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GR focus review

The geological history of northwestern South America: from Pangaea to the early collision of the Caribbean Large Igneous Province (290–75 Ma)

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ABSTRACT

Northwestern South America preserves a record of the assembly of western Pangaea, its disassembly and initiation of the far western Tethys Wilson Cycle, subsequent Pacific margin magmatism and ocean plateau–continent interaction since the Late Cretaceous. Numerous models have been presented for various time slices although they are based on either spatially restricted datasets, or dates that are inaccurate estimates of the time of crystallisation. Here we review a very large quantity of geochronological, geochemical, thermochronological, sedimentological and palaeomagnetic data that collectively provide tight constraints for geological models. These data have been collected over a trench (Pacific)-parallel distance of >1500 km (Colombia and Ecuador), and reveal important temporal trends in rifting and subduction. The temporal framework for our model constraints are obtained from robust, concordant zircon U-Pb ages of magmatic rocks during 290–75 Ma. The Late Cretaceous thermal history of the margin (<350 °C) is described by $^{40}Ar/^{39}Ar$ and fission track data, and the higher temperature and thus older (pre-75 Ma) history are constrained by apatite U-Pb thermochronology. Variations in the isotopic compositions of Hf (zircon), Nd (whole) and O (quartz) with time have been used to track the evolution of the source of magmatism, and are used as proxies for crustal thickness. Atomic chemical compositions, combined with isotopes and dense mineral assemblages are used to differentiate between continental and oceanic environments. These data show that rifting within western Pangaea started at 240 Ma, leading to sea floor spreading between blocks of Central and South America by 216 Ma. Pacific active margin commenced at 209 Ma, and continued until 115 Ma above an east-dipping subduction zone that was rolling back, attenuating South America and forming new continental crust. The opening of the South Atlantic drove South America westwards, compressed the Pacific margin of northwestern South America at 115 Ma and obducted an exhumed subduction zone. Passive margin conditions prevailed until the Oceanic Plateau and its overlying intra-oceanic arc (The Rio Cala Arc) collided and accreted to South America at 75 Ma.

Contents

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1. Introduction

The northwestern South American plate hosts a Grenvillian basement, which was modified during the amalgamation and disassembly of Pangaea, subsequent prolonged active margin magmatism and the collision of the voluminous Caribbean Large Igneous Province, which added new crust to South America. This manuscript is mainly a review of a very large quantity of data, although some new U-Pb (apatite) and $^{40}Ar/^{39}Ar$ dates are presented. These data are used to generate robust constraints for any model that describes the disassembly and fragmentation of western Pangaea, the subsequent evolution of the Pacific margin offshore northwestern South America during the Jurassic–Early Cretaceous, and the early evolution of the Caribbean region and its interaction with South America. The review is organised into sections according to geological time, and compares the evolution of northwestern South America (north of 5°S) with the margin of Peru during 290–75 Ma.

Wide disagreements exist over the tectonic origin of voluminous magmatic units, including Triassic anatectites, Jurassic–Early Cretaceous arc rocks, obducted M-HP/LT rocks and allochthonous units that comprise the western cordilleras and the forearc. These contrasting interpretations result in significantly different interpretations for plate reconstructions during the Triassic–Late Cretaceous (e.g. Litherland et al., 1994; Spikings et al., 2001; Pratt et al., 2005; Pindell and Kennan, 2009; Villagómez and Spikings, 2013; Cochrane et al., 2014a). Contrasting models partly exist because of the misinterpretation of K/Ar and Rb/Sr dates that were published in the 1980's and 1990's as accurate estimates of crystallisation age, ignoring the effects of daughter isotope loss. We discard K/Ar and Rb/Sr dates in favour of recently published concordant zircon U-Pb dates, which are more accurate estimates of crystallisation age. The U-Pb dates are combined with geochemical and isotope data, sedimentological data and field relationships to constrain the magmatic source regions and tectonic environment within which the rocks formed. The tectonic histories are subsequently investigated using thermochronological and palaeomagnetic data.

We show that western Pangaea started to disassemble by rifting of continental crust of Central America from South America at ~240 Ma, and that these had completely separated by ~216 Ma. The northwestern margin of South America remained passive until ~209 Ma within Pangaea, and arc magmatism occurred during 209–114 Ma, accompanying the separation of North and South America at ~180 Ma. The Jurassic magmas formed in a continental arc, which questions previous interpretations that place the Jurassic trench far from the location of the Jurassic arcs, due to the presence of suspect continental terranes. We draw a single east-dipping subduction zone during 209–114 Ma, which retreated oceanward and extended the South American margin, culminating in compression that drove rock uplift and exhumation. Finally, we present evidence for an east-facing intra-oceanic arc, which