

## Evolution of the Gondwanan margin of the northern Andes

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The Andes represent the locus of continued plate convergence from the Early Palaeozoic to the present day. However the early evolution of much of the proto-Andean margin remains poorly understood. This is because exposures of pre-Andean basement rocks are in many places extremely limited, either being obscured by later tectonic events along the convergent margin or buried by the ubiquitous volcanic cover. This problem is particularly acute in the northern Andes, where Precambrian basement is not exposed for over 2000 km along strike. This corresponds to the distance between the northern extent of the Arequipa-Antofalla block (Fig. 1), a Proterozoic crustal block which has experienced Grenville metamorphism (Loewy et al., 2004) and the southernmost basement exposures in Colombia, the Proterozoic Garzón inlier (Restrepo-Pace et al., 1997). This zone, extending from 15° S in southern Peru to 2° N in southern Colombia (Fig. 1) is also characterized by substantial development of Andean foreland sediments to the east, so that the basement geology peripheral to the orogen is not known with any degree of certainty.

However, in the Eastern Cordilleras of Peru and Ecuador, Palaeozoic metasedimentary sequences are well exposed, along with several generations of cross-cutting Palaeozoic granitoid intrusions. Most of these sequences, including the Marañon Complex in Peru and the Isimanchi Formation of the Cordillera Real in Ecuador are considered to be autochthonous with respect to the Gondwanan margin. Hence their heavy mineral assemblages, and in particular their detrital zircon populations, should reveal information regarding their source areas - in this case the Gondwanan margin of the northern Andes. Furthermore, granitic magmas which intrude these sequences can carry inherited zircon during ascent. These inherited zircons can also provide source information, particularly with respect to deeper crustal levels which would otherwise be impossible to sample.

This study incorporates U-Pb LA-ICPMS dating of detrital zircons from various Gondwanan margin sequences in Peru and Ecuador. Additionally, conventional U-Pb zircon and U-Pb titanite dating was undertaken to constrain the timing of metamorphism and magmatism in the Eastern Cordillera of Peru.

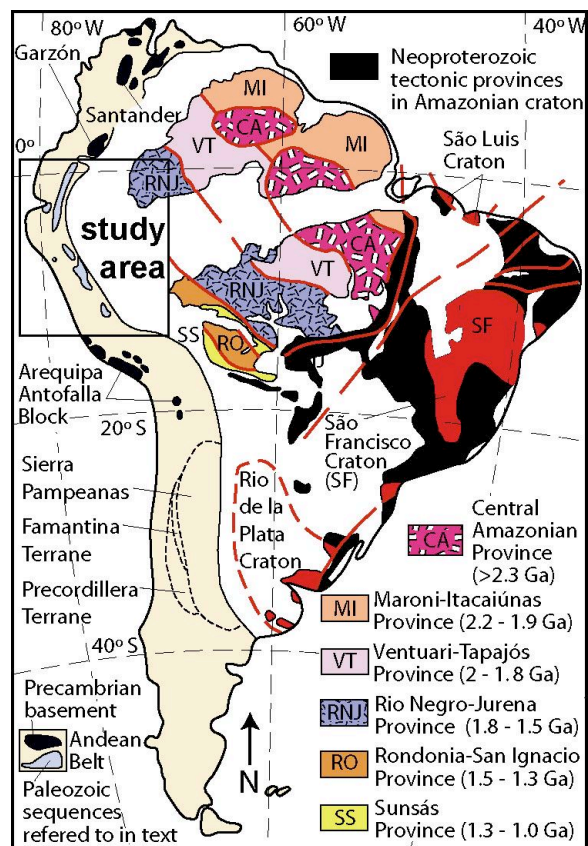


Figure 1. Geology of South America illustrating tectonic provinces and region of interest in this study.

### U-Pb LA-ICPMS detrital zircon data

All samples exhibit prominent peaks between c. 0.45 – 0.65 Ma and c. 0.9 – 1.3 Ga, and display a minimal amount of detritus older than c. 2 Ga. Between a third and a half of all grains in each sample lie within the 0.45 – 0.65 Ma age range. Nearly all samples exhibiting a prominent peak between 0.45 and 0.5 Ga, which temporally overlaps with the onset of subduction-related magmatism in the Famantinian terrane (Fig. 1) of northern Argentina, the Arequipa terrane of Southern Peru (Fig. 1, Loewy et al., 2004), Venezuela (the

Caparo Arc of Bellizzia & Pimentel, 1994) and Colombia. Further prominent peaks are found within the c. 0.5 – 0.65 Ga age range, ages typical of the Brasiliano / Pan African orogenic cycles. The nearest rocks of equivalent age within the Andean chain are the c. 535 Ma subduction-related granitoids of the Sierra Pampeanas (Fig. 1) in northern Argentina (Rapela et al., 1998) or the Neoproterozoic (c. 650-580 Ma) basement gneisses in Venezuela (Bellizzia & Pimentel, 1994). Additionally, there are no rocks of equivalent age exposed on the western side of the Amazonian craton – the extensive Neoproterozoic tectonic provinces of Brazil (the Brasiliano orogenic cycle) are located on the eastern side (Fig. 1). It is difficult to invoke the eastern Amazonian craton as a potential source because the minimal amount of old detritus (i.e. Archean and Paleoproterozoic) argues that the core of the Amazonian craton (Fig. 1) was not a significant source of detritus to the Gondwana margin during the Palaeozoic.

Significantly less detritus lies within the c. 0.7 – 0.9 Ga age range, while between a third and a half of all grains in each sample lie within the 0.9 – 1.3 Ga age range, with the largest peaks commonly encountered between 1 and 1.2 Ga. The Sunsas orogen of the SW Amazonian craton is invoked as a potential source region for the abundant c. 0.9 – 1.3 Ga peaks observed. It is interpreted that the Sunsas orogen continues in a northwestern direction underneath the thick pile of foreland sediments that are developed to the east of the Northern Andes (Fig. 1), where it is likely to be contiguous with the c. 1 Ga gneissic basement inliers in the Columbian Andes (Fig. 1, Restrepo-Pace et al., 1997).

We envisage that the basement to the Gondwanan margin to the northern Andes was composed of a metamorphic belt of Grenvillian age, upon which was sited a late Neoproterozoic – Early Palaeozoic (subduction-related?) magmatic belt, similar to the Sierra Pampeanas of northern Argentina.

### Timing of Early Palaeozoic Metamorphism in Peru

Existing age constraints on the timing of metamorphism of the Eastern Cordillera of Peru (Marañon Complex) are very poor. The pronounced c. 480 Ma detrital zircon peak observed in Marañon Complex rocks in this study implies

that the metamorphism must be post-480 Ma, and that the c. 600 Ma U-Pb zircon ages from granulitic gneisses in central Peru of Dalmayrac et al. (1980) are a result of inheritance. Additionally, we have constrained the timing of metamorphism in at least part of the Marañon Complex to Silurian or younger. High-grade metamorphic assemblages (c. 650° C, 11 kb) are developed within orthogneisses which yield U-Pb magmatic zircon ages of  $442.4 \pm 1.4$  Ma (TIMS) and  $444.2 \pm 6.4$  Ma (LA-ICPMS). The timing of metamorphism is currently refined by a combination of Sm-Nd garnet, Ar-Ar hornblende and U-Pb titanite dating.

The U-Pb detrital zircon data imply that orogenic belts equivalent in age to the Famantinian / Pampean and Grenville (= Sunsas) orogenies were available to supply detritus to the Palaeozoic sequences of the Northern Andes. Combined with evidence that metamorphism of the Eastern Cordillera of Peru document is Silurian or younger, it appears the Early Palaeozoic evolution of the Gondwanan margin of the Northern Andes is similar to that of both northern Argentina and Colombia / Venezuela, with broadly comparable tectonic histories over several thousand kilometers along strike.

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