Lu-Hf zircon analysis as a discriminator for retreating and advancing stages in accretionary orogens: A case study of Devonian to early Carboniferous igneous rocks in northwestern Patagonia

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The geodynamic evolution of accretionary orogens is essentially ruled by variations in plate behavior, where a compressional upper plate stage defines advancing orogens, while an extensional upper plate stage characterizes retreating orogens (Cawood et al. 2009). Lu-Hf isotopes in igneous rocks have been demonstrated to be a sensitive system capable of distinguishing tectonic stage variations during orogenic growth (Marcos et al. 2023 and references therein). An advancing orogen stage produces magmatic rocks with negative εHf values linked to crustal melting processes resulting from the shortening and thickening of the continental crust. In contrast, a retreating orogen occurs when extensional settings prevail, leading to juvenile-mantle input that is detected by positive εHf values. Additionally, negative and positive εHf slopes across geological time allow for the identification of switches between these stages.

The Terra Australis Orogen was an accretionary orogen that encompasses most of the Paleozoic rocks (~ 570 to 300 Ma) distributed along the eastern and western boundaries of Gondwana Supercontinent. The Devonian to early Carboniferous igneous-metamorphic basement is predominantly constrained along two basement segments in southern South America, marking the end of the Terra Australis Orogen. The northern segment is limited between 27° 30´ and 37° 30´ S, whereas the southern segment (39 - 43°S) comprises the oldest pre-Andean rocks in the northwestern Patagonian region. This study uses U-Th-Pb and Lu-Hf zircon isotopic coupling results to distinguish between compressional and extensional tectonic stages in the northwestern Patagonian basement. Contrasting settings with the northern segment are also summarized.

The Devonian to Early Carboniferous igneous rocks in northwestern Patagonia could be divided into two main stages with extensional and compressional settings, respectively. The Early-Middle

Devonian stage (~ 400 to 380 Ma) includes several isolated igneous and metaigneous outcrops that are widely distributed in the Patagonian Cordillera and surrounding regions. The εHf evolution from these rocks show progressive extensional conditions, transitioning from continental-arc magmatism with εHf values close to zero during early Devonian times (~ 400 to 390 Ma) to forearc and retroarc magmatism with positive εHf values during the early-middle Devonian (~ 395 to 385 Ma). The isotopic signature of the earliest stage suggests a significant juvenile magmatic source, particularly evident in forearc and retroarc regions. This pattern might be linked to an upper crust extensional stage characterized by the rise of the asthenospheric mantle through a thin continental crust. Deep subduction of the proto-Pacific plate is considered the most important tectonic factor triggering the retreating orogen phase (Marcos et al. 2023 and references therein). The second stage is characterized by a magmatic lull and the beginning of regional metamorphism during late Devonian – early Carboniferous times. Although positive εHf records persist in the forearc region, a negative εHf slope developed from the first to the second stage would evidence the beginning of a compressional stage. The transition from retreating to an advancing orogen configuration is possibly linked to a progressive shallowing of the proto-Pacific plate subduction reaching its climax during late Paleozoic times.

A contrasting geodynamic evolution between the northern and southern segments of the Devonian to Early Carboniferous basement is distinguishable when comparing εHf data. The Devonian magmatism evolved within a compressive tectonic setting in the northern segment linked to negative εHf values and inboard magmatism migration, whereas the widespread Early Carboniferous magmatism could be attributed to an extensional phase triggered by a retreating orogen stage (Dahlquist et al. 2021).

References

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