

# MINERAL COMPOSITIONS OF MAGMATIC DIKES CUTTING ACROSS KHE PHEN GRANITES (HUONG TRA, THUA THIEN HUE, CENTRAL VIETNAM)

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**Abstract.** The Khe Phen granite quarry located in Huong Tra district (Thua Thien Hue province) has been confirmed as a part of the Ba Na granitoid complex (G/K<sub>2bn</sub>), mostly composed of two-mica granite and porphyritic granite. Field survey data show that the granites here are cut across by five distinct narrow dikes (about 50–70 cm wide), including granite pegmatite, granite aplite, aplite, granodiorite, and lamprophyre. The mineral compositions of the granite pegmatite and aplite dikes are similar to those of the host granite, which is mainly comprised of quartz (27–35%), orthoclase (45–58%), plagioclase (4–15%), biotite (1–3%), and a few opaque minerals. Meanwhile, the granodiorite and lamprophyre dikes are melanocratic and compositionally much more mafic, particularly lamprophyre, evidenced by a presence of hornblende (50–55%), plagioclase (33–40%), quartz (3–15%), calcite (5–17%), etc. The origin and emplacement age of the latter dikes have not been reported so far and thus, are needed for further studies based on geochemical and isotopic data.

**Keywords:** dike, granite, Khe Phen, mineral composition

## 1 Introduction

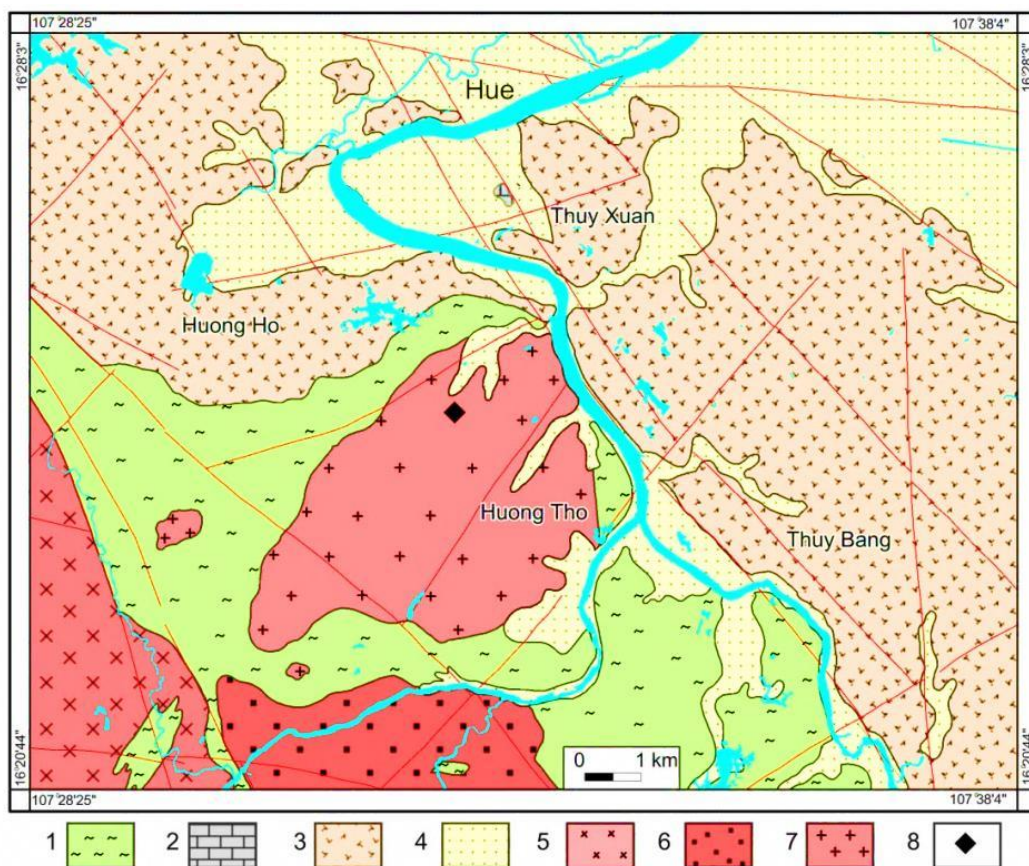
Magmatic dikes form when magma intrudes into and crystallizes in cracks as a sheet intrusion, either cutting across layers of rock or through a contiguous mass of rock [1]. Dikes are tabular, often vertical or steeply dipping sheets that cut across the trend of structure (for example, bedding) of invaded rocks [2]. A dike set is composed of several parallel dikes. They have a wide range of rock compositions and commonly have a porphyritic texture. The width of dikes varies from a few centimeters to more than ten meters. Studying mineralogy, isotopic compositions, and geochemical systematics of dikes could reveal petrogenesis of host rocks as well as tectonic setting, emplacement evolution and geodynamic significance [3, 4, 5].

The Khe Phen granite quarry belongs to the Ba Na complex [6], composed of one intrusive phase and one dike phase. The former includes biotite granite, muscovite-bearing biotite granite, two-mica granite, granodiorite, and tonalite. The latter includes aplite and tourmaline-bearing pegmatite [6, 7, 8, 9]. The current field survey has revealed that besides leucocratic dikes as described above, the granites are also cut across by melanocratic dikes, which have not been mentioned so far. Therefore, the purpose of this paper is to provide initial observations on petrographic and mineral description, which is necessary for further studies on the origin and the emplacement of such dikes.

## 2 Geological features

The area is located about 4 km to the southwest from Hue city. On the geological map scale 1: 200.000 compiled by Nguyen Van Trang et al. [6], it is a component of the A Vuong-Long Dai structure zone, including the Long Dai formation (terrigenous sediments of rhythmic and banded structure, interbedded with from intermediate to felsic effusives), the Co Bai formation (carbonate sediments), and the Tan Lam formation (terrigenous sediments). These rocks are often covered by quaternary sediments and weathering soils. Intrusive rocks in the area include a

continuously differentiated intrusive series from gabbrodiorite to granite of the Ben Giang-Que Son complex, two-mica granite of the Hai Van complex, and biotite granite, coarse-grained two-mica granite, and aplite granite of the Ba Na complex. Among them, the granitoids of the Ba Na complex have been estimated to be the latest intrusive unit with the K-Ar age of 130–140 Ma [6, 10]. Nevertheless, Sr-Rb isotopic analyses for the Ba Na granites have yielded a much earlier age at  $245 \pm 3$  Ma corresponding to Early Triassic [11, 12]. U-Pb zircon age of the Ba Na biotite granite is also at 242–240 Ma [13].



**Fig. 1.** Geological sketch map of the Khe Phen granite quarry and adjacent area (modified after [13]). 1– Ordovician – Silurian terrigenous sediments; 2– Devonian carbonate sediments; 3– Devonian terrigenous sediments; 4– Quaternary sediments; 5– Permian gabbrodiorite, diorite, granodiorite and granite; 6– Late Triassic two–mica granite; 7– Cretaceous biotite granite, coarse-grained two–mica granite and aplite granite; 8– Study site

### 3 Samples and analytical methods

Five representative samples were collected for thin section preparation, including granite pegmatite, granite aplite, aplite, granodiorite, and lamprophyre dikes (Fig. 2a–e), which are about 50–70 cm wide and whose dip angles are constantly steep at 70–90°. Two melanocratic

dikes of granodiorite and lamprophyre are shown in Fig. 3. The mineral compositions of the dikes were determined under a polarized microscope situated at the Optical Crystallographic Lab, Hue University of Sciences and were re-examined at Vietnam Institute of Geosciences and Mineral Resources.



Fig. 2. Hand specimen samples: a– Granite pegmatite, b– Granite aplite, c– Aplite, d– Granodiorite, e– Lamprophyre



**Fig. 3.** Exposed melanocratic dikes in the Khe Phen granite quarry

## 4 Results and discussions

### 4.1 Petrography and mineral compositions of the dikes

Combined naked-eyes observation and optical microscope examination revealed five categories of dikes in the Khe Phen quarry. A summary of representative mineral composition data for the dikes is given in Table 1. Mineral contents are all given in volume percent.

*Granite pegmatite.* The rock is light-colored, irregular coarse-grained with large feldspar phenocrysts. It has massive texture and high hardness. The mineral association is relatively similar to that of the host granites, mainly composed of quartz (27–30%), orthoclase and ortho-perthite (45–47%), plagioclase (10–15%), and biotite (2–3%). Secondary minerals (4–5%) including sericite, chlorite, etc. are products

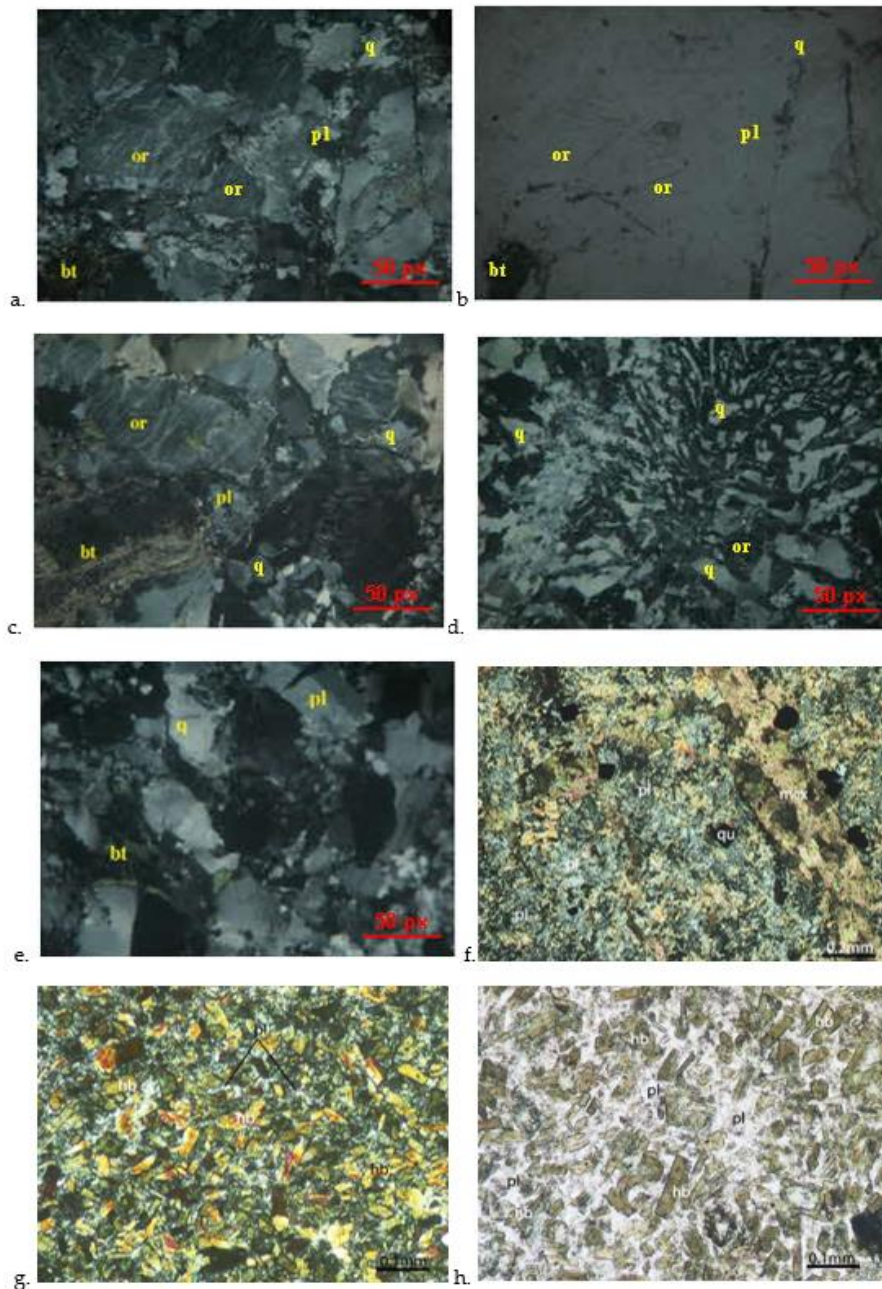
altered between feldspar and biotite. Opaque is very rare (Fig. 2a, 4a, b).

Quartz has an anhedral, light-gray, and very low relief and smooth, clear surface. Most of the quartz crystals are small and commonly fill up gaps among feldspar crystal boundaries to form a typical cement texture for the rock (Fig. 4a, b). Orthoclase occurs in the forms of coarse, unequigranular, and tabular-shaped crystals, which are light-gray, angular, unclear cleavage, and sub-anhedral. Under a microscope, the perthite texture of the rock is effortlessly observed due to the development of many incipient entities on the crystals' surface. At places, they look cloudy and high relief because of saussuritization alteration along grain boundaries and cracks (Fig. 4a, b). Plagioclase occurs as stubby prismatic crystals, which are subhedral and has a clear lamellar twinning. They have associatively developed with fine-grained quartz and filled up either gaps or fractures in the rock (Fig. 4a, b). Biotite is sparsely present in the rock as irregular tabular or flaked crystals with a dark-brown color and a perfect cleavage plane. Many of the biotite have been partly altered to chlorite (Fig. 4a, b).

**Table 1.** Mineral composition data (vol.%) for dikes in Khe Phen granite quarry

Samples	Granite pegmatite	Granite aplite	Aplite	Granodiorite	Lamprophyre
Quartz	27–30	30–35	30–35	5–13	3–5
Feldspar	45–47	50–55	55–58	–	–
Plagioclase	10–15	5–7	4–5	37–43	33–40
Biotite	2–3	1	1–2	–	–
Hornblend	–	–	–	–	50–55
Chlorite	2–3	1–2	1–2	13–15	2–3
Sericite	2–3	1–2	1–2	17–25	–
Calcite	–	–	–	10–17	5
Opaque	1–2	1	1–2	2–3	rare
Other minerals	–	–	–	actinolite, apatite zircon	epidote





**Fig. 4.** Thin section microphotographs of granite pegmatite (a, b), granite aplite (c, d), aplite (e), granodiorite (f) and lamprophyre diorite (g, h). b and h are plane-polarized light images. Symbols: q– quartz, pl– plagioclase, or– orthoclase, bt– biotite, cx– calcite, hb– hornblende, qu– opaque.

*Granite aplite* is a light-gray, massive, equigranular fine-grained rock. Mineral composition essentially includes quartz (30–35%), orthoclase and ortho-perthite (50–55%), plagioclase (5–7%), and biotite (1%). Secondary minerals and opaque are very rare, occupying up to 2% of the rock (Fig. 2b, c, d).

Quartz is anhedral inequigranular, light-

gray, colorless-transparent. All of the quartz has no cleavage, a low relief, and a clear surface. Undulose extinction is commonly observed in the rotation of the stage. In general, the quartz crystals are regularly distributed in the rock; at places, they are concentrated as minute clusters, resulting in graphic texture (Fig. 4d). Orthoclase,

ortho-perthite is regularly distributed in the form of unequigranular as well as tabular crystal. Most of the orthoclase is anhedral, grey colored, poor cleavage, lumpy, and cloudy plane due to pelitic process. In comparison with orthoclase, ortho-perthite is much more abundant in the rock. This mineral is grey colored, relatively equigranular, and characterized by a development of white-colored incipient neocrysts of albite on the crystals' surface (Fig. 4c, d). Plagioclase approximately occupies 5–7% in the form of subhedral tabular. Lamellar twinning is indistinctly observed since the crystals are altered to fine-grained and flaked clusters of sericite, biotite and chlorite, etc. (Fig. 4c, d). Biotite is present in the rock as small flake-shaped minerals with brown to greenish-brown color and perfect cleavage. Most of them have been changed by a weak chloritic process and distributed in terms of either filling up gaps along the rest minerals' boundaries or developing on feldspars' surface (Fig. 4c, d).

*Aplite.* The Khe Phen aplite is fine-grained, milky white, massive, and hard rock (Fig. 2c). Leucocratic components include quartz (30–35%), orthoclase (55–58%), and plagioclase (4–5%). Biotite and opaque occupy up to 2–3%.

Quartz is anhedral, light-grey colored, inequigranular grains with colorless-transparence, very low relief, and glossy surface. They largely distribute in the sample; some are developed along feldspar grains' boundaries (Fig. 4e). Orthoclase occurs in the form of grey sub-anhedral tabular-shaped crystals. Their cleavage is not discernible, whilst twinning is relatively good. The orthoclase crystals have partly been altered after a pelitic process and surrounded by aggregates of fine-grained quartz (Fig. 4e). Plagioclase is grey sub-anhedral stubby prismatic grains, which are characterized by a perfect lamellar twinning. The crystals have intergrown

with the orthoclase and have been modified by a weak saussuritization process (Fig. 4e). Biotite is present in the samples as fine flakes with perfect cleavage. They largely distribute along the rest minerals' grain boundaries, particularly along quartz and feldspar crystals, and have been altered by a weak chloritized process resulting in a typical greenish-brown color (Fig. 4e).

*Granodiorite* is a massive porphyritic rock, characterized by a greenish-black color due to a strong alteration to chlorite and sericite of primary minerals such as plagioclase (Fig. 2d). Mineral compositions of the dike are remnant plagioclase (37–43%), sericite (17–25%), quartz (5–13%), calcite (10–17%), and chlorite (13–15%). Minor components include actinolite, zircon, apatite, and opaque.

The dike matrix is abundantly occupied by aligned distorted- and prismatic-shaped plagioclase, whose plane is densely covered by secondary mineral aggregates of sericite and chlorite flakes, and unequigranular calcite and opaque crystals. Anhedral distorted quartz grains could be obviously observed in the mass as well, and they are irregularly associated with plagioclase. Calcite and quartz also occur in the form of micro-veins cutting across the matrix with a width of about 0.08–0.50 mm, while actinolite is scarcely distributed in the form of needles (Fig. 4f).

Lamprophyre has massive poikilitic texture and is greenish-black in hand specimen (Fig. 2d). The dike is narrow as about 50–70 cm wide (Fig. 3). The mineral assemblage is characterized by hornblende (50–55%), plagioclase (33–40%), and quartz (3–5%). Calcite, chlorite are secondary minerals; apatite, epidote, and opaque are rare. The rock is also called spessartite, belonging to an intermediate magmatic group.

Hornblende is the most dominant mineral in the rock, occurring as rod and prismatic crystals, irregularly intersecting with distorted plagioclase at places. Most of them are pleochroic brownish-green; their extinction angle varies in a range of 13–23°, and some located in the rim are pleochroic green because of being converted to actinolite. Locally, the hornblende develops on the plagioclase plane, producing a poikilitic texture for the rock (Fig. 4g, h). Plagioclase is mostly distorted, and some are in the form of rods and stumpy prisms, which are moderately converted to sericite and clay minerals. The remnants are characterized by polysynthetic twinning (Fig. 4g, h). Only a few quartz crystals are angular and have a clear undulatory extinction; the rest is distorted and occurs in the form of filling up gaps among hornblende and plagioclase grains. Nests of calcite and chlorite intergrown with few epidotes could be restrictedly determined in the sample. The calcite has locally penetrated into plagioclase crystals, which might be attributed to a certain hydrothermal process. At places, the chlorite clusters are pseudomorphous after large-sized dark-colored, tabular-shaped minerals, including hornblende. The chlorite crystals have a green pleochroism (Fig. 4g, h).

Accessory minerals include apatite and opaque. The apatite is prismatic and has dark-gray interfere and poikilitic on the orthoclase crystal plane. The opaque rarely distributes as hedral granular grains with highly metallic reflectivity.

#### 4.2 Implications of mineral compositions of the dikes

Among five detected dikes in the Khe Phen quarry, granodiorite and lamprophyre dikes have not been reported so far. Noticeably, the melanocratic dikes are relatively abundant and efficiently observed not only in the Khe Phen site but also in granite

quarries nearby. On the geological map scale 1:200.000, Huong Hoa-Hue-Da Nang sheet, the Ba Na granites have been determined to be compositionally acidic and the latest intrusive rocks (K-Ar age of 130–40 Ma, corresponding Cretaceous Paleogene [6, 10]); the more intermediate and mafic rocks involving gabbro and gabbroproyenite of the Chaval complex and gabbrodiorite, diorite, and granodiorite of the Ben Giang-Que Son complex all have been assigned ages of from Permian to Late Triassic. An interpretation origin and relative age of the dark dikes consequently come up against difficulties. Thus, petrological problems of the dikes might be further deciphered from their geochemical data, coupled with Sr-Rb and U-Pb isotopic ages for the Ba Na granites reported by Nguyen Trung Minh et al. [11, 12] and Le Duc Phuc [13], as well as geological setting of the area during Mesozoic stage.

## 5 Remarks

Field surveys and petrographically optical observations of five distinct magmatic dikes cutting across the Khe Phen granites could lead to following remarks: (1) Five distinct dikes have been detected within the Khe Phen granite quarry, namely: granite pegmatite, granite aplite, aplite, granodiorite, and lamprophyre with a width of 50–70 cm; (2) The leucocratic dikes including granite pegmatite, granite aplite and aplite are compositionally similar to the host granites, containing quartz (27–35%), orthoclase (45–58%), plagioclase (4–15%), biotite (1–3%), and secondary minerals and opaque. Meanwhile, the melanocratic dikes involving granodiorite and lamprophyre are more mafic in comparison with the granites, composed of plagioclase-sericite-quartz-calcite-chlorite and hornblende-plagioclase-quartz-calcite-chlorite; (3) Origin and emplacement age, as well as relationship with a

particular intrusive phase of the granodiorite and lamprophyre dikes, should be further studied from the geochemical data and geological setting of the area.

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