Lithos 160–161 (2013) 228–249

Contents lists available at SciVerse ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

Thermochronology and tectonics of the Central and Western Cordilleras of Colombia: Early Cretaceous–Tertiary evolution of the Northern Andes

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ARTICLE INFO

Article history:
Received 22 September 2012
Accepted 15 December 2012
Available online 24 December 2012

Keywords:
Thermochronology
Colombia
Northern Andes
Plate tectonics
Geodynamics

ABSTRACT

New thermochronological data record a complex cooling history in the Central and Western Cordilleras of Colombia that is a function of Early Cretaceous to late Miocene tectonic events. Alkali-feldspar $^{40}Ar/^{39}Ar$ cooling ages of ~138–130 Ma immediately post-date the cessation of Jurassic arc-magmatism and a major unconformity within the retro-foreland region of the northern Andes. We interpret these ages as cooling driven by exhumation in response to either compression driven by subduction of a seamount, or extension and oceanward migration of the slab during the earliest Cretaceous, giving rise to the Lower Cretaceous Quebradagrande arc sequence. Biotite and alkali-feldspar $^{40}Ar/^{39}Ar$ data from the palaeocontinental margin reveal the presence of a younger cooling event at 117–107 Ma, which was contemporaneous with hornblende $^{40}Ar/^{39}Ar$ cooling ages obtained from medium–high P–T metamorphic relicts of a Late Jurassic–Early Cretaceous subduction channel. This cooling event is attributed to exhumation driven by the collision and accretion of a fringing arc against the continental margin, and obduction of the subduction channel onto the forearc. Inverse modelling of zircon and apatite fission track and (U–Th)/He data from throughout the Central and Western Cordilleras reveals three periods of rapid cooling since the Late Cretaceous. The earliest phase is recorded by Jurassic and Cretaceous granitoids that cooled rapidly during 75–65 Ma. We attribute cooling to exhumation of the continental margin during ~75–70 Ma (~1.6 km/My), which was forced by the collision and accretion of the Caribbean Large Igneous Province in the Campanian. The Central Cordillera exhumed at moderate rates of ~0.3 km/My during ~45–30 Ma, which are also observed over widely dispersed regions along the Andean chain, and were probably caused by an increase in continent–ocean plate convergence rates. Exhumation rates drastically increased in the middle–late Miocene, with the greatest amount occurring in southern Colombia as a consequence of the collision and subduction of the buoyant Carnegie Ridge at 15 Ma.

1. Introduction

The Cretaceous and Tertiary subduction history of the northern Andes is unique within the Andean chain because it was interrupted by the collision and accretion of arc and oceanic plateau rocks, which are not recognised south of 5°S. This study aims to quantify i) the timing of accretion of arc and plateau rocks, and ii) the thermal and exhumational response of the buttressing continental and indenting oceanic rocks to collision, accretion and post-accretion subduction in Colombia. The conclusions of the study constrain the evolution of the post-rift Western Tethys Wilson Cycle and the early history of the Caribbean Plate, and provide an example of how active continental margins respond to changing plate kinematics and collision, subduction and accretion of heterogeneous oceanic crust.

The Central Cordillera of Colombia consists of Triassic and older metamorphic rocks that were partially melted during Triassic rifting of Central American basement units away from northwestern South America (Villagómez et al., 2011a). Jurassic subduction beneath the Colombian margin formed a continental arc, and an Early Cretaceous fringing arc erupted through either continental (Nivia et al., 2006) or oceanic basement, with accompanying sedimentation within a marginal basin (e.g. Pindell and Kennan, 2009), culminating in compression and basin closure. Subsequent subduction was interrupted by the collision of the Late Cretaceous, Caribbean Large Igneous Province (oceanic plateau and its overlying arc) with the northern Andes during the Late Cretaceous–Early Tertiary (Kerr et al., 1997; Spikings et al., 2010; Vallejo et al., 2006). The ocean–continent suture zone within the northern Andes is well exposed in Colombia along the western flank of the Central Cordillera. The Chocó–Panamá block collided with the Colombian margin during either 25–23 Ma (Farris et al., 2011), at ~13 Ma (Duque-Caro, 1990) or during the Late Miocene–Pliocene (Mann and Corrigan, 1990). Finally, the aseismic Carnegie Ridge currently subducts beneath southern Colombia and northern Ecuador, although the

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0024-4937/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.lithos.2012.12.008

proposed timing of collision varies between 15 Ma (Spikings et al., 2001) and 1 Ma (Lonsdale and Klitgord, 1978).

We combine hornblende, alkali feldspar and biotite $^{40}Ar/^{39}Ar$, zircon and apatite fission track (FT) and zircon and apatite (U–Th)/He data to generate semi-continuous Cretaceous and Tertiary thermal history paths through ~550 °C–40 °C for crystalline and sedimentary rocks exposed along the Central Cordillera and accreted rocks exposed in the Western Cordillera. These paths have been used to construct exhumation histories since ~140 Ma, which have been combined with i) the sedimentological histories of surrounding basins, ii) U–Pb (zircon) ages of plutonic and metasedimentary rocks (Villagómez et al., 2011a), and iii) geochemical analyses of intrusive and volcanic rocks (Kerr et al., 1997; Villagómez et al., 2011a) to precisely determine the timing of collision events, quantify the exhumational response and constrain the post-accretionary history of the Colombian margin. Improving our understanding of these processes is useful because they resulted in net crustal growth of the South American Plate and can be used to improve reconstructions of the southern margin of the Caribbean Plate, and hence the entire Caribbean region.

2. Geological framework of the Central and Western Cordilleras of Colombia

Previous work in Colombia divided the region into a continental and an oceanic province, which are juxtaposed across three major

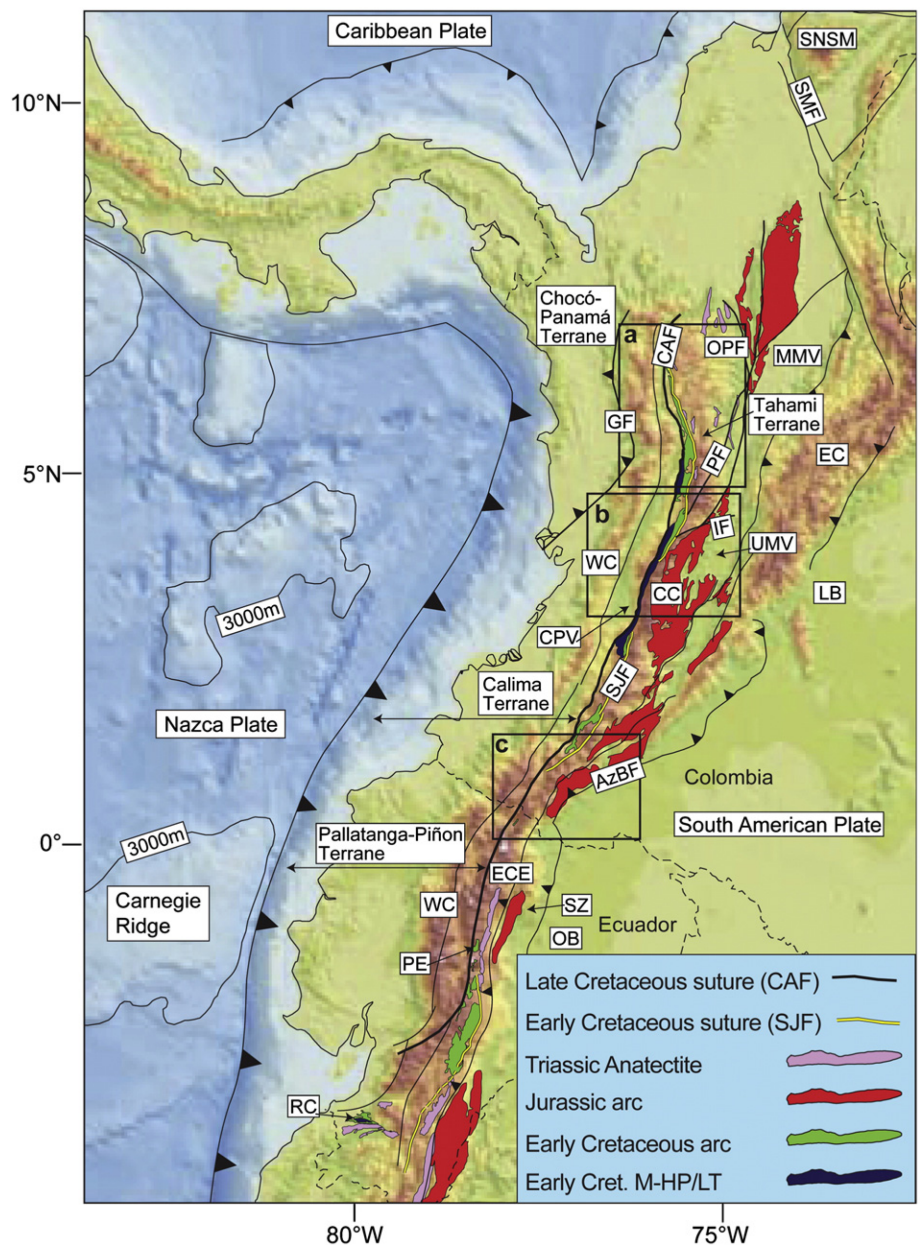

Fig. 1. Digital elevation model of northwestern South America and surrounding tectonic plates showing the main cordilleras, faults and the subducting Carnegie Ridge (background model from Gómez et al., 2007). Cretaceous sutures are shown as thick black and yellow lines, and the three sample regions (a, b and c) are highlighted (Fig. 2). Major rock sequences of the Central Cordillera (Colombia) and Eastern Cordillera (Ecuador) are shown. AzBF: Amazon Border Fault, CAF: Cauca–Almaguer Fault, CC: Central Cordillera, CPV: Cauca–Patía Valley, EC: Eastern Cordillera, ECE: Eastern Cordillera Ecuador, GF: Garrapatas Fault, IF: Ibagué Fault; LB: Llanos Basin, MMV: Middle Magdalena Valley Basin, OB: Oriente Basin, OPF: Otú–Pericos Fault, PE: Peltetec Unit, PF: Palestina Fault, RC: Raspas Complex, SJF: San-Jeronimo Fault, SMF: Santa Marta–Bucaramanga Fault, SNSM: Sierra Nevada de Santa Marta, SZ: Sub-Andean Zone (Ecuador), UMV: Upper Magdalena Valley Basin, WC: Western Cordillera.