Geochemistry on the Yucheon granites and their mafic enclaves: Double injections of mafic magma

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1. INTRODUCTION

Enclaves in granitic rocks provide lots of information on the pluton: emplacement process and origin of granitic magma, various types of magma interaction, etc. (Didier, 1973). Petrographical and geochemical studies on the enclaves of Cretaceous to Tertiary granites in Korea have revealed that the majority are neither xenolith nor restite but MME (Kim, et al., 2004). The Yucheon granites possess lots of mafic enclaves whose origin and interaction processes are important for understanding the evolutionary history of the granitic magma. In this study, new geochemical features, such as element behavior during mafic-felsic interaction and variation of chemical composition of major minerals, are combined with previous petrographical characterizations (Kim et al., 2002) to evaluate possible explanations for the petrogenesis and injection mode of the MMEs within the Yucheon granites.

2. GEOLOGICAL OUTLINE

The Yucheon granites crop out in the Cheongdo district of the central part of the Gyeongsang Basin, southeastern Korea. The late Cretaceous Yucheon group and Bulguksa intrusive rocks are widely distributed in the district (Hong and Choi, 1988). The Yucheon group, composed predominantly of volcanic materials, is generally classified into two units: Jusasan andesitic rocks and Unmunsa rhyolitic rocks (Kim and Lee, 1981). The Yucheon granites intruding the volcanic rocks can be divided into three rock facies in terms of grain size and texture (Kim et al., 2002): medium-grained equigranular granite (hereafter MEG), porphyritic granite (hereafter PG), and fine-grained equigranular granite (hereafter FEG). The mafic enclaves are even more abundant in the PG than in the MEG, while they are absent in the FEG. The mafic enclaves in the study area can be classified into three types in terms of scale: (1) microenclave, (2) MME, and (3) hybrid zone which is defined as a mappable body.

3. DESCRIPTION OF OUTCROPS

In the study area the MMEs have a diverse range of grain size of constituent minerals, various contact configurations with host rock, and color indices, indicating that the interactions between mafic and granitic magmas occurred under variable physicochemical environments. In order to examine the variations of geochemical behavior according to the

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differential mesoscopic features of the MMEs, two distinctive outcrops were chosen for representative core sampling: (1) Group A from site H-166 (Fig. 1A and 1B) and (2) Group B from site SK-8 (Fig. 1C and 1D). In addition, we collected nine samples without special regard to grain size and contact relationship in order to examine the geochemical behavior in relation to variable color indices of the MMEs and host rock. These samples, located near site SK-8, were labeled as M-.

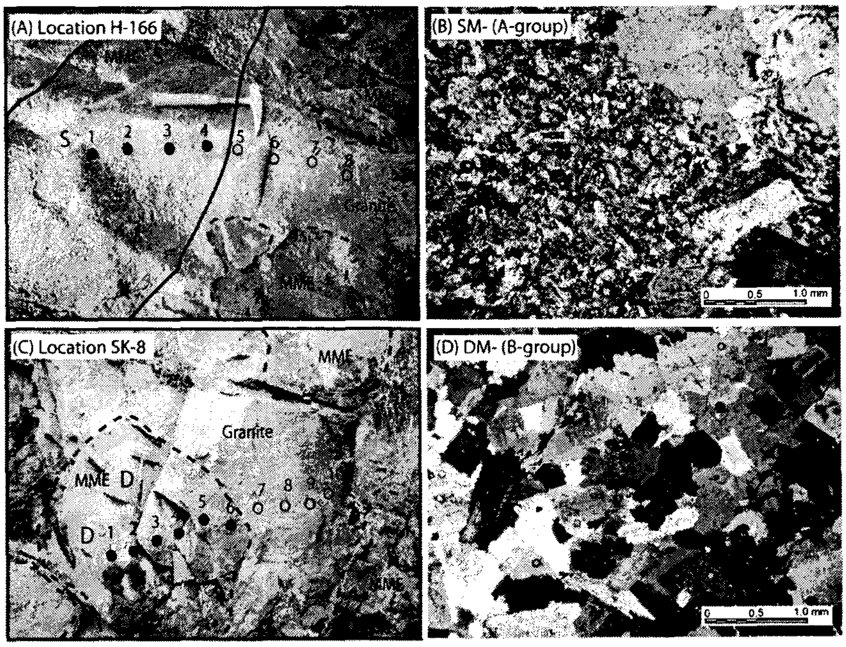

Fig. 1. Sampling point and textural difference between MME SM-(Group A) and DM-(Goup B). (A) in location H-166, MME showing ellipsoidal shape and chilled margin. (B) Very fine grain size of MME SM- and large quartz and plagioclase phenocrysts from granitic magma. (C) in location SK-8, MME and granite showing gradual boundary and no chilled margin. (D) Equigranular texture of MME DM- showing relatively large grain size to the SM-.

4. RESULTS AND CONCLUSIONS

New geochemical features of the Yucheon granites and their mafic microgranular/ magmatic enclaves (MMEs) are combined with previous petrographical characterizations to evaluate possible explanations for petrogenesis and injection mode of the MMEs. The Yucheon granites in the Gyeongsang basin, Korea, are divided into three rock facies including MEG, porphyritic granite, and FEG. All facies possess an abundance of mafic enclaves with the exception of the FEG. Our geochemical results confirm that the MMEs originated from magma mixing/mingling. Mesoscopic and microscopic features indicate that mechanical mixing operated heterogeneously to produce the MMEs with a wide range of size and the coexistence of phenocrysts with various textures. However, chemical compositions of amphibole, biotite, and rim of plagioclase of both the MMEs and the host granites are approximately identical, indicating that the chemical mixing was prolonged after the mechanical mixing and homogenized their constituent minerals to some extent. The compositions of plagioclase core, however, are variable depending on host rocks and/or sampling locations, suggesting sluggish equilibrium of plagioclase. Based on the TiO_2 variation diagram (Fig. 2), the MMEs are divided into two groups: 1) Group A (low-TiO2, very fine-grained, with chilled margin) and 2) Group B (high-TiO_2, fine- to medium-grained, no chilled margin). Two possible reasons can be considered in explaining the coexistence of two groups: One is the difference of interaction intensity of mafic and felsic magmas in case of a single injection, and the other is discrete double injections of mafic magma. Based on the grain sizes and chilling intensities of two groups, Group A experienced more rapid cooling and interacted with granitic magma for a shorter time than Group B. However, Group A samples possess lower TiO_2 contents and are less enriched in HREEs than Group B. These results are unexpected in case of that the groups were simultaneously produced by a single injection. The injection mode of the MMEs in the study area is, thus, explained by double injections.

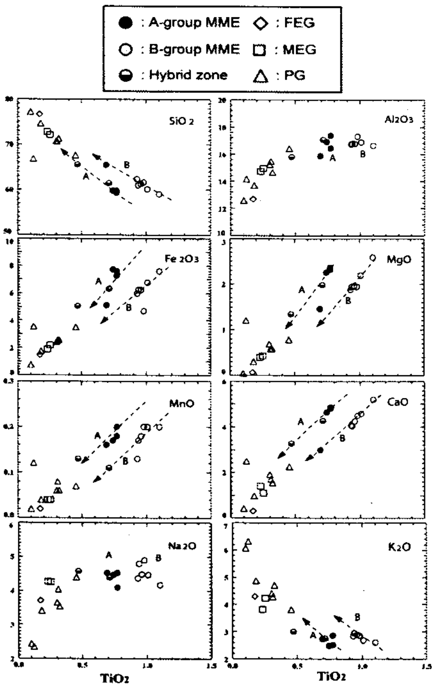

Fig. 2. TiO_2 vs. major element variation diagrams for the granites and enclaves. A: low-TiO_2 trend, B: high-TiO_2 trend.

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