Preliminary Study on Petrography and Geochemistry of Granitic Rocks in the Khao Phra - Khao Sung area, Amphoe Nong Bua, Changwat Nakhon Sawan, Central Thailand

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Abstract

Granitic rocks exposed Khao Phra - Khao Sung area, Amphoe Nong Bua, Changwat Nakhonsawan are one of an important part of the magmatic rocks in central Thailand to understand the magmatism and tectonics. The granitic rocks can be classified into monzodiorite and alkali granite/syenite. The monzodiorite is dominated by plagioclase, quartz, K-feldspar, Biotite, and some accessory minerals and clearly presents ophitic texture. The alkali granite/syenite is composed of mainly K-feldspar, quartz, plagioclase, and biotite. Moreover, the graphic intergrowth texture of quartz and K-feldspar together with perthitic texture of K-feldspar and albite are clearly observed in the alkaline granite/syenite. Geochemically, these granitic rocks have different compositions as herein nomenclature. However, both monzodiorite and alkali granite/syenite can be classified into I-type granite and were formed by hydrous calc-alkaline magma related to arc subduction of Palaeo-Tethys beneath Indochina Terrane. In addition, these granitic rocks are comparable with the Eastern Belt Granite of Thailand together with corresponding to the Loei Fold Belt.

Keywords: Petrography, Geochemistry, Granite, Thailand

1. Introduction

Granitic rocks distributed in several parts of Thailand (Fig. 1a) and Southeast Asia have been reported by numerous studies (e.g., Cobbing et al., 1986, 1992; Charusiri, 1989; Mahawat et al., 1990; Nakapadungrat and Putthapiban, 1992; Charusiri et al., 1993; Searle et al., 2012; Ng et al., 2015a, 2015b). The granitic rocks in Thailand have been classified into Eastern Belt Granite (EBG), Central Belt Granite (CBG), and Western Belt Granite (WBG) from east to west, respectively (Fig. 1a). Each granite belt present individual characteristics (Nakapadungrat and Putthapiban, 1992; Charusiri et al., 1993; Putthapiban, 2002) which were resulted from the ancient tectonic events of this region (Bunopas and Vella, 1983, 1992; Nakapadungrat and Putthapiban, 1992; Charusiri et al., 2002; Sone and Matcalfe, 2008; Metcalfe, 2002; 2011a, 2011b, 2013; Zaw et al., 2014; Salam et al., 2014; Kamvong et al., 2014, Fanka et al., 2016, 2018). The EBG covers large area of Thailand (Fig. 1a) including micro-tectonic terranes of Thailand e.g. Loei Fold Belt (LFB) which show several kinds of magmatic rocks (Bunopas, 1981; Zaw et al., 2007, 2014). The LFB located along edge of Khorat Plateau containing variety of both plutonic rocks (Charusiri, 1993; Nakapadungrat and Putthapiban, 1992; Khositanont et al., 2008; Morley et al., 2011; Zaw et al., 2014; Salam et al., 2014) and volcanic rocks (e.g., Jungyusuk and Khositanont, 1992; Intasopa, 1993; Intasopa and Dunn, 1994; Panjasawatwong et al., 2006; Khositanont et al., 2008; Barr and Charusiri, 2011; Boonsoong et al., 2011; Kromkhun et al., 2013; Vivatpinyo et al., 2014; Salam et al., 2014; Kamwong et al., 2014; Qian et al., 2015) correspond to the part of the EBG (Fig. 1) (Charusiri et al., 1993).

The granitic rocks in the LFB have been mainly reported in the Loei - Petchabun - Nakhon Ratchasima - eastern Thailand by several researchers (Putthapiban, 2002; Salam et al., 2014; Khositanont

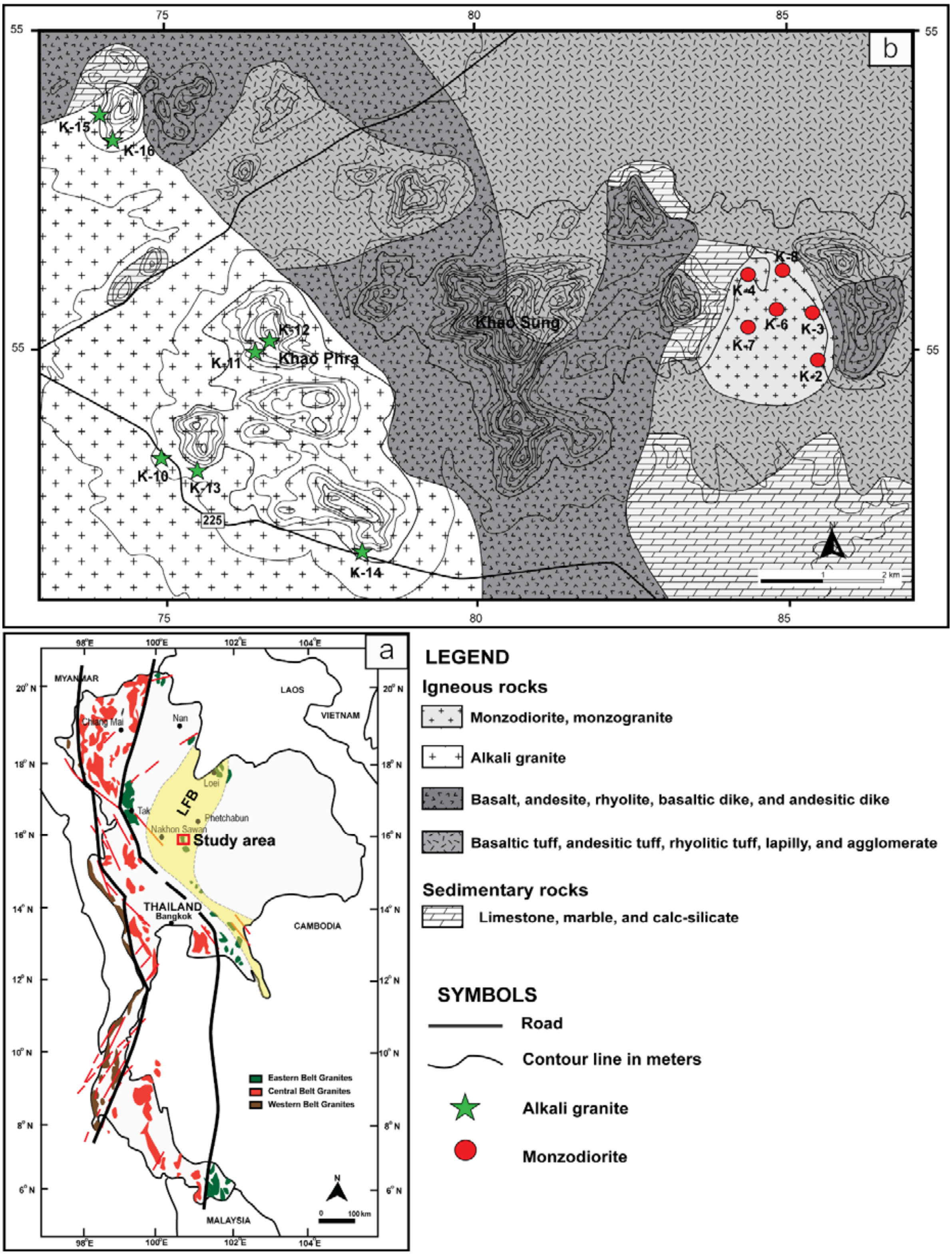

Figure 1 (a) Index map of Thailand showing distribution of main granite belts rocks (modified after Nakapadungrat and Putthapiban, 1992) together with Loei Fold Belt (LFB; after Zaw et al., 2014) and the study area in the Khao Phra-Khao Sung area, Amphoe Nong Bua, Changwat Nakhonsawan, central Thailand. (b) The simplified geological map of the study area (modified after Bahae et al., 2008, Aukkanit et al., 2008, and Fanka et al., 2008) showing the sample locations under this study.

et al., 2008; Kromkhun et al., 2013; Fanka et al., 2016, 2018).

However, the granitic rocks in the Khao Phra-Khao Sung area, Amphoe Nong Bua, Changwat Nakhonsawan, Central Thailand have not been published to understand the genetic of rocks. Therefore, this study aims to study the petrography together with the whole-rock geochemistry of these exposed granitic rocks in the study area. The obtained results can lead to understand the petrogenetic of rocks and also guideline for further detailed researchs to understand the geology of the area and this region.

2. General geology

Khao Phra-Khao Sung area, Amphoe Nong Bua, Changwat Nakhonsawan, Thailand is located in the central part of Thailand (Fig. 1). Geologically, this area mainly contains the plutonic rocks and volcanic rocks (Fig. 1b) with some exposure of sedimentary rocks which detailed mapped by Bahae et al., 2008, Aukkanit et al., 2008, and Fanka et al., 2008. The plutonic rocks in this area are traditionally located in the central part of the Eastern Belt Granite (Fig. 1a) which are mainly composed of monzodiorite and monzogranite in the and alkali granite (Fanka et al., 2008). These plutonic rocks are also located into the Loei Fold Belt (Bunopas, 1981; Zaw et al., 2007, 2014; Kamwong et al., 2014; Burret et al., 2014) (Fig. 1a). The variety of volcanic rocks including basalt, andesite, rhyolite, basaltic dike, and andesitic dike cover as the wide area (Fanka et al., 2008) especially the high mountains in the central part of the study area (Fig. 1b) together with pyroclastic rocks including basaltic tuff, andesitic tuff, rhyolitic tuff, lapilli, and agglomerate (Bahae et al., 2008; Aukkanit et al., 2008; Fanka et al., 2008). For the sedimentary rock, the limestone is the main exposure of sedimentary rock (Fig. 1b) as the basement rock in this area which have been locally metamorphosed to be marble and calc-silicate (Bahae et al., 2008; Aukkanit et al., 2008; Fanka et al., 2008).

3. Methodology

Fifteen representative samples of igneous rocks including eight alkaline granite, seven monzodiorite, and four volcanic rocks are collected from the study area (Fig. 1). These rocks are prepared for thin section at the Department of Geology, Faculty of Science, Chulalongkorn University, Thailand. The petrographic study was used a polarizing microscope. The plutonic rock samples were prepared for 10 x 10 cm rock slabs for modal analysis by stains techniques combination using Sodium Cobaltinitrite ($Na_3CO(NO_2)_6$) to stain K-feldspar to become yellow and Amaranth ($C_{20}H_{11}N_2Na_3O_{10}S_3$) to stain plagioclase to become red together with image processing analysis by Image Pro Plus software.

The whole-rock geochemistry was analyzed using an X-ray Fluorescence (XRF) spectrometer, Bruker Model AXS S4 PIONEER, based at Department of Geology, Faculty of Science, Chulalongkorn University. Nine major and minor oxides (i.e., SiO_2, TiO_2, FeO_{total}, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5) were measured in calibration with rock standards including JA-2, JG-2 and JR-1 provided by Geological Survey of Japan (GSJ) and DTS-2B, PCC-1, GSP-2 and BHVO-2 provided by United States Geological Survey (USGS). Moreover, FeO contents were determined by titration with standard dichromate solution using diphynylamine sulfonic acid as the indicator (Shapiro 1975). The result of the representative igneous rocks in the study area is presented in Table 1.

4. Results

4.1 Field occurrence

The granitic rocks in Khao Phra-Khao Sung area (Fig. 1), alkali granite and monzodiorite, are found in different exposure and lithology based on the occurrences and outcrop exposure. The alkali granite occurring as a large boulder can be found at a high land (Khao Phra) in the southwestern area (Fig. 2a) which surround Khao Phra. This rock show clearly pink colour (Fig. 2b – 2c) because of K-feldspar composition. In addition, this rock are

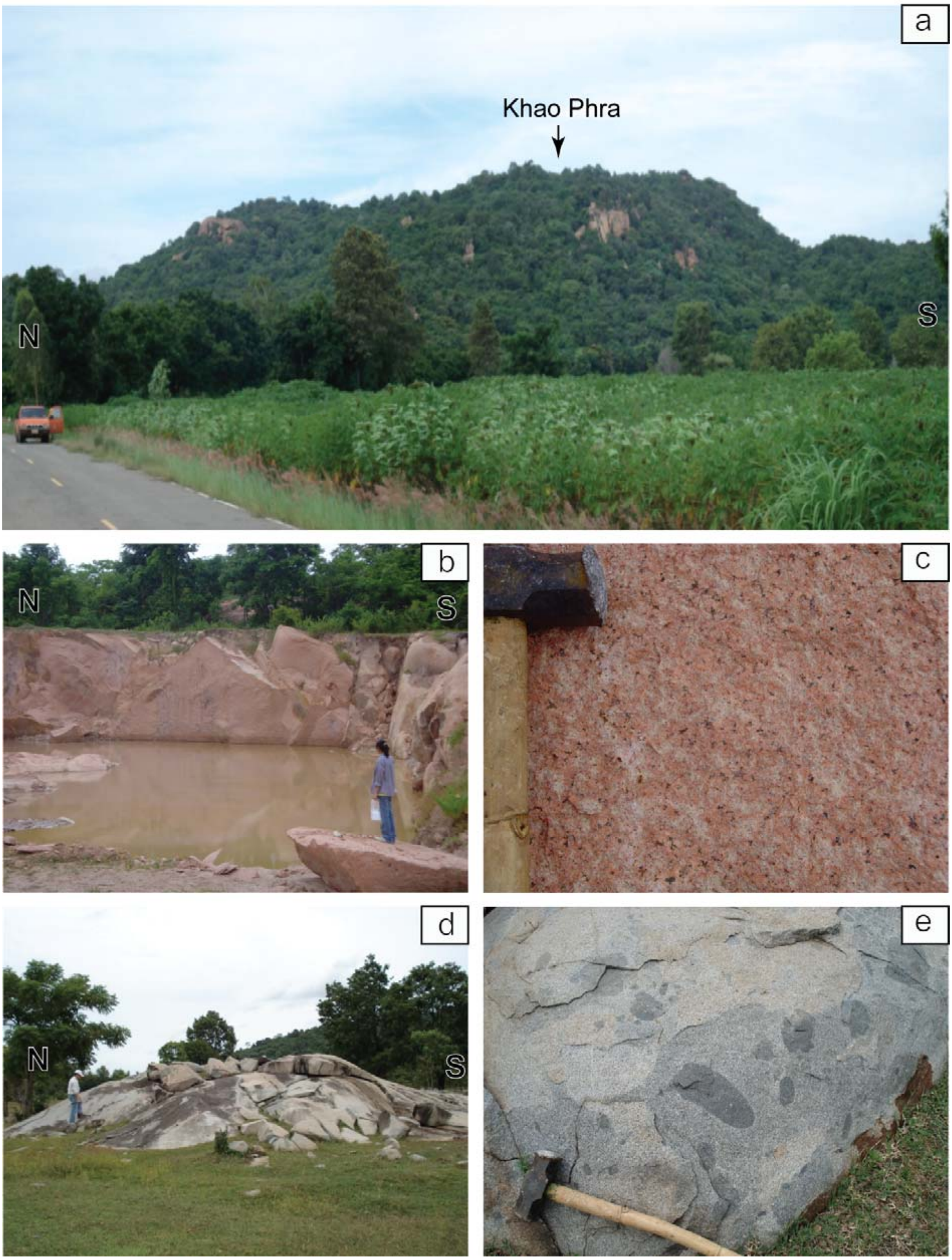

Figure 2 Exposures of the granitic rocks in the study area: (a) natural outcrop exposures of alkali granite/syenite as the mountain (Khao Phra), (b) the alkali granite/syenite quarry and (c) lithological feature as the pink granite, (d) the natural outcrop of the monzodiorite in the low land with (e) typical mafic enclaves.

exposed as a large boulder or massive exposure. These characters can lead to be a dimension stone quarries (Fig. 2b) of this rock. The alkali granite show varies from coarse-grained alkali granite in the southern part and fine-grained alkali granite in the northern part.

The monzodiorite are exposed in the low land as a circular in the eastern part (Fig. 1b). This rock show fine- to coarse-grained monzodiorites. The outcrop exposure always present the thin to thick exfoliation layers (Fig. 2d) for fine-grained and coarse-grained monzodiorite, repectively. Moreover, the round shape of mafic enclaves (Fig. 2e) are commonly found in the monzodiorite body.

4.2 Petrography

Granitic rocks in Khao Phra-Khao Sung area, are classified as alkali granite/syenite, and monzodiorite based on the study on petrography (Fig.3) and modal analysis (Fig. 4). The nomenclature of plutonic rocks based on Steckeisen (1974)(Fig. 4). The details of petrographic characters are explained below.

The monzodiorites contain the abundance of plagioclase (73.32-85.02 %), quartz (0.03-6.41 %), K-feldspar (0.03-19.92 %), biotite (2-5 %), and hornblende (2-5 %) with less abundance of opaque minerals (Fig. 3c-d).

Plagioclase (0.5-2 mm) mainly forms as euhedral to subhedral grains which shows commonly zoning texture and ophitic texture (Fig. 3c-d). The euhedral to subhedral crystals biotite (0.5-1 mm) and hornblende (0.5-1 mm) exhibit commonly twin. Alkali granite is composed of mainly quartz (3.80-43.20 %), K-feldspar (50.29-95.53 %), plagioclase (<5.87 %), and biotite (0.02-10.31 %).

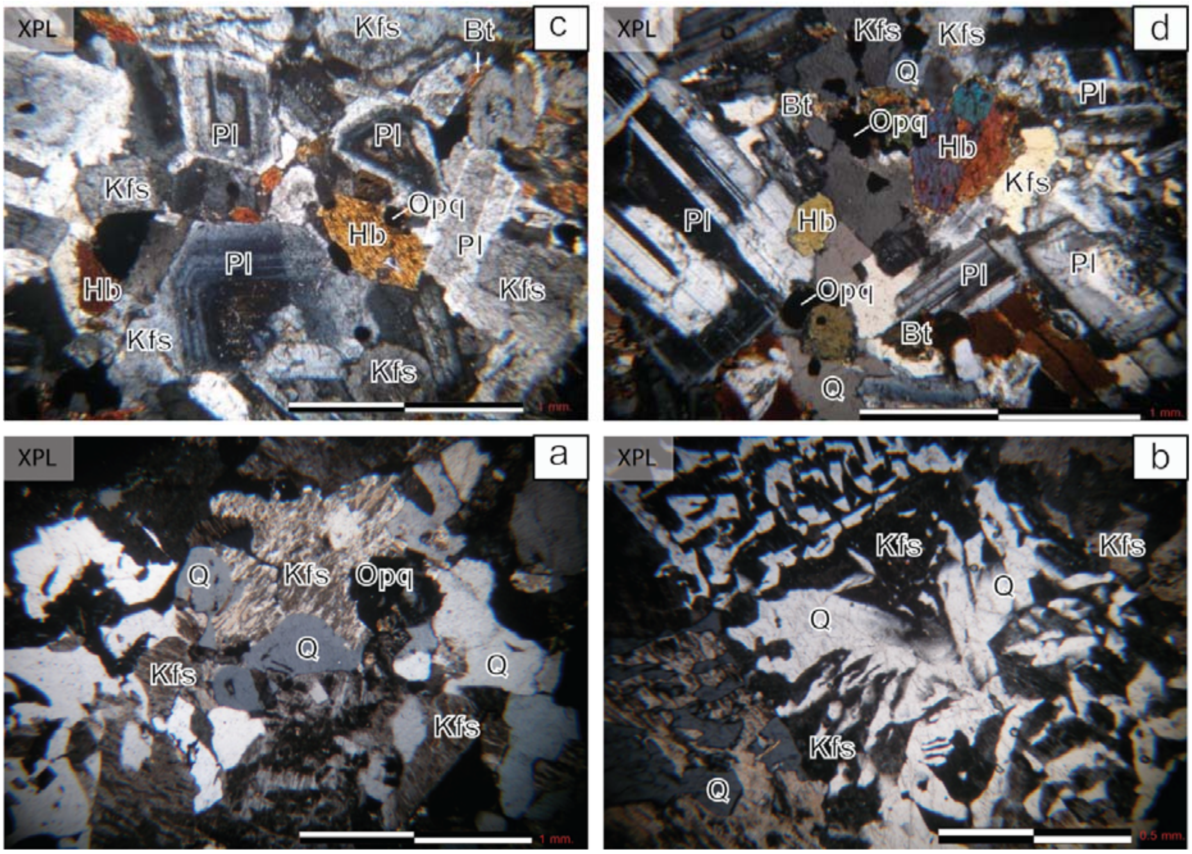

Figure 3 Photomicrographs under cross-polarized light (XPL) showing mineral assemblages and typical textures: (a – b) dominant plagioclase, quartz, K-feldspar with the zoning texture of plagioclase in the monzodiorite, (c – d) abundant compositions of K-feldspar, quartz with the graphic and perthitic texture in alkali granite/syenite. Mineral abbreviations: Q (quartz); Pl (plagioclase); Kfs (K-feldspar); Hb (hornblende); Bt (biotite); Opq (opaque minerals).

These rocks show fine- to coarse-grained (0.5-2mm) phaneritic texture with redish brown to pink. Subhedral K-feldspar commonly shows perthitic texture which is intergrowth between K-feldspar and albite (Fig. 3a-b). The micrographic intergrowth texture of K-feldspar and quartz are commonly found (Fig. 3b).

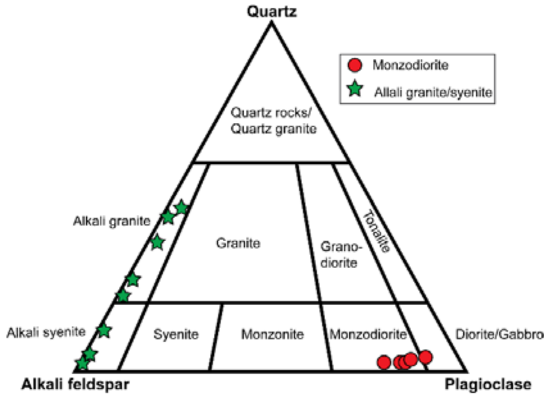

Figure 4 Modal QAP classification diagram (Streckeisen, 1974) for granitic rocks in the Khao Phra-Khao Sung area, Amphoe Nong Bua, Changwat Nakhonsawan, central Thailand (Q = modal quartz; A = modal K-feldspar; P = modal plagioclase).

4.3 Whole-rock geochemistry

Whole-rock geochemistry including major and minor compositions of granitic rocks from Khao Phra - Khao Sung area, Nakhonsawan Thailand were analyzed and the results are summarized in Table 1. The alkali granite/syenite shows relatively SiO_2-rich composition ranging from 70.90 to 73.65 wt% while the monzodiorite shows SiO_2 contents between 54.18 – 63.60 wt%. Moreover, the alkali granite/syenite reveal higher Na_2O+K_2O contents (10.09 – 10.79 wt%) than the monzodiorite (5.88 – 7.86 wt%) which is reflected by the abundance of K-feldspar composition. In contrast, the alkali granite/syenite presents the lower CaO contents (0.34 – 1.35 wt%) than those of the monzodiorite (4.74 – 8.09 wt%). In addition, the alkali granite/syenite shows low MgO/(MgO+FeO) (0.07 – 0.35 wt%), TiO_2 (0.07 – 0.17 wt%), Al_2O_3 (12.67 – 14.67 wt%), FeO_t (0.99 – 2.36 wt%) than the monzodiorite which presents MgO/(MgO+FeO) (0.49 – 0.59 wt%), TiO_2 (0.48 – 0.97 wt%), Al_2O_3 (16.50 – 18.30 wt%), FeO_t (3.46 – 7.07 wt%). These compositions clearly correspond to the mineral assemblages of the rocks e.g. K-feldspar, plagioclase, biotite, hornblende. Plots of TAS diagram (after Cox et al. 1979) presenting the relations between SiO_2 and alkali (Na_2O+K_2O) of these granites (Fig. 5) show that the monzodiorite was plotted in the diorite to quartz diorite fields while the alkali granite/syenite was plotted in granitic composition (Fig. 5) which are consistent with those petrography and modal nomenclature (Fig. 4).

Harker variation plots of SiO_2 against other major and minor oxides (Fig. 6) reveal negative correlations between SiO_2 and TiO_2, Al_2O_3, FeO_t, MgO, MnO and CaO (Figs. 6a – 6f) whereas Na_2O and K_2O show positive correlations (Figs. 6g, 6h). The variation diagrams show different trends between the alkali granite/syenite and the monzodiorite (Fig. 6) which may reflect the different magmatic suit. Each group indicated by variation trends can support the magma fractional crystallization. However, the variation trends of both the alkali granite/syenite and the monzodiorite show similar trend which probably reflect some relationship of the magmatic source.

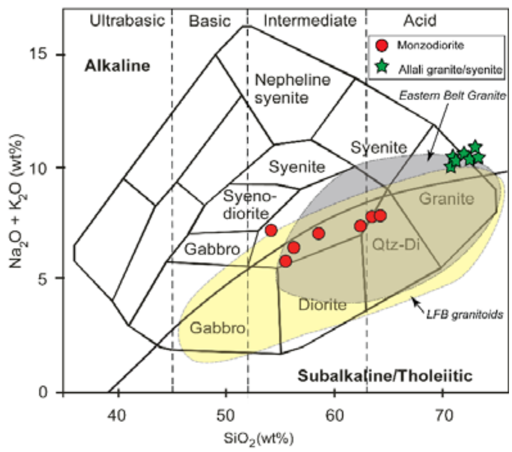

Figure 5 Discrimination diagram of plutonic rocks (after Cox et al., 1979). The studied granitic rocks fall within granite field for the alkali granite/syenite and diorite to quart-diorite fields for monzodiorite comparing with granitic rocks from EBG (grey shaded area from reported data by Nakapadungrat and Putthapiban, 1992; Putthapiban, 2002) and LFB (yellow shaded area from reported data by Fanka et al., 2016, 2018; Nualkhao et al., 2018).

Table 1 Representative whole-rock geochemistry of the granitic rocks in the Khao Phra-Khao Sung area, Amphoe Nong Bua, Changwat Nakhonsawan, central Thailand (major and minor oxide in wt%).

Oxides	Monzodiorite							Alkali granite/syenite							
	K-2	K-3A	K-3B	K-4	K-6	K-7	K-8	K-10	K-11	K-12	K-13	K-14	K-15	K-16A	K-16B
SiO_2	63.60	64.02	54.18	56.17	62.57	55.62	58.59	70.90	72.87	73.35	73.31	72.05	71.74	72.49	73.65
TiO_2	0.57	0.48	0.97	0.77	0.53	0.81	0.79	0.17	0.08	0.10	0.09	0.17	0.08	0.08	0.07
Al_2O_3	16.50	16.80	18.25	18.30	17.35	17.69	17.69	12.67	14.45	13.47	13.52	14.10	14.67	14.24	13.62
Fe_2O_3	1.55	1.50	3.67	2.84	1.90	3.83	2.38	1.38	0.79	1.02	0.77	1.12	0.68	0.61	0.54
FeO	2.08	1.96	3.40	3.04	1.90	2.94	2.92	0.98	0.26	0.28	0.22	0.40	0.34	0.50	0.54
MnO	0.09	0.08	0.22	0.16	0.09	0.15	0.12	0.05	0.01	0.01	0.02	0.03	0.02	0.02	0.02
MgO	2.26	1.88	3.78	3.57	2.20	4.15	2.82	0.23	0.09	0.05	0.06	0.22	0.08	0.04	0.04
CaO	4.92	4.74	7.44	7.73	5.32	8.09	6.80	1.35	0.34	0.48	1.02	0.87	1.33	1.15	0.53
Na_2O	4.89	5.18	5.24	4.80	5.23	4.90	4.95	5.42	5.11	4.97	6.12	5.47	4.97	5.26	5.28
K_2O	2.88	2.68	1.97	1.65	2.20	0.98	2.12	4.67	5.58	5.82	4.19	5.06	5.55	5.15	5.26
P_2O_5	0.23	0.27	0.51	0.53	0.31	0.43	0.32	0.04	0.00	0.02	0.02	0.03	0.00	0.00	0.01
Total	99.57	99.59	99.63	99.56	99.60	99.59	99.50	97.86	99.58	99.57	99.34	99.52	99.46	99.54	99.56

5. Discussion

According to field observation, granitic rocks usually show mafic enclaves (Fig. 2e) which indicate typical feature of calc-alkaline granitoid magma (Barbarin, 1991; Barbarin and Didier, 1992; Barbarin, 2005).

Moreover, the TAS diagram (Fig. 5) indicate the monzodiorite samples are subalkali/tholeiitic composition while the alkali granite/syenite seem to be plotted in the alkaline composition. However, both monzodiorite and alkali granite/syenite are comparable with those EBG and granitoids in LFB (Fig. 5). The mineral assemblages (Fig. 3) of these granitic rocks especially biotite and hornblende can indicate the hydrous magma (Best, 2003). The narrow trends of Harker variation diagrams (Fig. 6) can indicate the magma fractional crystallization of each group (Cox et al., 1979) which may be emplaced by different magmatic suit. Nevertheless, the similar trends of these granitic rocks suggest the relationship of the magmatic source which are similar to the EBG and granitoids in LFB and are also comparable with those typical arc setting (Fig. 6). The geochemistry plots of K_2O against Na_2O (after Chappell and White, 1974) clearly indicate that these granitic rocks are I-type granite (Fig. 7a) which is comparable with magnetite-series granite of Ishihara (1977). In addition, plots of Al/(Ca+Na+K) against Al/(Na+K) of Shand (1943) clearly indicate these rocks are mostly metaluminous with I-type granite field (Fig. 7b).

Moreover, plots of SiO_2 against FeO/(Feo+MgO) of Frost et al. (2001) reflect the monzodiorite is magnesian while the alkali granite/syenite sample is ferroan but both granitic rocks clearly fall in the I-type granite field (Fig. 7c). These characters are comparable to the EBG and granitoids in LFB (Fig. 7). The plots of SiO_2 and Na_2O diagram (after Peccerillo and Taylor, 1976) indicate these rocks correspond to the calc-alkaline to high calc-alkaline series related to arc setting (comparing with typical arc setting in Fig. 8) which also similar to those EBG and granitoids in LFB (Fig. 8).

The plots of tectonic discrimination diagram of R1 (4Si-11(Na+K)-2(FE+Ti)) and R2 (6Ca+2Mg+Al) (after Batchelor and Bowden, 1985) reflecting that these rocks appear to have been emplaced in different tectonic settings (Fig. 9) that the monzodiorite is mostly pre-plate uplift while alkali granite/syenite is late-orogenic. However, both are comparable to the tectonic setting of the occurrence of the EBG and granitoids in LFB (Fig. 9). These granitic rocks appear to have crystallized from calc-alkaline magma which may take place from different magmatic events related to arc subduction comparing with those typical arc magmatism reported by George et al. (2003), Kelemen et al. (2003), and Jicha et al. (2004) (Fig. 6 and 8).

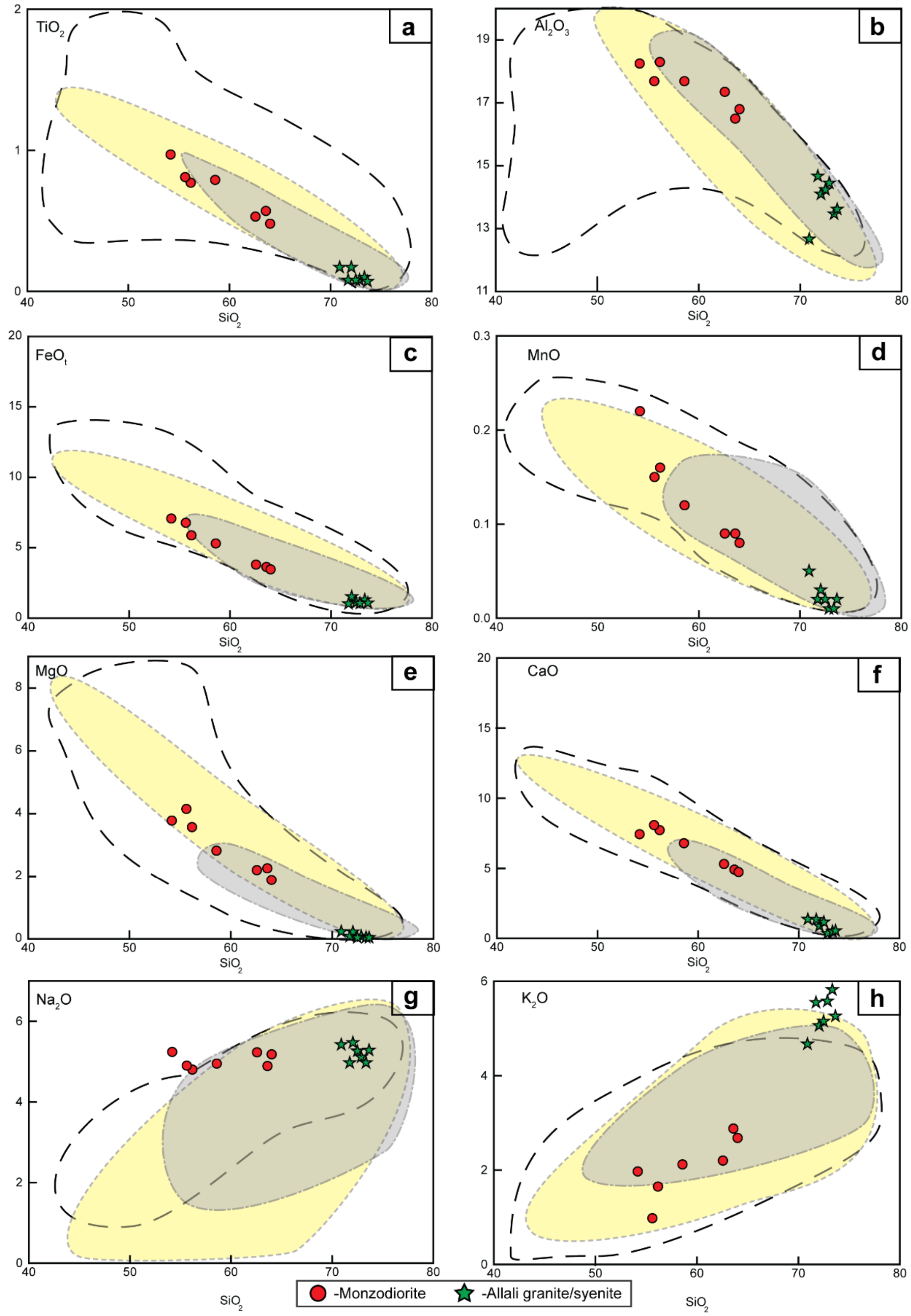

Figure 6 Harker variation diagrams (Harker, 1909) plotting of SiO_2 vs. major and minor oxides of the granitic rocks the study area in comparison with the granites from EBG (grey shaded area from reported data of Nakapadungrat and Putthapiban, 1992 and Putthapiban, 2002), LFB (yellow shaded area from reported data by Fanka et al., 2018, Nualkhao et al., 2018), and typical arc setting (long dashed line) summarized by George et al. (2003), Kelemen et al. (2003), and Jicha et al. (2004).

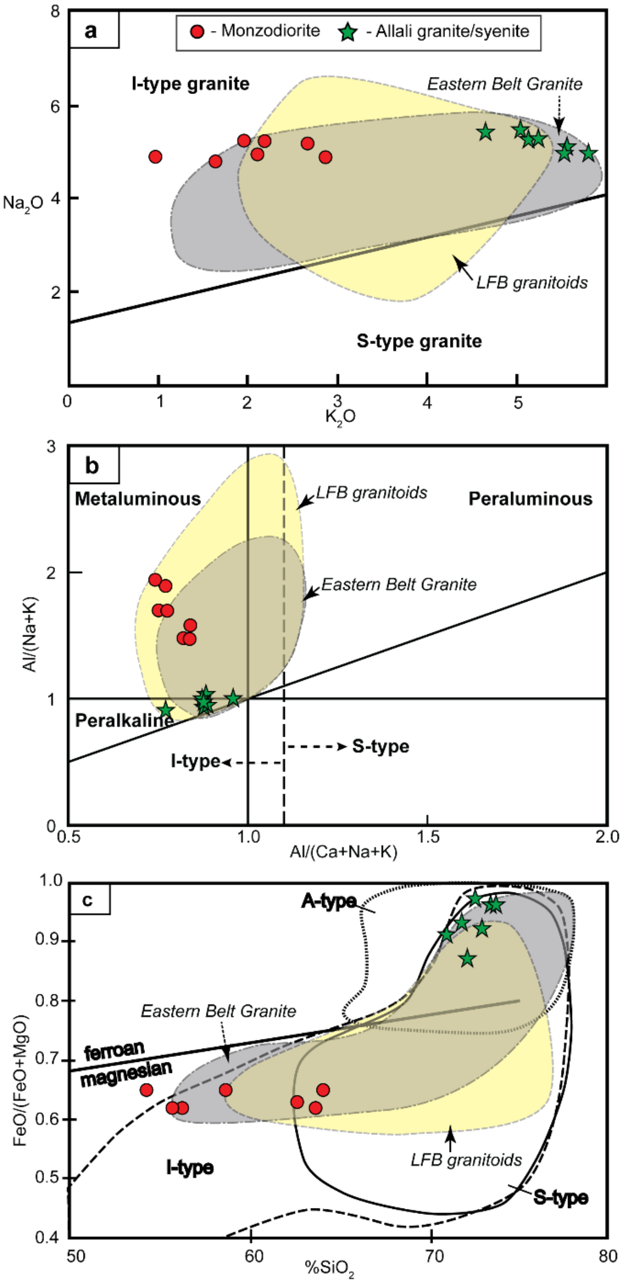

Figure 7 (a) SiO_2 vs. Na_2O diagram plots (Chappell and White, 1974) showing I-type granite; (b) Al/(Ca+Na+K) vs. Al/(Na+K) plots (Shand, 1943) showing I-type granite with most metaluminous field; (c) SiO2 and FeO/(FeO+MgO) plots (Frost et al., 2001) showing I-type granite corresponding to magnesian for monzodiorite and I-type granite with ferroen for alkali granite/syenite in comparison with granitic rocks from EBG (grey shaded area from reported data by Nakapadungrat and Putthapiban, 1992; Putthapiban, 2002) and LFB (yellow shaded area from reported data by Fanka et al., 2016, 2018; Nualkhao et al., 2018).

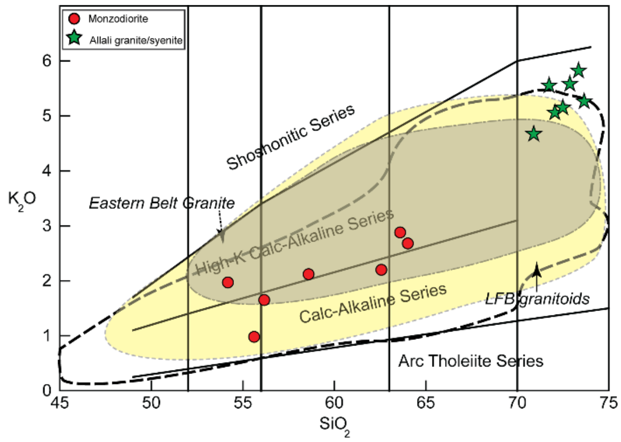

Figure 8 plots of SiO_2 vs. K_2O (after Peccerillo and Taylor, 1976; Rickwood, 1989) showing the calc-alkalne to high calc-alkaline series comparing with granitic rocks from EBG (grey shaded area from reported data by Nakapadungrat and Putthapiban, 1992; Putthapiban, 2002) and LFB (yellow shaded area from reported data by Fanka et al., 2016, 2018; Nualkhao et al., 2018).

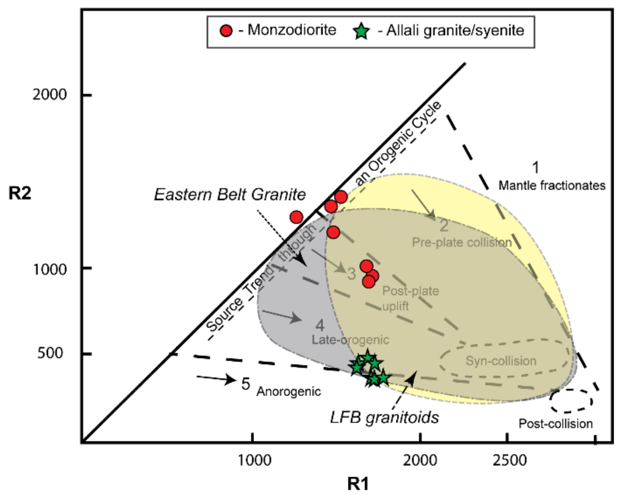

Figure 9 Plots of R1–R2 geotectonic discrimination diagram from major compositions (Batchelor and Bowden, 1985) of the granitic rocks in the study area comparing with the granites from EBG (grey shaded area from reported data of Nakapadungrat and Putthapiban, 1992 and Putthapiban, 2002), LFB (yellow shaded area from reported data by Fanka et al., 2018, Nualkhao et al., 2018).

From above geological features, both monzodiorite and alkali granite/syenite can be compared with the granitic rocks from other part of EBG reported by Nakapadungrat and Putthapiban (1992), and Putthapiban (2002). Moreover, these rocks are probably correspond to the granitic rocks along LFB which are reported by the several researchers e.g. Salam et al., 2014, Fanka et al., 2018, Nualkhao et al., 2018.

This study can support the magmatism of the EBG in Thailand reported by several studies (e.g., Cobbing et al., 1986, 1992; Nakapadungrat and Putthapiban, 1992; Charusiri et al., 1993; Putthapiban, 2002) and also well support the magmatism in the part of LFB which distribute along the edge of Khorat plateau to eastern Thailand (Kromkhun et al., 2013; Zaw et al., 2014; Salam et al., 2014; Kamvong et al., 2014, Fanka et al., 2018, Nualkhao et al., 2018) which have been suggested to be occurred by the arc related subduction of the subduction of Palaeotethys beneath Indochina Terrane (Zaw et al., 2014; Salam et al., 2014; Kamvong et al., 2014,Fanka, 2016; Fanka et al., 2016, 2018, Nualkhao et al., 2018) during Carboniferous to Triassic (Charusiri, 1989; Nakapadungrat and Putthapiban, 1992; Charusiri et al., 1993; Khositanont et al., 2008; Salam et al., 2014; Kamvong et al., 2014; Zaw et al., 2014; Fanka, 2016; Fanka et al., 2016, 2018, Nualkhao et al., 2018). However, the further detailed studies, e.g. petrology, mineral chemistry, geochemistry, and geochronology, need to be carried out to understand the geology of the study area and this region.

6. Conclusions

The study on petrography and geochemistry of the granitic rocks in the Khao Phra-Khao Sung area, Amphoe Nong Bua, Changwat Nakhonsawan, central Thailand can be indicate that these granitic rocks compose of monzodiorite and alkali granite/syenite.

According to petrography, the monzodiorite is composed of abundance of plagioclase, quartz, K-feldspar, Biotite, and some accessory minerals and clearly presents ophitic texture. The alkali granite/syenite comprise mainly K-feldspar, quartz, plagioclase, and biotite with clearly observed graphic intergrowth texture of quartz and K-feldspar, and perthitic texture of K-feldspar and albite. Geochemically, these granitic rocks have different compositions as herein nomenclature. However, both monzodiorite and alkali granite/syenite can be classified into I-type granite and were formed by hydrous calc-alkaline magma related to arc subduction of Palaeo-Tethys beneath Indochina Terrane which are comparable with the Eastern Belt Granite of Thailand together with corresponding to the Loei Fold Belt.

Acknowledgements

The authors would like to thank to Archan Malatee Taiyaqupt, for the guidance on geochemical study. Special thank is expressed to Mrs. Jiraprapa Neampan for helpful suggestion on geochemical study, Mr. Pragin Thogprachum for helpful suggestion on making thin section, Miss Sucheera Thaithonglarng, and many persons unnamed above who help to make this study completed. Finally, we would like to thank to the Department of Geology, Faculty of Science, Chulalongkorn University for all supports.

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