Geological Society of Malaysia Annual Geological Conference 2002
May 26–27 2002, Kota Bharu, Kelantan, Malaysia

EPMA characterisation of ilmenite from *amang* of the Kinta and Klang Valleys, Peninsular Malaysia

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Abstract: Samples of heavy minerals concentrates were collected from the Kinta Valley and the surrounding areas of the Klang Valley to characterise ilmenite ($FeTiO_3$) both physically and chemically using the EPMA (electronprobe microanalyzer).

The ilmenite grains in both valleys are not homogeneous and are associated with other heavy minerals that include monazite, xenotime, zircon, rutile, cassiterite, wolframite and topaz. Common textures of the ilmenite grains include replacement by leaching, intergrowths and exsolutions. In addition interesting exsolutions involving monazite, xenotime and ilmenorutile were observed. Generally the *amang* from the Klang Valley has more ilmenite while that from the Kinta Valley has more monazite, xenotime, zircon, rutile and wolframite.

The ilmenite from the two valleys were analysed on the EPMA to show the variations of TiO_2 and FeO from the different localities. The TiO_2 content for ilmenite, on the average, is quite similar for the Kinta and Klang Valleys, 49.7875–65.4251% to 49.0360–65.6274% respectively. The results show that the *amang* from both valleys have TiO_2 ranging from 49.4118% to 65.5263%.

INTRODUCTION

When Malaysia was the largest exporter of tin ore in the world in the last century, the processing of the associated heavy minerals or *amang*, in particular ilmenite, was also a major industry. Alot of *amang* was produced, in particular in the two main tin producing areas in Peninsular Malaysia, that is the Kinta Valley in the Ipoh area to the north and the Klang Valley in the Kuala Lumpur area to the south. Many *amang* factories mushroomed to process the *amang* from these 2 main areas.

The purpose of this paper is to characterise the ilmenite in the *amang*, physically and chemically, from these 2 areas with the aid of the EPMA (electronprobe microanalyzer).

Previous investigations on *amang* conducted include Lau (1979) in the Ipoh area and Jamlus (1979) in the Kuala Lumpur area.

MATERIALS AND METHODS

Samples of *amang* were collected from localities in the Kinta Valley and Klang Valley both from mines that were active and still operating and those inactive (Irdawati Hj. Lokman, 2001) (Fig. 1). Seven localities were sampled in the Kinta Valley, and these included Tekka Mine (TK1, TK2, Tekka), Kean Tong Mine (KT1, Kampar), SEK (M) Sdn. Bhd. (SEK1, Mambang Diawan), Cendera Harta Sdn. Bhd. (SMTD1, Mambang Diawan), Malim Nawar (TKSC1), New Lahat Mine (NLM1, Lahat) and Papan (PPN1).

The localities sampled in the Klang Valley include, Berjuntai Tin Consolidated (Btg. Berjuntai, BJT1), Marijusama Sdn. Bhd. (Bt. 16 Puchong, S1), Metreco Sdn. Bhd. (Bt. 16 Puchong, S2, S3, S5), Delima Industries (Bt. 2½, Dengkil, DISB1), Mines Shopping Fair (Serdang, MR1), Dayapi Lombong (Bt. 16 Puchong, DYP1), Kuari Tanjong Balai (Puchong, TJB1) and Taman Mas Sepang (Bt. 18 Puchong, TMS1).

The physical characteristics of the heavy minerals were studied under the binocular microscope, while intergrowths and textures were studied using polished sections under the Leitz Laborlux reflected light microscope. The EPMA (electronprobe microanalyzer) was later used to identify more precisely the heavy minerals, their intergrowths textures, inclusions and their chemical compositions (Teh, 2000).

The mineral grains were studied using the secondary electron (SE) and backscattered electron (BSE) images under the Cameca SX100 EPMA and X-ray mapping was performed to differentiate the different heavy minerals like ilmenite, cassiterite, zircon, xenotime, monazite, wolframite and others. Such X-ray maps are used in the grain count of the different heavy minerals present (Fig. 2).

On the other hand, the EDS (energy dispersive spectrometer) on the EPMA, was able to provide a scan of the REEs (rare earth elements) present, thus instrumental in differentiating monazite (Ce, La, Nd, Th)PO_4 from xenotime (YPO_4) (Fig. 3).

RESULTS AND DISCUSSION

Using the EPMA, it was easy to see that many of the ilmenite grains from *amang* are not homogenous showing Fe leaching out along fractures, cracks and cleavages and this will result in the grains showing zones, dendrites or laminations of Fe-poor and Fe-rich areas. The BSE image will show Fe-poor areas (invariably enriched in Ti) to be grey while the Fe-rich areas are bright (Fig. 5). Similarly exsolutions of iron oxide in ilmenite were clearly discernible in BSE images (Figs. 4 and 6).

EPMA studies of the associated heavy minerals also revealed many interesting exsolutions that include:

(i) the occurrence of exsolution bodies containing Fe, Mn, Nb, W, O (or ilmenorutile) (Fleischer, 1983) in TiO_2 (rutile) (Fig. 7).

(ii) the exsolution bodies of monazite in xenotime (YPO_4) (Fig. 8).

(iii) the exsolution bodies of xenotime in monazite and vice-versa in an intergrown monazite-xenotime grain (Fig. 9).

(iv) exsolution bodies of uranium in xenotime (Fig. 10).

(v) exsolutions of U-Th in monazite (Fig. 11).

On the abundance of heavy minerals in the *amang*, the Klang Valley generally has more ilmenite while the Kinta

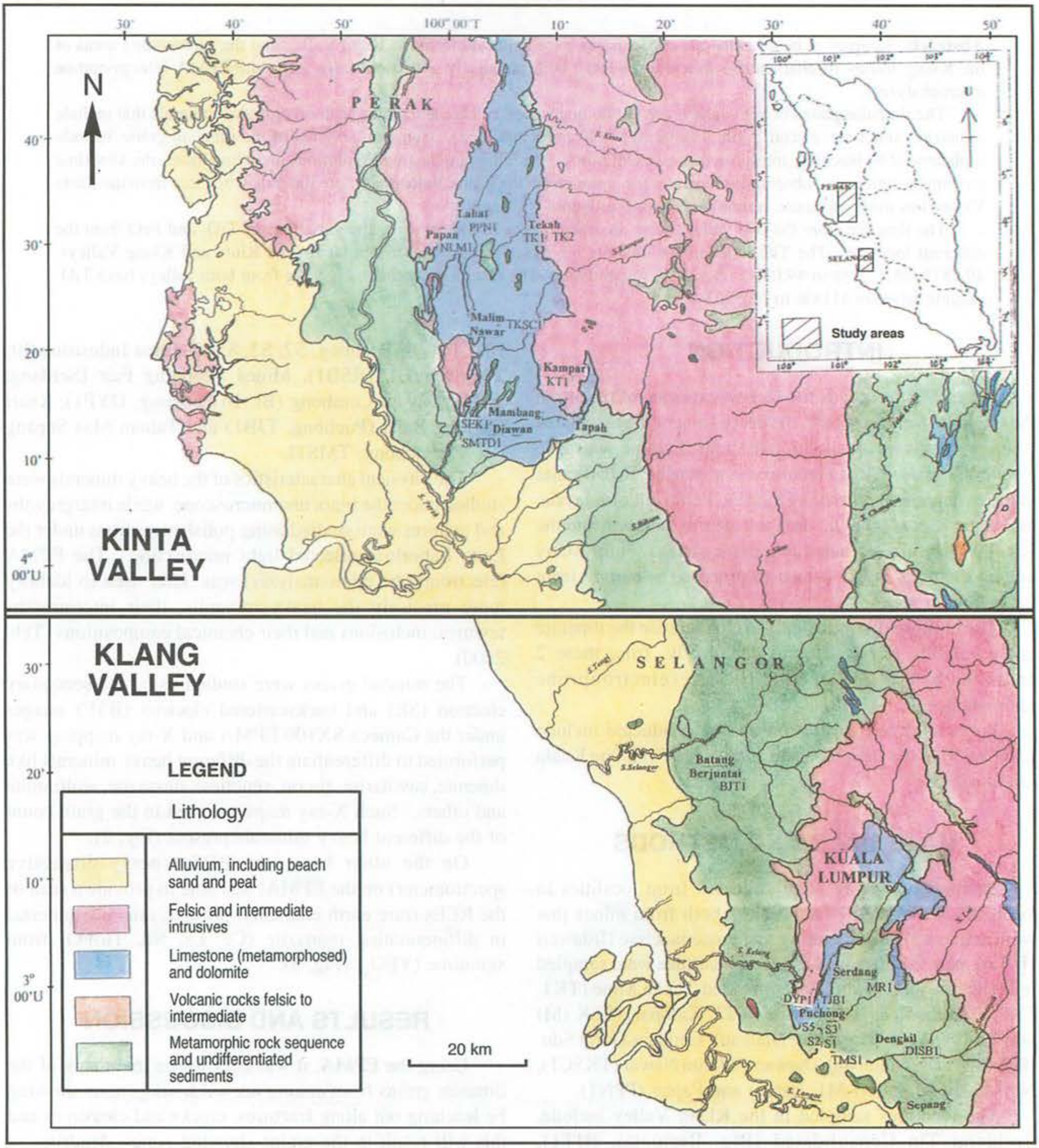

Figure 1. Map showing sample localities in the Kinta and Klang valleys.

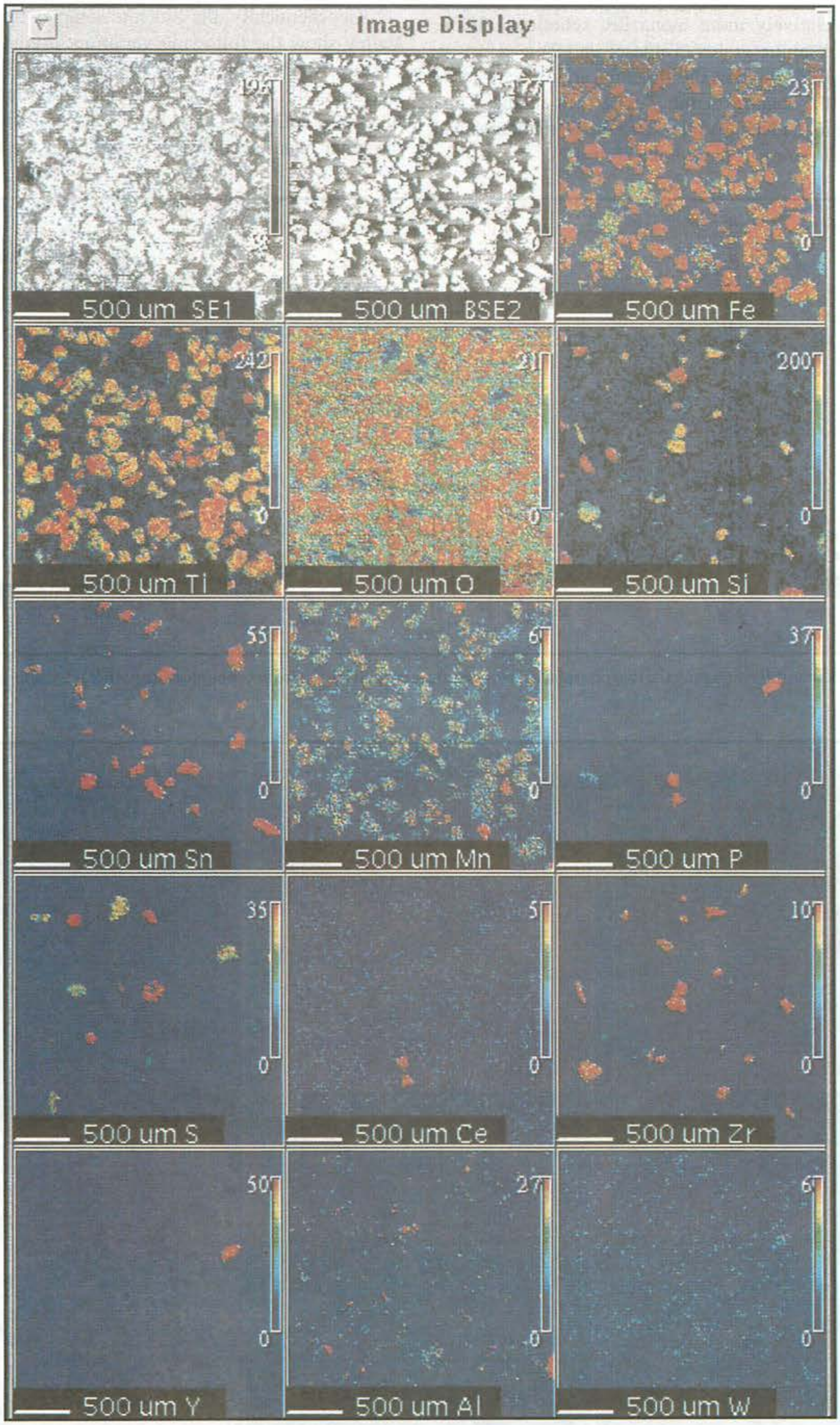

Figure 2. X-ray map of *amang* sample S3 from 16 mile Puchong used for point counting of heavy minerals present. The sample has alot of ilmenite (Fe, O, Mn), some grains of cassiterite (Sn), zircon (Zr), pyrite (Fe, S), one grain of xenotime (Y, P) and two grains of monazite (Ce, P).

Valley has relatively more monazite, xenotime, zircon, rutile and wolframite grains (Tables 1 and 2).

The results show that the ilmenite grains were more abundant in the *amang* in the Tekka area in the Kinta Valley while in the Klang Valley area the Dengkil area had more ilmenite grains in the *amang* (Fig. 12).

Geochemically, the ilmenite samples from the Klang Valley show the following variation in contents of TiO_2 (Table 3), Puchong 49.6750–67.6800% TiO_2, Batang Berjuntai 48.5309–60.2154% TiO_2, Serdang 49.0600–68.6400% TiO_2 and Dengkil 48.8780–65.9740% TiO_2. On the other hand the ilmenite grains from the Kinta Valley

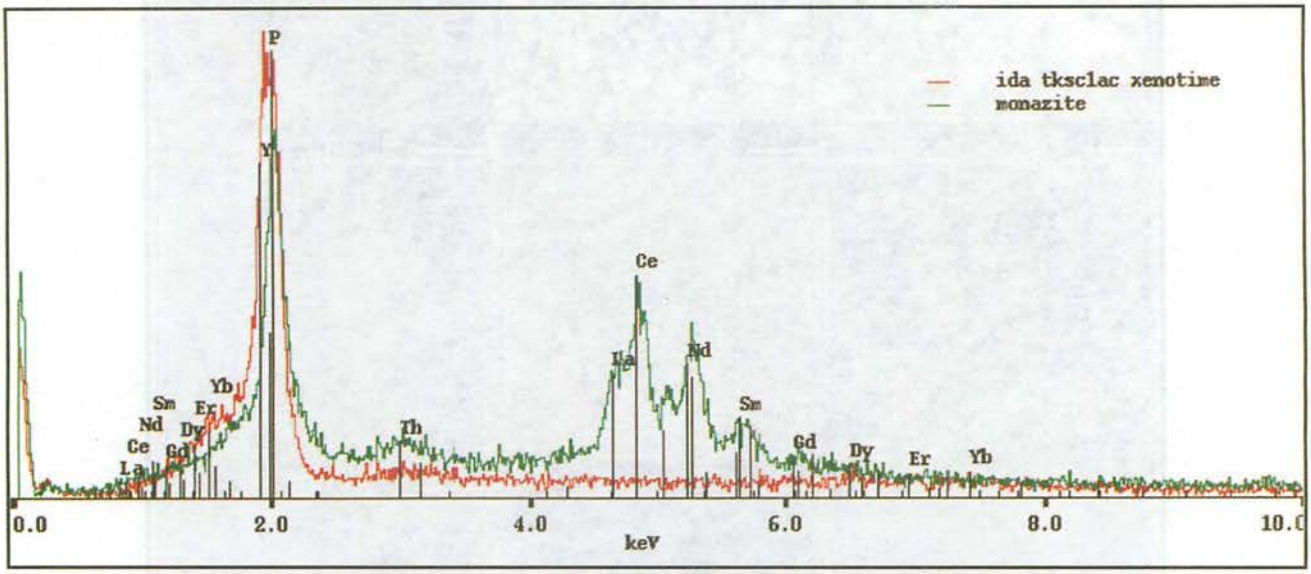

Figure 3. EDS scan differentiating the two phosphates, monazite (green with REEs) from xenotime (red, with Y). Sample TKSC1, Malim Nawar.

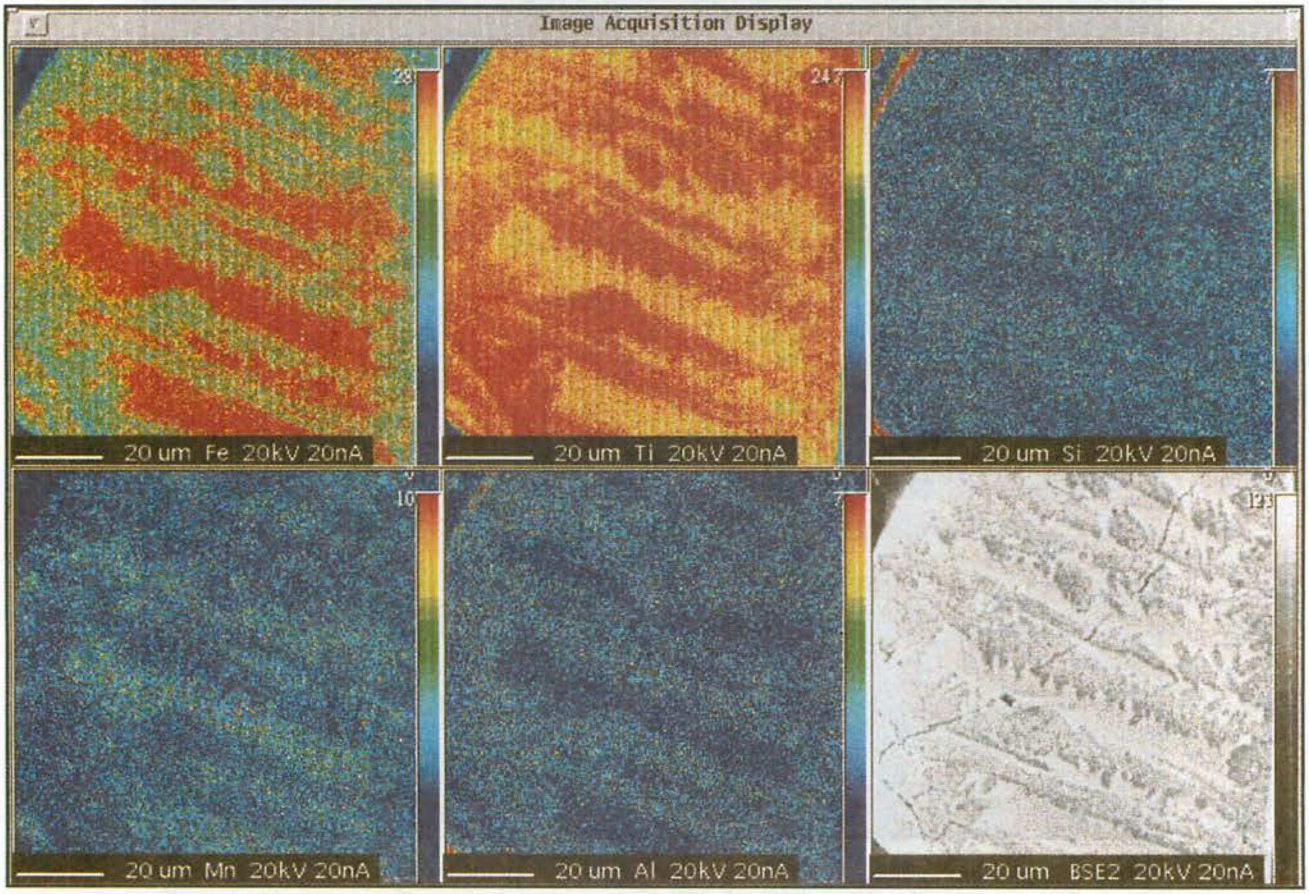

Figure 4. X-ray map differentiating Fe-rich from Ti-rich areas of ilmenite grain. Sample S1, 16 mile Puchong.

(Table 4) show the following TiO_2 contents: Tekka 49.9000–68.9310% TiO_2, Lahat 57.0011–63.2200% TiO_2, Mambang Diawan 48.6670–68.6440% TiO_2, Papan 46.3790–59.0220% TiO_2, Malim Nawar 47.2380–63.4370% TiO_2 and Kampar 49.5400–69.2970% TiO_2.

The TiO_2 content for ilmenite, on the average, is quite similar for the Kinta and Klang Valleys, 49.7875–65.4251% to 49.0360–65.6274% respectively. The results show that the *amang* from both valleys have TiO_2 ranging from 49.4118% to 65.5263%. For the Kinta Valley, the lowest TiO_2 content for *amang* was found at Papan (46.3790%), the highest at Kampar (69.2970%). For the Klang Valley,

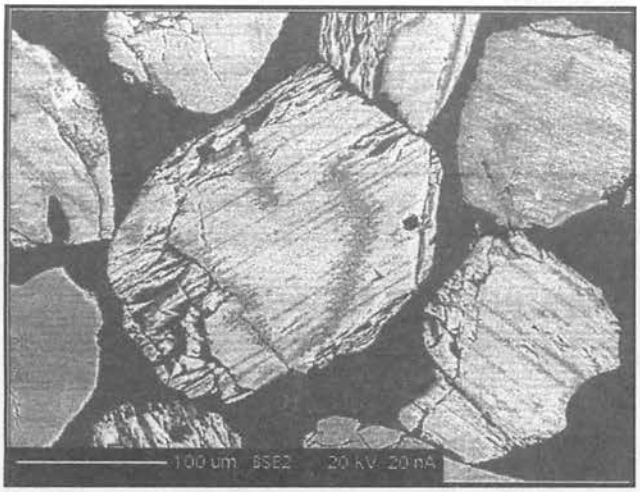

Figure 5. BSE image of ilmenite grains showing Ti-poor areas (darker grey) along fractures and cleavages.

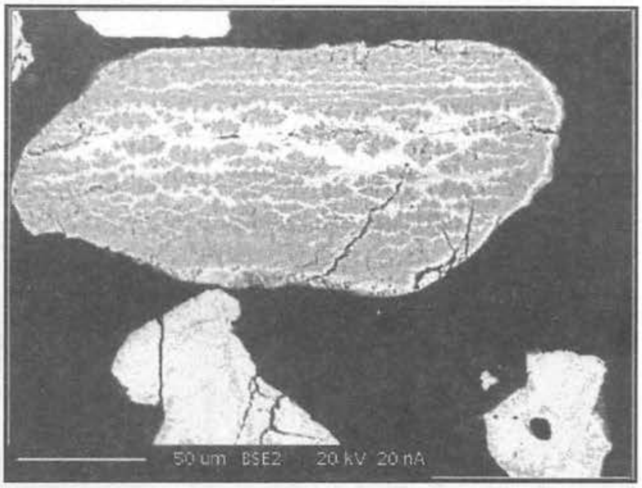

Figure 6. BSE image of ilmenite grain showing Fe oxide exsolutions (white). The other light grey grains are cassiterite. Sample S2, 16 mile Puchong.

Table 1. Number of grains of individual heavy minerals from sample locations in the Kinta Valley.

Sample	Ilmenite	Monazite	Tourmaline	Zircon	Xenotime	Topaz	Rutile	Wolframite	Pyrite
TKSC1	60	1	15	2	1	13	11	3	30
TK1	160	6	26	80	3	19	21	1	50
TK2	92	2	7	10	0	14	1	0	35
KT1	32	20	7	2	2	0	32	150	15
NLM1	31	0	23	0	0	5	31	0	12
SMTD1	42	5	7	3	4	5	42	200	23
SEK1	77	4	68	21	0	0	17	0	10
PPN1	85	13	68	101	3	14	98	85	1
Total:	479	51	221	217	13	70	243	439	176

Table 2. Number of grains of individual heavy minerals from sample locations in the Klang Valley.

Sample	Ilmenite	Monazite	Tourmaline	Zircon	Xenotime	Topaz	Rutile	Wolframite	Pyrite
S1	93	0	62	0	0	4	2	0	0
S2	72	0	11	0	0	2	4	0	2
S3	24	2	7	16	1	5	9	0	6
S5	24	3	25	6	1	24	18	0	4
TMS1	82	1	40	2	1	29	30	0	0
DYP1	66	1	65	5	1	19	66	1	1
TJB1	127	6	58	43	4	4	0	1	10
MR1	10	3	35	8	1	26	0	6	10
DISB1	137	1	11	8	1	11	0	6	20
BJT1	100	3	4	9	1	7	8	8	13
Total:	735	26	318	97	11	131	137	24	66

the lowest TiO2 content was found at Batang Berjuntai (48.5309%) and the highest at Puchong (67.6800%).

CONCLUSION

The study has shown that the *amang* from the Kinta and Klang Valleys contain varying amounts of ilmenite as well as heavy minerals like monazite, xenotime, zircon, rutile and wolframite.

EPMA studies revealed interesting textures among the heavy minerals including the radioactive nature of monazite and xenotime.

It is hoped that this knowledge of the ilmenite composition from different *amang* sources will be useful to researchers, purchasers and miners of heavy minerals in the country.

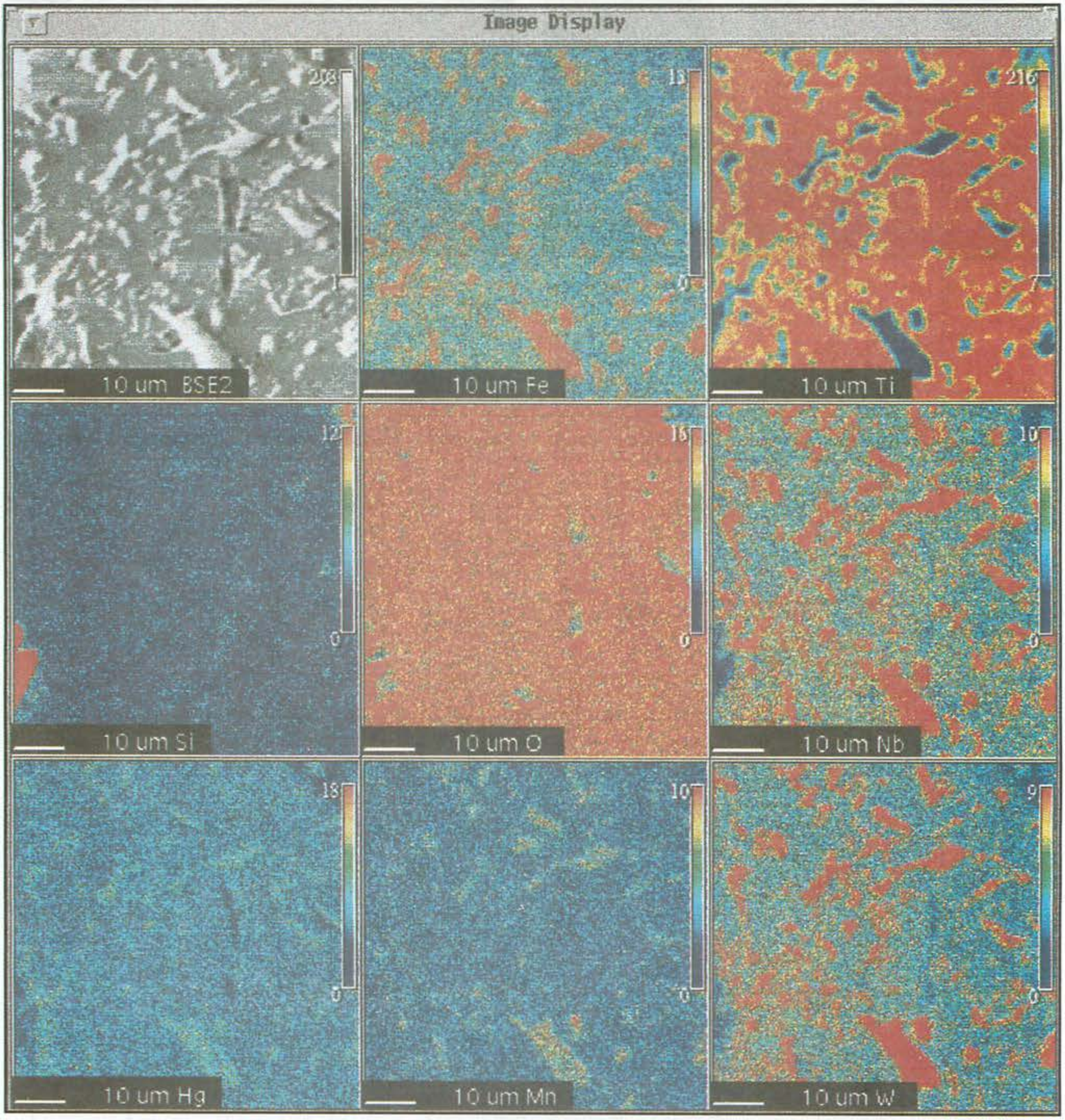

Figure 7. X-ray map showing ilmenorutile exsolutions (with high Fe, Nb, W, Mn and O) in rutile (TiO_2). Sample NLM, New Lahat Mine.

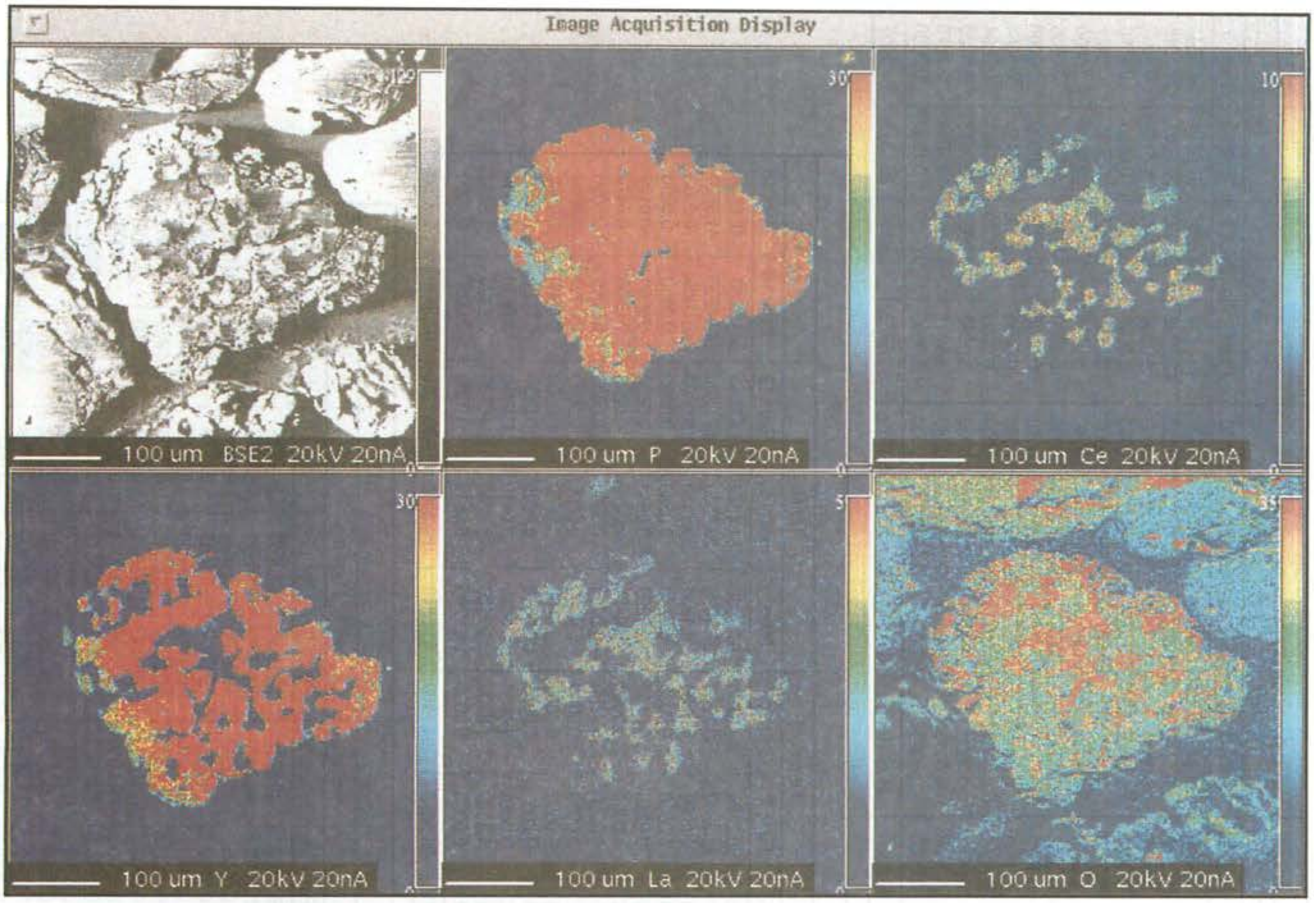

Figure 8. X-ray map showing monazite exsolution bodies in xenotime (YPO_4). Sample S5, Puchong.

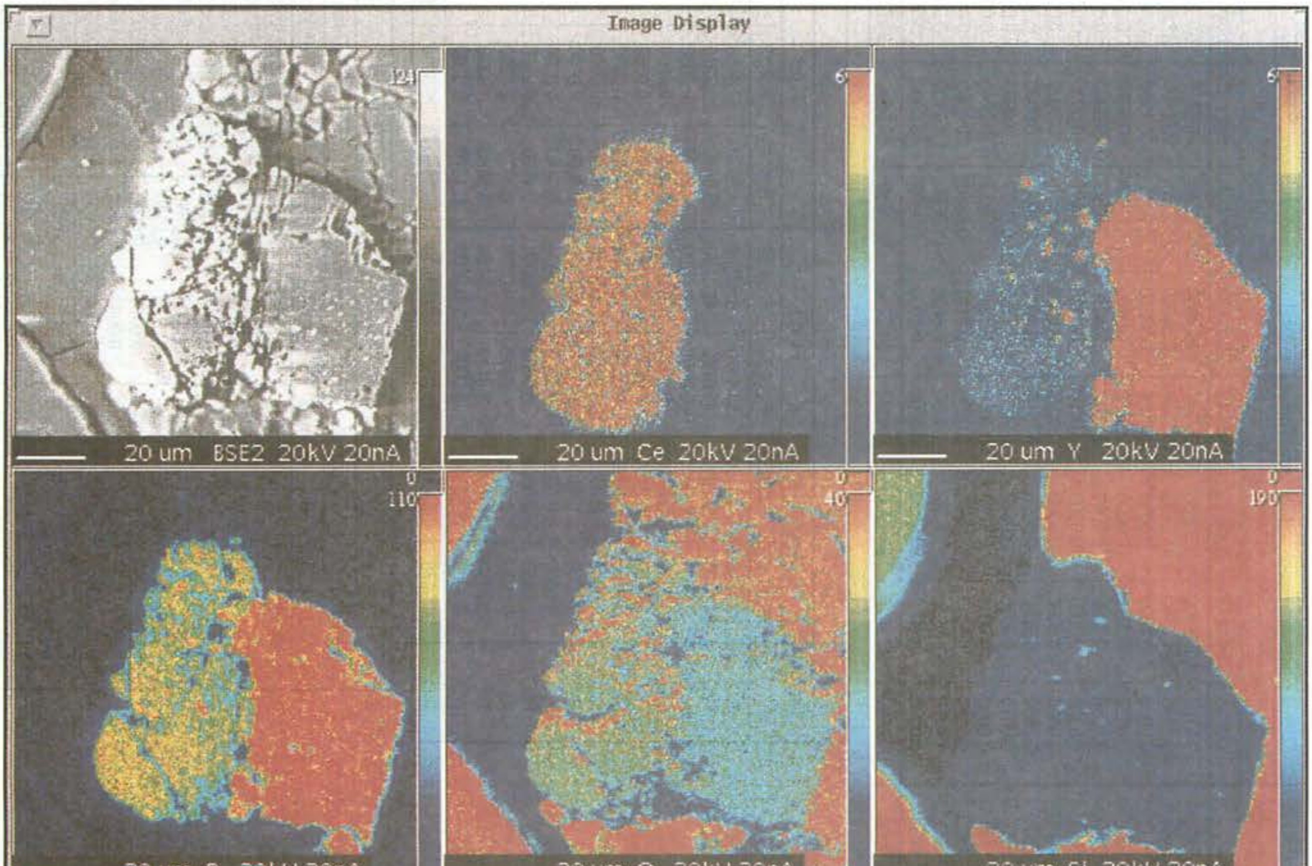

Figure 9. X-ray map showing intergrown monazite-xenotime grain showing exsolutions of one mineral in the other and vice-versa. Sample TK2, Tekka.

Table 3. EPMA analysis of ilmenite grains from different localities in the Klang Valley (wt%).

Okside	S1				S2					S3				TJB1			
	Ti-rich		Fe-rich		Ti-rich			Fe-rich		Ti-rich		Fe-rich		Ti-rich		Fe-rich	
	Point 15	Point 17	Point 16	Point 19	Point 23	Point 24	Point 25	Point 20	Point 21	Point 26	Point 32	Point 27	Point 30	Point 7	Point 8	Point 3	Point 6
TiO_2	59.1110	67.6800	52.6880	52.7240	66.4350	67.0890	65.8740	51.6500	53.5860	63.6050	63.5990	52.4930	52.5620	49.6735	50.2307	61.5014	61.0244
FeO	29.1220	21.3790	41.5530	41.7800	22.4800	21.2720	20.1200	42.8840	41.9730	27.7211	23.7450	42.0511	41.5420	43.1202	42.2493	23.3007	22.5018
Al_2O_3	0.0000	0.0500	0.0000	0.0000	0.3210	0.0000	0.1950	0.0000	0.0000	0.0870	0.0470	0.0000	0.0000	0.0000	0.0000	0.3174	0.3552
SiO_2	0.0020	0.0790	0.0000	0.0090	0.0500	0.0400	0.0610	0.0000	0.0000	0.0180	0.0030	0.0020	0.0000	0.0000	0.0000	0.0535	0.1348
Cr_2O_3	0.0350	0.0220	0.0000	0.0010	0.0270	0.0350	0.0000	0.0100	0.0120	0.1080	0.0470	0.0000	0.0000	0.0132	0.0365	0.0015	0.0117
SnO	0.0170	0.0000	0.0000	0.0000	0.0180	0.0400	0.0000	0.0220	0.0000	0.0000	0.0000	0.0000	0.0140	0.0000	0.0000	0.0000	0.0000
Nb_2O_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ZrO_3	0.0000	0.0000	0.0000	0.0250	0.0000	0.0000	0.0000	0.0000	0.0070	0.0370	0.0110	0.0000	0.0040	0.0000	0.0000	0.0000	0.0000
P_2O_5	0.0070	0.1000	0.0000	0.0000	0.1160	0.0920	0.0950	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0435	0.0664
PbO	0.0000	0.0030	0.0000	0.0000	0.1240	0.2330	0.2240	0.0000	0.0000	0.0000	0.0460	0.0000	0.0000	0.0000	0.0000	0.1465	0.0894
As_2O_3	0.0180	0.0310	0.0670	0.0690	0.0110	0.0650	0.0360	0.0110	0.0740	0.0000	1.7900	0.0000	0.0050	0.0660	0.0066	0.0673	0.0330
ThO_2	1.9470	1.5510	1.1780	2.0050	0.6630	1.9060	1.7130	0.0000	1.1800	0.0000	0.0000	0.2360	1.0640	1.8241	4.4367	3.5662	2.9870
WO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1539	0.0000
Total:	90.2590	90.8670	95.4860	96.6140	90.2440	88.3630	88.3630	94.5770	96.8330	91.6010	89.3340	94.7830	95.1910	94.6970	96.9597	89.1519	87.2037

Okside	S5				TMS1					DYP1				
	Ti-rich		Fe-rich		Ti-rich			Fe-rich		Ti-rich			Fe-rich	
	Point 37	Point 39	Point 34	Point 38	Point 2	Point 3	Point 5	Point 7	Point 6	Point 15	Point 17	Point 19	Point 16	Point 18
TiO_2	53.1090	53.6410	50.4570	51.3590	61.5030	59.4650	61.0260	50.2320	49.6750	57.6630	61.4370	56.0040	49.3560	48.8370
FeO	34.4700	39.7690	43.0780	42.1120	23.3010	23.8270	22.5020	42.2500	43.1210	28.4920	23.3850	29.9280	42.4200	41.3620
Al_2O_3	0.0000	0.0000	0.0000	0.0000	0.3170	0.2050	0.3550	0.0000	0.0000	0.1330	0.2180	0.0000	0.0000	0.0000
SiO_2	0.0000	0.0400	0.0050	0.0000	0.0540	0.0200	0.1350	0.0000	0.0000	0.0280	0.0580	0.0000	0.0040	0.0000
Cr_2O_3	0.0050	0.0180	0.0260	0.0110	0.0010	0.0060	0.0120	0.0360	0.0140	0.0300	0.0640	0.0230	0.0000	0.0170
SnO	0.0430	0.0390	0.0230	0.0110	0.0000	0.0330	0.0000	0.0000	0.0000	0.0400	0.0210	0.0230	0.0200	0.0470
Nb_2O_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ZrO_3	0.0000	0.0240	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0060	0.0000
P_2O_5	0.0000	0.0000	0.0220	0.0000	0.0440	0.0100	0.0000	0.0000	0.0000	0.0280	0.0640	0.0000	0.0000	0.0000
PbO	0.0050	0.0000	0.0000	0.0000	0.1470	0.2820	0.0660	0.0000	0.0000	0.0060	0.0920	0.0130	0.0000	0.0000
As_2O_3	0.0320	0.0080	0.0610	0.0370	0.0670	0.0030	0.0900	0.0060	0.0660	0.0030	0.0410	0.0610	0.0010	0.0080
ThO_2	3.2930	5.1010	1.6140	3.6200	3.5660	1.9320	0.0340	4.3600	1.8200	5.2100	3.8740	4.6700	2.0120	1.9680
WO_3	0.0000	0.0000	0.0000	0.0000	0.1540	0.0000	2.9870	0.0000	0.0000	0.0240	0.0510	0.0000	0.0000	0.0000
Total:	90.9570	98.6400	95.2860	97.1510	89.1550	85.8080	87.2060	96.9610	94.7000	91.6570	89.3060	90.7250	93.8190	92.7250

Okside	MR1				DISB1				BJTI				
	Ti-rich		Fe-rich		Ti-rich			Fe-rich	Ti-rich			Fe-rich	
	Point 38	Point 43	Point 37	Point 42	Point 8	Point 9	Point 12	Point 6	Point 23	Point 24	Point 27	Point 25	Point 26
TiO_2	63.0940	68.6400	51.6940	49.0600	65.9740	58.8530	58.8700	48.8780	60.2154	59.3063	56.8327	48.5309	49.1031
FeO	17.5550	14.0590	32.8780	36.4190	20.4330	26.3330	25.7590	44.1400	24.4199	25.4761	28.5483	42.3070	41.7707
Al_2O_3	0.4170	0.6370	0.0000	0.0000	0.4560	0.1300	0.0950	0.0000	0.2475	0.1644	0.0000	0.0000	0.0000
SiO_2	0.0110	0.1720	0.0000	0.0100	0.0890	0.0630	0.0100	0.0000	0.0834	0.1005	0.0278	0.0000	0.0128
Cr_2O_3	0.0030	0.0490	0.0000	0.0340	0.0000	0.0000	0.0240	0.0250	0.0307	0.0000	0.0088	0.0044	0.0000
SnO	0.0050	0.0430	0.0260	0.0110	0.0000	0.0160	0.0000	0.0000	0.0635	0.0340	0.0000	0.0965	0.0000
Nb_2O_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ZrO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000
P_2O_5	0.1110	0.0400	0.0000	0.0000	0.1230	0.0330	0.0540	0.0000	0.0619	0.0344	0.0000	0.0000	0.0000
PbO	0.0400	0.2450	0.0000	0.0000	0.1430	0.0290	0.0180	0.0060	0.0000	0.0377	0.0000	0.0000	0.0420
As_2O_3	0.3010	0.1550	0.0500	0.0200	0.0470	0.0340	0.0240	0.1600	0.0383	0.0053	0.0832	0.0898	0.0568
ThO_2	4.8000	18.5810	2.6500	2.2500	1.9130	5.4120	3.2440	3.3880	3.3375	2.5660	1.5089	1.9139	2.3008
WO_3	0.0390	0.2760	0.0000	0.0710	0.0000	0.0000	0.2170	0.0000	0.1589	0.0782	0.0000	0.0000	0.0542
Total:	86.0580	102.8980	87.2990	87.8750	89.1790	90.9020	88.3150	96.4530	88.6571	87.8043	87.0095	93.0662	93.3404

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Table 4. EPMA analysis of ilmenite grains from different localities in the Kinta Valley (wt%).

Okside	TK1					TK2					NLM1		
	Ti-rich				Fe-rich	Ti-rich				Fe-rich	Ti-rich		Fe-rich
	Point 48	Point 50	Point 51	Point 53	Point 49	Point 54	Point 55	Point 56	Point 57	Point 59	Point 46	Point 47	Point 45
TiO_2	56.9530	60.5220	56.1610	58.7850	49.9000	68.9310	60.7180	63.9140	65.1180	49.9180	62.4500	63.2200	57.0011
FeO	27.8100	24.3750	26.3630	26.2790	39.9950	15.0350	24.7710	19.2020	18.9100	41.5100	23.1070	20.2800	31.3579
Al_2O_3	0.0000	0.2970	0.0000	0.0000	0.0000	0.4190	0.0000	0.1920	0.2960	0.0000	0.0610	0.1510	0.0000
SiO_2	0.0000	0.0040	0.0370	0.0160	0.0000	0.0730	0.0540	0.0560	0.0590	0.0000	0.0090	0.0020	0.0000
Cr_2O_3	0.0220	0.0000	0.0000	0.0310	0.0090	0.0290	0.0070	0.0090	0.0180	0.0060	0.0110	0.0100	0.0000
SnO	0.1110	0.0780	0.1740	0.0000	0.0150	0.0700	0.0000	0.0620	0.0180	0.0440	0.0280	0.0700	0.0070
Nb_2O_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ZrO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0050	0.0000	0.0000	0.0000	0.0050	0.0140	0.0000	0.0000
P_2O_5	0.0070	0.0740	0.0000	0.0240	0.0000	0.1540	0.0400	0.0640	0.1140	0.0000	0.0000	0.0320	0.0000
PbO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0850	0.0000	0.0000	0.1500	0.0000	0.0000	0.0410	0.0000
As_2O_3	0.0710	0.0410	0.0420	0.0280	0.0410	0.0000	0.0490	0.0000	0.0290	0.0120	0.2790	0.3500	0.1350
ThO_2	3.3480	3.9820	3.7460	4.2420	3.9820	8.0570	4.0270	4.0950	5.0330	3.3530	2.4900	2.6790	1.3310
WO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total:	88.3220	89.3740	86.5230	89.4040	89.3740	92.8600	89.6650	86.8750	89.7460	94.7870	88.5000	86.8350	89.8340

Okside	SMTD1							SEK1			PPN1			
	Ti-rich	Fe-rich						Ti-rich		Fe-rich	Ti-rich			Fe-rich
	Point 3	Point 1	Point 2	Point 4	Point 5	Point 6	Point 7	Point 50	Point 52	Point 51	Point 28	Point 32	Point 35	Point 24
TiO_2	68.6440	50.5110	50.1630	49.8170	50.3710	50.9010	50.3420	57.0830	60.3920	48.6670	46.3790	59.0220	57.0610	50.2040
FeO	11.8090	40.3390	41.4340	42.2250	39.9490	39.9900	41.8380	28.3100	24.5080	42.4270	26.7480	25.2750	28.4390	40.3920
Al_2O_3	0.2540	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1730	0.4500	0.0000	0.0000	0.2170	0.1160	0.0000
SiO_2	0.1830	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0350	0.0000	0.0000	0.0920	0.0670	0.0000
Cr_2O_3	0.0000	0.0000	0.0010	0.0000	0.0000	0.0030	0.0030	0.0030	0.0210	0.0080	0.0080	0.0470	0.0310	0.0160
SnO	0.0000	0.0090	0.0040	0.0350	0.0210	0.0210	0.0000	0.0780	0.0520	0.0590	0.0000	0.0240	0.0140	0.0000
Nb_2O_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ZrO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0090	0.0070	0.0000
P_2O_5	0.0440	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0110	0.0170	0.0000	0.0000	0.0270	0.0000	0.0000
PbO	0.4890	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0310	0.0410	0.0000	0.0000	0.1510	0.2030	0.0000
As_2O_3	0.3700	0.0700	0.0130	0.0370	0.0620	0.0620	0.0650	0.0050	0.0000	0.0500	0.0460	0.0320	0.0330	0.0440
ThO_2	7.3940	2.8290	3.0640	1.6900	2.5550	2.5550	3.2250	4.1530	0.5090	3.6400	1.1880	1.8030	1.6350	2.9630
WO_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0280	0.0400	0.0000	0.0600	0.0000	0.0470	0.0000
Total:	89.1870	93.7580	94.6790	93.8040	93.4890	93.4890	95.4730	89.8770	86.0660	94.8540	74.4280	86.6990	87.6530	93.6180

Okside	TKSC1					KT1					
	Ti-rich			Fe-rich		Ti-rich		Fe-rich			
	Point 49	Point 46	Point 45	Point 47	Point 48	Point 11	Point 12	Point 8	Point 9	Point 10	Point 13
TiO_2	63.0470	63.4370	63.1240	47.2380	48.6070	67.8870	69.2970	49.5460	49.6080	49.9450	49.5400
FeO	17.8620	16.7830	17.2430	43.8920	40.7190	14.5350	14.1030	41.2230	41.3280	41.6150	41.2660
Al_2O_3	0.7960	0.5100	0.7280	0.0000	0.0000	0.5260	0.5870	0.0000	0.0000	0.0000	0.0000
SiO_2	0.0800	0.1260	0.1150	0.0000	0.0000	0.2290	0.1870	0.0000	0.0000	0.0000	0.0000
Cr_2O_3	0.0000	0.0190	0.0370	0.0040	0.0100	0.0060	0.0190	0.0140	0.0000	0.0060	0.0000
SnO	0.0100	0.0000	0.0310	0.0230	0.0000	0.0340	0.0050	0.0000	0.0000	0.0080	0.0000
Nb_2O_3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ZrO_3	0.0000	0.0000	0.0000	0.0280	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P_2O_5	0.0850	0.0950	0.0730	0.0000	0.0000	0.0000	0.0460	0.0000	0.0000	0.0000	0.0000
PbO	0.2290	0.0350	0.2560	0.0000	0.0000	0.0460	0.4150	0.0000	0.0000	0.0000	0.0000
As_2O_3	0.0440	0.0010	0.0290	0.0260	0.0200	0.3670	0.3640	0.0210	0.0490	0.0200	0.0330
ThO_2	3.4810	4.6310	2.5820	2.1970	3.6760	11.5870	10.0130	2.1250	3.4220	4.1270	3.7380
WO_3	0.1380	0.0000	0.0000	0.0710	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total:	85.7710	85.6370	84.2190	93.4780	93.0330	95.0360	95.0360	92.9300	94.4070	95.6240	94.5770

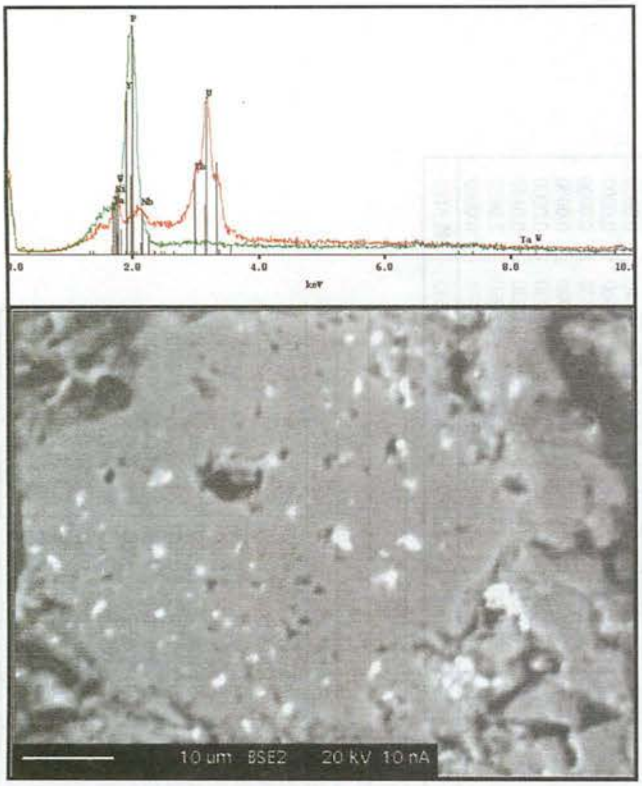

Figure 10. BSE image of xenotime with exsolutions of uranium (white) as confirmed by EDS scan (above, red). Sample TKSC1, Malim Nawar, Perak.

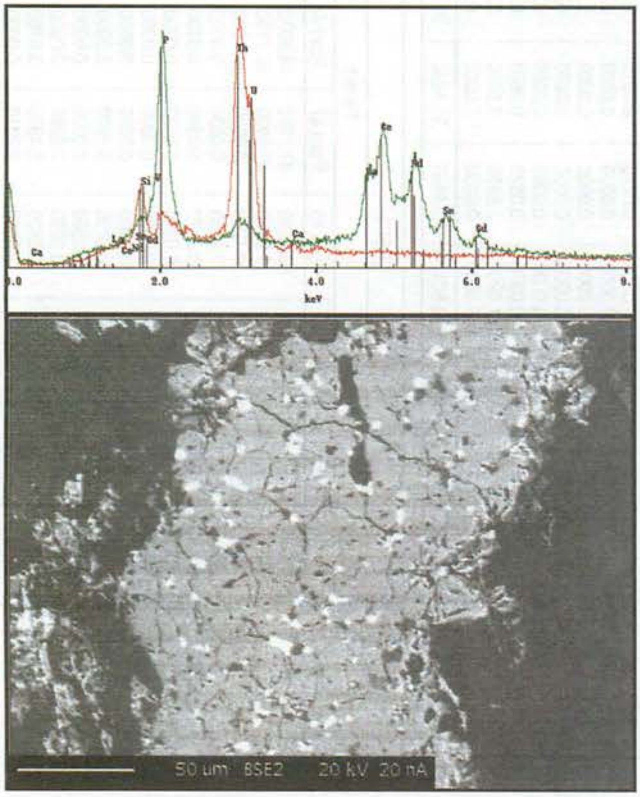

Figure 11. BSE image of U-Th exsolutions (white) in monazite. EDS scan confirmed the presence of U-Th (red). Sample S5, 16 mile Puchong.

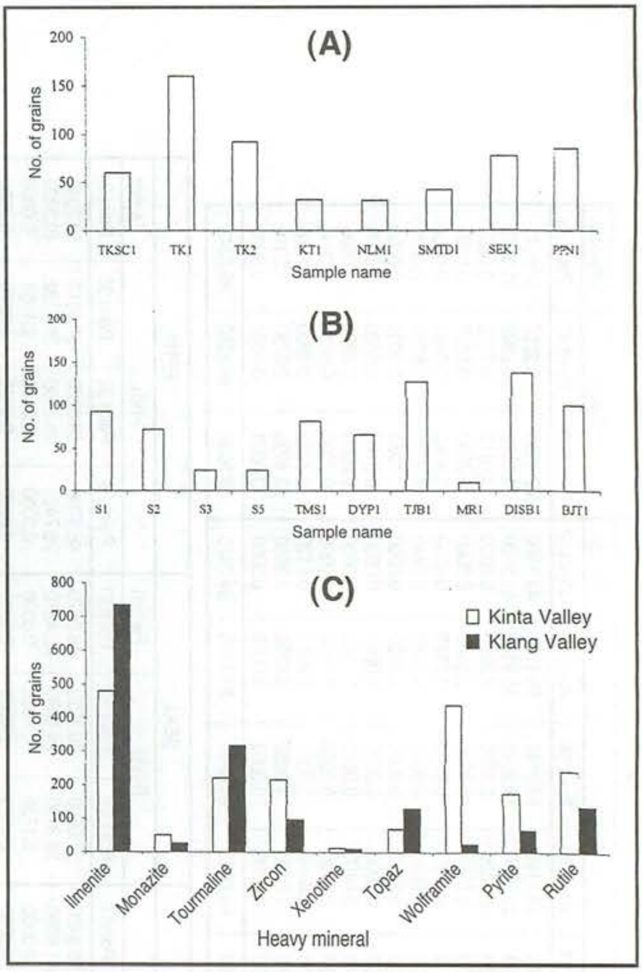

Figure 12. A shows the abundance of ilmenite from different localities in the Kinta Valley, while B is for the Klang Valley. C compares the abundances of different heavy minerals from the two valleys.

ACKNOWLEDGEMENT

Financial assistance from the University of Malaya for the research is appreciated.

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