Precambrian Research 191 (2011) 58–77

Contents lists available at SciVerse ScienceDirect

Precambrian Research

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

The Putumayo Orogen of Amazonia and its implications for Rodinia reconstructions: New U–Pb geochronological insights into the Proterozoic tectonic evolution of northwestern South America

Mauricio Ibanez-Mejia[a,*], Joaquin Ruiz[a], Victor A. Valencia[b], Agustin Cardona[c], George E. Gehrels[a], Andres R. Mora[d]

[a] Department of Geosciences, The University of Arizona, Tucson, AZ, USA
[b] School of Earth & Environmental Sciences, Washington State University, Pullman, WA, USA
[c] Smithsonian Tropical Research Institute, Balboa-Ancon, Panama
[d] Instituto Colombiano del Petroleo ICP, ECOPETROL, Piedecuesta, Santander, Colombia

ARTICLE INFO

Article history:
Received 13 June 2011
Received in revised form 12 August 2011
Accepted 13 September 2011
Available online 17 September 2011

Keywords:
South America
Amazonia
Putumayo Orogen
Rodinia
Grenville
U–Pb geochronology

ABSTRACT

Outcrops of late Meso- to early Neoproterozoic crust in northwestern South America are restricted to isolated exposures of basement inliers within the northern Andes of Colombia, Peru and Venezuela. However, evidence for the existence of an autochthonous Stenian–Tonian belt in northern Amazonia that is undisturbed by Andean orogenesis has not been recognized so far. Here we report ~1200 new single-zircon U–Pb geochronological analyses from 19 Proterozoic rock samples of northwestern South America collected from the Garzón and Las Minas Andean cordilleran inliers, drill-core samples from the foreland basin basement, and outcrops of cratonic Amazonia in eastern Colombia (western Guyana shield). Our new geochronological results document the existence of a previously unrecognized Meso- to Neoproterozoic orogenic belt buried under the north Andean foreland basins, herein termed the Putumayo Orogen, which has implications for Proterozoic tectonic reconstructions of Amazonia during the assembly of the supercontinent Rodinia. Based on the interpretations of new and pre-existing data, we propose a three-stage tectonometamorphic evolution for this orogenic segment characterized by: (1) development of a pericratonic fringing-arc system outboard of Amazonia's leading margin during Mesoproterozoic time from ~1.3 to 1.1 Ga, where the protoliths for metaigneous and metavolcanosedimentary units of the Colombian and Mexican inliers would have originated in a commonly evolving Colombian–Oaxaquian fringing-arc system; (2) amphibolite-grade metamorphism and migmatization between ca. 1.05 and 1.01 Ga by inferred amalgamation of these parautochtonous arc terranes onto the continental margin, and (3) granulite-grade metamorphism at ~0.99 Ga during continent–continent collision related to Rodinia final assembly. Along with additional paleogeographic constraints, this new geochronological framework suggests that the final metamorphic phase of the Putumayo Orogen was likely the result of collisional interactions with the Sveconorwegian province of Baltica, in contrast to previously proposed models that place this margin of Amazonia as the conjugate of the Grenville province of Laurentia.

1. Introduction

Many reconstructions for the early Neoproterozoic supercontinent Rodinia predict interactions between a Laurentia–Baltica–Amazonia triple joint along internal collisional orogens (e.g. Hoffman, 1991 or Li et al., 2008 for a recent review). These different orogenic segments developed diachronously during late Mesoproterozoic to early Neoproterozoic times, and their timing defines the chronology for the collisional interactions that took place between different crustal blocks and microcontinents as Rodinia was assembled. In South America the Amazon Craton is the largest of the Precambrian blocks that constitute the continental platform (Tassinari and Macambira, 1999), and its role in the supercontinent cycle has for long been recognized (Cordani et al., 2009). Records of the participation of Amazonia in the supercontinent Rodinia are expressed as: (a) metamorphosed passive-margin and rift sequences of the Sunsás-Aguapei and Nova Brasilandia belts in western Brazil – eastern Bolivia (review by Teixeira et al., 2010), (b) scattered intracratonic magmatic events and shear-zones developed obliquely with respect to the colliding margin (review by Cordani et al., 2010), and (c) paleomagnetic evidences obtained from late Mesoproterozoic volcanic and sedimentary rocks of the Rondonia region in Brazil indicating proximity and interaction of this margin of Amazonia with respect to (modern) SE Laurentia

* Corresponding author.
E-mail address: ibanezm@email.arizona.edu (M. Ibanez-Mejia).

0301-9268/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.precamres.2011.09.005

(Tohver et al., 2002; D'Agrella-Filho et al., 2008). Although the involvement of Amazonia in Rodinia is in general a well-accepted hypothesis (e.g. Li et al., 2008), many details and questions regarding intercratonic orogen correlations and the evolution of Meso-Neoproterozoic collisional belts of the Amazon Craton are far from being resolved. An example of this issue is the observation that the Sunsás margin of Amazonia has been correlated by different authors with virtually every segment of the Grenville margin of Laurentia (see Tohver et al., 2004a, and references therein), in part due to the fact that the lack of geological and robust geochronological information from northwestern South America has left its role in many of these reconstructions mostly unconstrained.

As a result of dense vegetation cover, heavy tropical weathering, and the development of Phanerozoic sedimentary basins, there are still sizable areas in northern South America where its Precambrian basement remains poorly studied or even completely unknown. This is the case of the north Andean foreland basins, where a large portion of northern Venezuela, eastern Colombia, eastern Ecuador and eastern Peru (Fig. 1) comprise an area in excess of 800,000 km^2 of covered basement. However, with the exception of K–Ar and Rb–Sr ages from wells presented by Kovach et al. (1976) and Feo-Codecido et al. (1984) nothing else is known about the geochronology of this vast region.

Paleogeographic models that juxtapose the Sunsás margin of Amazonia against southeastern Laurentia implicitly predict that the Meso-Neoproterozoic orogen of the Amazon Craton should extend north of the Sunsás-Aguapei orogen, partly as a conjugate margin to the Laurentian Grenville province under the Amazon River basin, and possibly by interaction with a third continental mass even further north (e.g. Hoffman, 1991; Tohver et al., 2002, 2006; Fuck et al., 2008; Li et al., 2008; Cardona et al., 2010). This interpretation has benefited from the occurrence of high-grade metamorphic inliers included within the north Andean orogen in Colombia such as the Garzón and Santa Marta massifs, among others (Restrepo-Pace et al., 1997; Cordani et al., 2005; Ordonez-Carmona et al., 2006; Cardona et al., 2010). However, given the complex deformational history of the northern Andes (Aleman and Ramos, 2000), in particular its strong Meso-Cenozoic margin-parallel strike-slip transport component (Bayona et al., 2006, 2010) and possible involvement in later terrane collision event after the amalgamation of Pangea (Vinasco et al., 2006), the relationship between the cordilleran inliers and the non-exposed basement of the adjacent foreland basins remains uncertain.

The main objective of this paper is to present new zircon U–Pb geochronological results from Proterozoic basement rocks of northwestern South America, in an attempt to clarify many of these long-standing questions and provide a geochronological framework that can shed light on paleogeographic correlations involving the northwestern margin of the Amazon Craton. Samples reported in this contribution lie along a broadly NW–SE transect that covers most of the width of southern Colombia, ranging from exposures of cratonic Amazonia (W Guyana shield), to samples from Precambrian cordilleran inliers included within the Andean orogen (Fig. 2). In addition to refining the geochronology for various magmatic and metamorphic episodes in the north Andean cordilleran blocks and the western Guyana shield area, we present the first zircon U–Pb ages obtained from basement drill-core samples of the north Andean foreland basins as well as detrital zircon (DZ) analyses from high-grade metasedimentary units in the area. Our results comprise the first geochronological evidence for the existence of a previously unrecognized segment of an Ectasian to Tonian orogenic belt underlying the modern foreland cover, herein termed the Putumayo Orogen, which has a distinct geological evolution with respect to its Amazonian analog the Sunsás-Aguapei orogen. As will be discussed below, recognition of this new belt provides a better cratonic reference for linking the Andean cordilleran inliers with autochthonous Amazonia basement, improves our knowledge about the evolution of the Proterozoic orogens of South America and provides an additional piercing point in Amazonia for establishing intercratonic correlations with other late Meso- to early Neoproterozoic orogens worldwide.

2. Geological setting – known provinces of the Amazon Craton

The Amazon Craton has been broadly subdivided in six different Precambrian provinces (Fig. 1) and its evolution spans over 2 Ga of Earth's history. A detailed discussion about the general crustal configuration of the Amazon Craton is beyond the scope of this paper and only a brief summary of most relevant events are presented below. The interested reader is referred to the works of Teixeira et al. (1989), Tassinari and Macambira (1999), Santos et al. (2000), Cordani and Teixeira (2007), and Santos et al. (2008) for a more in depth discussion on this subject. In general, it is thought that after the amalgamation of Archean microcontinents along the Maroni-Itacaiunas (MI) province during the Transamazonian orogeny, the Ventuari-Tapajos (VT) and Rio Negro-Juruena (RNJ) belts evolved through the continuous accretion of intraoceanic arcs to this proto-Amazonia nucleus. The two marginal provinces located towards the southwestern portion of the craton, the Rondonia-San Ignacio (RSI) and the Sunsás-Aguapei (SA), are the result of accretionary and collisional tectonics that took place throughout the Mesoproterozoic (Sadowski and Bettencourt, 1996; Cordani and Teixeira, 2007).

The RSI orogeny, which took place during the time interval from ca. 1.56 to 1.30 Ga, is characterized by the accretion of early Mesoproterozoic arc terranes overprinted by high-grade metamorphism during the mid Mesoproterozoic by inferred collision of a microcontinent – the Paragua block – against the RNJ continental margin (Bettencourt et al., 2010). Collision of the Paragua block against Amazonia resulted in high-grade metamorphism of the Chiquitania gneisses and the Lomas Manechis granulites at about 1.33 Ga (Bettencourt et al., 2010; Santos et al., 2008), also coinciding with cessation of arc magmatism in the Pensamiento granitic complex (Matos et al., 2009).

Following the 1.33 Ga accretion event, a passive margin developed in the area and a long-lasting period of tectonic quiescence with localized intraplate extension followed, resulting in the deposition of the Sunsás/Vibosi groups (Litherland and Bloomfield, 1981; Litherland et al., 1989) and the Nova Brasilândia aulacogen sedimentary sequences (Tohver et al., 2004b), respectively. These basins were later inverted and metamorphosed during the Sunsás orogeny ca. 1.1 Ga (Teixeira et al., 2010), synchronous with deformation occurring along the Llano segment of the Grenville margin of Laurentia (Mosher et al., 2004). Collisional interactions affecting this portion of SW Amazonia during the late Mesoproterozoic have been used as evidence for the participation of the Amazon Craton during the amalgamation of Rodinia.

3. The Proterozoic of NW South America (Colombia–Venezuela–Peru–Ecuador)

3.1. Cratonic Amazonia

The northwestern-most outcrops of the Amazon Craton in South America are found in the Orinoco and Amazonas regions of eastern Colombia, western Venezuela and northwestern Brazil (Figs. 1 and 2). Most of the geological mapping in Colombia, along with the only geochronological study available from this area, was conducted during the PRORADAM project (Galvis et al., 1979; Proradam, 1979; Priem et al., 1982). The craton in this region