Contact metamorphic aureole as a marker of plutons associated with major eruptive histories

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Contact metamorphic aureoles are thermal imprints recording the transport of magma through the crust. Quantitative modeling of the thermal effects of magma intrusion can be used to estimate temperature-time histories of individual rocks within these aureoles, and this approach opens the possibility of using contact metamorphism as a natural laboratory to examine the response of geological materials to heating over time scales of up to 10^6 years—many orders magnitude greater than possible in a normal laboratory experiment. Many studies of this kind use thermal models based on instantaneous intrusion of magma (e.g., Joesten et al., 1983; Tagami & Shimada, 1996). However, independent estimates of the thermal structures of aureoles around plutons commonly show significant differences with such instantaneous models (e.g., Cook & Bowman, 1994; Annen, 2017). Revised thermal modeling that incorporates detailed geochronology has shown one of the main reasons for the discrepancy is that the building of plutons commonly takes place over long periods of time invalidating the instantaneous intrusion approximation (e.g., Annen, 2017; Coleman et al., 2004).

Incorporating extended periods of time for pluton formation to be complete can help explain the development of narrow aureoles, because the amount of hot magma present in any given time frame is limited. However, a new compilation of aureoles surrounding silicic plutons around the world shows that there are also numerous examples of aureoles broader than can be explained easily by either instantaneous intrusion models or incremental growth of plutons. In general, such broad aureoles may be explained by 1) unusually high crustal temperatures just before intrusion, 2) intense magma convection, and 3) the contribution of magma that has subsequently been lost from the pluton system due to eruption.

The Shinshiro tonalite and the Busetsu granite are two plutons that formed in the same Hongusan area and have similar zircon U–Pb ages (Takatsuka et al., 2018). Although the Busetsu granite has a larger volume, it is associated with a much narrower aureole than the Shinshiro tonalite. Because the intrusions formed at the same time in the same area, the difference in aureole widths cannot be explained by contrasting background crustal temperatures. Thermal modeling that out of these possible models only eruptive loss of magma can adequately account for the characteristics of the Shinshiro tonalite aureole. Combining petrological studies of metamorphic aureoles with thermal modeling has the potential to detect which plutons developed in association with major eruptions. Identifying differences between plutons associated with large eruptions and those that are not can be used to test ideas of what controls whether a magma will reach the earth’ s surface and erupt or remain in the crust.

Annen (2017). doi:10.3389/feart.2017.00082; Cook & Bowman (1994). Am. Min, 79, 513–525; Coleman et al. (2004). doi:10.1130/G20220.1; Joesten (1983). Am. Jour. Sci., 283A, 233–254; Tagami & Shimada (1996). doi:10.1029/95jb02885; Takatsuka et al. (2018). doi:10.1016/j.lithos.2018.03.018

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