

PETROGRAPHY AND OCCURRENCE OF CENOZOIC VOLCANIC ROCKS IN SOUTHERN MARGIN OF KHORAT PLATEAU

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ABSTRACT

Cenozoic volcanic rocks in southern margin of the Khorat Plateau are cropped out from Nakhon Ratchasima, Buri Ram, Surin, Si Sa Ket, and Ubon Ratchathani Province. The volcanic rocks have occurred as a lava flow, volcanic cone, volcanic vent/plug, and dike. The rocks are mainly composed of mafic igneous rocks. Ultramafic and sedimentary rock xenoliths are observed in some areas. Petrographically, 27 representative volcanic rocks from the areas are texturally classified into 2 groups including porphyritic and seriated textures. Porphyritic basalt is consisted of fine- to medium-grained olivine, clinopyroxene, and plagioclase phenocrysts/microphenocrysts. Groundmass is mainly of plagioclase lath with interstitial of clinopyroxene, and opaque mineral. Seriated basalt is composed of fine- to medium-grained plagioclase, olivine, clinopyroxene, nepheline and opaque minerals. Serpentine/chlorite and iddingsite are altered from mafic minerals whereas sericite is altered from plagioclase. Calcite and zeolite have occurred as secondary minerals in vesicles. Cenozoic volcanic rocks in these areas have been previously interpreted to be the within plate volcanic environment.

Keywords: *Cenozoic volcanic rocks, Khorat plateau, Basalt, Petrography*

1. Introduction

Cenozoic volcanic rocks of Southeast Asia have erupted in many countries, including Vietnam, Laos, Thailand, Cambodia, and China. Most of the rock has occurred as scatter, especially in Thailand. Cenozoic volcanic rocks of Thailand were reported to be found in northern, central, northeastern and eastern by the department of mineral resources (DMR), Thailand (Figure 1).^[1] In the northeastern region of Thailand or Khorat Plateau, the Cenozoic volcanic rocks were expanded in the southern margin with the east-west trend.^[2] Barr and

MacDonald 1978, Barr and MacDonald 1981, Jungyusuk and Sirinawin 1981 reported, the occurrences of these rocks in the area are sheet-like or flow, volcanic vent, plug, and dike. Xenoliths were found at the Phu Ngoen area in Si Sa Ket province. Petrography and geochemical compositions were reported base on major oxide composition. The Cenozoic volcanic rocks in Khorat Plateau are divided into 2 main groups included 1) basanitoid basalts and 2) hawaiitic basalts. Age of basaltic rocks in Khorat Plateau was reported by Barr and Macdonald in 1981 from Khao Kradong basalt, and Phu Fai diabase which are 0.92 ± 0.30 Ma and 3.28 ± 0.48 Ma, respectively.^{[3][4][5]} Trace element and Nd-Sr-Pb-Hf isotopic compositions were studied in 1990 by Barr and James, in 1997 by Zhou and Mukasa, in 2018 by Yan *et al.*, that indicated the Cenozoic volcanic rock composition is likely oceanic island basalts (OIB).^{[6][7][8]} In 1994, Sutthirat *et al.* concluded, that these rocks resulted from the 6th Cenozoic volcanic erupted event in Thailand.^[9] Most of the basaltic rocks in Khorat Plateau are hawaiitic basalts except Si Sa Ket basalt (Phu Ngoen, Phu Khmint, Phu Fai and Phu Kom). The Si Sa Ket basalt is also included basanitoid basalts that are associated with gem-bearing basalts.^{[10][11]} From the previous study, the geochemical data provided a similar composition in each basaltic rock. In present, the basaltic rocks in the area have much mining that reveals more outcrop and sampling locations to study. In this study, the purpose is focused to distinguish the variation of petrography and occurrences to review the relationship between each basaltic mass.

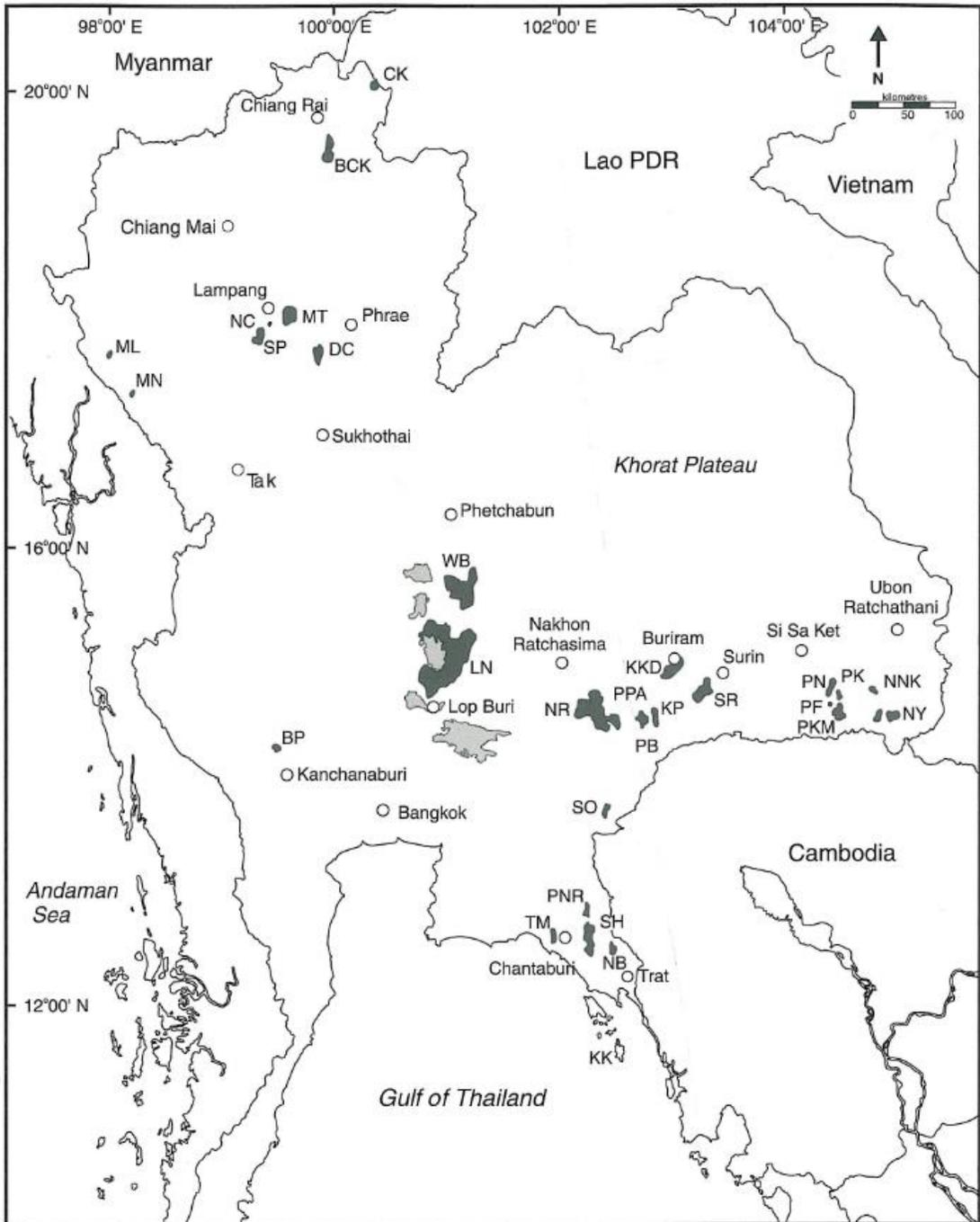


Figure 1 Cenozoic volcanic rocks in Thailand (Barr S.M., Charusiri P.U., Volcanic rocks.

The Geology of Thailand. Geological Society, London. 2011:415-439.)

2. Geological setting of Cenozoic volcanic rocks in Khorat Plateau

2.1 Literature review

Geology of north-eastern Thailand is composed of complex Paleozoic rocks in the western part of Khorat plateau, Mesozoic Khorat group, and Cenozoic volcanic rocks. Cenozoic volcanic rocks were distributed along southern margin of Khorat plateau from Nakhon Ratchasima to Ubon Ratchathani provinces (Figure 2).^{[1][2][3][4]} From field investigation by the department of mineral resources, the Cenozoic volcanic rocks were divided into 12 masses that is overlying the Mesozoic Khorat group (Kok Kruat and Maha Sarakham formation). These rocks were referenced by local name including Nakhon Ratchasima basalt, Phu Phra Angkhan basalt, Khao Phanom Rung basalt, Khao Prai Bat basalt, Khao Kradong basalt, Surin basalt, Phu Fai diabase, Phu Ngoen basalt, Phu Kom basalt, Phu Khmint basalt, Ban Nong Nam Khun basalt, and Nam Yun basalt.^[5]

Most basaltic masses occur as basaltic flow plain that usually show columnar joint structure and was covered by red soil (at the weathered surface). Vesicular basalt commonly occurs on top of the massive basalt of basaltic flow. The volcanic landform in these zones is small hill or hillock that often occurs with flood basalt in Buri Ram, Surin and Si Sa Ket province included Khao Kradong, Khao Phanom Rung, Khao Prai Bat, and Khao Phanom Sawai. The basaltic lava nearby volcanic vent landform occurs as vesicular basalt, scoriaceous and volcanic bomb. Only Phu Fai has occurred as a dike or plug of diabase. Xenolith was reported at the Phu Ngoen basalt area included sandstone, siltstone, and ultramafic nodule.^{[3][5]}

In previous petrographic studies, the Cenozoic basaltic rocks in Khorat plateau were mostly porphyritic with olivine and clinopyroxene phenocrysts. Groundmass shows intergranular or intersertal texture that is composed of plagioclase, clinopyroxene, magnetite and/or glass. Diabasic texture was observed in diabase from Phu Fai and basalt from Phu Khmint in Si Sa Ket province.^{[4][5]}

From geochemical data, an alkali-silica diagram indicated the basalts in these zones are alkaline. Classification of the alkaline rocks based on their normative compositions provided 2 main groups of these rocks including basanitoid basalt (nepheline mugearite, nepheline hawaiiite, basanite, nephelinite) and hawaiitic basalt (mugearite, hawaiiite, alkali olivine basalt).^[3] Total alkali-silica diagram indicated samples from Nakhon Ratchasima, and Khao Kradong basalt are sub-alkali basalt/basaltic andesite and alkali basalt, respectively while Phu Phra Angkhan, Khao Phanom Rung, Khao Prai Bat, Khao Phanom Sawai and Phu Fai basalts are basaltic trachyandesite.^[6] Trace element component data and Hf-Sb-Pb-Th isotope compositions indicated petrogenesis of Cenozoic volcanic rocks in Khorat Plateau is similar to within-plate basalt or oceanic island basalt (OIBs).^{[7][8]}

Geochronological data by K-Ar dating from Phu Fai and Khao Kradong samples. Phu Fai diabase (Nepheline mugearite) shows 3.28 ± 0.48 Ma while Khao Kradong basalt (Hawaiite) shows 0.92 ± 0.30 Ma. These basaltic lavas were the latest erupted event of Cenozoic volcanic eruption in Thailand.^[9]

Gem deposits were found as residual deposits in Nam Yun basaltic mass nearby the outcrop of hawaiite, but geochemical data indicate that most gem-quality deposits likely associated with basanitoid basalt. However, the basanitoid basalt in Nam Yun may be eroded.^{[10][11]}

2.2 Study area and Methodology

The study areas are located along Nakhon Ratchasima to Ubon Ratchathani province follow highway 226 and 24. The Cenozoic volcanic rocks will be collected on the field investigation. 27 freshest rock samples were collected from each basaltic mass at the old and productive quarry location (Figure 2). Sample naming refers to a location near the outcrop. Some basaltic mass uses a new name i.e. Phu Din basalt, Nam Om basalt which is the new names of Phu Ngoen basalt and Phu Kom basalt, respectively.

All rock samples were prepared and studied by petrography at the Department of Geological Sciences, Faculty of Science, Chiang Mai University. The detail of the hand specimen description is presented in table 1.

3. Occurrences of Cenozoic volcanic rocks in Khorat Plateau

Basaltic rocks in Khorat Plateau have commonly found as flood basalt or basaltic lava landform covering small areas. Red soil is weathered from a basaltic rock is commonly overlain on a top surface (Figure 3a). Besides, Laterite is found overlies on the basaltic rocks in Nakhon Ratchasima and Nam Yun area, but the contact boundary is not clear. Each basaltic flow landscape has a covered red soil layer on the top, vesicular basalt layer below follows by platy-joint and columnar-joint basalt (Figure 3b). The thickness of flow is estimated to range from 5 to 20 meters. The dominant well-shaped columnar basalt structure is found in Phu Phra Angkhan, Buriram while Nakhon Ratchasima basalt, Si Sa Ket basalt (Phu Din, Phu Khmint, Nam Om), and Nam Yun basalt are more irregular columnar shape (Figure 3c, 3d). Multiple layers of the lava flow are well exposed in Phu Phra Angkhan (Figure 3e). Pahoehoe basalt fragment is found in Nam Om basalt at Wat Phu Din Daeng, Si Sa Ket province (Figure 3f). Ultramafic and sedimentary rock (usually sandstone) xenolith have observed in massive basalt at Phu Din and Phu Khmint basalt in Si Sa Ket province. Ultramafic xenolith is highly weathered and less common than the sedimentary rock xenolith.

Volcanic landforms are commonly found at Khao Kradong, Khao Prai Bat, Khao Phanom Rung, Khao Phanom Sawai, and Nam Yun basalt at Wat Pa Kiri Banpot Phu Noi in Buri Ram, Surin and Ubon Ratchathani province, respectively. These areas have normally found an outcrop of vesicular basalt near the volcanic vent. The basaltic lava flow landform is found around volcanic vent within a 3- to 5-kilometer radius. However, basaltic lava flow landform is not found in Khao Prai bat and Khao Phanom Rung areas, Buri Ram.

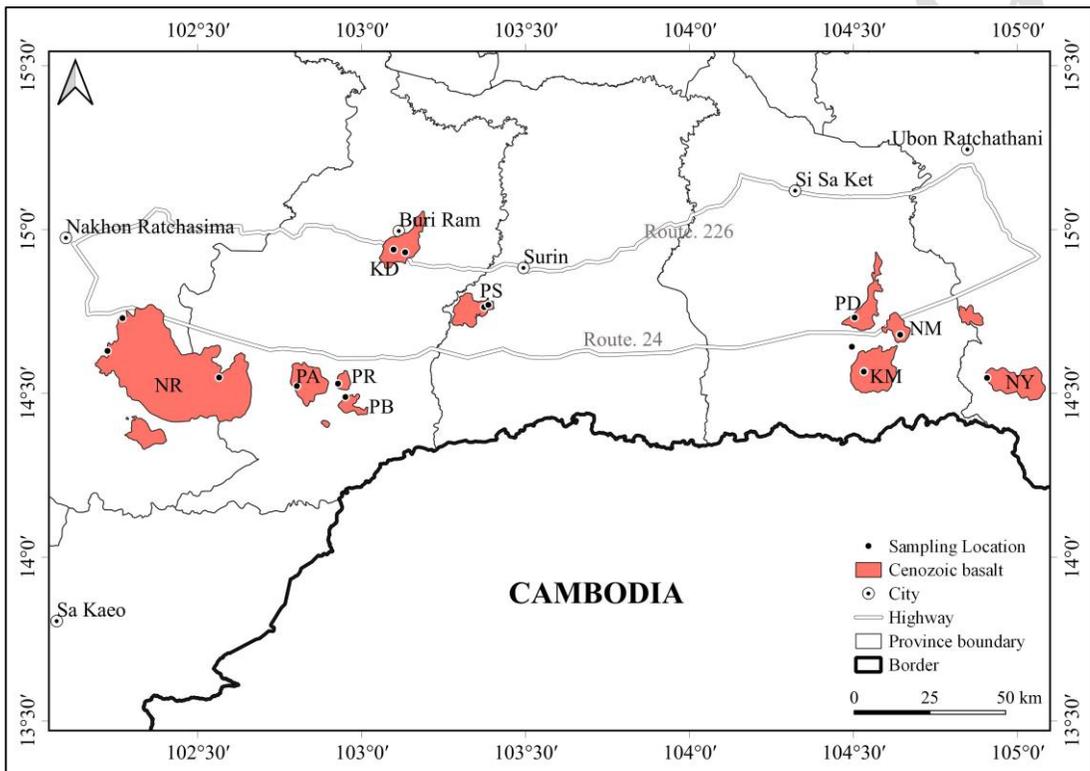


Figure 2 Study areas and sampling location (modify from 1:250,000 geological map of Thailand, department of mineral resources, Thailand).

Table 1 Collected sample locations and description

Sample	Location	Lithology	Remark
NR01	14°43'46"N 102°16'13"E	Basalt: Dark grey, amygdaloidal texture, fill with calcite	Nakhon Ratchasima basalt (NR)

NR02	14°37'46"N 102°13'29"E	Basalt: Dark grey, 1) porphyritic texture with pyroxene and olivine phenocryst, 2) Vesicular texture with calcite (secondary mineral)	Nakhon Ratchasima basalt (NR)
NR03	14°37'46"N 102°13'29"E	Basalt: Dark grey, porphyritic texture with weathered olivine phenocryst, secondary mineral consists of calcite, white mineral	Nakhon Ratchasima basalt (NR)
NR04	14°32'54"N 102°33'54"E	Basalt: Dark grey, porphyritic texture with olivine phenocryst	Nakhon Ratchasima basalt (NR)
NR05	14°32'54"N 102°33'54"E	Basalt: Dark grey, porphyritic texture with olivine and pyroxene phenocryst	Nakhon Ratchasima basalt (NR)
PA01	14°31'20"N 102°48'09"E	Basalt: Dark grey to black, aphanitic texture	Phu Phra Angkhan basalt (PA)
PA02	14°31'20"N 102°48'09"E	Basalt: Dark grey to black, aphanitic texture	Phu Phra Angkhan basalt (PA)
PA03	14°31'20"N 102°48'09"E	Basalt: Dark grey to black, aphanitic texture	Phu Phra Angkhan basalt (PA)
PB01, PB02	14°29'20"N 102°57'01"E	Basalt: Dark grey to black, aphanitic texture	Khao Prai Bat basalt (PB)
PR01	14°31'46"N 102°55'40"E	Vesicular Basalt: Dark grey to black, vesicular texture	Khao Phanom Rung basalt (PR)
KD01	14°56'21"N 103°05'50"E	Vesicular Basalt: Dark grey to black, vesicular texture filled by calcite	Khao Kradong basalt (KD)
KD02	14°55'50"N 103°07'57"E	Basalt: Grey, aphanitic texture	Khao Kradong basalt (KD)
PS01	14°45'48"N 103°22'11"E	Basalt: Dark grey to black, aphanitic texture	Khao Phanom Sawai basalt (PS)
PS02	14°46'13"N 103°23'11"E	Basalt: Grey, aphanitic texture	Khao Phanom Sawai basalt (PS)
PD01	14°43'53"N 104°30'13"E	Basalt: Dark grey to black, vesicular texture filled by calcite. Yellowish green xenolith/xenocryst (weathered) is observed.	Phu Din basalt (PD)
PF01	14°38'32"N 104°29'42"E	Gabbro/Diabase: Grey to dark grey, phaneritic texture that is consists of pyroxene, plagioclase, and olivine	Phu Fai diabase (PF)

PF02	14°38'28"N 104°29'42"E	Gabbro/Diabase: Grey to dark grey, phaneritic texture that is consists of pyroxene, plagioclase, and olivine	Phu Fai diabase (PF)
NM01	14°40'43"N 104°38'30"E	Basalt: Grey to dark grey, aphanitic texture with altered olivine (Reddish brown)	Nam Om basalt (NM)
NM02	14°40'44"N 104°38'36"E	Vesicular Basalt: Grey to dark grey, vesicular texture	Nam Om basalt (NM)
NM03	14°40'44"N 104°38'32"E	Vesicular Basalt: Grey to dark grey, vesicular texture	Nam Om basalt (NM)
KM01	14°34'02"N 104°31'55"E	Basalt: Grey to dark grey, aphanitic texture with Weathered yellowish green xenolith/xenocryst. Secondary minerals are consisting of calcite and white mineral	Phu Khmint basalt (KM)
KM02	14°33'58"N 104°31'53"E	Basalt: Dark grey, porphyritic texture with reddish brown mineral and plagioclase phenocryst	Phu Khmint basalt (KM)
KM03	14°33'58"N 104°31'53"E	Vesicular Basalt: Black, vesicular texture filled by calcite	Phu Khmint basalt (KM)
NY01	14°32'50"N 104°54'26"E	Basalt: Dark grey to black, porphyritic texture with pale green mineral	Nam Yun basalt (NY)
NY02	14°32'50"N 104°54'26"E	Basalt: Dark grey to black, aphanitic texture	Nam Yun basalt (NY)
NY03	14°32'50"N 104°54'26"E	Basalt: Dark grey to black, porphyritic texture with pale green mineral, Secondary mineral is calcite.	Nam Yun basalt (NY)

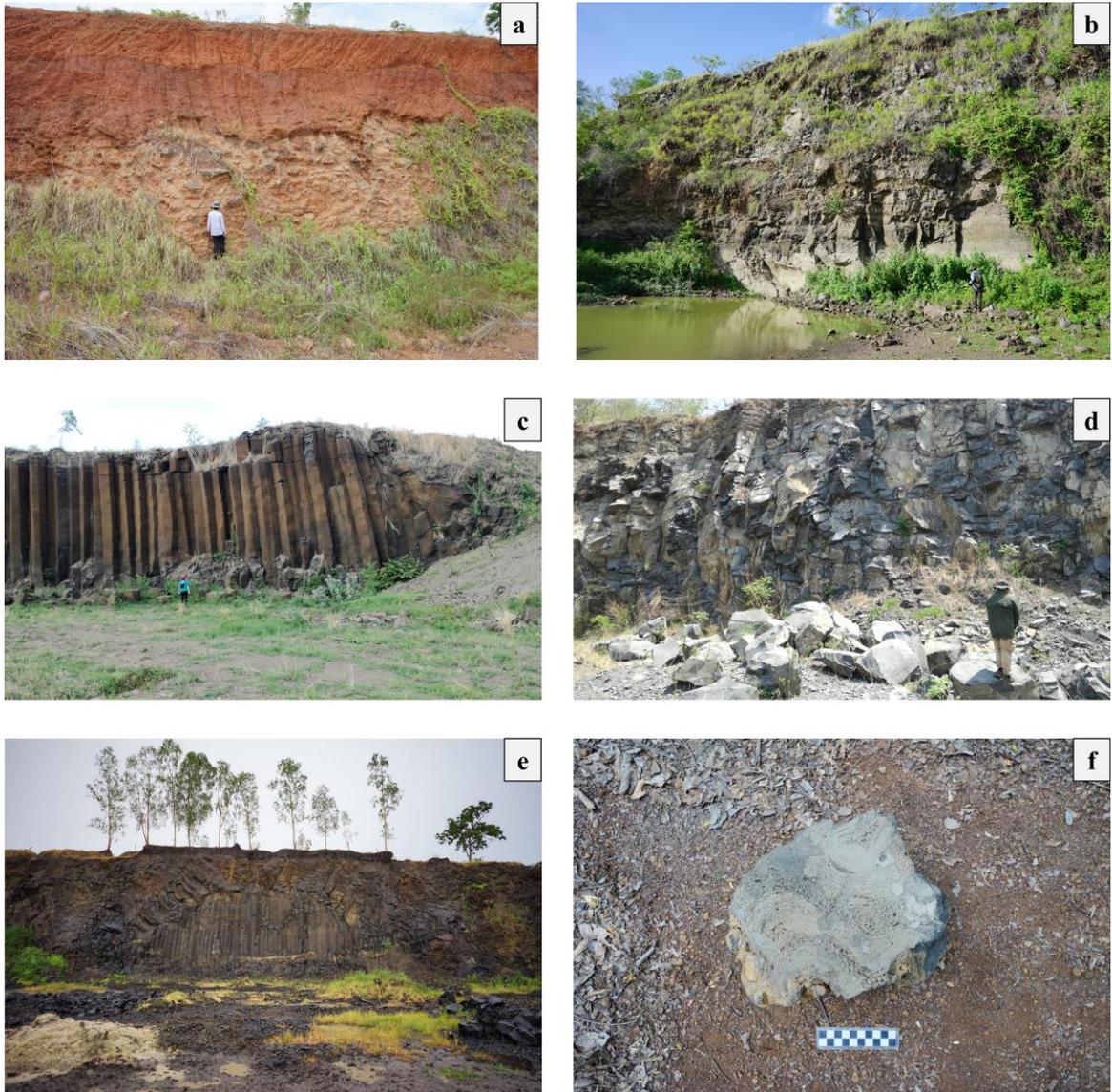


Figure 3 Occurrences and basaltic landform of Cenozoic basaltic rocks in Khorat Plateau.

4. Petrography of Cenozoic volcanic rocks in Khorat Plateau

Samples of Cenozoic volcanic rocks in southern part of Khorat Plateau were prepared to 27 thin sections in the department of geological sciences, Chiang Mai University. The thin sections were studied by polarized-light microscope.

Nakhon Ratchasima basalt displays porphyritic texture. Phenocrysts/microphenocrysts are composed mostly of olivine, minor clinopyroxene and, some plagioclase with size up from fine- to medium-grained. Olivine and clinopyroxene from some samples occur as glomerocryst. Zoning is commonly presented in clinopyroxene (Figure 4a). Groundmass is composed of lath-plagioclase intergranular by clinopyroxene and opaque mineral (magnetite). Lath-plagioclase groundmass shows a felty texture in sample NR03 and NR04 while shows a parallel-like structure or trachytic texture in sample NR01. Alteration product found in the sample is normally iddingsite and sericite.

Phu Phra Angkhan basalt shows porphyritic texture. Phenocrysts/microphenocrysts are composed mostly of olivine, minor clinopyroxene, and plagioclase. Phenocrysts/microphenocrysts occur as single grain with size up to fine-grained. Olivine is highly altered to iddingsite. Plagioclase has An-content about 40 to 50 refer to andesine. Groundmass is composed of lath-plagioclase intergranular with clinopyroxene and opaque mineral (magnetite). Lath-plagioclase groundmass occurs as a flow structure or trachytic texture.

Khao Prai Bat basalt occurs as a porphyritic texture. Phenocrysts/microphenocrysts in sample PB01 were replaced by calcite (Figure 4b) but crystal structure refers to olivine with size up from fine- to medium-grained. Groundmass is composed of lath-plagioclase intersertal with opaque mineral (magnetite) and glass. The sample PB02, phenocrysts/microphenocrysts are composed of olivine, clinopyroxene, and plagioclase with size up to fine-grained set in plagioclase intergranular with opaque mineral (magnetite) and clinopyroxene. Plagioclase phenocryst/microphenocryst has An-content about 40 to 50 refer to andesine. Lath-plagioclase presents a trachytic texture.

Khao Phanom Rung basalt presents porphyritic texture. Phenocryst/microphenocryst is composed of olivine that occurs as single grained with size up to fine-grained. Olivine phenocryst/microphenocryst shows skeleton texture in some grain and altered to iddingsite. Groundmass is composed of plagioclase intersertal with glass and opaque mineral (magnetite). Lath-plagioclase shows a felty texture.

Khao Kradong basalt presents porphyritic texture in sample KD01. Phenocryst/microphenocryst is composed of olivine with a size up to fine-grained. Most grain is highly altered to iddingsite. Groundmass is composed of plagioclase. Zeolite filled in void occurs as a secondary mineral. Sample KD02 present inequigranular with seriate texture. Minerals are composed of plagioclase, olivine, and clinopyroxene with size up to fine-grained. Opaque mineral (magnetite) occurs as an equigranular texture with size up to fine-grained.

Khao Phanom Sawai basalt shows porphyritic texture. Phenocryst/microphenocryst is composed of olivine with a size up to fine-grained (Figure 4c). Groundmass is composed of

plagioclase intergranular with clinopyroxene and opaque mineral (magnetite). Glass occurs as intersertal in the groundmass.

Phu Din (Phu Ngoen) basalt displays inequigranular with porphyritic texture composed of olivine phenocryst set in a groundmass of plagioclase, clinopyroxene and opaque mineral (magnetite). Olivine grain varies of grain size from very fine- to fine-grained. Olivine is highly altered to iddingsite. Groundmass crystal grain size is fine-grained. Zeolite occurs as a secondary mineral.

Phu Fai diabase shows phaneritic with seriate texture (Figure 4d). Minerals are composed of plagioclase, olivine, clinopyroxene, opaque mineral (magnetite) and some nepheline with size up varies from fine- to medium-grained. Plagioclase has An-content in range 44 to 53 refer to andesine-labradorite. Some plagioclase grain shows undolose extinction and zoning. Clinopyroxene shows sieve texture and zoning. Olivine is normally altered at crystal rim and fracture to iddingsite. Some olivine grain was embayed by plagioclase. Apatite occurs as inclusion mostly in clinopyroxene with acicular shape. Calcite and chlorite have occurred as secondary minerals.

Nam Om (Phu Kom) basalt presents porphyritic texture in sample NM01. Phenocryst/micro phenocryst is composed of olivine with size up from fine- to very fine-grained. Olivine is highly altered to iddingsite. Groundmass is composed of plagioclase intersertal/intergranular with glass and opaque mineral (magnetite). Sample NM02 and NM03 show inequigranular with seriate texture composed of olivine, clinopyroxene plagioclase opaque mineral (magnetite) and glass. Olivine and plagioclase megacryst are medium- and fine-grained, respectively. Plagioclase megacryst has An-content about 44 refer to andesine.

Phu Khmint basalt shows a porphyritic texture. Phenocrysts/microphenocrysts are composed mostly of olivine and minor clinopyroxene with size up to fine-grained (Figure 4e). Olivine is highly or completely altered to iddingsite. Groundmass is composed of plagioclase intergranular with clinopyroxene and opaque mineral (magnetite). Xenolith is mainly composed of quartz. For sample KM02, Phenocryst/microphenocryst are composed of plagioclase and clinopyroxene (Figure 4f).

Nam Yun basalt shows a porphyritic texture. Phenocrysts/microphenocrysts are composed of olivine and clinopyroxene with size up fine-grained. Iddingsite is slightly or completely altered from olivine. Groundmass is composed of plagioclase intergranular/intersertal with olivine, clinopyroxene, opaque mineral (magnetite) and glass. Nepheline occurs as groundmass in sample NY02 and NY03.

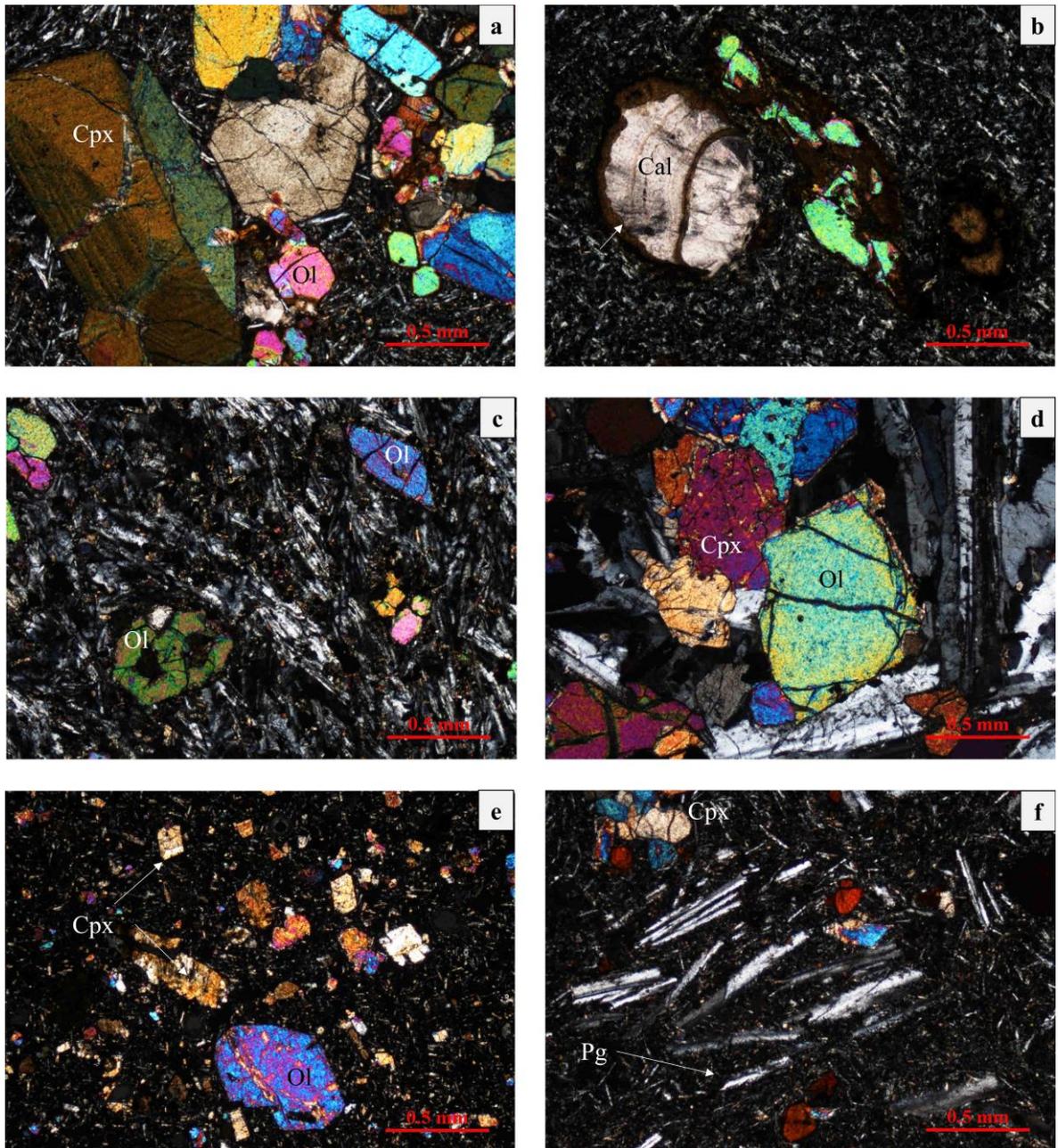


Figure 4 Microphotograph of Cenozoic volcanic rocks in Khorat Plateau with 4X magnification. Ol:olivine, Cpx:clinopyroxene, Pg:plagioclase, Cal:calcite

5. Discussion

The Cenozoic basaltic rocks in Khorat Plateau from Nakhon Ratchasima to Ubon Ratchathani provinces mostly occur as volcanic landform and flood basalt landform except for Phu Fai diabase in Si Sa Ket province has occurred as volcanic plug/dike. The covered red soil in areas that have clearly occurred in flood basalt areas indicates a contrast of basaltic rocks location from Mesozoic Khorat group, especially in satellite photography. The flood basalt landforms have less distributed on east-west trend from Nakhon Ratchasima to Ubon Ratchathani province and volcanic landforms are only distributed in Buri Ram and Surin. In Phu Phra Angkhan, Khao Kradong, Khao Phanom Sawai areas, the basaltic flow has appeared next to the volcanic vent. The petrographic study indicated that the Cenozoic basaltic rocks in the Khorat Plateau present mainly 2 different textures included porphyritic texture and seriate texture. Mostly basaltic rock displays porphyritic texture except for Phu Fai diabase. Seriate texture is displayed in Phu Fai sample. In addition, Khao Kradong and Nam Om basalts are also shown seriate texture. From the study area map (figure 2), the basaltic rocks displayed 2 textures are located around central areas in southern margin of Khorat Plateau from Buri Ram to Si Sa Ket provinces. Medium-grained size of phenocrysts/micro phenocrysts has appeared in 2 areas including Nakhon Ratchasima and Khao Prai Bat basalts while other areas are mostly fine-grained. Nam Om basalt shows size up from fine- to very fine-grained of phenocrysts/microphenocrysts. In comparison with the variation of rock textures, the phenocrysts/micro phenocrysts in porphyritic texture have the smallest grained size in central areas of basaltic rocks in the Khorat Plateau. For further interpretation, the details of a petrochemical study about the basaltic rock samples are in progress.

6. Conclusion

The Cenozoic volcanic rock in southern margin of Khorat Plateau is divided into 2 groups according to petrographic texture criteria. First, the porphyritic texture group including all basaltic mass except Phu Fai diabase in Si Sa Ket province. Another group is a seriate texture group including Phu Fai diabase, Khao Kradong, and Nam Om basalts. The common mineral assemblages are composed of olivine, clinopyroxene, plagioclase, and opaque mineral. For porphyritic texture, phenocryst is mostly observed as olivine, minor clinopyroxene, and plagioclase. Xenolith is observed in 2 samples including PD01 and KM01 from Phu Din and Phu Khmint, Si Sa Ket province.

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