

# Anatomy of the Cretaceous Ushikiri-yama granodiorite, north Kyushu, SW Japan: Internal structure of a pluton, and its genesis

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The building of plutons involves the generation, segregation, ascent, and emplacement of melts in the crust (Petford et al., 2000). These processes are accompanied by fractional crystallization, assimilation of wall rocks, crystal-melt separation, and magma mixing as well as recharge and drainage of magmas by igneous activity.

Cretaceous to Paleogene granitoids are extensively exposed in the Inner zone of Zone of SW Japan. One of these, the Cretaceous Ushikiri-yama granodiorite shows a zoned pluton with two distinct cells. The granodiorite is exposed below the roof and its thickness is thought to be ca. 600 m. The Ushikiri-yama body should, therefore, provide an excellent opportunity to investigate the internal structure and its genesis of granitoids pluton, and hence assesses the history of emplacement, filling, and solidification, as well as the processes responsible for the zoning, including fractional crystallization, assimilation, and crystal-melt separation. In this study, we address field occurrence, petrography, geochemistry, and geochronology of the granodiorite, and discuss the plutonism and internal structure of Cretaceous Ushikiri-yama granodiorite. It is thought that we can contribute to clearly understand the formation of Cretaceous granitoids batholith in north Kyushu by anatomizing of the isolated small pluton.

The Ushikiri-yama granodiorite forms a part of the north Kyushu batholith, and is located in north of Tagawa city, Fukuoka prefecture. The granodiorite is isolated as a small intrusion that intrudes metamorphic rocks and limestone blocks in the Permian accretionary complex. The granodiorite is regarded as the early stage of igneous activity of the batholiths and emplacement depth would be below 10 km from the surface (Eshima and Owada, 2015, 2017). The granodiorite is subdivided into North and South bodies separated by fine-grained granodiorite, and formed two-cells zoned pluton. It shows hypidomorphic granular texture and consists mainly of plagioclase, biotite, hornblende, quartz, K-feldspar, and trace amounts of euhedral magmatic epidote with  $Fe^{3+} / (Fe^{3+} + Al^{3+})$  values between 25% and 27%. The granodiorite shows flow structure defined by preferred orientation of mafic minerals and plagioclase along the outline of the granodiorite intrusion, and locally contains fine-grained mafic magmatic enclaves (MME). In addition, Sr1 value and K-Ar mineral ages of South and North bodies of the Ushikiri-yama granodiorite shows a different value. Three kinds of dikes with 1 to 5m widths intrude the host rocks and the granodiorite. The dikes are classified into granite porphyry, plagioclase porphyry and hornblende porphyrite, and boundary between plagioclase porphyry and South body contains straddling crystal (Hb). Biotite from granite porphyry gives K-Ar age of  $101.4 \pm 2.6$  Ma. Modal distributions both of North and South bodies show concentric patterns, respectively; modal  $Kfs / (Qz + Kfs + Pl)$  values increase to the central part of each zoned cell.

We considered petrogenetic relations among the granodiorite and three kinds of dikes to investigate magma processes of the Ushikiri-yama granodiorite. The granite porphyry can be formed by fractional crystallization from South body of Ushikiri-yama granodiorite magma in terms of isotopic study and model calculation using mineral and whole rock chemistries. On the other hand, the plagioclase porphyry is formed by magma mixing between the already assimilated granodiorite magma in South body and hornblende porphyrite. The hornblende porphyrite shows the chemical composition of *Sanukitic* HMA

similar to Cretaceous HMA bodies in the north Kyushu batholiths. Consequently, the Ushikiri-yama granodiorite and related dikes were formed by various igneous processes such as magma mixing, fractional crystallization and assimilation.

Keywords: plutonism, mixing, fractional crystallization, assimilation