Stable and transient isotopic trends in the crustal evolution of Zealandia Cordillera

JOSHUA J. SCHWARTZ1,*,†, SOLISHIA ANDICO1, ROSE E. TURNBULL1, KEITH A. KLEPEIS3, ANDY J. TULLOCH2, KOUKI KITAJIMA4, AND JOHN W. VALLEY4

1Department of Geological Sciences, California State University – Northridge, 18111 Nordhoff Street, Northridge, California 91330, U.S.A.
2GNS Science, Private Bag 1930, Dunedin, New Zealand
3Department of Geology, The University of Vermont, Burlington, Vermont 05405, U.S.A.
4WiscSIMS, Department of Geoscience, University of Wisconsin, Madison, Wisconsin 53706, U.S.A.

ABSTRACT

We present >500 zircon δ¹⁸O and Lu-Hf isotope analyses on previously dated zircons to explore the interplay between spatial and temporal magmatic signals in Zealandia Cordillera. Our data cover ~8500 km² of middle and lower crust in the Median Batholith (Fiordland segment of Zealandia Cordillera) where Mesozoic arc magmatism along the paleo-Pacific margin of Gondwana was focused along an ~100 km wide, arc-parallel zone. Our data reveal three spatially distinct isotope domains that we term the eastern, central, and western isotope domains. These domains parallel the Mesozoic arc-axis, and their boundaries are defined by major crustal-scale faults that were reactivated as ductile shear zones during the Early Cretaceous. The western isotope domain has homogenous, mantle-like δ¹⁸O (Zrn) values of 5.8 ± 0.3‰ (2 St.dev.) and initial ε⁰ (Zrn) values of +4.2 ± 1.0 (2 St.dev.). The eastern isotope domain is defined by isotopically low and homogenous δ¹⁸O (Zrn) values of 3.9 ± 0.2‰ and initial ε⁰ values of +7.8 ± 0.6. The central isotope domain is characterized by transitional isotope values that display a strong E-W gradient with δ¹⁸O (Zrn) values rising from 4.6 to 5.9‰ and initial ε⁰ values decreasing from +5.5 to +3.7. We find that the isotope architecture of the Median Batholith was in place before the initiation of Mesozoic arc magmatism and pre-dates Early Cretaceous contractual deformation and transpression. Our data show that Mesozoic pluton chemistry was controlled in part by long-lived, spatially distinct isotope domains that extend from the crust through to the upper mantle. Isotope differences between these domains are the result of the crustal architecture (an underthrusted low-δ¹⁸O source terrane) and a transient event beginning at ca. 129 Ma that primarily involved a depleted-mantle component contaminated by recycled trench sediments (10–20%). When data showing the temporal and spatial patterns of magmatism are integrated, we observe a pattern of decreasing crustal recycling of the low-δ¹⁸O source over time, which ultimately culminated in a mantle-controlled flare-up. Our data demonstrate that spatial and temporal signals are intimately linked, and when evaluated together they provide important insights into the crustal architecture and the role of both stable and transient arc magmatic trends in Cordilleran batholiths.

Keywords: Cordilleran magmatism, Zealandia, zircon, O isotopes, Hf isotopes; Isotopes, Minerals, and Petrology: Honoring John Valley

INTRODUCTION

The crustal architecture of continental margins plays an important role in influencing the location of Cordilleran-arc magmatism and the geochemical and isotope evolution of arc magmas from their source to emplacement (e.g., Ducea et al. 2015a). Geochemical and isotope data from arc magmas are often used as important features in evaluating source regions and differentiation processes that ultimately lead to the generation of continental crust through time (Rudnick 1995; Taylor and McLennan 1995; Ducea and Barton 2007; Scholl and von Huene 2007; Hawkesworth et al. 2010; Voice et al. 2011; Ducea et al. 2017). However, the record of pre-existing crustal sources and their relationship to terrane and intra-terrane faults is commonly highly disrupted by various factors, including voluminous magmatic intrusions, polyphase metamorphism, and various phases of brittle and ductile faulting. The end result is that surficial exposures of long-lived Cordilleran arcs preserve an incomplete record of crustal sources and the pre-batholithic architecture of the arc that were once key factors in its temporal and spatial magmatic evolution.

One of the problems in understanding isotope variations in arc magmas is that isotope signals can be influenced by several competing factors, including spatially controlled features such as the crustal and upper mantle architecture and composition of the arc (Armstrong 1988; Ducea and Barton 2007) vs. various transient tectonic and non-tectonic processes that can introduce new sources. The latter may include processes such as delamination and arc root foundering (Kay et al. 1994; Ducea 2002; Ducea et al. 2017)