Grain-scale zircon Hf isotope heterogeneity inherited from sediment-metasomatized mantle: Geochemical and Nd-Hf-Pb-O isotopic constraints on Early Cretaceous intrusions in central Lhasa Terrane, Tibetan Plateau

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Abstract

Clarifying the mechanism of recycling of pre-existing continental crustal materials into the source of mantle-derived magma is a challenging effort that can be of great value to improving our understanding of mantle processes and continental crust growth. This study presents an integrated investigation of whole-rock and mineral geochemical and Nd-Hf-O-Pb isotopic data for dolerites and diorites intruded in the central Lhasa Terrane of Tibetan Plateau at ca. 120 Ma (zircon U-Pb ages). These intrusions have similar distributions of trace elements that are characterized by depletion in Nb-Ta relative to Th, Ba, and U, and moderately negative whole-rock εHf(t) (~5.0 to –1.7) values. Magmatic zircon shows dramatically variable εHf(t) values (from ~5.0 to +13.7 in the same rock, including up to 12 epsilon unit variability in single grains). On the other hand, the zircon δ18O values are relatively uniform (~6.0‰ to +7.7‰). The constant 208Pb/206Pb values of clinopyroxene crystallized at ca. 500–900 MPa suggest no contamination with lower continental crust. The lack of covariation between Hf and O isotopes from the same grains, and the lack of relationship between Hf isotopes and trace elements (e.g., Hf, Th/U, and Yb/Gd) in the magmatic zircons, together with the absence of ancient zircon xenocrysts, imply limited upper crustal contamination. In combination with high-whole-rock Th/La (>0.29) ratios, we interpret the zircon Hf isotope heterogeneity as inherited from a depleted asthenospheric mantle with the addition of 1–4% Hf from isotopically heterogeneous sediments. Our study therefore emphasizes the need for caution when using complex Hf isotopic zonation in zircon as an argument for intracrustal hybridization of two end-member magmas derived from distinct reservoirs. In addition, the high-Zr/Y ratios and no negative Zr-Hf anomalies of the Aruo intrusions imply a high surface temperature of the down going slab that was able to fully dissolve zircons in the subducted sediments. This requires a special geodynamic condition that was most likely related to the steepening of flatly subducted Neo-Tethyan lithosphere at ca. 120 Ma according to a synthesis of regional tectonic-magmatic-sedimentary records.

Keywords: Zircon Hf heterogeneity, sedimentary recycling, mantle metasomatism, magma mixing, Lhasa Terrane

Introduction

Recycling of pre-existing continental crustal materials in magmatic arcs is a fundamental process controlling the chemistry and evolution of the continental crust. The involvement of a crustal component in arc-related magmas has been widely recognized and is typically manifested by the enriched radiogenic (e.g., Sr-Nd-Hf) isotope composition. This can be achieved in two profoundly different ways, either in the mantle through the addition of subducted material (mostly sediments), or in the crust by assimilation and contamination of mantle-derived precursors (e.g., Hawkesworth and Vollmer 1979; Gasparon et al. 1994). Distinguishing the two opposing mechanisms is not easy unless unequivocal evidence, for example sediment-derived magmas intruding the peridotite mantle wedge, is preserved (e.g., Zeng et al. 2016; Spencer et al. 2017), but is crucial to determining the rates and volumes of continental growth and recycling.

Zircon is an ideal mineral to trace source complexity and evolution of the parent magma, as it is chemically stable and has the potential to provide information on crystallization age (U-Pb), radiogenic (Hf), and stable (O) isotopes, as well as on melt compositions (Valley et al. 2005; Kemp et al. 2007; Grimes et al. 2015). Studies based on combined U-Pb, Hf, and O isotopes measured within single zircon grains have significantly advanced our capacity to understand the role of mantle and sediment (or mature continent crust) components in the petrogenesis of granitoid, as well as to enhance our insight into the timing of continental crust growth (e.g., Kemp et al. 2007). Substantial variation of zircon εHf(t) values has been recognized in granitoid worldwide and is commonly interpreted as evidence of mixing of magma derived from isotopically different reservoirs (Kemp et al. 2007).