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7th International Symposium on Andean Geodynamics (ISAG 2008, Nice), Extended Abstracts: 337-338

Tectono-magmatic evolution and crustal growth along west-central Amazonia since the late Mesoproterozoic: Evidence from the Eastern Cordillera of Peru

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Whereas the Cretaceous to recent orogenic cycle is well characterised (Ramos and Aleman; 2000), the knowledge of the early Phanerozoic and Proterozoic evolution of the Andes is increasingly fragmentary with age due to paucity of exposed lithologies. The problem is less pronounced along the Peruvian segment of the orogen where a lacuna in the ubiquitous Cenozoic volcanic cover is interpreted to have resulted from the flat slab subduction of the Nazca ridge (Jaillard *et al*., 2000). Batholiths of the Eastern Cordillera of Peru which straddle the tectonic boundary between the allochthonous western Amazonian tectonic provinces of San Ignacio (1.57-1.24 Ga) and Sunsás (1.19-0.92 Ga) on one side and comparatively few parautochthonous to allochthonous crustal domains (1.9-1.8 Ga Arequipa-Antofalla; 150 Ma Olmos-Amotape terrane) on the other, thus provide an optimal record of the nature and rate of crustal growth at a long lived, non-accretionary cratonic margin. Despite its fortuitous setting however, the timing of magmatism in the central Andes is relatively poorly understood with most of the geochronological work so far relying heavily upon whole rock Rb-Sr and K-Ar techniques, both of which are known to yield ambiguous dates thanks to low retention temperatures and a possibility of isotopic disturbance by subsequent tectono-thermal episodes. This is a particularly acute problem in Peru considering ~150 Ma of uninterrupted compressive tectonism of the last Andean cycle (Benavides, 1999).

We use a combination of *in situ* U-Pb geochronology and Lu-Hf isotopic tracing of plutonic zircons along the strike of the Eastern Cordillera of Peru to construct a detailed geochronological framework and identify sources of consecutive magma pulses in order to define cratonic domains and track crustal evolution of the proto-Andean margin of Amazonia. By relating the secular changes in magma sources to the tectono-magmatic cycles of continental assembly and breakup over the last 1.1 Ga, we can test both the current geodynamic scenarios for the evolution of the western Amazonian shield with particular focus on the poorly understood break up of Rodinia (Meert and Torsvik, 2003; Loewy *et al*., 2003; Cordani *et al*., 2003; Fuck *et al*., 2008; Li *et al*., 2008) and the models constraining the relative contributions of Phanerozoic and Neoproterozoic arc magmatism in the formation of the continental crust (Condie, 2001; Davidson and Arculus, 2005).

The results of a laser ablation ICPMS U-Pb isotopic study on zircons from 60 Eastern Cordilleran intrusives of Peru reveal 1.15 Ga of magmatic activity along the central western Amazonian margin that is largely dominated by mid-Phanerozoic plutonism related to the assembly and break up of Pangea. A Carboniferous-Permian (340-285 Ma) continental arc is identified along the orogenic trend from Ecuadorian border (6ºS) to the inferred inboard extension of the Arequipa –Antofalla terrane in the southern Peru (14ºS). The widespread crustal extension and thinning which affected the western Gondwana throughout Permian and Triassic resulted in the central late to post orogenic La Merced-San Ramón-type anatectites dated between 275 and 220 Ma while the emplacement of the southern Cordillera de Carabaya peraluminous granitoids in the late Triassic to early Jurassic (220-190 Ma) represents, temporally and regionally, a separate tectono-magmatic event likely related to re-suturing of the Arequipa-Antofalla block. Alkaline volcano-plutonic complexes and stocks associated with the onset of the modern Andean cycle in southeastern Peruvian Andes cluster between 170-180 Ma. A volumetrically minor intrusive pulse of Oligocene age (~30 Ma) is detected near the SW Cordilleran border with Altiplano, and only one remnant of the late Ordovician intrusive belt is recognised in the Cuzco batholith (446.5 ± 9.7 Ma) indicating that the Famatinian arc system previously identified in Peru only along the north-central Cordillera Oriental and the coastal Arequipa terrane had also developed inboard of this para-autochthonous crustal fragment. Both post-Gonwanide and Precambrian plutonism are restricted to isolated occurrences spatially comprising less than 15% of the Eastern Cordillera intrusives. Hitherto unknown occurrences of the late Mesoproterozoic and middle Neoproterozoic granitoids from the south central cordilleran segment define magmatic events at 691 ± 13, 751 ± 8, 985 ± 14, and 1071 to 1123 ± 23 Ma that are broadly coeval with the Braziliano and Grenville-Sunsás orogenies. Our data suggest the existence of a contiguous orogeny > 3800 km along western Amazonia during the formation of Rodinia and its "early" fragmentation prior to 690 Ma.

In addition to dating the emplacement of plutonic rocks, we performed an *in situ* the LA MC-ICPMS survey of the Hf isotope systematics on magmatic zircons from the Eastern Cordillera batholiths. These are invariably characterised by a range in the initial $^{176}Hf/^{177}Hf$ compositions for a given intrusive event suggesting mixing of material derived from the Paleoproterozoic crustal substrate and variable Neoproterozoic to recent juvenile sources. The periods of well documented compressive tectonics correspond to negative mean eHf_i values of -6.73, -2.43, -1.57 for the Ordovician Famatinian, Carboniferous-Permian and late Triassic respectively, suggesting the minimum crustal contribution between 74% and 44% by mass. The average initial Hf systematics from granitoids associated with intervals of regional extension such as the middle Neoproterozoic, Permian-Triassic and Cenozoic Andean back arc plutonism are consistently shifted toward the positive values (mean eHf_i = -0.7 to +8.0) indicating systematically larger inputs of juvenile magma (22% to 49%). In the absence of evidence for lateral accretion of exotic crust, the time integrated Hf record from the central proto-Andean margin of western Amazonia suggests crustal reworking as the dominant process during episodes of arc magmatism and implies that most of continental growth took place vertically via crustal underplating of isotopically juvenile, mantle derived magma during intervals of crustal attenuation.

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