chemical composition of the columbite-tantalite (Table 1) shows the predominance of Nb over Ta in most analyses, except in analy. no. 5, 6, and according to known classification (Palache *et al.,* 1957, Von Knorring et al., 1981), they are columbite. In analy. no. 5 and 6, Ta is predominant (Nb: Ta atomic ratios are .64 and .98 respectively) hence they are a tantalite. Iron and manganese contents are also variable and there is a predominance of Fe except for analy. no. 5, 6. Among minor elements titanium and tungsten are commonly present, sometimes in significant amounts. In the samples from Kinta Valley and Kuala Lumpur areas (analy. 7, 8, 9), titanium and tungstenian columbite have been observed. Substitution of W^{6+} for $(Nb, Ta)^{5+}$ in the columbite structure is in some cases compensated by the incorporation of Ti^{4+} and hence the presence of moderately high titanium content in the tungstenian columbites.

Nb-Ta rutile

The alluvial samples examined indicated that Nb-Ta rutile is mainly confined to the Western Tin Belt. It is rather common and found in small quantities in the tin fields to the north of Kuala Lumpur, but is rather scarce in the Kuala Lumpur tin fields and to its south.

This mineral is rather magnetic, and separation from the heavy mineral fraction is effectively made using a magnetic seperator. Normally it is collected in the magnetic

TABLE 1

ELECTRON-PROBE MICROANALYSES OF COLUMBITE-TANTALITES

Analy. No.	1	2	3	4	5
TiO_2	1.24	1.20	.70	1.01	.00
MnO	2.99	3.43	3.10	4.85	14.16
FeO	14.84	16.07	15.13	12.62	1.57
Nb_2O_5	74.84	72.21	69.16	57.59	22.91
SnO_2	.07	.06	.12	.44	.14
Ta_2O_5	6.21	7.55	10.98	19.39	60.07
WO_3	.20	.01	1.0	2.72	.00
Total %	100.42	100.53	100.19	98.62	98.84
	6	7	8	9	10
TiO_2	.00	.94	7.25	2.57	.43
MnO	15.92	7.66	5.20	7.24	5.62
FeO	.01	9.53	13.09	13.26	13.77
Nb_2O_5	30.80	47.02	43.63	42.63	47.01
SnO_2	.67	.68	4.12	.97	.12
Ta_2O_5	52.17	27.69	21.34	28.16	33.40
WO_3	.00	4.01	4.87	4.76	.08
Total	99.56	99.53	99.51	99.59	100.43

1, 2 Columbite, Bakri Quarry, Bakri
3 Columbite, Wei Yip Mine, Bakri
4 Columbite, Soon Lee Mine, Bakri
5, 6 Mn-tantalite, Bakri Mining Co, Bakri
7 Columbite, Yew Hing Mine, Ponsoon Road, Kuala Lumpur
8 Tungstenian Columbite, French Tekka, K. Dipang
9 Tungstenian Columbite, Poh Wan Mine, K. Dipang
10 Ferro-columbite, Foong Seong Mine, Semiling

TABLE 2

X-RAY FLUORESCENCE ANALYSES OF Nb-Ta RUTILES

Analy. No.	1	2	3	4
Magnetic fraction (amps)	0.5	0.6	0.7	0.8
TiO_2	62.82	54.21	69.41	77.08
MnO	1.19	1.10	.50	.30
FeO	12.54	8.42	5.99	4.80
Nb_2O_5	11.18	14.55	11.51	9.31
SnO_2	4.39	4.69	3.60	3.78
Ta_2O_5	7.94	14.88	9.24	5.39
WO_3	.74	.97	.82	.82
ZrO_2	.04	.08	.04	.04
Total %	100.84	98.90	101.11	101.52
Ta:Nb	.71	1.02	.80	.58

Samples from Kampong Gajah, Kinta Valley.

fraction between 0.4–0.8 amps with the separator settings set at 15° forward slope and 10° side tilt. Its magnetic property is mainly due to the iron content, and could be seen in the analyses (Table 2).

Except for specimens from Chenderiang and Salak North, the Nb-Ta rutiles are found as tiny grains of less than 2 mm maximum dimension. The specimen from Chenderiang and Salak North probably associated with the pegmatites of these areas, are found as pebble-sized grains, often inter-growned, with cassiterites.

The present specimens show that Nb-Ta rutile assumes many different crystal habits. In the undistorted type, it displays bipyramidal and prismatic forms conforming to the tetragonal system (Fig. 1). The basic form is often distorted during growth and produces prismatic e(101) crystals which may terminate in either a 'spear' s(111) or 'wedge' e(101) form. Sahama (1978) attributed the distortion of this mineral to the substitution of $(Nb, Ta)^{5+}$ for Ti^{4+}.

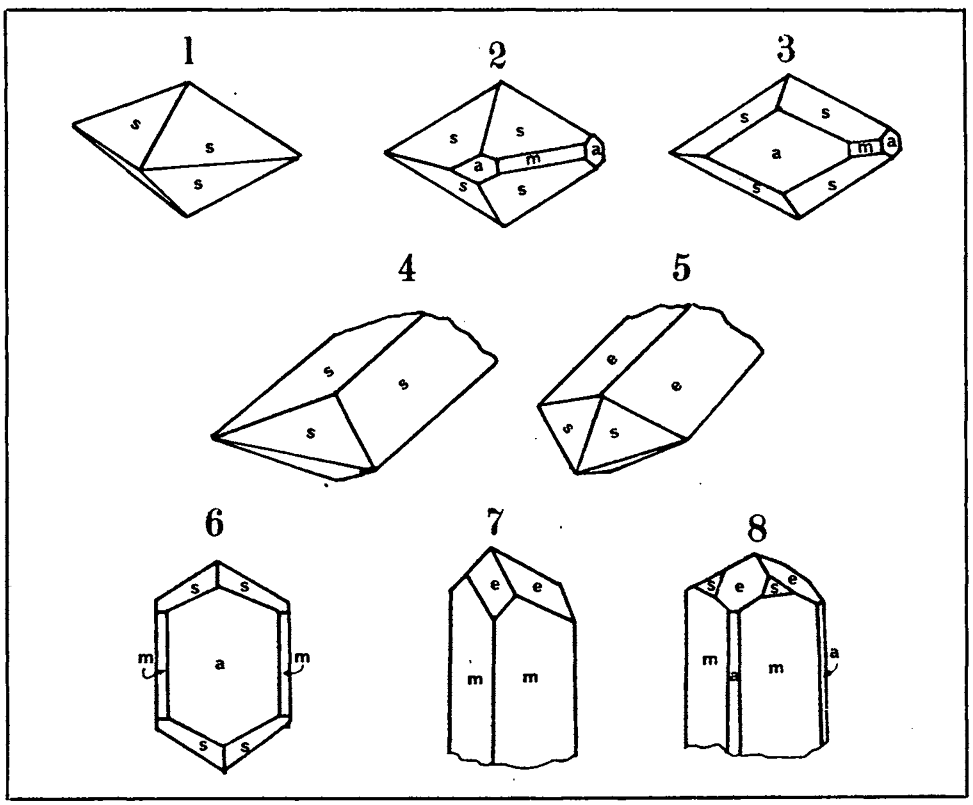

Fig. 1. Crystal habits of Nb-Ta rutile.
1, 2, 3. Squat bipyramidal form s(111), with short tetragonal prismatic faces a(100), m(110).
4. Prismatic form s(111) with 'wedge-shaped' termination.
5. Prismatic form e(101) with 'spear-shaped' termination.
6, 7, 8. Tetragonal prismatic forms m(110), a(100) with pyramidal terminations e(101) and s(111).

Examination of polished grains showed that almost all of the magnetic Nb-Ta rutile grains and a large proportion of the weakly magnetic grains are inhomogenous, manifested by the presence of exsolved phases. The inhomogeneity is not clearly visible in ordinary reflected light, due to the low contrast between the reflectivities of the Nb-Ta rutile and the exsolved phases. However, it is clearly seen under crossed polars and even clearer using the BEI mode of the electron-probe (Plate 1).

Examination of the polished sections under the Electron-probe indicated the presence of 5 different mineral phases:

1. Nb-Ta rutile host
2. Columbite-ixiolite phase
3. Ilmenite phase
4. Rutile phase

Identification of the individual mineral phases were based mainly on their compositions (Table 3), as the size of the phases were too small for ordinary

TABLE 3

ELECTRON-PROBE ANALYSES OF THE MINERAL PHASES IN THE Nb-Ta RUTILE

Analy. No.	1	2	3	4	5	
TiO_2	4.97	4.52	2.17	4.12	6.75	
MnO	3.07	.96	9.52	2.37	.53	
FeO	14.37	17.50	9.31	15.14	16.66	
Nb_2O_5	56.61	57.45	62.19	57.11	55.49	
SnO_2	.78	6.10	.28	.55	1.01	
Ta_2O_5	16.68	5.06	11.61	13.45	12.67	
WO_3	3.30	8.18	4.95	5.14	4.26	
Total %	99.79	99.77	100.01	97.88	97.37	
	6	7	8	9	10	11
TiO_3	3.42	5.42	3.44	3.14	53.84	82.40
MnO	1.30	.21	8.69	.27	1.94	.02
FeO	15.09	18.35	10.29	1.08	42.97	4.37
Nb_2O_5	58.53	48.55	46.93	2.25	.34	7.52
SnO_2	.42	.66	1.41	89.00	.06	3.77
Ta_2O_5	15.03	17.79	29.28	3.93	.38	1.84
WO_3	5.54	9.66	1.81	.56	.00	.76
Total %	99.34	100.64	99.90	100.23	99.53	100.69

1 Columbite-ixiolite phase, Yap Kow & Sons Mine, Chenderiang
2, 3. Columbite-ixiolite phase, Malayan Tin Dredging, Kg. Gajah
4, 5. Columbite-ixiolite phase. Fook Wan Foh Mine, Chenderiang
6 Columbite-ixiolite phase, Kg. Gajah
7 Columbite-ixiolite phase, Kampar
8 Columbite-ixiolite phase, Sen Long Mine, Bakri
9 Cassiterite phase, Yap Kow & Sons Mine, Chenderiang
10. Ilmenite Phase, Kampong Gajah
11. Rutile phase, consolidated mine, Tg. Tualang

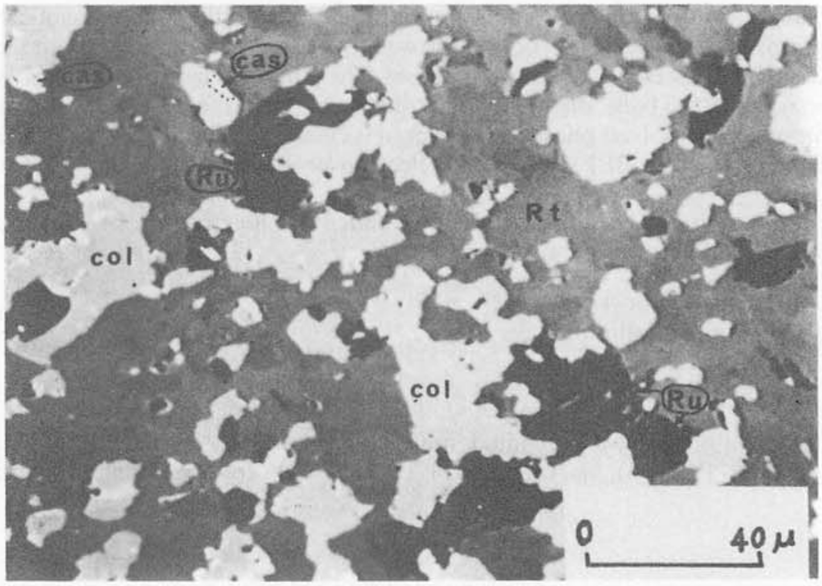

Plate 1. Back-Scattered Electron Image (BEI) of the various mineral phases in a typical Nb-Ta-rutile. In this image 4 mineral phases were recognised: Nb-Ta-rutile host (Rt), exsolved rutile (Ru, as black masses), Columbite-ixiolite (col) and cassiterite (cas, specks, whiter than columbite-ixiolite).

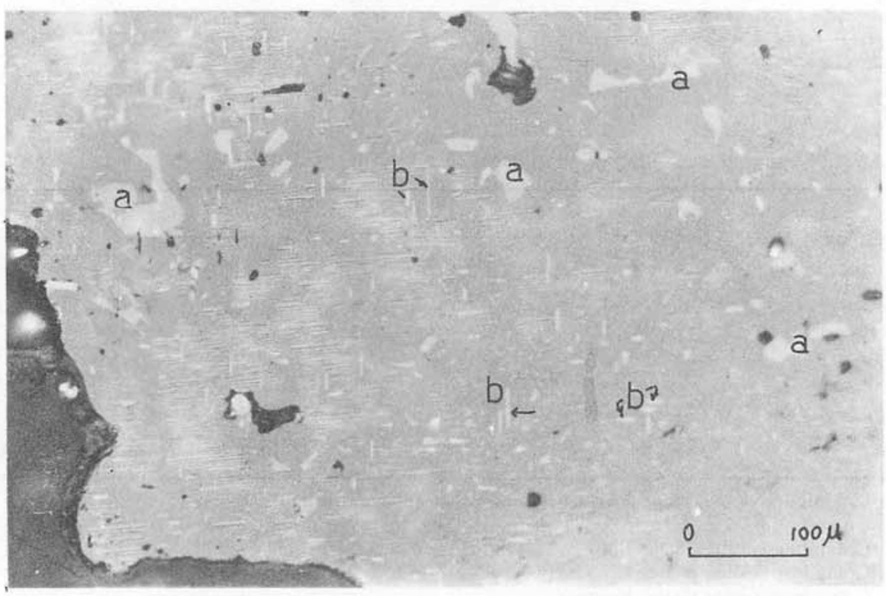

Plate 2. Photograph showing mineral bodies in a grain of cassiterite.
a. Coarse, unoriented bodies
b. Fine, rod-like, oriented bodies.
Reflected-light photomicrograph, oil immersion.

microscopic identification. On compositional basis, columbite could not be differentiated from ixiolite and due to the size limitation, no X-ray diffraction determination could be made; hence this mineral is presently called columbite-ixiolite.

Considering the individual phases, niobium and tantalum are found in almost all the phases, but their main residence are in the rutile host (6–18 % Nb_2O_5, 0–29 % Ta_2O_5), and the columbite-ixiolite phase (43–65 % Nb_2O_5, 5–29 % Ta_2O_5). The cassiterite phase is commonly anomalous in niobium and tantalum (0–2.4 % Nb_2O_5, 1.4–4.7 % Ta_2O_5) and also contains considerable amount of titanium (0.4–1.6 % TiO_2) and iron (0.1–1.6 % FeO). The ilmenite and rutile phases also contain niobium and tantalum but their amounts are seldom greater than 1 %. The composition of the Nb-Ta rutile host is very variable (Table 4). In this host mineral niobium and tantalum are usually high (5–15.25 % Nb_2O_5, 8.53–29.92 % Ta_2O_5), tin is found in significant amount (0.94–6.6 % SnO_2) while tungsten is present in minor to trace amounts.

Bulk compositions of the Nb-Ta rutiles (Table 2) show that the major components of the mineral include titanium (40–77 % TiO_2), niobium (9–17 % Nb_2O_5), tantalum (5–26 % Ta_2O_5), iron (5–13 % FeO) and tin (2–7 % SnO_2), while tungsten (0.5–1.0 % WO_3), manganese (0.2–2.0 % MnO_2) and zirconium (0–0.2 % ZrO_2) constitute minor to trace components.

Some of the columbite-ixiolite phase show orientation, but the majority occur in irregular masses evenly dispersed throughout the Nb-Ta rutile host. Textural relation of the columbite-ixiolite suggest that it is an exsolved rather than an included phase. Previous workers (Edwards, 1940, Cerny *et al.*, 1964, Siivola, 1970, Sahama, 1978 and Fadipe, 1980) unanimously favoured an exsolution origin for the columbite-ixiolite phase.

Nb-Ta minerals in cassiterites

The association of niobium and tantalum with cassiterites is generally well-known (e.g. Hockin, 1957, Ramdohr, 1961). In the present study, polished sections of cassiterite samples from various parts of the peninsula have been examined. It was noted that certain cassiterite fractions from Semiling and Bakri showed the presence of Nb-Ta mineral phases, and they are found in two forms (Plate 2):

a. as relatively coarse, unoriented grains, of up to 250 μ maximum dimension.

b. as very fine rod-like oriented bodies and emulsion, with their maximum dimension seldom exceeding 100 μ.

The former type may possibly be included Nb-Ta mineral grains, but the latter type, with its oriented texture, fits the description of exsolution bodies (Schwartz 1931, 1942). However, it is very difficult to tell whether the numerous rounded blebs of columbite-tantalite, found widely scattered in the cassiterite host, are inclusion or exsolution bodies.

The density of these mineral phases in the cassiterite host increases with the

TABLE 4

ELECTRON-PROBE ANALYSES OF Nb-Ta RUTILE HOSTS

Analy. No.	1	2	3	4	5
TiO_2	61.21	58.74	77.49	60.79	59.21
MnO	.01	.05	.49	.07	.48
FeO	6.26	6.62	2.57	6.00	5.11
Nb_2O_5	11.54	12.63	7.20	5.00	15.25
SnO_2	3.78	6.60	3.11	.94	6.23
Ta_2O_5	18.07	16.17	8.53	25.07	13.22
WO_3	.00	.00	.00	.00	.42
Total %	100.87	100.81	99.38	97.87	99.92
	6	7	8	9	10
TiO_2	58.35	58.72	69.27	51.12	60.40
MnO	.05	.26	.00	.47	.04
FeO	7.67	6.19	5.86	8.29	7.02
Nb_2O_5	13.49	13.12	12.55	8.86	8.63
SnO_2	1.89	6.28	1.09	1.52	1.18
Ta_2O_5	16.77	14.66	10.36	29.92	22.24
WO_3	1.29	.41	.00	.25	.30
Total %	99.54	99.64	99.13	100.43	99.80

1, 2 Yee Mun Mine, Selim.
3, 4 Galian Kalumpang, Kalumpang.
5 Kim Seng Mine, Bidor.
6 Y & Z Mine, Segari.
7 Yap Kow and Sons Mine, Chendering.
8 Fook Wan Foh Mine, Chendering.
9 Goldig Mine, Bakri.
10 Sen Long Mine, Bakri.

magnetism of the cassiterite; the grains containing most columbite-tantalite phase were very magnetic and were able to be picked up by a strong hand-magnet.

These mineral phases, though common in the magnetic cassiterite fraction, were also noted but rather uncommon in the non-magnetic cassiterite fractions. Such phases have also been occasionally observed in cassiterites from Kinta Valley and Kuala Lumpur areas but they are no where as common as the ones from Semiling.

However, magnetism in cassiterites alone does not ensure the presence of the Nb-Ta phase, since it is found only in columbite-tantalite-bearing tin deposits. Equally magnetic black cassiterite grains collected from Pelepah Kanan and Gambang on similar examination, do not contain any columbite-tantalite mineral bodies.

Electron-probe Microanalyses of these mineral phases in the various cassiterite grains gave the following typical compositions (Table 5). In samples from Semiling, all the Nb-Ta mineral phases have columbite composition, and columbite-tantalite in Kinta Valley, while in Bakri, it ranges from columbite, through tantalite to tapiolite.

TABLE 5

ELECTRONE-PROBE ANALYSES OF SOME MINERAL PHASES IN CASSITERITESAnaly. No.

Analy. No.	1	2	3	4	5
TiO_2	3.55	2.42	1.27	1.13	.88
MnO	4.53	5.16	5.65	5.76	4.58
FeO	14.38	13.24	13.46	13.63	10.26
Nb_2O_5	52.27	59.25	54.89	53.08	22.13
SnO_2	1.21	1.34	1.22	.65	.48
Ta_2O_5	23.48	18.56	22.47	22.80	60.12
WO_3	1.21	.55	.78	.99	1.32
Total %	100.62	100.53	99.79	98.04	99.77
	6	7	8	9	10
TiO_2	.40	.50	1.00	8.99	3.87
MnO	4.74	.84	2.88	10.58	8.02
FeO	13.64	13.46	14.37	2.94	7.99
Nb_2O_5	62.17	6.60	42.22	15.60	31.95
SnO_2	.04	1.62	.43	8.42	1.12
Ta_2O_5	17.74	77.07	37.86	54.34	43.11
WO_3	.00	.73	.69	1.84	2.45
Total %	98.73	100.82	99.45	102.71	98.53

1, 2 Columbite phase, Choong Chum Fah Mine, Semiling
3, 4 Columbite phase, Foong Seong Mine, Semiling.
5, 6, 7 Tantalite, Columbite and tapiolite phases, Bakri Mining Co., Bakri.
8 Columbite phase, Sen Song Mining, Bakri.
9, 10 Tantalite and columbite phases, Siamese Tin Mine, Kinta Valley.

Besides the columbite-tantalite phase, niobium and tantalum were also found in anomalous amounts as solid-solution in the cassiterite matrix, and typical analyses of such matrix are given in Table 6.

The niobium-tantalum content in the cassiterite matrix reflects the nature of the Nb-Ta mineral phases formed. In the Semiling cassiterite, where Nb is predominant in the cassiterite lattice, columbite mineral phase is exsolved. In Bakri, where Ta is relatively abundant columbite as well as tantalite and also tapiolite are found.

The amount of niobium and tantalum in solid solution in the cassiterite is probably responsible for the abnormal shapes of some of the cassiterite crystals found in association with the pegmatites. Samples of pegmatitic cassiterites from Semiling and Bakri in Malaysia, Kirengo in Rwanda and Ankole in Uganda have been examined and it was observed that besides the bipyramidal crystal forms usually associated with pegmatitic cassiterites (Hosking 1974), certain peculiar prismatic crystals were also found. These crystals have prismatic form and have two kinds of terminations; the 'wedge' and the 'spear' forms (Fig. 2).

TABLE 6

ELECTRON-PROBE ANALYSES OF CASSITERITE HOSTS

Analy. No.	1	2	3	4	5
TiO_2	.57	.44	.76.	.56	.21
MnO	.11	.14	.12	.12	.06
FeO	1.05	.96	2.16	1.05	.48
Nb_2O_5	3.43	2.52	3.39	3.43	1.35
SnO_2	93.95	93.70	92.07	93.95	97.72
Ta_2O_5	1.17	1.13	.71	1.18	.63
WO_3	.15	.11	.01	.16	.03
Total %	100.43	99.00	99.22	100.45	100.48
	6	7	8	9	10
TiO_2	.17	.31	.05	.00	.04
MnO	.03	.01	.07	.00	.00
FeO	.37	.45	.52	1.72	1.15
Nb_2O_5	.73	.13	.84	.11	.00
SnO_2	98.69	97.46	96.73	97.26	97.38
Ta_2O_5	.23	2.36	1.75	.00	.00
WO_3	.19	.35	.00	.18	.18
Total %	100.38	101.07	99.96	99.26	98.75

1, 2 Paramagnetic cassiterite, Semiling.
3, 4 Paramagnetic cassiterite, Choong Chum Fah Mine, Semiling.
5, 6 Non-magnetic cassiterite, Lombong Perbadanan, Semiling.
7, 8 Paraomagnetic cassiterite, Soon Lee Mine, Bakri.
9 Ferromagnetic cassiterite, Ming Soon Mine, Bt. Payong.
10 Ferromagnetic cassiterite, Pelepah Kanan.

Fersmite

Fersmite is a rare calcium niobate of AB_2O_6 group, first described from the pegmatites of Vishnevye Mountains, Central Urals, Russia, by Bohnstedt-Kupletskaya and Burova (1946).

In the present study fersmite occurs as a replacement product of columbite and is associated with tantalite, cassiterite, monazite and gahnite in the alluvial concentrates from Bakri. Polished section studies revealed that fersmite is replacing columbite along grain boundary as well as along cleavage planes (Plate 3). Its reflectivity is low and appears as dark-grey mineral, darker than columbite and has a distinct bireflectance. It is anisotropic but this anisotropism is masked by strong yellow-brown internal relfection.

An X-ray powder photograph of the fersmite grains revealed relatively strong principal reflection lines of fersmite superimposed on the equally strong columbite lines. The reflection lines in the present fersmite (Table 7) correspond closely to the principal lines of fersmite obtained by Hess and Trumpour (1959).

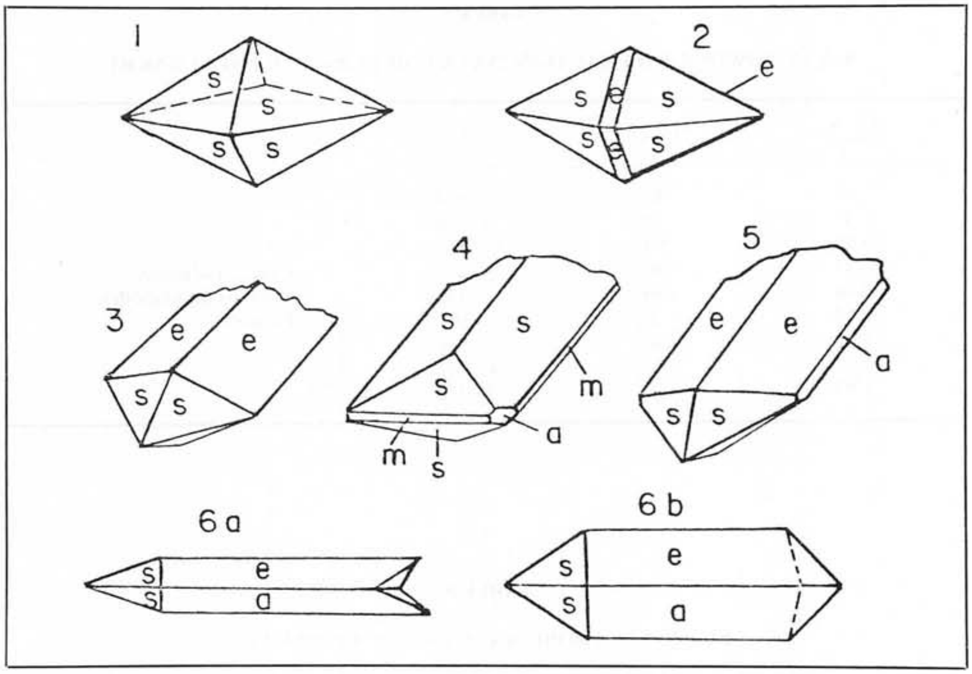

Fig. 2. Forms of pegmatite casiterite crystals.
1, 2 Normal bipyramidal crystals
3, 5, 6. Abnormal "spear-shaped" crystals
4. Abnormal "wedge-shaped" crystals

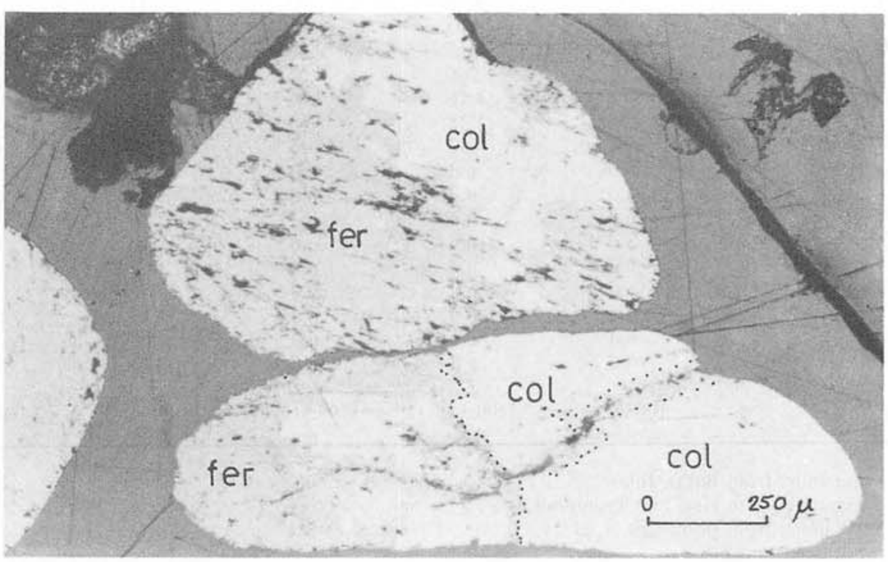

Plate 3. Reflected light photograph showing fersmite (fer) replacing columbite (col). Sample from Bakri Mining Co., Bakri.

TABLE 7

X-RAY POWDER DIFFRACTION DATA FOR FERSMITE FROM BAKRI

d_{obs} A°	I_{estm}	hkl	
7.47	40	020	
5.35	30	110	
3.76	60	130,117	
3.43	30	121	$CuK_{\alpha 1}$ radiation
3.06	100	131	Siemans Kristalloflex
2.50	20	060	Camera.
1.86	40	260	
1.77	50	062,232	
1.53	70	351,312	

TABLE 8

ELECTRON-PROBE ANALYSES OF FERSMITE

Analy. No.	1	2	3	4	5
TiO_2	1.47	.67	.52	2.01	3.21
MnO	.18	4.85	.04	.11	.48
FeO	.09	14.83	.01	.34*	1.71
Nb_2O_5	73.48	70.55	70.96	74.44	70.12
SnO_2	.05	.08	.07	n.d.	n.d
Ta_2O_5	8.08	8.26	7.86	—	—
WO_3	.53	1.28	.60	n.d	n.d
CaO	16.91	.02	15.45	15.02	14.42
SiO_2	n.d	n.d	n.d	.32	.72
REO	n.d	n.d	n.d	6.36	4.79
ThO_2	n.d	n.d	n.d	.10	n.d
Al_2O_3	n.d	n.d	n.d	.10	1.28
MgO	n.d	n.d	n.d	n.d	.98
Na_2O	n.d	n.d	n.d	—	.46
F	n.d	n.d	n.d	—	1.87
U_3O_8	n.d	2.n	n.d	.08	n.d
H_2O	n.d	n.d	n.d	.18	.72
Total %	100.79	100.54	95.51	99.04	100.83

1, 2, 3 Fersmite, from Bakri, Johor.
4 Fersmite, form Hess and Trumpour.
5 Fersmite, from Bohnstedt et. al.
n.d. not determined
— not detected
* analysed as Fe_2O_3.

The composition of the Bakri fersmite, of which only partial analysis were made (Table 8) conforms closely to the formula AB_2O_6 originally proposed by Bohnstedt-Kuplexskaya and Burova (oo. cit.). A typical chemical formula for the Bakri fersmite could be written as:

$$Ca_{0.99} \quad Nb_{1.82} \quad Ta_{0.12} \quad Ti_{0.06} \quad W_{0.01} \quad O_6$$

The low total in Analysis 3 is probably due to the presence of rare earth elements, not detected in the present work but reported to be present in significant amounts in the fersmites from Ravalli county, Montana and the Urals of Russia.

Wodginite

Wodginite is a rare tin-tantalate and in the peninsula it has been found only in Bakri in association with columbite-tantalite and cassiterits in the alluvial concentrates.

TABLE 9

ELECTRON-PROBE MICROANALYSES OF WODGINITES

Analy. No.	1	2	3	4	5
TiO_2	0.40	0.20	0.17	0.20	0.03
MnO	8.40	6.02	6.69	9.80	8.58
FeO	3.79	6.61	4.93	2.99	6.37
Nb_2O_5	4.07	6.01	1.43	10.70	6.03
SnO_3	14.40	13.54	11.05	9.93	16.89
Ta_2O_5	67.58	66.61	75.72	65.85	61.40
WO_3	.09	.52	.21	.02	.02
Total %	98.73	99.51	100.20	99.32	99.31
	6	7	8	9	10
TiO_2	.02	.08	.08	.02	.02
MnO	9.42	8.21	8.63	10.25	1.43
FeO	.05	2.98	2.82	.08	12.21
Nb_2O_5	8.68	1.58	2.18	9.60	5.80
SnO_2	11.74	15.47	12.22	11.08	2.60
Ta_2O_5	68.82	71.90	73.76	67.99	77.25
WO_3	.00	.00	.07	.00	.00
Total %	98.73	100.22	99.77	99.02	99.30

1, 2, 3 Wodginite, Siah Guan Mine, Bakri
4, 5, 6 Wodginite, Bakri Mining Co, Bakri
7, 8, 9 Wodginite, Sen Long Mine, Bakri
10 Tapiolite exsolved phase, Bakri Mining Co.

This mineral is present as orange to red-brown rounded grains often with striations parallel to the length of the grains. Some grains are mottled brown and black due to partial replacement of Mn-tantalite by wodginite. Cassiterite grains are found in the wodginite as relatively large, randomly scattered inclusions. Tapiolite has also been observed in the wodginite as tiny irregular blebs, constituting most probably an exsolution phase.

Microprobe analyses of the wodginites are given in Table 9. Tantalum (61.4–75.7% Ta_2O_5), tin (9.9–20.0% SnO_2), manganese (6.0–10.3% MnO), niobium (1.4–10.7% Nb_2O_5) and iron (0.1–6.6% FeO) are the major components of this mineral, while titanium and tungsten are present in trace amounts.

CONCLUSIONS

1. Columbite-tantalite in economically significant quantities is found only in Semiling and Bakri where it is associated with granite and green monazite and genetically related to the pegmatites of the two areas.

2. Nb-Ta rutile is a common mineral in the Malaysian tin-fields. This mineral is found to be highly inhomogenous and contains exsolved phases of columbite-ixiolite, cassiterite, rutile and ilmenite.

3. On the whole, the Eastern Tin Belt of the peninsula is relatively poor in tantalum and niobium compared to the Western Tin Belt, as columbite-tantalite, Nb-Ta rutile and other Nb-Ta minerals are rare.

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