



CHAPTER V

GEOCHEMISTRY

5.1 Whole-rock chemical analysis

5.1.1 Sample Preparation

As a supplement to the petrographic studies, forty-four rock samples were selected for whole-rock chemical analysis. The collected samples were non-weathered and least altered rocks. The studied samples were prepared for whole-rock chemical analysis by firstly splitting into conveniently sized fragments, and then crushing into small chips (approximately 0.5 mm across) using a Rocklabs hydraulic splitter/crusher. These crushed fragments were cautiously chosen to avoid vesicles, amygdale minerals, veinlets, xenocrysts, xenoliths, rock fragments and weathered surfaces. The selected chips were blown by compressed air to remove undesired and dusty materials. Approximately 70 g aliquots of the cleaned chips were pulverized for a few minutes using a Rocklabs tungsten-carbide ring mill. All the procedures described were performed at the Department of Geological Sciences, Chulalongkorn University (Thailand) and the Department of Applied Earth Sciences, Akita University, Akita (Japan).

5.1.2 Analytical techniques

The powdered volcanic samples were analyzed for 19 majors and minor oxides. These major oxides including SiO_2 , TiO_2 , Al_2O_3 , Fe_2O_3 , MnO , MgO , CaO , Na_2O , K_2O , P_2O_5 , SO_3 and loss on ignition and a number of some selected trace element (Nb) were analyzed using XRF at Akita University. Rock standards provided by Geological survey of Japan, including JG-1, JG-2, JA-1, JA-2, JB-1, JB-2, JB-3, and JGB-1, were used of calibration.

The 19 samples were analyzed for some trace elements (Cr, Ba, Li, V, Zn, Mg, Cu, Ni, Rb, Sr, Sc, Ce, Y and Zr) using ICP-OES in comparison with the same rock standards at Department of Apply Earth Science, Akita University.

The 3 representative samples of the unweathered and least-altered volcanic samples were analyzed for some trace elements (Sc, Mn, Co, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Cs and Ba) and rare-earth elements (REE) (i.e., La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Pb, Bi, Th and U), using ICP-MS in comparison JG-1 rock standard at Department of Apply Earth Science, Akita University.

5.1.3 Magmatic affinities and rock types

The studied volcanic rocks of the C-H pits were selected 19 samples for geochemical analyses on the basis of petrographic investigation. Chemical analysis data are reported in Table 5.1. All units of volcanic rocks, except monomictic breccia unit, have been analyzed. The coherent rocks have high SiO_2 contents ranging from about 50 to 65%. The average content of SiO_2 in the coherent unit is about 56.41%. The Na_2O contents of the coherent unit ranges considerably from 0.12 to 0.57 %. The average content of Na_2O of this unit is about 1.25%. MgO contents range from 3.09 to 7.28%, and Al_2O_3 contents range from 13.59 to 17.5%. SO_3 range considerably from 0.16 to 8.15 %, the K_2O contents show similar scenario, ranging considerably from 0.38 to 9.9. CaO contents of the coherent unit range from 1.91 to 9.85. TiO_2 content doesn't vary much, from 0.43 to 0.81 and MnO contents range from 0.17 to 0.19 %. The contents of Fe_2O_3 vary considerably from 5.34 to 15.47 in the coherent rocks.

The polymictic breccia rocks have extensive SiO_2 contents ranging from 49.31 to 90.57 %. Na_2O contents of this unit range from 0.01 to 2.57 %. P_2O_5 shows consistent contents varying from 0.06 to 0.28 %, MgO contents vary considerably from 0.33 to 6.31 %. Similarly, Al_2O_3 contents vary largely from 3.03 to 20.55 %. However, SO_3 contents of the polymictic breccia rocks range from 0.12 to 1.87% and K_2O contents range from 0.55 to 4.95%. TiO_2 contents range from 0.13 to 0.71 % and MnO contents vary from 0.09 to 0.37

% in the polymictic breccia rocks Fe_2O_3 and CaO contents show very similar situations, FeO and CaO contents vary considerably from 1.2 to 11.71 % and from 0.5 to 9.3 % in the volcanic breccia unit, respectively.

The fiamme breccia rock show extensive SiO_2 contents ranging from 51.28 to 67.06 %. Na_2O and P_2O_5 contents of the fiamme show less variation in contents from 0.17 to 2.79 %, and from 0.09 to 0.2 % respectively, MgO contents range from 2.59 to 7.52 %. Al_2O_3 and SO_3 contents in fiamme rocks do not vary much from 15.8 to 17.1 %, and 0.1 to 0.8 %, respectively. Similarly, K_2O contents show similar range to that of the volcanic breccia, i.e., 0.14-3.62 %. CaO contents fall with in the same range of the volcanic unit, viz. from 3.79 to 8.37 %. TiO_2 contents range from 0.41 to 0.81 %. MnO contents do not vary much from 0.11 to 0.28. Similarly situation is true for the Fe_2O_3 contents of the fiamme unit from 6.4 to 11.67 %.

Because zirconium is the immobile element and varies considerably from 7 to 97 ppm. So it can be use for the Harker diagram construction. Figure 5.1 shows the Harker diagram for the Zr contents versus the other major-oxide contents. The increase some trace element (such as Ni) in relation to Zr. Their result, suggest that all the volcanic suites are closely related both temporally and spatially. The other types of Harker diagrams, such as MgO versus major oxide and trace element contents, as shown in Figures 5.2. The increase in some major oxides (such as TiO_2) in relation to MgO and the decrease in some oxides (such as SiO_2) in relation to MgO, , as shown in Figures 5.3. The increase in some major oxides (such as MgO, Fe_2O_3 ,) in relation to TiO_2 , Figures 5.4 The decrease in some major oxide (such as MgO) and mainly major oxide vary in relation to SiO_2 . Trace element data in the Harker diagrams also show similar situation.

Positive trend of Harker diagrams data present highly differentiation and negative trend of Harker diagrams data present primitive magma.

The respectively, also show similar scenarios. These results point to the suggestion that these volcanic units may have occurred from the same source rocks. Harker SiO_2 diagram present alteration rock. Because as shown in the previous chapter regarding the petrographic result. It is found that the studied volcanic rocks were hydrothermally altered. So amount of silica present does not imply the good magmatic differentiation trend. Therefore, in order to explain the differentiation trend of the studied volcanic rocks, it is more appropriate to use the Hager diagram with the x-axis of some less mobile elements which in this case TiO_2 and MgO were selected for this study. It is observed that only some plots can be well correlated and show well linear trend, as shown in Figures 5.2 to 5.3

According to the discrimination diagram proposed by Irvine and Baragar (1971), these volcanic rocks of the C-H pit are constituted largely by subalkaline affinity with a very few alkaline affinity (Figure 5.5). As shown in the FeO-Alk-MgO triangular diagram (Irvine and Baragar.,1971), it is suggested that the volcanic rocks of the C-H pit are mainly calc-alkaline, with a minority of tholeiitic affinity (Figure 5.6). However, the relative amounts of Zr/TiO_2 and SiO_2 (Winchester and Floyd., 1977) indicate that for the Chatree volcanic rocks are subalkaline, andesite rhyodacite and dacite (Figure 5.7). The relative amounts of Nb/Y and Zr/TiO_2 for the Chatree volcanic rocks are mainly limited to subalkaline basalt and alkaline basalt, with a few of andesite (Figure 5.8) (Winchester and Floyd, 1977).

As shown in Figures 5.11 and 5.12 do not show the tectonic setting pointing to all subduction. However, the other diagrams display subduction related tectonic setting scenario. Therefore it is possible to believe that the studied rocks must take place in the subduction environment. This is the reason that the REE pattern must be applied to this study in order to explain the suitable tectonic scenario.

Table 5.1. Major-oxide contents of the Chatree volcanic rocks determined using XRF method.

Sample	Coherent Unit									Polymictic Unit						Fiamme Unit			
	AP001	AP004	AP002	AP003	AP005	AP015	AP006	A0003	A0004	PMRB1	PMAB1	PMAB2	PMAB3	PMAB4	PMAB5	PMAB6	FBG01	FBG02	FBR01
Na[2]O	0.59	0.01	1.60	1.46	3.25	1.03	1.41	1.79	0.01	2.57	0.01	0.01	1.83	0.42	0.73	0.01	2.79	0.17	1.88
P[2]O[5]	0.31	0.30	0.12	0.16	0.21	0.17	0.12	0.21	0.57	0.06	0.26	0.28	0.22	0.22	0.23	0.11	0.14	0.20	0.09
MgO	6.66	5.07	6.28	5.15	7.28	5.82	5.16	6.21	3.09	2.07	4.35	3.72	5.72	5.33	6.31	0.33	7.52	3.81	2.59
Al[2]O[3]	16.66	15.25	14.87	13.59	16.21	17.50	15.02	14.69	15.57	13.18	16.95	16.72	15.76	20.55	15.86	3.03	17.09	17.05	15.85
SiO[2]	52.55	49.55	59.10	65.83	53.36	52.97	60.78	58.18	55.45	72.78	61.57	58.03	56.41	49.31	55.53	80.57	51.28	59.81	67.06
SiO[3]	1.37	2.48	0.48	1.26	0.16	0.47	0.57	0.21	8.15	0.26	1.84	0.64	0.54	0.54	0.12	1.87	0.09	0.84	0.06
K[2]O	9.90	2.39	4.75	4.60	0.38	4.52	5.81	4.05	6.71	1.86	4.68	4.49	2.57	0.55	4.95	1.96	3.62	0.14	1.33
CaO	2.04	8.60	3.42	2.18	9.85	5.79	2.68	3.38	1.91	3.33	1.47	6.90	5.22	9.91	4.28	0.56	3.79	8.37	3.90
TiO[2]	0.78	0.43	0.56	0.44	0.81	0.64	0.54	0.88	0.49	0.31	0.67	0.67	0.68	0.62	0.71	0.13	0.81	0.43	0.41
MnO	0.50	0.46	0.19	0.22	0.17	0.33	0.23	0.38	0.17	0.09	0.26	0.37	0.37	0.22	0.37	0.00	0.28	0.16	0.11
Fe[2]O[3]	8.80	15.47	8.03	5.34	7.98	10.24	7.38	9.61	7.32	3.50	7.89	7.90	10.35	11.71	10.40	1.20	11.67	8.67	6.40
Nb	11.43	11.94	11.44	11.29	11.29	11.29	11.29	11.29	11.40	11.29	11.29	11.63	11.29	11.29	11.29	11.29	11.29	11.33	11.29

Table 5.2. Trace and selected REE concentrations of the Chatree volcanic rocks determined using ICP OES method.

Sample	Coherent Unit										Polymictic Unit						Fiamme Unit		
	AP001	AP004	AP002	AP003	AP005	AP015	AP006	A0003	A0004	PMRB1	PMAB1	PMAB2	PMAB3	PMAB4	PMAB5	PMAB6	FBG01	FBG02	FBR01
Cr	4.62	25.63	20.36	25.64	79.52	31.89	19.82	4.29	11.64	2.21	7.25	10.99	8.16	23.47	10.98	10.31	31.65	27.65	13.65
Co	147.97	57.30	164.59	127.82	301.73	134.97	94.55	94.55	80.34	171.16	47.29	121.41	124.36	280.74	78.89	29.80	245.77	243.35	200.58
Fe	1566.86	676.65	1623.48	881.43	111.37	1298.52	1091.86	1091.861	1879.77	422.45	23.94	694.12	409.32	110.12	1024.57	927.04	1383.18	53.31	27.83
Li	230.50	142.19	144.97	119.27	223.53	126.04	203.44	203.44	211.16	29.35	260.03	101.80	255.32	225.09	220.56	104.60	248.78	160.15	101.02
V	230.50	178.28	144.97	120.18	223.53	197.87	203.44	203.44	211.16	29.35	260.03	175.18	255.32	225.09	220.56	24.77	248.78	160.15	101.02
Zn	89.74	91.31	46.94	47.27	71.35	68.88	70.06	70.06	71.64	33.72	65.72	65.72	76.66	71.37	70.40	9.67	57.05	55.97	47.90
Mg	25364.34	20941.49	20910.65	17948.54	22950.27	22458.87	24005.17	24005.17	13413.49	6180.19	19119.97	14083.23	22776.27	21165.34	24614.78	387.82	27002.57	15848.96	6921.73
Cu	117.27	69.03	51.950	39.82	41.91	83.50	114.06	114.06	118.31	25.53	78.14635	83.28	99.98	158.19	82.90	28.46	138.56	180.01	32.27
Ni	0.00	4.72	2.140	0.00	14.06	4.54	9.21	9.21	0.00	0.00	0.00	4.59	5.56	0.00	5.84	0.00	8.00	0.00	0.00
Rb	518.14	88.24	271.83	196.96	867.12	211.81	863.24	863.24	473.06	144.98	386.59	285.11	847.06	808.78	843.51	72.33	203.261	813.60	884.28
Sc	37.95	45.63	30.34	43.11	899.42	55.81	904.62	904.63	36.84	27.14	48.24	45.32	884.65	837.11	886.48	25.99	40.27	843.96	920.89
Ce	26.77	25.67	16.36	18.52	23.78	13.54	29.49	29.49	14.17	21.88	20.68	25.42	25.45	21.89	23.82	10.24	17.83	16.72	21.92
Y	17.95	8.14	18.10	13.07	16.55	12.21	21.09	21.09	12.18	41.92	14.99	14.85	19.80	16.38	14.96	6.02	18.92	14.65	20.03
Zr	46.41	12.78	30.13	29.71	62.10	21.36	53.11	53.11	10.84	41.93	32.00	31.04	45.23	26.90	5.66	8.72	22.70	21.82	38.41

Table 5.3. Trace and REE concentrations of the Chatree volcanic rocks determined using ICP MS method.

Sample	AP006	PMAB1	PMAB5
Sc	22.5	23.32	25.30
Mn	1887	3303	3688
Co	15.89	25.83	22.33
Cu	78.89	83.32	95.77
Zn	79.91	76.32	101.5
Ga	13.32	23.01	21.06
Rb	74.62	136.80	97.86
Sr	111.60	35.86	71.51
Cs	0.00	1.89	0.94
Ba	1074.00	208.90	786.10
La	3.56	5.51	6.70
Ce	8.35	12.34	14.78
Pr	1.12	1.67	1.82
Nd	4.92	7.74	8.17
Sm	1.19	2.03	2.17
Eu	0.87	0.61	0.91
Gd	1.61	2.47	2.01
Tb	0.25	0.39	0.33
Dy	1.73	2.44	2.30
Ho	0.41	0.52	0.46
Er	1.42	1.53	1.34
Tm	0.21	0.25	0.21
Yb	1.36	1.68	1.28
Lu	0.20	0.29	0.22
Hf	1.04	1.48	1.16
Ta	0.07	0.17	0.20
Pb	2.26	7.19	1.17
Bi	0.02	0.01	0.00
Th	0.59	0.95	0.70
U	0.19	0.33	0.19

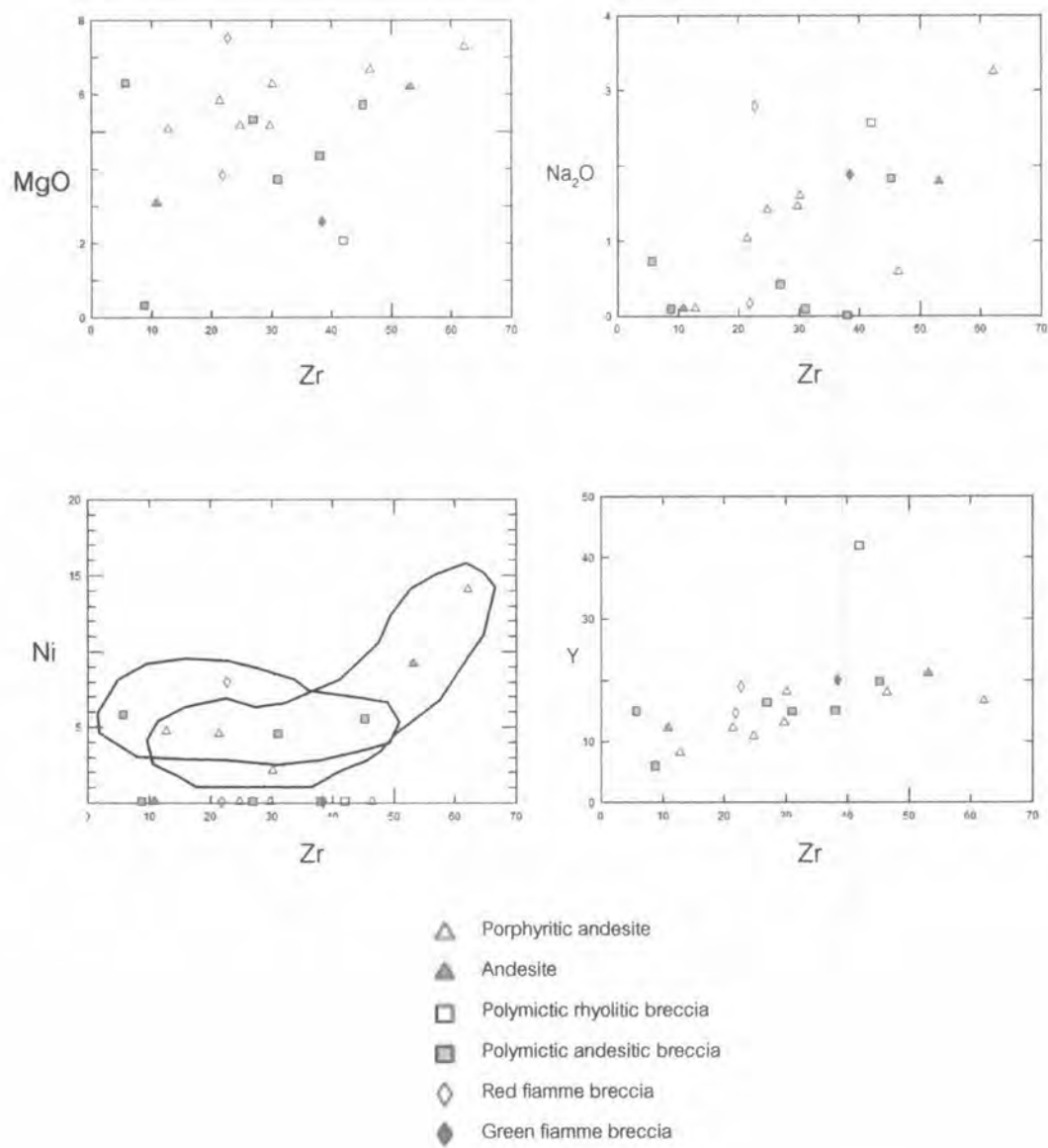


Figure 5.1. Harker diagrams of major oxide and trace elements versus Zr for volcanic rock at the Chatree gold mine, Phichit.

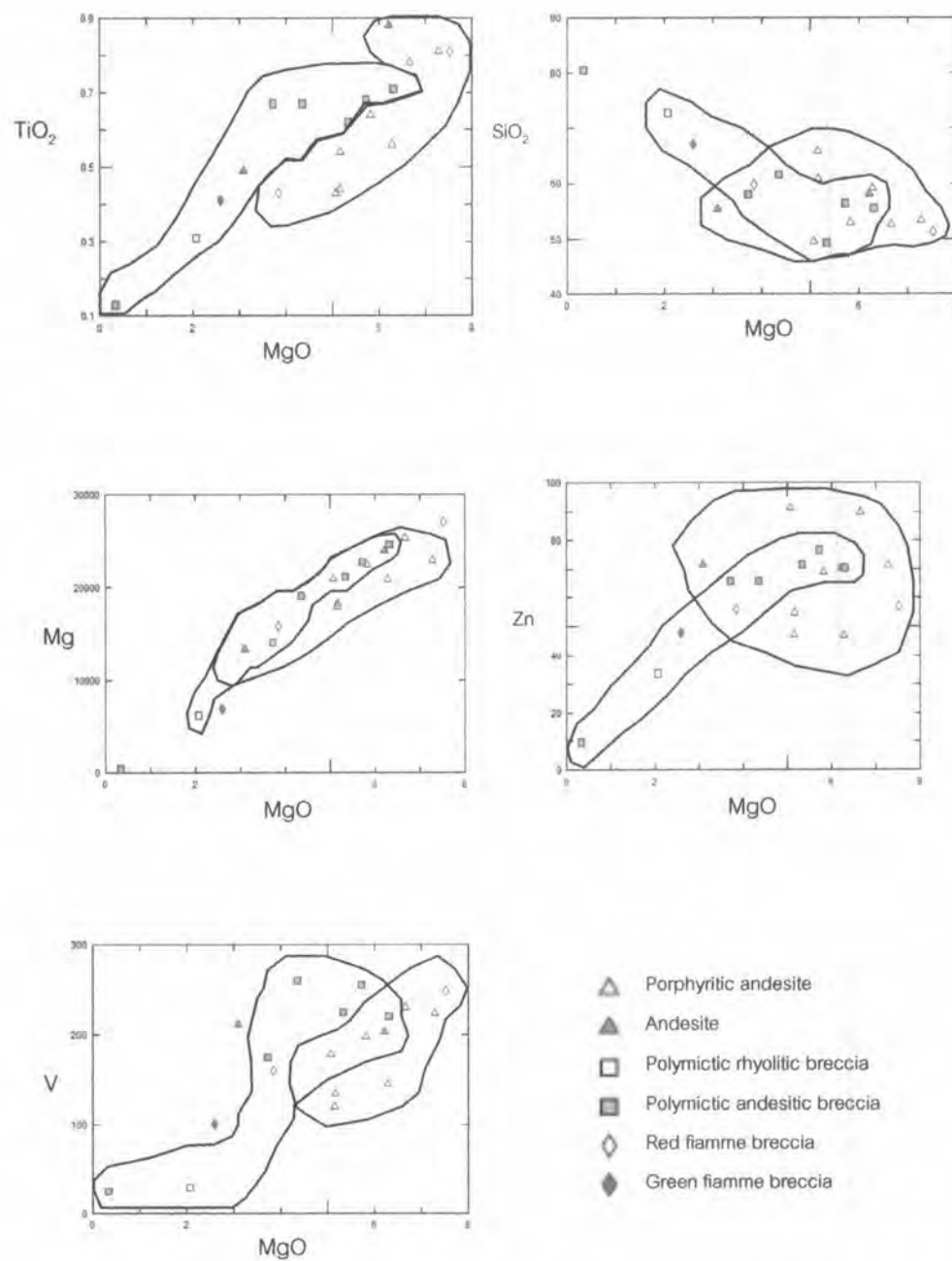


Figure 5.2. Harker diagrams of major oxide and trace elements versus MgO for volcanic rocks at the Chatree gold mine, Phichit.

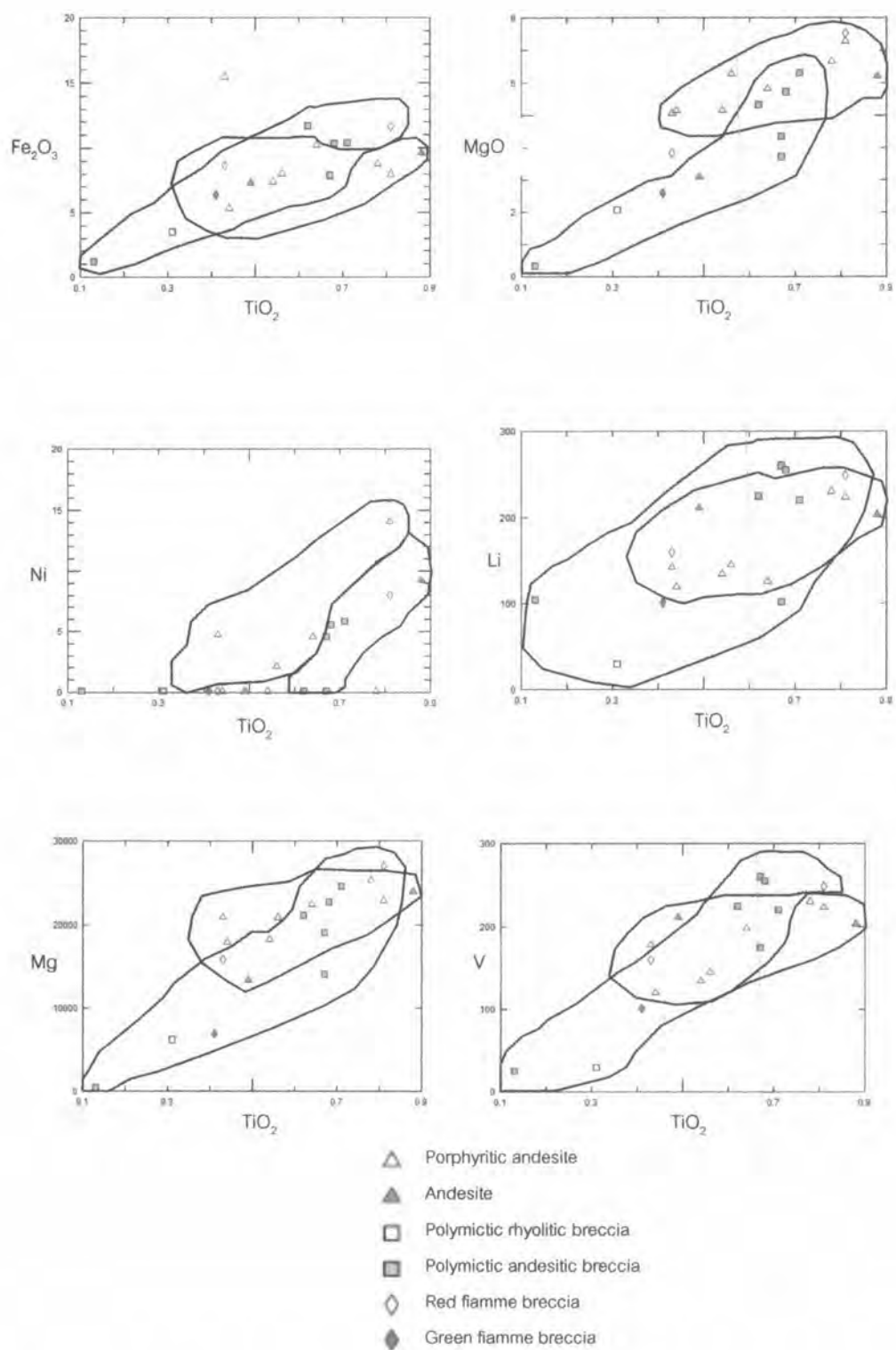


Figure 5.3. Harker diagrams of major oxide and trace elements versus TiO_2 for volcanic rocks at the Chatree gold mine, Phichit.

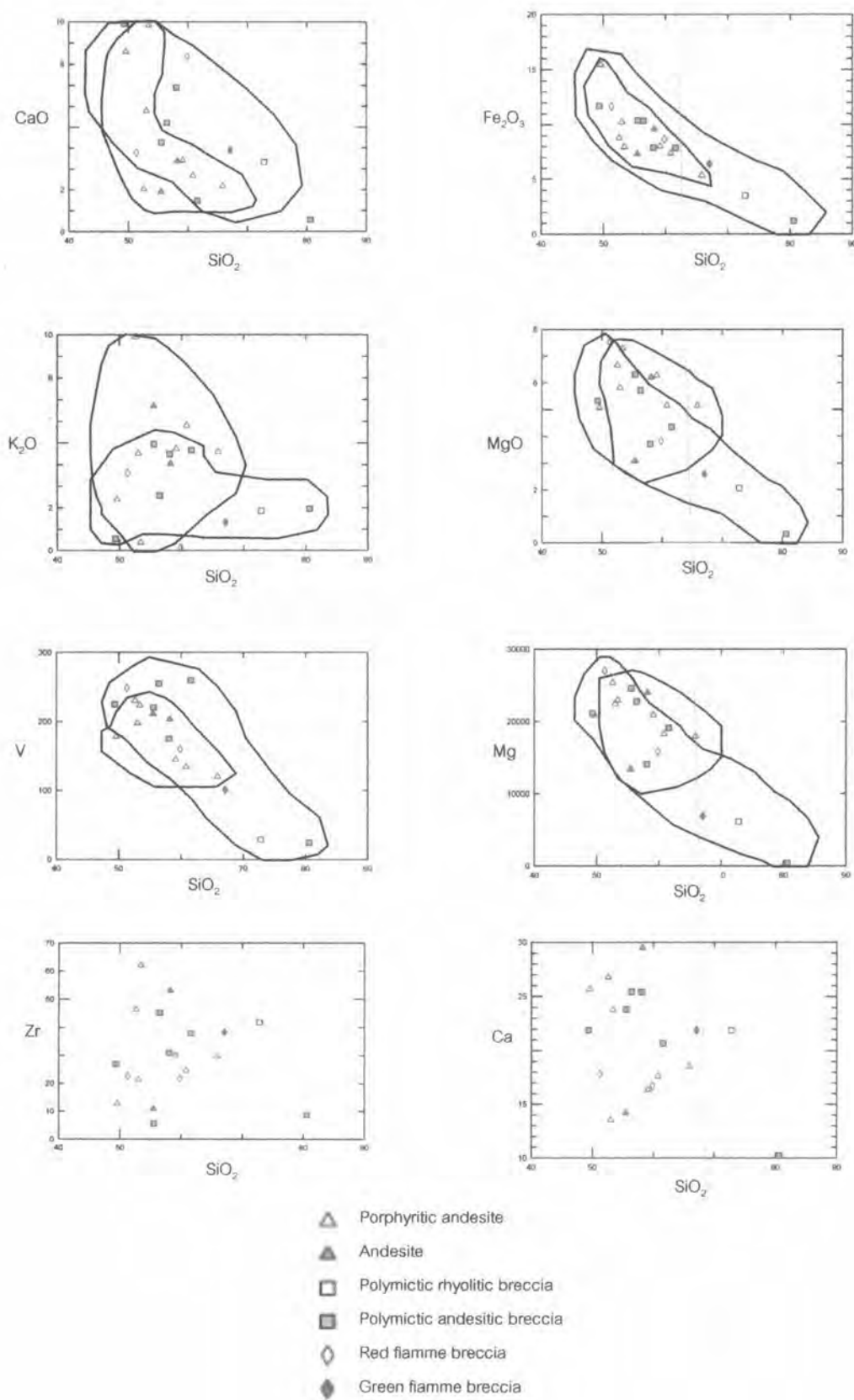


Figure 5.4. Harker diagrams of major oxide and trace elements versus SiO_2 for volcanic rocks at the Chatree gold mine, Phichit.

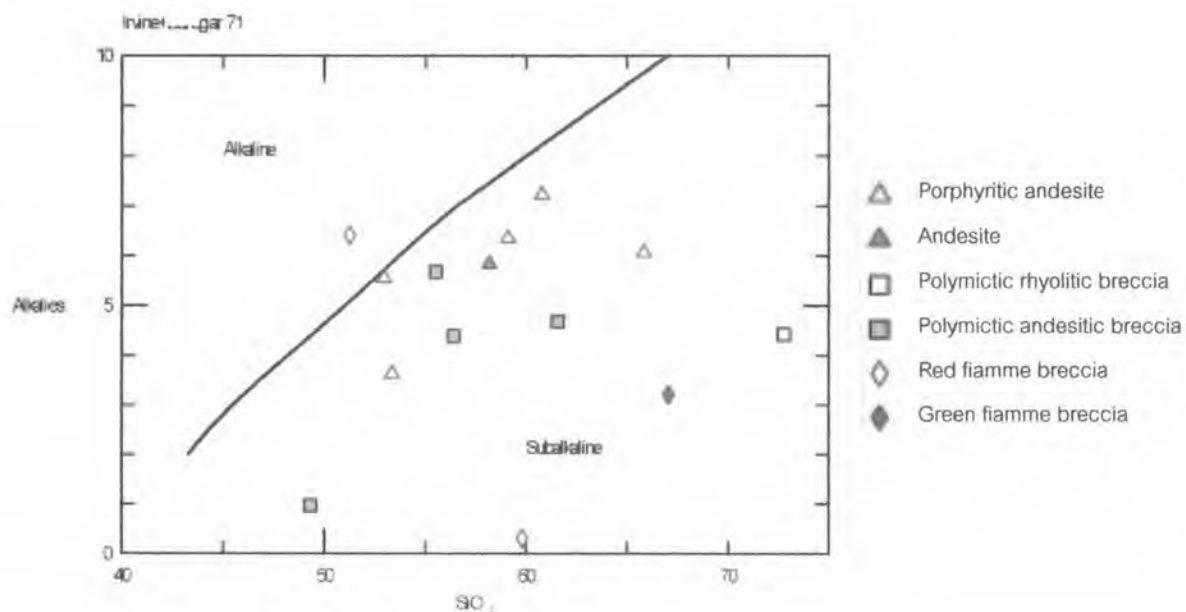


Figure 5.5. $\text{SiO}_2\text{-Na}_2\text{O}+\text{K}_2\text{O}$ plot indicates that Chatree volcanic rocks are in subalkaline (fields after Irvine and Baragar, 1971)

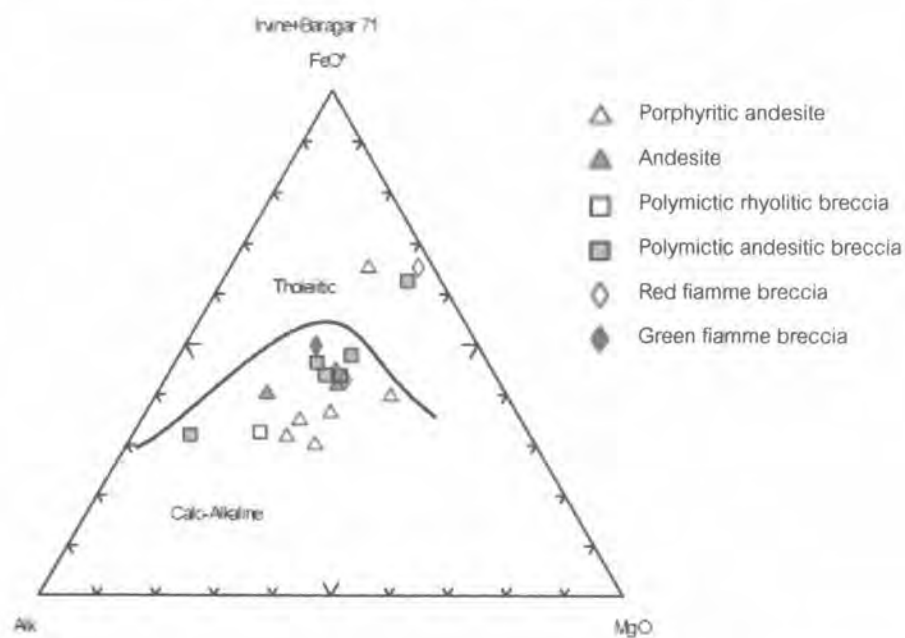


Figure 5.6. FeO-Alk-MgO variation triangular diagram showing data of the Chatree volcanic rocks plotted in mainly calc-alkaline. Diagram from Irvine and Baragar (1971).

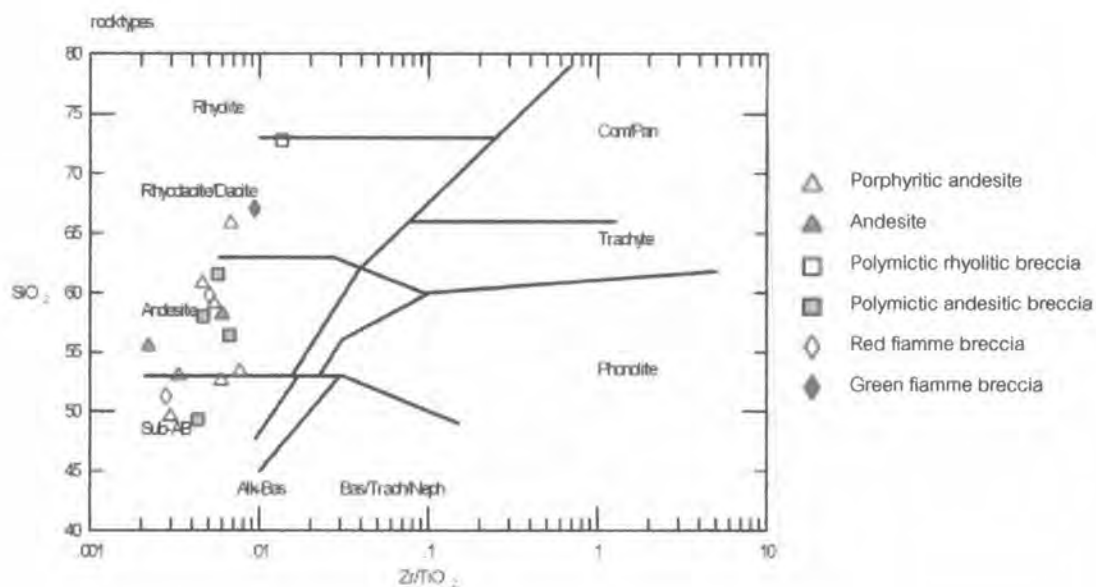


Figure 5.7. Plots of Zr/TiO_2 versus SiO_2 for the Chatree volcanic rocks are very dispersed varying from subalkaline basalt to dacite fields based on the diagram of Winchester and Floyd (1977).

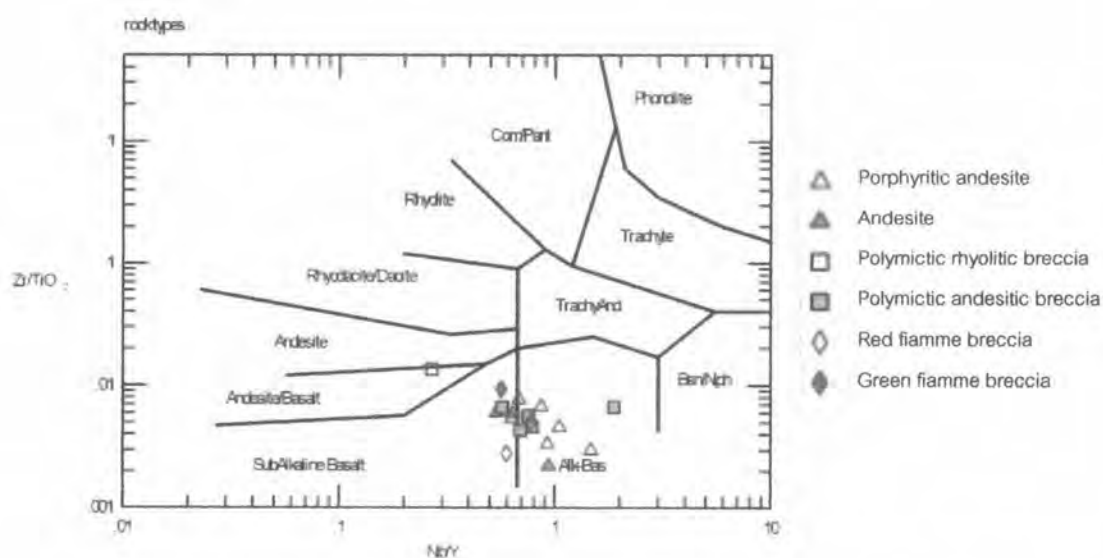


Figure 5.8. Plots of Nb/Y versus Zr/TiO_2 for the Chatree volcanic rocks are mainly limited to subalkaline basalt and alkaline basalt based on the diagram of Winchester and Floyd (1977).

5.1.4 Major and minor oxide analyse

The studied Akara volcanic rocks has extensive P_2O_5 ranging from 0.06 to 0.57 , K_2O ranges from 0.14 to 9.9, TiO_2 ranges from 0.13 to 0.81. The data point for P_2O_5 , K_2O , TiO_2 , and In this account, the data for major and minor oxides are plotted as triangular diagram of Pearce et al. (1975). This TiO_2 - K_2O - P_2O_5 diagram is all most continent plate field, mainly high K_2O data (Figure 5.9).

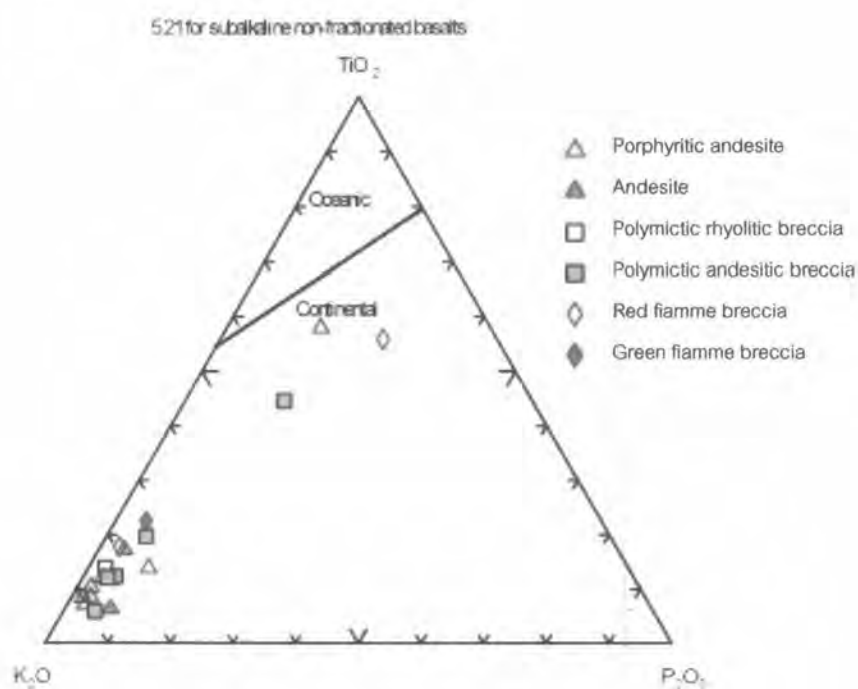


Figure 5.9. TiO_2 - K_2O - P_2O_5 variation triangular diagram (Pearce et al., 1975) showing data of the Chatree volcanic rocks plotted in the field of continental.

5.1.5 Trace and REE analysis

A. Trace element

In volcanic rocks, Cr, Ba, Li, V, Zn, Mg, Cu, Ni, Rb, Sr, Sc, Ce, Y and Zr are generally incompatible elements. Cr range from 2.21 to 79.52 , Ba range from 23.94 to 1879.77 , Li range from 29.35 to 260.03 , V range from 24.77 to 260.03 , Zn range from 9.67 to 91.31 , Mg range from 387.82 to 27022.57 , Cu range from 25.53 to 180.01 , Ni range from 2.14 to 14.06 , Rb range from 72.33 to 884.27 , Sr range from 29.80 to 280.74 , Sc range from 25.99 to 920.89 , Ce range from 10.24 to 29.49 , Y range from 8.14 to 41.92 , Zr range from 5.66 to 62.09 .

Up to present, many empirical diagrams for discriminating tectonic setting of eruption have appeared in literature. These diagrams are calc-alkaline basalt. Therefore, the chatree volcanic are plotted mainly in volcanic arc basalt of Y-Cr diagram (Pearce, 1982) (Figure 5.10). The Chatree volcanic are plotted of Ce/Zr-Cr diagram in mainly volcanic arc basalt (Pearce, 1982) (Figure 5.11). The chatree volcanic are plotted of Zr-Zr/Y diagram in mainly volcanic arc basalt, few in term mid oceanic ride basalt (Pearce and Norry, 1979)(Figure 5.12). The chatree volcanic are plotted of Th-Ta-Hf/3 triangular diagram in mainly volcanic arc basalt (Wood, 1980)(Figure 5.13). The chatree volcanic are plotted of $2\text{Nb-Zr}/4\text{-Y}$ triangular diagram in mainly volcanic arc basalt (Meschede, 1986)(Figure 5.14). The chatree volcanic are plotted of Ti/1000-V diagram in mainly arc tholeiitic (Shervais, 1982) (Figure 5.15). The chatree volcanics are plotted of Ta/Yb -K₂O/Yb diagram in mainly volcanic arc basalt and calc alkaline (Pearce, 1982)(Figure 5.16). These data are mostly close to the volcanic arc field.

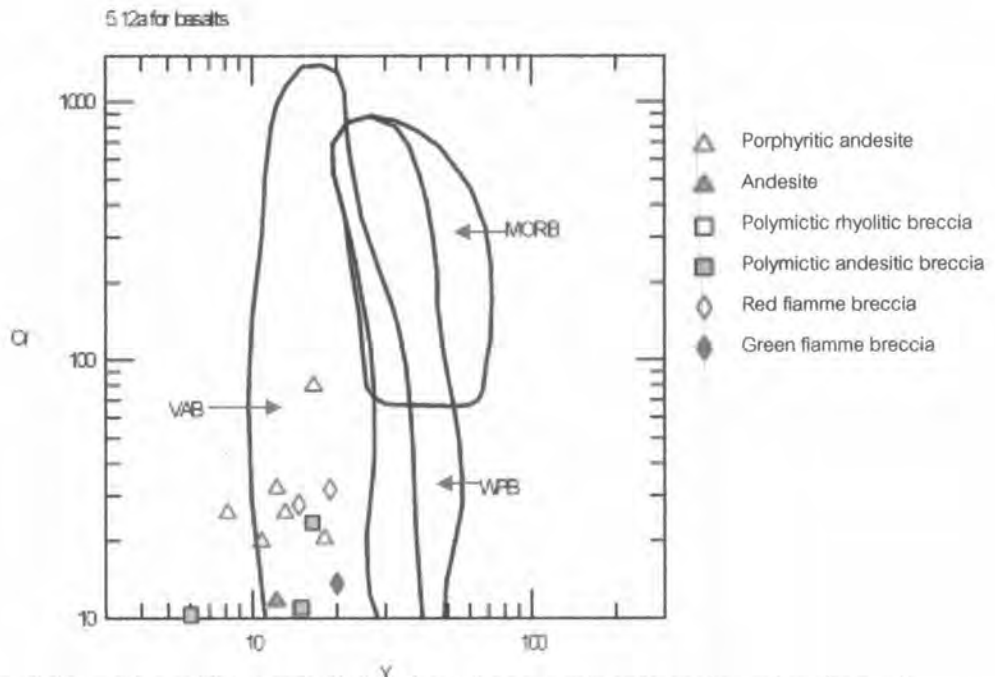


Figure 5.10. Plots of Y versus Cr for the Chatree volcanic rocks in the field of volcanic arc basalt based on the diagram of Pearce (1982).

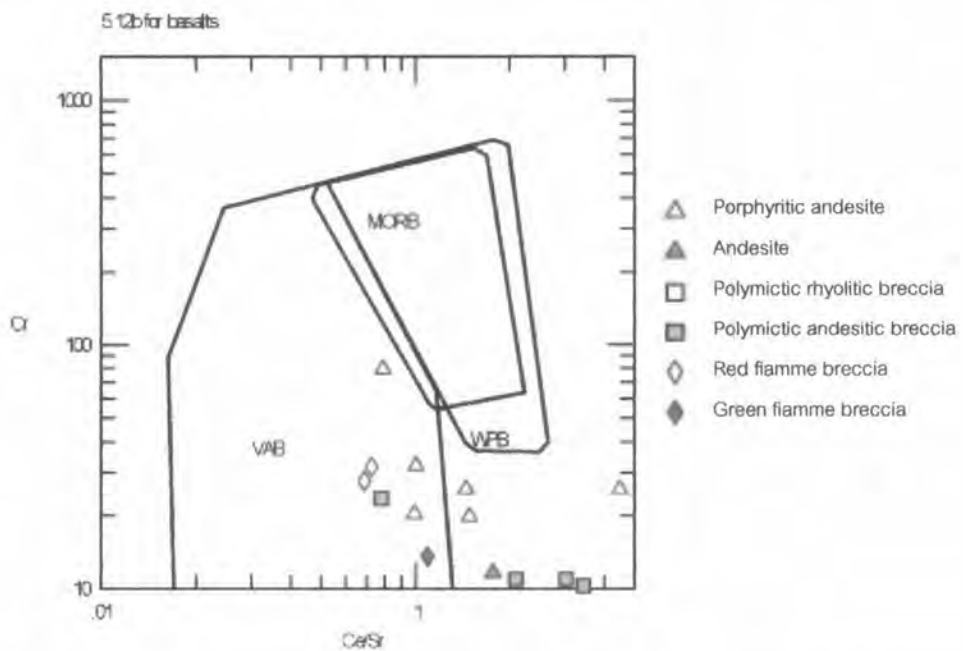


Figure 5.11. Ce/Sr versus Cr plot indicates the volcanic rocks are in the arc field. (diagram based on Pearce, 1982)

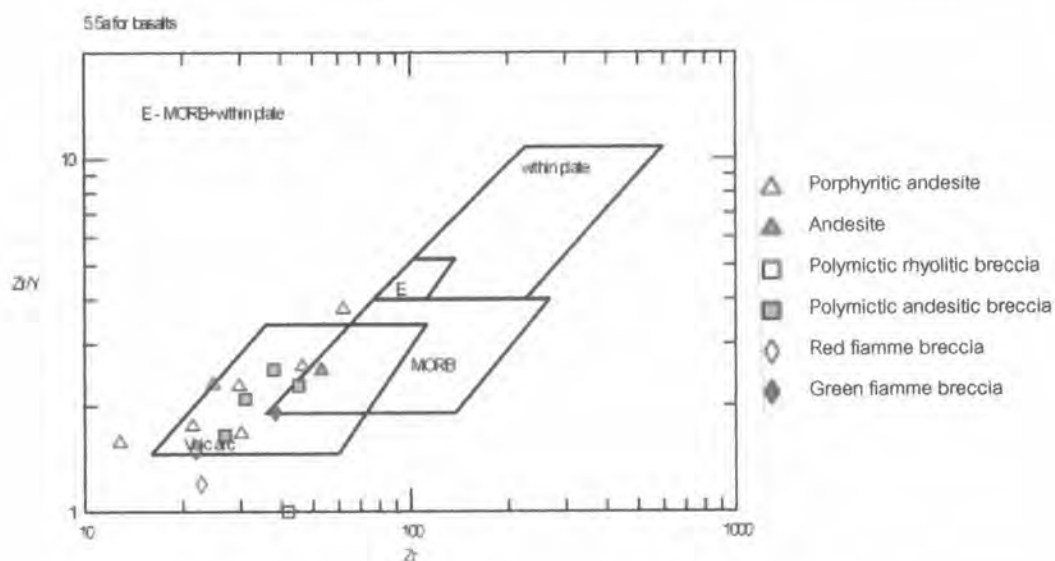


Figure 5.12. Plots of Zr versus Zr/Y for the Chatree volcanic rocks are mostly in volcanic arc basalt fields based on the diagram of Pearce and Norry (1979).

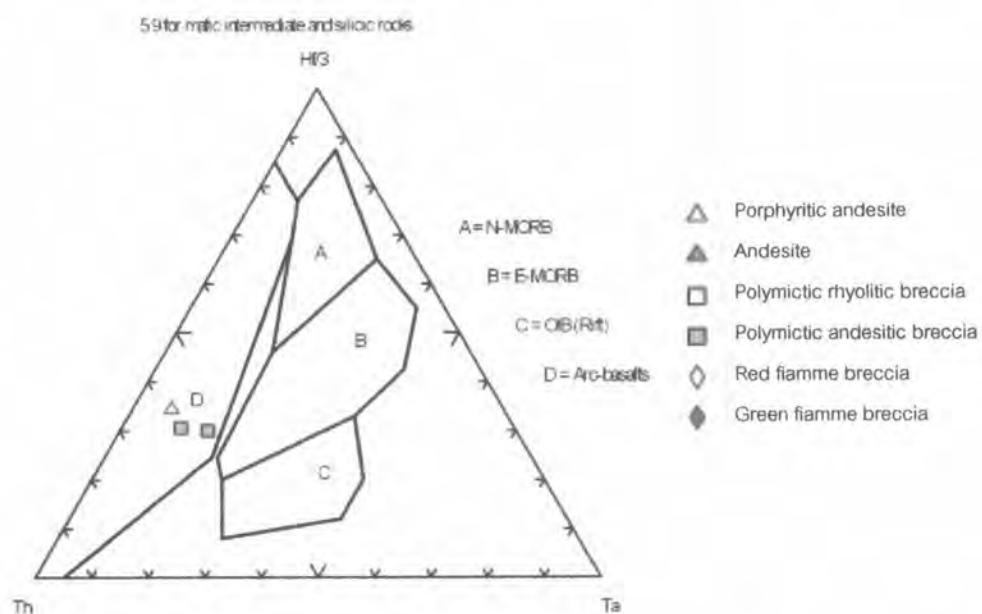


Figure 5.13. Th-Ta-Hf/3 variation triangular diagram showing data of the Chatree volcanic rocks plotted in the field of volcanic-arc basalts. (diagram from Wood, 1980).

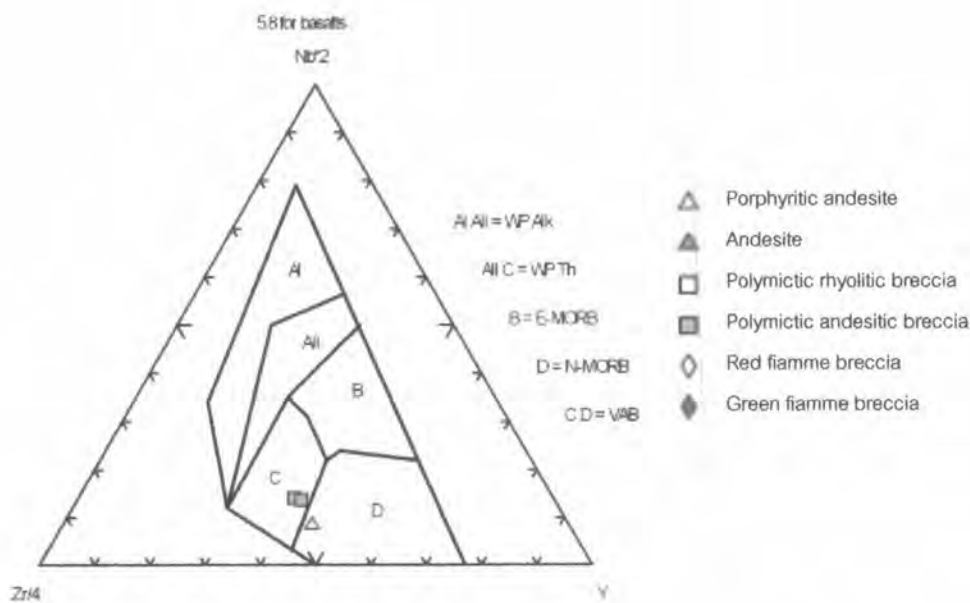


Figure 5.14. 2Nb-Zr/4-Y variation triangular diagram showing data of the Chatree volcanic rocks plotted in the field of volcanic-arc basalts. Diagram from Meschede, 1986.

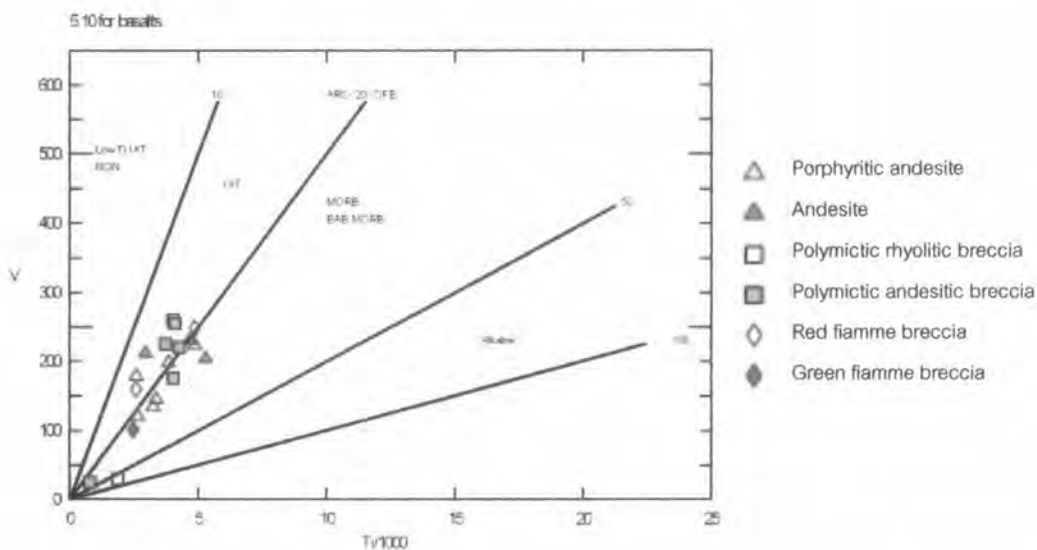


Figure 5.15. Ti/1000 -V plot indicates the Chatree volcanic rocks are in the arc field. (Diagram from Shervais, 1982)

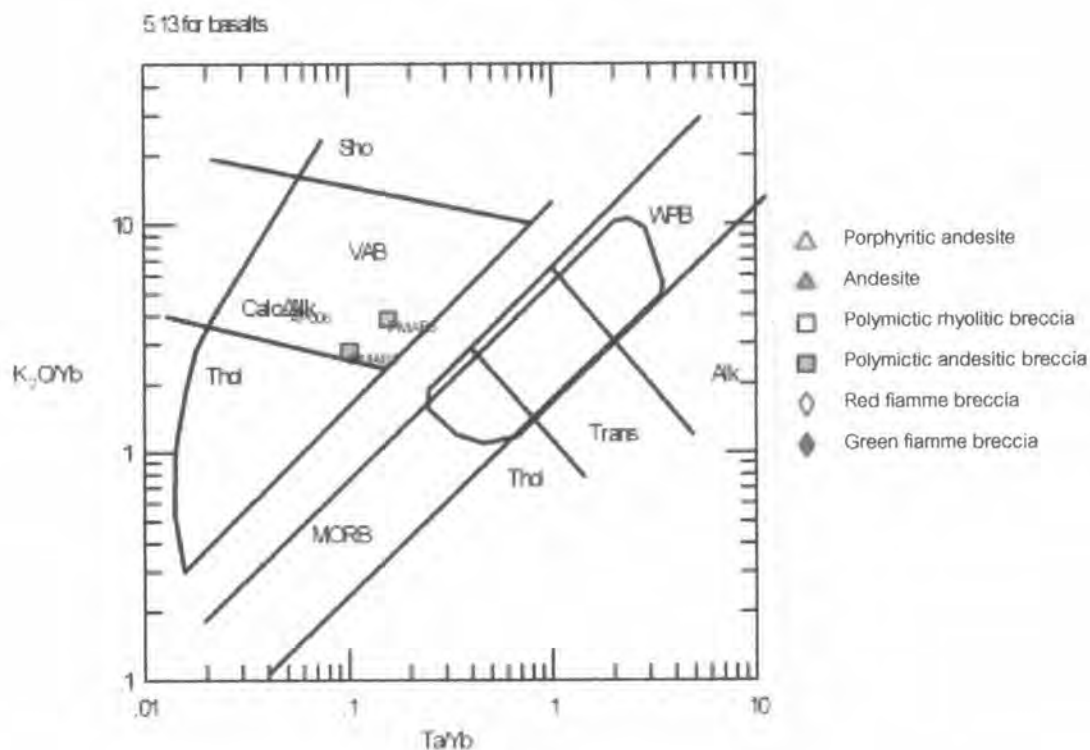


Figure 5.16. Ta/Yb -K₂O/Yb plot indicates the Chatree volcanic rocks are in the volcanic arc and calc alkaline fields. (diagram from Pearce,1982).

B. REE analyses

REE analyses for three representatives of the Chatree volcanic samples (sample no AP6, PMAB1 and PMAB 5) are reported in Table 5.3. Their rock/condrite values are plotted in diagram after Sun and Mcdon (1989). The results, in terms of REE pattern, Tertiary, subduction-related (Figure 5.17), show that the Chatree volcanics are closely analogous to Mayon and Taal Volcanoes, Southern Luzon, Philippines (Castillo et al., 2003). As a consequence, it is confirmed that the studied Chatree volcanic rocks were erupted in subduction environment.

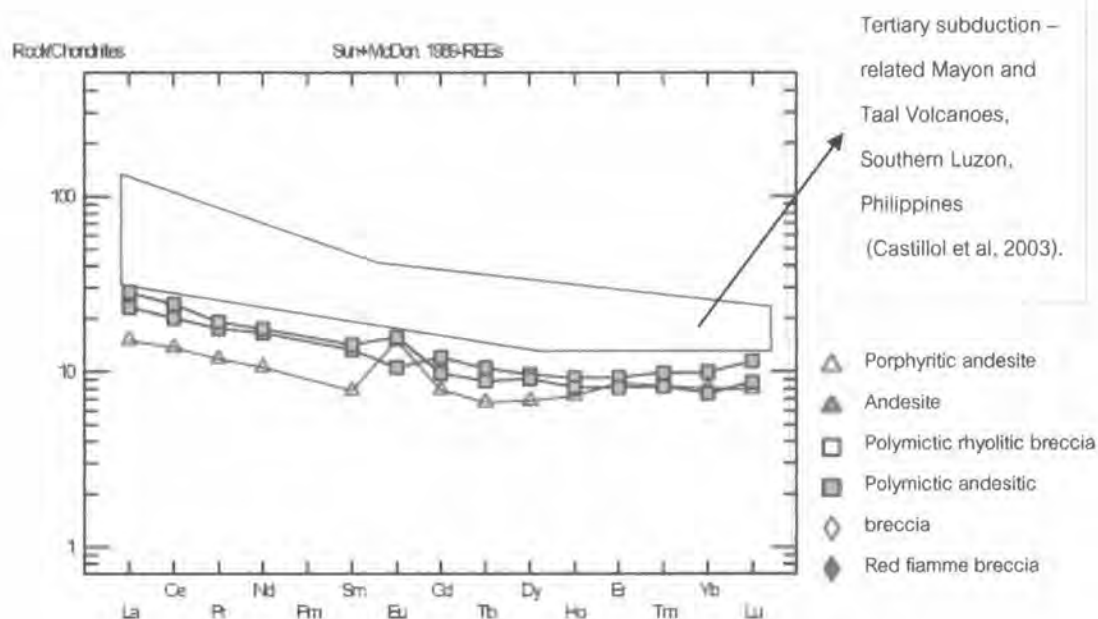


Figure 5.17. Chondrite-normalized REE patterns for the volcanic rocks from 3 samples of the Chatree gold mine in comparison with Mayon and Taal volcanic rocks which is the field of subduction.

5.2 Isotope Geochemistry

5.2.1 Results

The use of stable isotopes of oxygen and carbon in calcite to access source of mineralization determinations, such as to distinguish between carbonates of different origins (Taylor 1974, Onuma et al 1972, Sheppard 1977, Granham and Harman 1983 and Hoefs 1987). These are based mainly on the premise principle that fresh waters are depleted in both heavy carbon ($\delta^{13}\text{C}$) and heavy oxygen ($\delta^{18}\text{O}$) relative to marine water (Rolinson, 1983).

The isotopic compositions of oxygen are reported in terms of $^{18}\text{O}/^{16}\text{O}$ ratio. The ($\delta^{18}\text{O}$) relative to the two standards, the SMOW and PDB. The SMOW (Standard Mean Ocean Water) was originally hypothetical water sample with oxygen and hydrogen isotope ratios similar to those of standard ocean water. The SMOW was define by Craig

(1961) with reference to a large volume of distilled water that distributed by the National Bureau of Standard in the United States (Faure,1986). The PDB standard was originally used by Urey and his colleagues at the university of Chicago for express the isotope composition of oxygen in carbonate, particularly palaeotemperature determinations based on CO₂ produced from Cretaceous Belemnite of the Peedee Formation in South Carolina (Rollinson, 1993; Faure,1986).

The conversion of resulting between the SMOW and PDB values have been illustrated by Friedman and Nions (1977) as

$$\delta^{18}\text{O}_{\text{SMOW}} = 1.03086 \delta^{18}\text{O}_{\text{PDB}} + 30.86$$

The carbon isotope composition of calcite is subsequently presented in term of the relative abundance between ¹³C and ¹²C ratios (‰) comparing with PDB standard as well as of δ¹⁸O values.

Isotopic results

Oxygen isotope

Totally 7 isotopic analyse of calcite (Table 5.4) of C-H pit in the Chatree gold mine display the δ¹⁸O values from -19.4 to -16.4 per mil with an average of -17.84 permil (PDB).

Carbon isotope

The 7 calcite samples (Table 5.4) show the carbon isotopic values ranging from -4.9 to -2.5 per mil (PDB) with an average of -3.71 per mil (PDB).

Table 5.4. Result of C- and O- isotope analyses for the C-H pit, Chatree gold mine, Phichit.

Sample no.	$\delta^{13}\text{C}$ ‰(PDB)	$\delta^{18}\text{O}$ ‰(PDB)	$\delta^{18}\text{O}$ SMOW
A3	-3.2	-18.4	11.89
A4	-2.5	-16.4	13.95
AP1	-4.7	-17.3	13.03
AP4	-4.9	-19.2	11.06
PMAB1	-2.9	-19.4	10.87
PMAB3	-3.5	-17	13.33
PMAB5	-4.3	-17.2	13.13
Average	-3.71	-17.84	12.46
Maximum	-2.5	-16.4	13.95
Minimum	-4.7	-19.4	10.87
SD			

5.2.2 Interpretation

Marine carbonates are commonly show positive $\delta^{18}\text{O}$ values, whereas the non-marine are generally less enrichment $\delta^{18}\text{O}$ values. The calcite in the study area is considered as a carbonate of marine origin, and displays average $\delta^{18}\text{O}$ value at 12.46 per mil with the maximum and the minimum values at 13.95 and 10.87 per mil on SMOW scale, respectively. These analogous to marine carbonate that generally illustrates positive $\delta^{18}\text{O}$ values between +20 per mil +30 per mil relative to SMOW (Faure, 1986)

Carbon – Oxygen isotope analysis from carbonate minerals (such as calcite, rhodochrosite, and limestone) was reported by Kromkhum (2006) for the volcanic rocks of the H pit. The $\delta^{13}\text{C}$ values range from -0.76 to 7.33‰ PDB and $\delta^{18}\text{O}$ values range from 7.49 to 14.92 ‰. These isotopic results are somewhat similar to this study.

The relationship of $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ (PDB) plots of calcite from the C-H pit (Fig.5.18) shows that the isotopic values are mostly located in field of carbonate of marine origin.

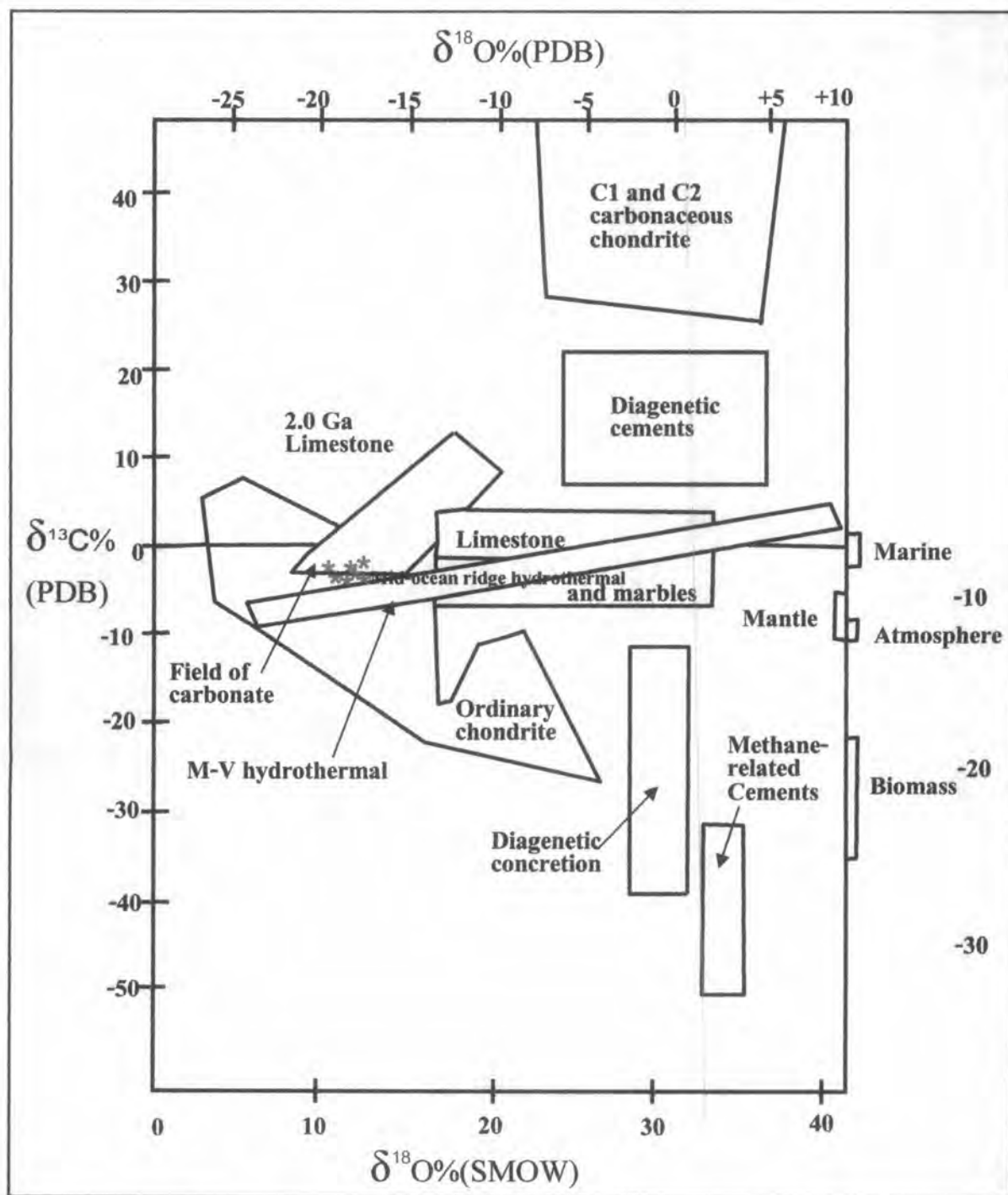


Figure 5.18. $\delta^{18}\text{O}$ vs $\delta^{13}\text{C}$ plot showing the C-H pit calcite vein in volcanic host are located in the field of carbonate, and possibly mixing origin (diagram from Rollinson, 1983).