A PETROCHEMICAL STUDY ON THE LATE CENOZOIC GRANITIC ROCKS IN SULAWESI,INDONESIA

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Sulawesi Island, located in the central part of the Indonesian Archipelago, has been a subject of debate on its geological setting among earth scientists. The multi-armed shape of the island, with different lithologic sequences suggests that it is a complex assemblage of tectonic terranes, leading to the wide range of interpretation for the evolution of the island. One of the most problematic features in Sulawesi is the occurrence of various contrasting granitic rocks in space and time. Despite intensive scientific research, there is an ongoing controversy about the source of the granitic magmas and the processes responsible for their petrogenesis as well as the geodynamic setting and the relationship between the granitic magmatism and metallogenic province. This research focuses on petrochemical study, including petrography, geochemistry (whole-rock, trace and rare earth elements, radiogenic and stable isotopes), geochronology, mineral chemistry and magnetic susceptibility of the granitic rocks from eleven plutons in Sulawesi. The main objectives of this study are to provide a new petrography, geochemistry, isotope geology (Sr-Nd-Pb and O), Ar-Ar age data, mineral chemistry and magnetic susceptibility of the granitic rocks and to place constraints on the petrogenesis, origin and nature, geothermobarometry and geodynamic significance of the granitic rocks in Sulawesi. In addition, discussion on the relationship of the granitic magmatism with regional metallogeny in Sulawesi is also provided. This dissertation consists of 7 chapters in which each chapter contain a different objective.

Chapter 1 introduces the background of this study and elaborates the objectives that are intended to be achieved. The structure and contents of the dissertation are also given. A list of commonly used acronyms is also provided.

Chapter 2 consists of a review of previous works on tectonic setting and geology of Sulawesi Island. This chapter compiles what we know about the tectonic setting and the history of formation of Sulawesi Island.

Chapter 3 discusses the petrography, geochemistry (including isotope geology) and magnetic susceptibility of the granitic rocks from Sulawesi from 11 areas. The granitic rocks consist of granodiorite, quartz monzonite, monzonite, monzodiorite, syenite through granite with enclaves of diorite. Major element composition (SiO_2 and K_2O) indicates that the plutons can be classified into high-K or shoshonitic (HK), high-K calc-alkaline (CAK) and low-K to tholeiitic series. Most of the granitic rocks are metaluminous I-type granitic rocks. With an exception of tonalitic rocks in the Gorontalo area in the northern part of the island, the trace and rare earth element pattern of all studied granitic rocks resemble that of the upper continental crust. Most of the rocks show high $^{87}Sr/^{86}Sr$ but low $^{143}Nd/^{144}Nd$, suggesting a strong upper crustal component source except the tonalitic rocks from the Gorontalo area which has lower $^{87}Sr/^{86}Sr$ but higher $^{143}Nd/^{144}Nd$, suggesting more basic source. Whole-rock $\delta^{18}O$ from the granitic rocks are in the range of +5.7 to +9.6 ‰ (outlier three samples lower than +5.1 ‰ and two samples higher than +12 ‰). $^{40}Ar/^{39}Ar$ ages on hornblende and biotite separated from the granitic rocks in Sulawesi range between 11.3 and 8.2 Ma suggesting that the cooling age occurred during Late Miocene to Late Pliocene in the Western Sulawesi Province. The magnetic susceptibility of the granitic rocks varies between 0.08 x 10^{-3} SI to 18.5 x 10^{-3} SI, corresponding respectively to ilmenite-series (< 3x 10^{-3} SI; reduced type) which widely distributed in the central-western part of the Western Sulawesi Province and magnetite-series (> 3x 10^{-3} SI; oxidized type) granite which can be found in the northwestern part of the Western and Northern Sulawesi Province.

Chapter 4 focuses on geothermobarometry of the granitic rocks constrained from the mineral chemistry

and three new $^{40}Ar/^{39}Ar$ ages and previous age data from 5 different plutons. The results show that the granitic rocks of the Mamasa pluton and the Masamba pluton were crystallized at pressure of 0.91 to 1.2 kbar and temperature of 677 to 729 °C and 2.3 to 2.8 kbar at temperature of 756 to 774°C, respectively. The Lalos-Toli and Sony plutons were crystallized at 3.1 to 3.3 and 3.2 to 3.4 kbar at temperature of 731 to 736°C and 601 to 609°C, respectively whereas the Gorontalo pluton was crystallized at pressure of 2.6 to 2.7 kbar and temperatures of 662 to 668°C. Crystallization depths of the Mamasa and Masamba plutons were estimated as 3.2 to 4.3 km and 8.2 to 10 km respectively whereas the Lalos-Toli and Sony plutons show deeper crystallization depth (11.3 and 11.6 km, respectively). The oxygen fugacity calculation showed that the Mamasa, Masamba and Lalos-Toli plutons were classified as reduce-I type to granitic rocks whereas the Sony and Gorontalo plutons were akin to normal-I type granitic rocks.

Chapter 5 reports for the first time the REE geochemistry of the weathered granitic crust from Mamasa and Palu regions. The total REE content of the weathered crust are relatively elevated compared to the parent rocks, particularly in the lower part of horizon B in Mamasa profile and in horizon C in Palu profile, suggesting that REE-bearing accessory minerals may be resistant against weathering and may remain as residual phase in the weathered crust.

Chapter 6 discusses the petrogenesis, origin and geodynamic significance of the granitic rocks and the relationship between granitic magmatism and the regional metallogeny based on data acquired in the previous chapters. Geochemical data show that the petrogenesis of the granitic rocks was controlled not only by fractional crystallization processes but also by crustal contamination, particularly for the HK and CAK granitic rocks in the Western Sulawesi Province. Radiogenic isotopic data suggests that the HK and CAK granitic rocks were derived from partial melting of lower crustal sources with an arc signature. Low-K to tholeiitic series in the granitic rocks from Gorontalo Pluton originated from amphibolite in the lower to mid crust which were partially melted and mixed with a crustal source indicated by low $^{87}Sr/^{86}Sr$ and high $^{143}Nd/^{144}Nd$. Geochemical and geochronological data suggest that the occurrence of granitic rocks were linked to the geodynamic setting of collision to subduction of the plate particularly in the Western Sulawesi Province. The low-K to tholeiitic granitic rocks in the Masamba and Mamasa pluton share a similarity with the Lamasi Complex. The subduction of a lower crustal segment of the Celebes Sea was responsible for the granitic rocks in the Northern Sulawesi Province. Both reduced- I type ilmenite- and normal-I type magnetite-series granitic rocks in Sulawesi are associated with ore mineralization (e.g. Cu, Au, Ag and Mo). The normal-I type magnetite-series rocks distributed in the Northern Sulawesi Province are more closely associated with ore mineralization than the reduced-I type ilmenite-series rocks in the Western Sulawesi Province. It is suggested from this study that redox condition played an important role in regional metallogeny in Sulawesi.

Finally, Chapter 7 concludes what has been reported and discussed in the previous chapters and contains final deductions that have been raised from this study. In addition some suggestions for future works related with this study will be stated.