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Research Article

Petrography of Volcanic Rocks at Q-prospect, Akara Gold Mine, Pichit Province, North Central Thailand

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Abstract

Permo-Triassic volcanic rocks at Q-prospect, northern Akara gold mining area in Phichit Province, north central Thailand, can be subdivided into porphyritic andesite, andesitic tuff and rhyolitic tuff which are mostly cross cut by late stage andesite dike. All of these volcanic rocks and dike were sampled for this study. Porphyritic andesite samples usually show hypocrystalline with microporphyritic to porphyritic textures. Their groundmass usually contains plagioclase microlite and glass. In addition, adularias are rarely present as fine-grained crystals and as rhombic forms in some veinlets. Andesitic tuff contains up to 20 % volcanic fragments (ranging in size from 0.05-2 mm) embedded in volcanic ash and glassy materials. Rhyolitic tuff usually present 0.5-2 mm quartz grains and wedge-shaped rock fragments, mainly replaced by chlorites; these crystals and rock fragments are set in microcrystalline quartz and glass. Andesite dike samples normally show subophitic texture, small plagioclase enclosed partly by pyroxene crystals. Based on whole-rock geochemistry, Zr/TiO_2 versus SiO_2 diagram indicates that volcanic hosts are equivalent to andesite/sub-alkaline basalt to rhyodacite/dacite and rhyolite. They appear to have derived from cogenesis calc-alkaline magma. Zr-Ti tectono diagram suggest that these rocks may have originated in vicinities of island arc tholeiite and/or volcanic arc.

Keywords: Geochemistry, Gold, Tectonic, Thailand, Volcanic rocks

1. Introduction

Akara gold mining field is located on the western edge of Khorat plateau in Phichit province, north central Thailand. Gold reserve herein this deposit, so called Chatree Deposit, has been proven as the largest one of the country. Recently, approximate 19 km^2 of 7 prospect areas have been pointed out and 7 mining pits have been in operation (James and Cumming, 2007). Geological setting is mainly occupied by Pre-Jurassic volcanic rocks which are part of Loei-Phetchabun-Ko Chang volcanic belt (Jungyusuk and Khositanont, 1992) (see Fig. 1). In general, volcanic rocks in the Chatree Deposit may have formed in island-arc volcanism (e.g., Marhotorn, 2008; Nakchaiya, 2008). Main structures of this area are recognized mainly within the NNE-SSW to N-S trends with minor trend along N-E direction. In this paper, we present detailed petrographic investigation and geochemical data of volcanic rocks and dike rock from Q-prospect in the northern mining area.

2. Geology and Stratigraphy

Volcanic host rocks in Chatree gold deposit can be subdivided generally into four units which are mostly cross-cut by andesitic to basaltic dikes probably after mineralization period. These volcanic hosts and their related sedimentary rocks appear to have occurred in a subaqueous-shallow marine environment (James and Cumming, 2007). Stratigraphic units are described from top to bottom as below.

Unit 1: contains lithic-rich fiamme breccia interbedded with fine-grained fiamme-rich sandstone, siltstone and thin layers of lapilli-rich siltstone and polymictic mud matrix breccia. This unit un-conformably overlies the lower units.

Unit 2: is composed of fine-grained epiclastic and minor sedimentary facies including laminated siltstone, mudstone and carbonaceous to calcareous (fossiliferous) siltstone.

Unit 3: comprises of polymictic andesitic breccias and polymictic andesitic basaltic breccias which are partly inter-bedded and overlain by Unit 2. This unit also includes thin isolated intervals of monomictic andesitic breccia, plagioclase phyric andesite and hornblende phyric andesite.

Unit 4: is the lowest intersected stratigraphic unit. It contains monomictic andesitic breccia, plagioclase phyric andesite, hornblende phyric andesite and minor polymictic andesitic breccias. It contains small isolated bodies of coherent dacite and rhyolite with associated thin zones of monomictic dacitic and rhyolitic breccia.

Andesite, dacite and basalt dikes cross-cut the whole succession (James and Cumming, 2007).

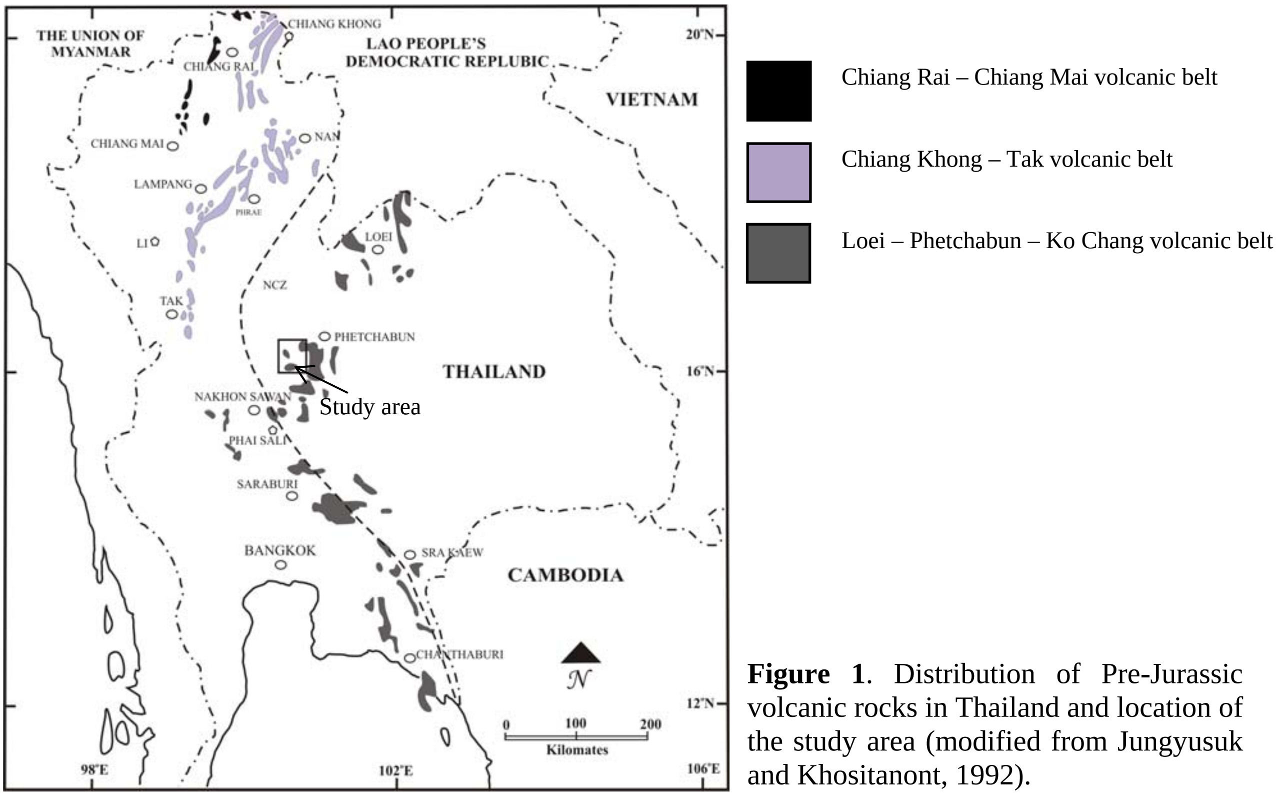

Figure 1. Distribution of Pre-Jurassic volcanic rocks in Thailand and location of the study area (modified from Jungyusuk and Khositanont, 1992).

3. Sample Collection and Methodology

Forty three rock samples were collected from 14 dill cores within Q-prospect. Ten thin sections and twenty polished-thin sections were prepared for petrographic investigation under a polarizing microscope. Subsequently, twenty five least-altered samples were selected for whole-rock analyses including major and some trace elements using an X-Ray Fluorescence (XRF) spectrometry at Akita University in Japan. All selected rock samples were crushed by an iron jaw crusher and subsequently powdered by an agate mortar. Powder rock samples were then fused to glass beads for analyses of 9 major oxides (i.e., SiO_2, TiO_2, FeO_t, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5) and 10 trace elements (i.e., Ba, Zn, Sr, Rb, Zr, Co, Cr, Ni, Y and V). Loss on ignition (LOI) was also measured by weighting rock powders before and after ignition at 900º C for 3 hrs in a TMF-200 electric furnace.

4. Petrography

Four rock units including porphyritic andesite, andesitic tuff, rhyolitic tuff and andesite dike were classified. Petrographic descriptions of these rocks are reported below.

Porphyritic Andesite is generally greenish grey to dark green with white spots. Porphyritic texture is clearly observed in these rock samples. Microscopically, phenocrysts are mainly composed of about 25% K-feldspar, 15% plagioclase and minor relic amphibole. Plagioclase and K-feldspar usually show subhedral to euhedral crystals ranging in size from 0.5-2 mm long (Fig. 2*a*). These phenocrysts embed in fine-grained groundmass of tiny lath-shaped feldspar and glass with subordinate opaque mineral. Feldspar laths usually form trachytic texture. Relic hornblende, wholly altered to sericite, still remains euhedral shape with perfect cleavages as shown in Fig. 2*b*. In addition, both plagioclase and K-feldspar have also been replaced partly by alteration products such as sericite, chlorite, quartz and calcite (Figs. 2*a* and 2*b*).

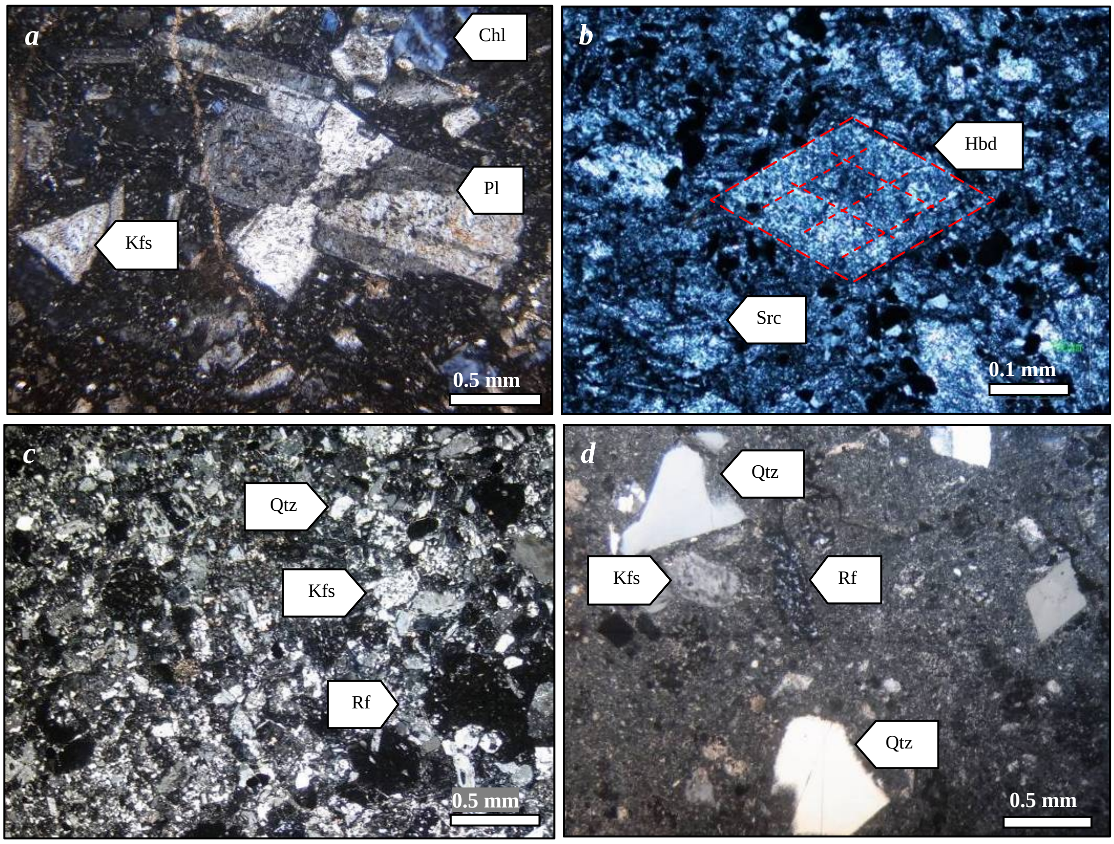

Figure 2. Photomicrographs showing (a) plagioclase (Pl) and K-feldspar (Kfs) phenocrysts with some replacement of chlorite (Chl) in a porphyritic andesite sample; (b) relic hornblende (Hbd) replaced by sericite (Src) in a porphyritic andesite; (c) Andesitic tuff sample containing quartz (Qtz), K-feldspar (Kfs) and rock fragments (Rf) which are characterized significantly by porphyritic andesite consisting of plagioclase phenocryst surrounded by glassy material; (d) subhedral quartz crystals (Qtz) and rock fragments (Rf) in a rhyolitic tuff sample.

Andesitic Tuff is commonly characterized by greenish grey to dark green rocks containing poorly sorted angular to subrounded clasts which may reach up to 20% mode. Clasts in these rock samples have different colors commonly green and reddish brown. Their sizes range from 0.05 to 2 cm. Under microscope, these lithic clasts are mainly recognized as porphyritic andesite (Fig. 2*c*) and occasionally by sedimentary rocks. Plagioclase and K-feldspar are subhedral to euhedral with quantity of about 30% whereas relic hornblende is sometimes recognized. Quartz usually occurs as angular fragments with amount of about 20%. This rock type commonly shows patchy alteration to chlorite and sericite.

Rhyolitic Tuff has various colors usually from white to pale pink and pale green. In general, their constituents are composed of about 40% quartz crystal, 40% ash and 20% lapilli (Fig. 2*d*); they appear to have been moderately to poorly sorted. Regarding to lapilli materials, they are mainly characterized by porphyritic andesite and rhyolite. Rock samples in this group also show local silicification.

Andesite Dike is the latest stage cutting through porphyritic andesite, andesitic tuff and rhyolitic tuff. It is normally moderate green color with black and white spots. Microscopically, theses rocks show hypocrystalline texture and contain approximately 40% glass, 25% plagioclase, 15% clinopyroxene, 10% quartz and 10% secondary minerals such as chlorite and epidote. Moreover, it shows subophitic texture, small plagioclase phenocrysts enclosed partly by pyroxene crystals, which is a characteristic of shallow intrusion.

5. Whole-Rock Geochemistry

Major and trace elements of representative rock samples from the Q-prospect are summarized in Table 1. Detail of chemical characteristic is explained below.

Porphyritic andesite comprises of silica content ranging from 43.77 to 54.82 wt% whereas MgO contents range from 4.50 to 9.26 wt%. In addition, these rocks are rather low TiO_2 contents (0.39–0.63 wt%), moderate Al_2O_3 contents (14.84–18.69 wt%), moderate to high K_2O contents (2.36-10.43 wt%), and low Na_2O contents (0.19-1.61 wt%). These volcanic samples have high loss on ignition (LOI) contents ranging from 3.22 to 9.74 wt%; it may indicate significant alteration which have affected on mobile elements.

Andesitic tuff consists significantly of SiO_2 contents ranging from 46.31 to 55.29 wt% and MgO contents vary from 4.77 to 9.23 wt%. These rocks have low TiO_2 conents (0.43–0.56 wt%), moderate Al_2O_3 contents (15.75–18.28 wt%), low Na_2O contents (0.16-0.21 wt%) and extremely high K_2O (6.98-10.12 wt%). The andesitic tuff has the same major oxide ranging within the same composition range of porphyritic andesite (see Fig. 3).

Rhyolitic tuff is composed of moderate to high SiO_2 contents (67.10-80.02 wt%), high MgO contents (0.76-3.33 wt%), moderate TiO_2 contents (0.13-0.32 wt%), moderate to high K_2O contents (2.03-8.38 wt%) and low to moderate Al_2O_3 contents (5.71-14.43 wt%). In conclusion, high silica contents of this rock group may be a result of silicification during hydrothermal alteration.

Andesite dike consists of 52.32-53.90 %SiO_2, 3.40-4.31 % MgO, 1.18-0.90 % TiO_2, 17.12-16.45 % Al_2O_3 and 3.26-4.32 % Na_2O. These rocks have relatively low K_2O contents (1.52-1.51 wt%) and high CaO contents (6.76-7.48 wt%). In addition, TiO_2, CaO, Na_2O and P_2O_5 contents of these andesite dikes are obviously higher than those of the former rocks; on the other hand, their MnO and K_2O contents are lower.

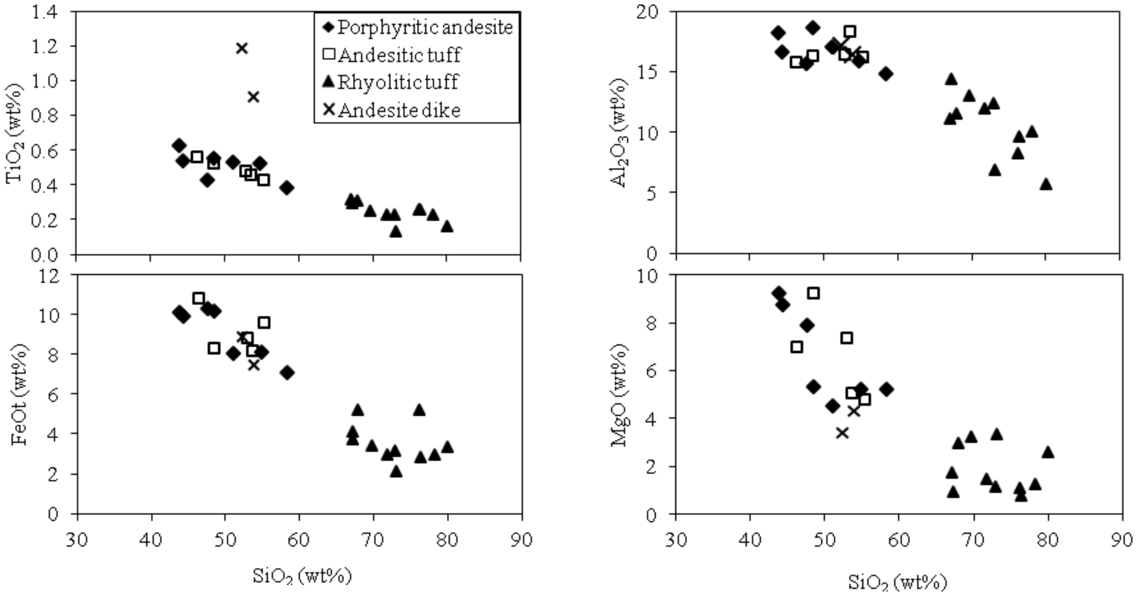

Figure 3. Harker diagrams plotting between SiO_2 against major oxides and some trace elements of rock samples under this study.

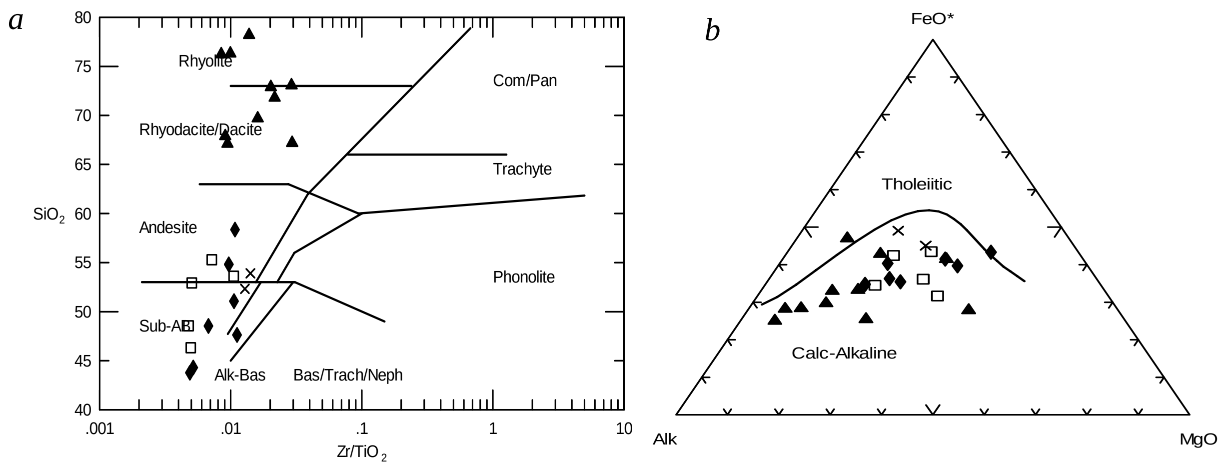

Figure 4. Classification and discrimination diagrams for rock samples from the Q-prospect (*a*) Zr/TiO_2 vs. SiO_2 plots show compositions of rock samples falling within fields of rhyolite, rhyodacite, andesite and sub-alkaline basalt (fields after Winchester and Floyd, 1977); (*b*) AFM diagram (after Irvine and Baragar, 1971) indicates that all rock samples fall in the vicinity of calc-alkaline magma. Symbols are same as Fig. 3.

Harker-type variation plots of SiO_2 against some major and minor oxides (e.g., TiO_2, Al_2O_3, FeO_t, MgO) appear to have negative correlations (Fig. 3) among volcanic hosts, i.e., pophyritic andesite, andesitic tuff and rhyolitic tuffs which indicate the important role of magma differentiation/crystal fractionation. On the other hand, analyses of andesite dike are clearly out of the relation trend. The andesite dikes are relatively composed of higher contents of TiO_2, CaO, Na_2O, P_2O_5 and Zr (see also Table 1).

However, classification diagram, plotting between Zr/TiO_2 and SiO_2 (after Winchester and Floyd, 1977), can be applied in these cases. In general, these volcanic samples fall within various fields of rhyolite, rhyodacite/dactite and andesitic basalt (Fig. 4*a*). Based on AFM plotting diagram (Irvine and Baragar, 1971), all samples are characterized by calc-alkaline magma series (Fig. 4*b*). Ti versus Zr variation diagram suggests that these rocks appear to have originated in an arc environment (Fig. 5).

6. Discussion and conclusions

Volcanic rocks in Q-prospect area at Chatree gold deposit are part of the Permo-Triassic Loei-Phetchabun-Ko Chang volcanic belt. They show a sequence of porphyrictic andesite, andesitic tuff and rhyolitic tuff, respectively from bottom to top; they were subsequently cross cut by andesite dike (Fig. 6). This appears to be similar to those observed throughout the deposit (Comming et al., 2006).

The results grained from this study indicate that volcanic and related rocks of Q-prospect; e.g., porphyritic andesite, andesitic tuff and rhyolitic tuff, may have erupted within a volcanic arc subduction-related environment. Calc-alkaline magma should be initial source of these rocks prior to magma differentiation yielding various compositions from andesitic to rhyolitic compositions. However, the late stage andesite dike may also have similar original provenance but its evolution appear to have been shifted from the initial magma source for the previous rocks.

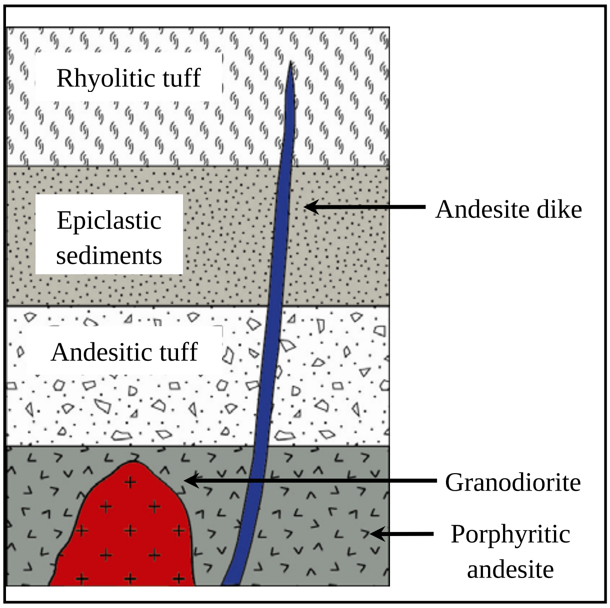

Figure 5. Plots of Ti-Zr for rock samples from Q-prospect (after Pearce and Cann, 1973). Similar symbols used in Fig. 3.

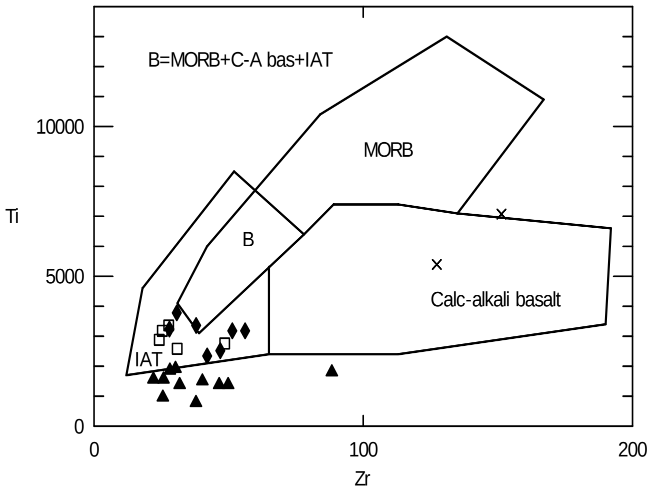

Figure 6. Simplified stratigraphic correlation of Q-prospect area, Chatree gold deposit, using geological survey and drill hole data (modified after Salam, 2008).

Regarding to tectonic model, these volcanisms would have formed in relation with eastward subduction of the Lampang-Chiang Rai oceanic plate (or slab) into the Nakhon Thai oceanic plate during Permo-Triassic Period (Charusiri et al., 2002). This event may form an island-arc environment (Marhotorn, 2008; Nakchaiya, 2008).

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Table 1. Whole-rock XRF analyses for the volcanic rocks from Q-prospect area

Rock	Porphyritic andesite							Andesitic tuff					Rhyolitic tuff											Andesite dike	
Sample	Q-4	Q-7	Q-8	Q-13	Q-24	A-34	A-35	Q-9	A-36	A-38	Q-43	A-28	A-27	Q-42	Q-14	Q-17	A-25	A-31	A-33	A-39	Q-40	Q-41	Q-22	Q-6	A-26
SiO_2	58.36	48.53	47.62	51.07	54.82	44.30	43.77	48.55	46.31	52.92	53.61	55.29	78.19	76.30	67.10	67.18	80.02	67.88	73.06	76.22	72.87	69.69	71.79	52.32	53.90
TiO_2	0.39	0.56	0.42	0.53	0.53	0.54	0.63	0.53	0.56	0.48	0.46	0.43	0.23	0.26	0.32	0.30	0.16	0.31	0.13	0.26	0.23	0.25	0.23	1.18	0.90
Al_2O_3	14.84	18.69	15.71	17.07	15.94	16.68	18.24	16.27	15.75	16.41	18.28	16.25	10.06	9.61	11.16	14.43	5.71	11.54	6.92	8.26	12.37	13.02	11.94	17.12	16.45
FeOt	7.10	10.18	10.33	8.06	8.10	9.94	10.12	8.33	10.84	8.82	8.16	9.59	2.98	2.83	4.12	3.74	3.36	5.25	2.15	5.19	3.18	3.40	2.99	8.89	7.45
MnO	0.33	0.31	0.23	0.44	0.43	0.18	0.17	0.30	0.48	0.46	0.31	0.28	0.02	0.11	0.16	0.07	0.09	0.17	0.26	0.10	0.03	0.13	0.07	0.14	0.15
MgO	5.20	5.31	7.89	4.50	5.23	8.76	9.26	9.23	6.97	7.34	5.08	4.77	1.28	0.76	1.74	0.95	2.59	2.97	3.33	1.09	1.14	3.24	1.45	3.40	4.31
CaO	0.94	0.81	3.58	2.20	2.28	3.45	3.61	0.83	3.19	0.23	0.36	0.24	0.40	0.75	3.41	1.05	1.53	1.27	4.29	1.07	0.34	0.54	1.95	6.76	7.48
Na_2O	0.67	0.30	0.19	0.19	0.19	1.44	1.61	0.20	0.15	0.20	0.21	0.16	0.12	0.22	0.16	0.20	0.13	0.16	0.12	0.14	0.19	0.18	2.26	4.32	3.26
K_2O	7.06	9.45	6.50	10.43	8.81	4.92	2.36	8.55	6.98	8.06	10.19	8.07	2.58	7.50	6.47	8.38	2.03	7.41	2.13	4.63	6.70	6.54	3.38	1.52	1.51
P_2O_5	0.08	0.12	0.03	0.12	0.12	0.15	0.14	0.11	0.09	0.06	0.09	0.08	0.07	0.09	0.10	0.06	0.05	0.07	0.04	0.06	0.06	0.07	0.06	0.30	0.23
LOI	3.78	5.19	6.76	4.40	3.22	7.29	9.74	6.12	7.06	4.40	3.64	4.58	3.25	1.42	4.06	3.22	3.22	2.60	7.00	1.81	2.71	2.80	3.22	2.24	3.83
Total	98.75	99.44	99.26	99.01	99.66	97.66	99.64	99.01	98.37	99.40	100.39	99.75	99.18	99.84	98.80	99.59	98.91	99.61	99.42	98.82	99.82	99.85	99.35	98.20	99.47
Ba	3411	4046	1579	2107	1328	887	88	3166	1988	2910	1684	3255	298	967	947	658	708	1014	456	1235	1569	1832	672	325	265
Cu	39	85	73	195	215	84	50	57	91	45	118	34	17	52	21	28	68	58	10	36	10	6	25	84	103
Zn	81	98	103	90	75	112	109	112	112	148	101	172	48	32	38	64	56	44	38	32	18	59	41	78	95
Pb	1	1	1	3	2	9	2	10	2	4	3	4	4	3	3	3	6	1	3	4	8	1	2	4	6
Zr	42	38	47	56	51	28	31	25	28	24	49	31	32	26	30	88	26	28	38	22	46	40	50	127	151
Rb	102	167	100	161	132	70	51	123	111	94	143	127	41	108	101	138	24	104	28	74	128	102	61	22	25
Sr	136	141	84	186	174	231	124	102	118	126	913	81	30	56	64	126	35	44	77	58	105	73	102	471	646
Nb	0	1	4	1	3	3	3	1	2	1	1	1	3	0	1	3	2	0	2	-1	2	1	2	4	6
Ce	58	63	28	36	26	9	5	47	8	47	28	46	4	19	17	21	13	12	18	10	13	29	24	24	29
Co	21	26	32	20	21	33	31	30	31	23	19	21	5	14	11	6	8	12	3	13	6	5	3	23	23
Cr	22	29	24	31	28	18	22	25	32	16	24	22	11	24	20	15	8	24	7	17	5	3	5	87	33
Ni	9	12	10	16	14	14	15	19	12	13	9	10	4	12	9	6	5	11	3	6	3	2	3	41	18
Th	18	15	15	20	10	13	15	0	13	13	17	17	-2	10	12	7	4	-7	-2	5	10	2	-5	2	7
Y	15	20	23	19	19	14	14	13	11	8	13	11	7	12	12	22	6	10	13	9	12	11	16	21	26
V	176	346	189	181	195	274	306	212	354	210	236	210	103	76	123	92	64	137	24	150	70	74	40	175	239