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NEOPROTEROZOIC TO EARLY MESOZOIC EVOLUTION OF THE WESTERN GONDWANA MARGIN: EVIDENCE FROM THE EASTERN CORDILLERA OF PERU

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INTRODUCTION

The Peruvian Andes represent the locus of plate convergence during most of the time between the Early Palaeozoic and the present day, except for Devonian and Permian-Triassic, for which we have neither a magmatic nor a sedimentary record. In the Eastern Cordilleras of Peru and Ecuador, supposedly Precambrian metasedimentary sequences are 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 (e.g., Haeberlin 2002). Our new U-Pb age determinations demonstrate that they were formed during Paleozoic orogenies, and we do not find any evidence for Precambrian basement for over 2000 km between the northern extent of the Arequipa-Antofalla block (e.g., Loewy et al. 2004), and the southernmost basement exposures in Colombia, the Proterozoic Garzón inlier (Restrepo-Pace et al. 1997). Detrital zircon populations of these metasediments as well as inherited zircons in the granitic intrusions should reveal information regarding their source areas - in this case the Gondwanan margin. Additionally, the timing of orogeny in these Palaeozoic medium-high grade metamorphic sequences of the Eastern Cordillera of Peru is very poorly-constrained. The metamorphic basement of the Eastern Cordillera is intruded by late Paleozoic to Mesozoic batholiths that span its entire length and exhibit profound and systematic variation in chemistry and timing of emplacement from north to southeast. This compositional variation may be used to constrain the nature of crustal and mantle contributions to this magmatism, as well as to reconstruct the still enigmatic tectonic environment along the margin. We present new U-Pb age determinations (laser-ablation ICP-MS, ion microprobe and ID-TIMS ages), which provide new constraints on timing of orogeny and magmatism, and the palaeogeography of the Gondwanan margin of the northern Andes during the Palaeozoic and early Mesozoic (Chew et al, submitted).

U-PB DATING OF DETRITAL ZIRCON IN METASEDIMENTS:

Metasediments from the Cordillera Real of Ecuador and from different localities within the Marañon Complex in the Cordillera Oriental of northern to central Peru have been analyzed by laser-ablation ICP-MS techniques. Probability-density-distribution diagrams with the data are shown in Fig. 1 along with the sampling sites. All samples exhibit prominent peaks between c. 0.45 – 0.65 Ma and c. 0.9 – 1.3 Ga. Nearly all samples exhibit a conspicuous peak between 0.45 and 0.5 Ga, which temporally overlaps with the onset of subduction-related magmatism, e.g., in the Famatinian terrane of northern Argentina (e.g., Lucassen and Franz 2005) or in the Arequipa terrane of Southern Peru (e.g., Loewy et al. 2004). Further prominent peaks are found within the c. 0.5–0.65 Ga age range, ages typical of the Brasiliano/ Pan African orogenic cycles. Significantly less detritus lies within the c. 0.7–0.9 Ga age range, while the largest peak is commonly encountered at ages typical for Grenville-Sunsas orogeny, between 1.0 and 1.2 Ga.

The Sunsas orogen of the SW Amazonian craton is invoked as a potential source region for the abundant *c.* 1.0–1.2 Ga peaks observed in the detrital zircon populations (Santos et al. 2002). 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, where it is likely to be contiguous with the *c.* 1 Ga gneissic basement inliers in the Columbian Andes. As the amount of older (> 1.2 Ga) detritus is minimal, the Sunsas orogen is invoked as a "topographic barrier" to the transport of detritus from the Paleoproterozoic-Archean Anazonian craton. 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 an Early Palaeozoic (subduction-related?) magmatic belt, similar to the Sierra Pampeanas of northern Argentina (Rapela et al. 1998).

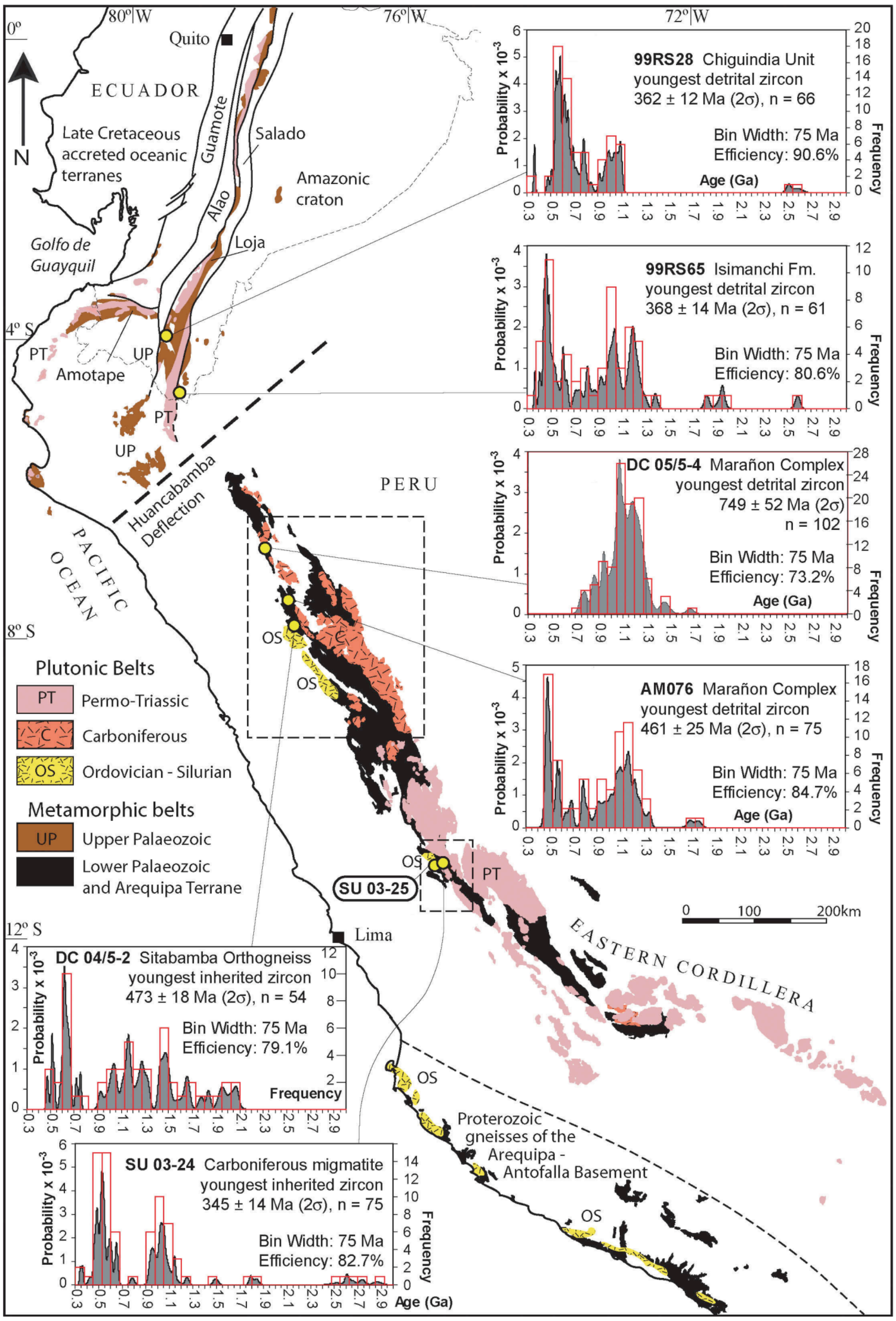

Fig. 1: New laser-ablation ICP-MS U-Pb age data of detrital zircon populations

ORDOVICIAN TO CARBONIFEROUS TECTONO-THERMAL EVENTS

U-Pb zircon data (both ion microprobe and ID-TIMS) from the sampling transect in the Eastern Cordillera of Central Peru clearly demonstrate that the Marañon Complex has been affected by two major orogenic events. The post-tectonic Pacococha Adamellite constrains polyphase deformation within the Marañon Complex east of Junín to have occurred prior to 474.2±3.4 Ma. A foliated leucosome from garnet-bearing paragneisses in the Marañon Complex south of the Balsas intrusion (northern Peru) yields a concordia age of 477.9±4.3 Ma, interpreted as dating leucosome generation. We therefore suggest that there is a *c.* 478 Ma orogenic event affecting part of the Marañon Complex for several hundred kilometers along the Eastern Cordillera in northern and central Peru. Importantly, the paragneiss host rock to the leucosomes contains no zircons younger than *c.* 750 Ma (DC05-5/4; Fig. 1). The presence of a younger, probably Silurian orogenic event in Northern Peru is indicated by an orthogneiss west of Pataz, hereafter termed Sitabamba orthogneiss: the crystallization of magmatic zircon was dated at an age of 442.4±1.4 Ma (DC04-5/2; Fig. 1), and 445.9±2.5 Ma, therefore the high-grade metamorphic assemblage (700 ˚C, 12 kbar) in the orthogneiss must be younger than this datum. Supporting this observation, a prominent peak in the detrital zircon population at *c.* 470 Ma not seen in the older Marañon Complex rocks have been obtained from a meta-sandstone from the same area (DC05-5/4; Fig. 1). This suggests that the Marañon Complex in this region (presently mapped as Precambrain basement) must be comprised of two separate units: an older unit which underwent metamorphism pre- 474 Ma, and a younger unit, which contains detritus presumably derived from the *c.* 470 Ma magmatic belt and then experienced a younger tectono-thermal event.

In Central Peru, the anatectic Huacapistana Granite close to Tarma, and adjacent syn-D2 migmatic paragneisses formed during an Upper Carboniferous high-grade tectonothermal event which is constrained by U-Pb zircon ages of 310.2±2.3 Ma and 312.9±3 Ma, respectively (thus (being part of the "Young" Marañon Complex). The timing of this Upper Carboniferous (*c.* 312 Ma) tectonothermal event is corroborated in the Tarma cross section by the presence of deformed plutons such as the Hualluniyocc Adamellite dated at 325.4±0.6 Ma and entirely undeformed plutons as the Utcuyacu Granite at 306.7±0.5 Ma. For the time slice between c. 440 and c. 350 Ma we lack any information, which would allow us to establish a geodynamic setting in the Peruvian segment of the Andes.

CARBONIFEROUS TO TRIASSIC BATHOLITHS IN THE EASTERN CORDILLERA

The Late Paleozoic to Mesozoic batholiths of the Eastern Cordillera of Peru exhibit profound variations in chemistry and timing of emplacement from north to south (Fig. 2). A striking geochemical relationship exists between three principal plutonic belts:

1) I-type belt: Mississippian to Pennsylvanian, I-type, metaluminous, hornblende and magnetite dominated granitoids are restricted to the segment north of 11S, and display calc-alkaline evolutionary trends characteristic of continental subduction zones. New precise ion microprobe and ID-TIMS U-Pb ages range from 343.6±2.6 Ma for the Balsas intrusion to 336.4±0.6 Ma for the Pataz intrusion.
2) Permian to Early Triassic, peraluminous, I to S-type, mica and ilmenite rich granitoids of the east-central Peru (as the Huacapistana, Hualluniyocc and Utcuyacu intrusions), are comagmatic with bimodal tholeiitic lavas of the Mitu Group, all of which are associated with transitional, post-orogenic (within-plate) suites, e.g., the 240-250 Ma old San Ramón granite.
3) Late Triassic, initially A-type monzogranitoids of the southern Cordillera de Carabaya terminate as peralkaline, SiO_2-undersaturated intrusives (Ne-syenites) emplaced in the Mitu Group shoshonites. The latter exhibit mineralogy characteristic of a shallow and dry source (< 1 kbar H_2O-saturated conditions).

Combined Sr-Nd-Pb isotope systematics from all three intrusive provinces, however, lacks variation and suggests uniformly large degrees of assimilation of the Proterozoic Amazonian basement. In addition to the systematic change in the plutonic chemistry, U/Pb as well as $^{39}Ar/^{40}Ar$ age determinations reveal a general younging-southward trend. The 20 m.y. long magmatism associated with the Mississippian arc in the north-central Eastern Cordillera culminated between 336-325 Ma (Pataz batholith). It was followed by *c.* 40 m.y. hiatus briefly punctuated during a 314-312 Ma episode of orogenic Au-Ag mineralization (Haeberlin 2002) associated with the period of tectonic uplift, coeval to crustal S-type magmatism in Central Peru. Resumption of the Permo-Triassic magmatism saw deposition of the bimodal Mitu Group volcanics contemporaneously with the intrusion of the post-collisional plutons in the central Eastern Cordillera (Carrizal, San Ramon batholiths). Sporadic magmatic activity throughout Triassic was marked by eruption of progressively more alkalic Mitu lavas and initiation of the A-type plutonism, which peaked in the latest Triassic in the southernmost Carabaya Batholith. The early Jurassic alkaline magmas of the Allincapac complex in the SE Peru mark the latest and most enriched pulse of rift magmatism.

CONCLUSIONS

The U-Pb detrital zircon data imply that orogenic belts equivalent in age to the Famantinian/Pampean (0.45-0.5 Ma and Grenville/Sunsas orogenies (1.0-1.2 Ga) supplied detritus to the Palaeozoic sequences of the Northern Andes. We provide evidence for polyphase metamorphism in the Ordovician (*c.* 480 Ma), Silurian (post-440 Ma) and Carboniferous (*c.* 310 Ma) in the Eastern

Cordillera of Peru. 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. For the first time the existence of an Ordovician magmatic arc is demonstrated for the Eastern Cordillera, coeval to the San Nicholas batholith in the Arequipa-Antofalla basement (Loewy et al. 2004; Mukasa and Henry 1990). Carboniferous to Triassic/Jurassic plutons are shown to have intruded the polymetamorphic basement.

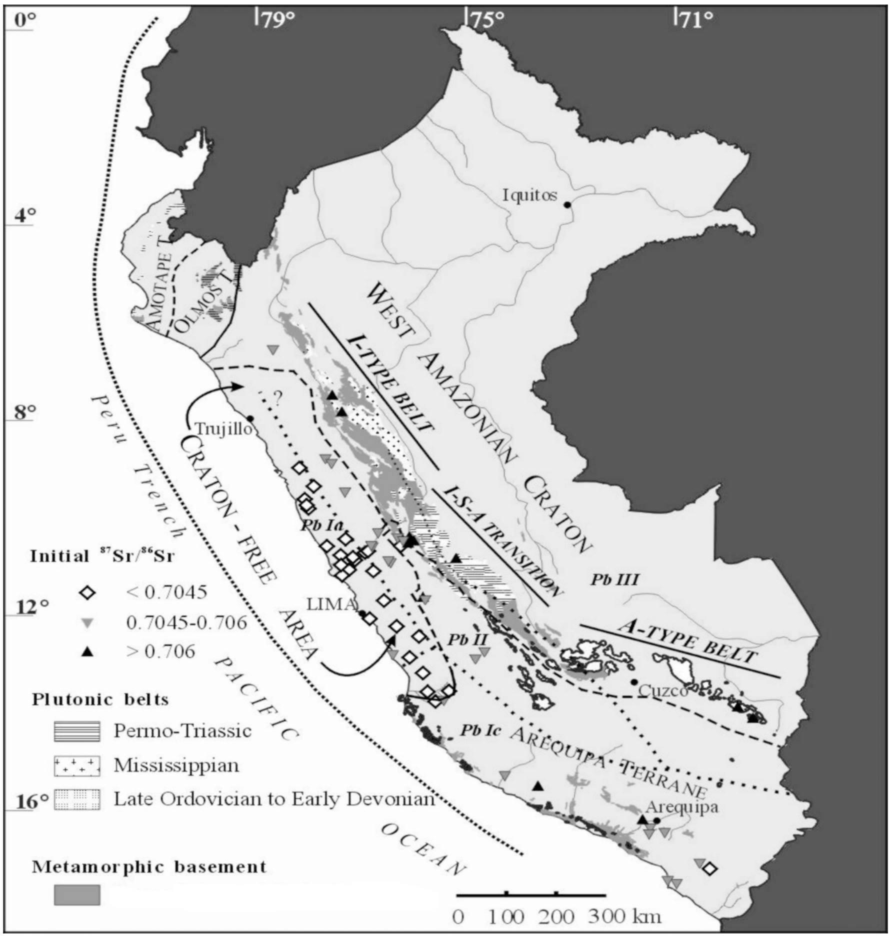

Fig. 2: Zonation of Paleozoic-Mesozoic magmatism in the Eastern Cordillera (modified after Haeberlin 2002)

Our preliminary geodynamic model for the Carboniferous envisions an originally orthogonal eastward subduction of the paleo-Pacific crust during the Late Devonian which became strongly oblique in the Late Carboniferous, thus imposing a sinistral strike-slip stress regime on the western Amazonian margin. Accretion of a buoyant segment of mafic crust (oceanic plateau, island-arc root?) eventually plugged the subduction zone in the late Carboniferous. This scenario explains both the “craton- free” basement underlying the present Western Cordillera of northern Peru (Polliand et al. 2005) and the sudden termination of arc-related magmatism along the northern Cordillera Oriental in Pennsylvanian (330 Ma). Subsequent uplift and eventual relaxation of the cratonic margin facilitated emplacement of the central S-type granitoids in mid-to-late Permian. The progressive strike-slip duplexing, development of transtensional ensialic basins and subsequent back-arc extension in Triassic-Jurassic occurred along the inherited suture between the Gondwanan craton and the Arequipa-Antofalla terrane.

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