American Mineralogist, Volume 109, pages 540–555, 2024

Multiple magmatic processes revealed by distinct clinopyroxene populations in the magma plumbing system: A case study from a Miocene volcano in West Qinling, Central China

Guo-Kun Zhang[1,2], Xiao-Wei Li[1,2,3,*], Ji-Feng Xu[1], Fang-Yue Wang[4], Thomas Bader[5], Guang-Yue Cao[6], Feng Huang[1], Xuan-Xue Mo[1], Wei Shan[3], Da-Peng Li[3], and Guo-Chen Dong[1]

[1]State Key Laboratory of Geological Processes and Mineral Resources, School of Earth Sciences and Resources, China University of Geosciences, Beijing 100083, China
[2]Research Center of Genetic Mineralogy, China University of Geosciences, Beijing 100083, China
[3]Shandong Institute and Laboratory of Geological Sciences, and Key Laboratory of Gold Mineralization Processes and Resource Utilization, Jinan 250013, China
[4]Ore Deposit and Exploration Centre, School of Resources and Environmental Engineering, Hefei University of Technology, Hefei 230009, China
[5]Key Laboratory of Orogenic Belts and Crustal Evolution, MOE, School of Earth and Space Science, Peking University, Beijing 100085, China
[6]Beijing SHRIMP Center, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China

Abstract

The application of whole-rock compositions to trace magma evolution or crystal-melt equilibrium may be called into question when foreign crystals are incorporated into host magmas. To address this challenge, establishing the origins (orthocrysts, antecrysts, xenocrysts, etc.) of minerals with variable textures in magmatic plumbing systems is necessary. In this paper, we describe complex oscillatory zoning patterns of clinopyroxenes (Cpx) from the Miocene Majuangou (MJG) alkali basalts from West Qinling, China. Our detailed petrographic, mineralogical, and geochemical analyses unravel the origins of various Cpx crystals with distinct textural patterns, thereby providing information about magma storage, recharging and/or mixing, and transportation, as well as the reactions between crystals and melts/fluids. Based on textural patterns, Cpx may be divided into four types: normal (Type-1 Cpx), simple oscillatory (Type-2 Cpx), complex oscillatory (Type-3 Cpx), and grains that lack zoning (Type-4 Cpx, suggested to be orthocrysts). Through the textural characterization of Cpx, the comparison between different types of Cpx, and the relationships between Cpx major compositions from different lithologies, we concluded that Type-1–3 Cpx cores are antecrysts or xenocrysts with diverse origins: primitive magma (Type-1 Cpx cores), magma mush (Type-2 Cpx cores), and crustal granulite (Type-3 Cpx cores). The zoning patterns and the compositions of these Cpx crystals indicate at least three batches of magmatic activity, i.e., the Batch-1 low-Mg# magma (Mg#: 47.4–53.3), the Batch-2 primitive magma (Mg#: 57.2–64.5), and the Batch-3 low-Mg# host alkali magma (Mg#: 47.2–54.6). Cpx-melt thermobarometry demonstrates that at least two crustal magma reservoirs existed in the magma plumbing system at depths of 30.1 and 40.9 km. The antecrystic/xenocrystic Cpx cores were captured by, continued to grow in, and subsequently reacted with ascending K-rich melt/fluid. The spongy textures in Cpx cores/mantles are attributed to this reaction, which may be expressed as: Melt 1 (primitive or evolved) + K-rich melts/fluids + Cpx ($CaMgSi_2O_6$) = K-feldspar ($KAlSi_3O_8$) + ilmenite ($FeTiO_3$) + Melt 2 (derivative). The products of this reaction (K-feldspar and ilmenite) filled the sieves in the spongy zones of Type-1–3 Cpx. This detailed investigation of compositional and textural features of Cpx antecrysts/xenocrysts suggests that the interactions between various interconnected magma reservoirs are widespread beneath the magmatic plumbing system. Our study emphasizes the importance of the incorporation of foreign crystals and the Cpx-melt/fluid reaction in magmatic plumbing system, which can significantly modify the whole-rock compositions and lead to the formation of spongy textures without the need for fractures and cracks in minerals.

Keywords: Alkali basalts, zoning texture, spongy texture, crystal-melt/fluid reaction, Cpx antecrysts/xenocrysts