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The lithosphere of Southern Peru: A result of the accretion of allochthonous blocks during the Mesoproterozoic

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Introduction

Southern Peru exhibits different juxtaposed structural blocks. These blocks have a distinct sedimentary, tectonic and magmatic evolution. They are bounded by complex, mainly NW-SE fault systems, locally marked by Cenozoic and Mesozoic magmatic units. The specific Mesozoic and Cenozoic geologic evolution of each structural block is ascribed to the high heterogeneity of the southern Peruvian depth lithosphere. This lithosphere results from the accretion of different lithospheric blocks during Laurentia-Amazonia collision at around 1000 Ma.

Structural domains

Southern Peru is characterized by the following morpho-structural domains (Figure 1):

- The Western Cordillera, which exposes siliciclastic and carbonate marine and non-marine formations correspondining to the filling of a Mesozoic though (the Western Peruvian Mesozoic Basin);
- The Western Altiplano, which acted as a structural high (the Cusco-Puno structural high) during the Mesozoic times and received more than 10 km of continental red beds during the Cenozoic;
- The Eastern Altiplano and the Eastern Cordillera, which show the Mesozoic sedimentary cover and the pre-Mesozoic basement of a second mainly marine basin (the Eastern Peruvian Mesozoic Basin), respectively.

The boundary between these domains is clearly marked by large fault systems that show evidence of activity at least since the Paleozoic. The boundary between the Western Cordillera and the Western Altiplano is marked by the NW-trending Cusco-Lagunillas-Mañazo (C-L-M) fault system (Figures 1 and 2, Carlotto, 1998). During the Mesozoic, SW-dipping faults of this system had normal movements and separate the Western Peruvian Basin from the Cusco-Puno structural high. They control the marine and continental depositions, which are thicker in the basin and thinner at the high, respectively (Figure 2). During the Cenozoic, these normal faults acted firstly as strike-slip faults and then, as reverse faults. Such activity resulted in the uplift of the NE margin of the Western Peruvian Basin and converted the Cusco-Puno structural high to continental synorogenic foreland basin. At this time, the strongest deformation and maximum shortening were concentrated along the C-L-M fault system that represented a NE-verging foreland front (Carlotto, 1998). Further to the north, the C-L-M fault system joins to a west-trending complex fault system, called Abancay-Andahuaylas (Fig. 1) that coincides with the boundary between the Arequipa and Paracas blocks (Ramos, 2008).

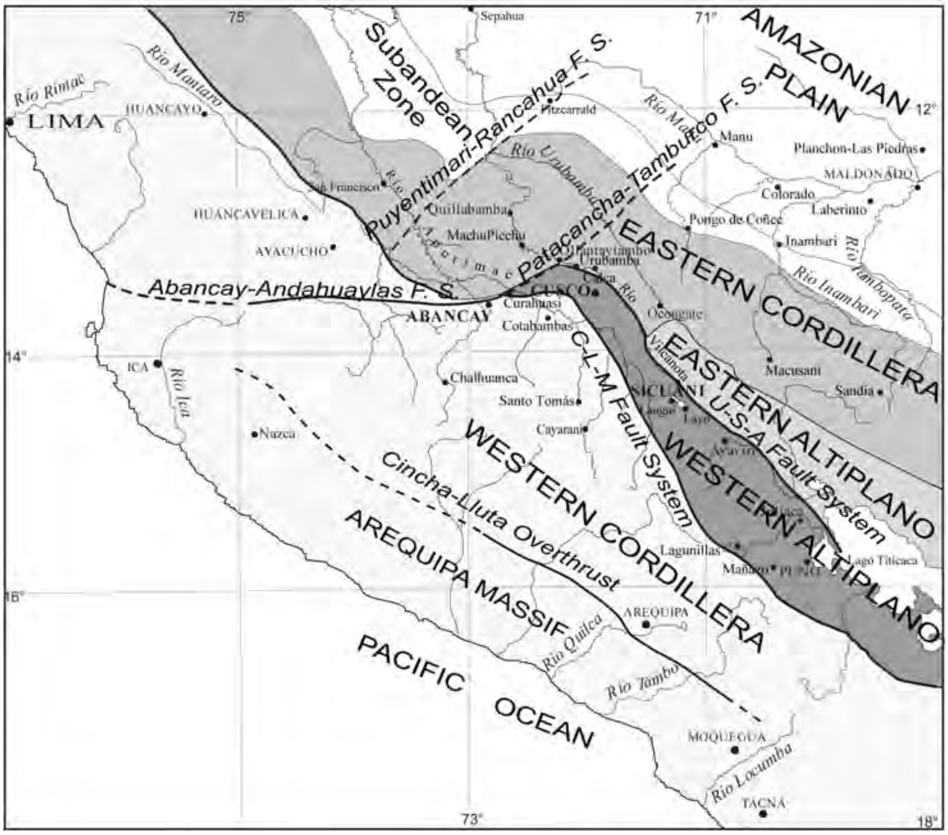

Figure 1: Morphostructural domains of Southern Peru showing the main fault system. C-L-M: Cusco-Lagunillas Mañazo Fault System, U-S-A: Urcos-Sicuani-Ayaviri Fault System

The boundary between the Western Altiplano and the Eastern Altiplano and the Eastern Cordillera corresponds to the Urcos-Sicuani-Ayaviri (U-S-A) or Cusco-Vilcanota fault system (Carlotto, 1998; Carlier *et al.*, 2005). This system behaves similarly to the C-L-M fault system. It separates the Cusco-Puno structural high and the Eastern Peruvian Mesozoic Basin (Figure 2). During the Mesozoic, it consists of normal, NE-dipping faults. During the Cenozoic, the system behaved as strike-slip or reverse, but SW-verging structures (Carlotto, 1998).

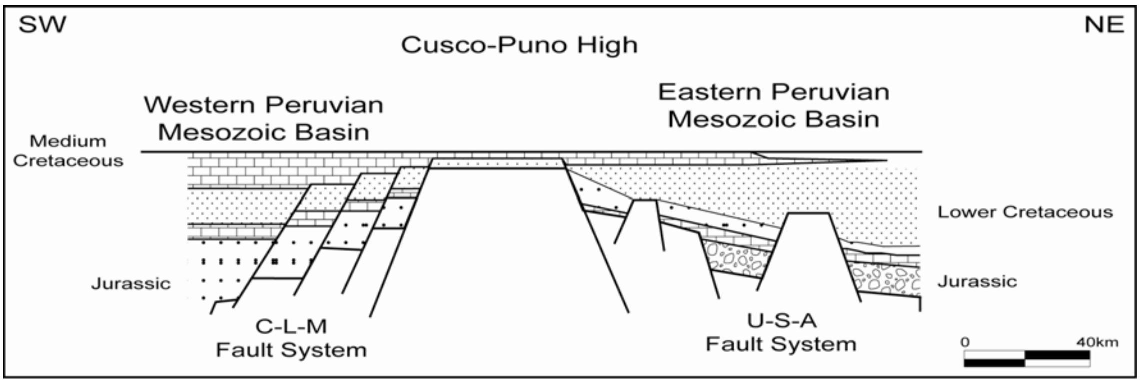

Figure 2: Mesozoic paleogeographic section viewing the bassin's boundary and the substrate.

Substrate

The Arequipa Massif

The Arequipa Massif is well exposed along the southern Peruvian coast. It locally preserves semi-grabens that show a Mesozoic cover unconformably deposited above Precambrian formations indicating that Arequipa Massif constitutes the basement of the Western Peruvian Mesozoic Basin. Along the Cincha-Lluta Thrust (Figure 1), this basement overlies the Mesozoic series of the Western Peruvian Mesozoic Basin. Arequipa Massif had a complex magmatic and metamorphic polycyclic evolution from early Proterozoic to Paleozoic. It includes 1) rocks displaying protolith ages of 1.9 Ga, affected by metamorphism between 1.9 and 1.8 Ga (Dalmayrac *et al*. 1977; Cobbing *et al*., 1977) and 2) rocks showing Mesoproterozoic protolith and metamorphism ages (1.2-1.0 Ga; Wasteneys *et al*., 1995; Loewy *et al*., 2004). The age of metamorphism (Martignole & Martelat, 2003), from 1064±45 Ma to 956±50 Ma, confirms that an old protolith of 1900 Ma underwent rejuvenation around 1000 Ma during a regional high-grade tectonic and metamorphic event related with the Sunsas or Grenville orogeny. Hence, the geologic history of the Arequipa Massif began with the collision between Laurentia and Amazonia, when a Paleoproterozoic terrain was trapped during the Mesoproterozoic times between these two cratonic blocks. The consequence of the collision between the two cratons is the formation of a mosaic of microblocks along the collisional suture. We suggest that this microblock mosaic later formed the substrate for the Western Altiplano and Eastern Altiplano.

Western Altiplano - Eastern Altiplano substrates

Recent mineralogical, petrological, geochemical and geochronological studies of Cenozoic magmatism in the southern Peruvian Altiplano (Carlier *et al*., 2005) reveal a variety of shoshonitic, calc-alkaline, acid, peraluminous and metaluminous rocks associated to alkaline potassic (P) and ultrapotassic (UP) rocks. This variety, together with the spatial distribution of this magmatism, implies that the deep lithosphere beneath the Andes of southern Peru consists of a mosaic of lithospheric blocks with different origins. In fact, P-UP rocks mostly derive from partial fusion of lithospheric mantle rocks. Mineralogical, geochemical, isotopic and geochronological data allow to distinguish three P-UP rock associations (Carlier *et al*., 2005). The first group, mostly composed of Oligocene phlogopite lamproites in the Eastern Altiplano (Figure 1), demonstrates the presence of a Paleoproterozoic to Archaic (TDM = 1130-2485 Ma; Nd = -5.0 to -11.4; $^{87}Sr/^{86}Sr_i$ = 0.7100-0.7159) metasomatized harzburgite mantle beneath this domain. Beneath the Western Altiplano (Figure 1), the deep lithosphere corresponds to a younger (TDM = 837-1259 Ma; Nd = +0.6 a –6.3; $^{87}Sr/^{86}Sr_i$ = 0.7048-0.7069) metasomatized lherzolithic mantle, as indicated by a second group of Oligocene and Miocene, P-UP, diopside-rich lavas (leucitites, tephrites with leucite, traquibasalt with olivine and diopside). A more recent (< 2 Ma) third group crops out at the boundary between both Altiplano domains and is composed of diopside phlogopite lamproites, kersantites, minettes and augite trachybasalts, showing a mantle source which probably includes an astenospheric component, apart from material derived from the two lithospheric mantles previously described (TDM = 612-864 Ma; Nd = -1.1 a -3.5; $^{87}Sr/^{86}Sr_i$ = 0.7051-0.7062). This third group, present as volcanic edifices, dikes, stocks, domes, etc., is located over the fault system, still active fault system of the U-S-A or Cusco-Vilcanota, and marks the boundary between both parts of the Altiplano.

Conclusions

The three large morphostructural domains (lithospheric blocs) previously defined evidently exhibits different kinds of substrate. The first one, beneath the Western Cordillera (Western Peruvian Mesozoic Basin), most probably corresponds to Arequipa Massif-like material, with ages between 1900 and 600 Ma. It probably reaches the C-L-M fault system zone. The second one, beneath the Western Altiplano, has a deep lithosphere corresponding to a metasomatized lherzolithic mantle. It is separated from the Western Cordillera by the C-L-M fault system and from the Eastern Altiplano by the U-S-A fault system. The third one, beneath the Eastern Altiplano, corresponds to a depth lithosphere with a Paleoproterozoic to Archaic metasomatized harzburgite mantle.

Thus, the lithosphere of the western margin of the South American Plate has to be considered as a mosaic of amalgamated lithospheric blocks (terranes) accreted to Amazonia during the Sunsas orogeny (at 1000 Ma). This orogeny resulted from the complex collision implicating, in addition of large cratons, several smaller lithospheric blocks such as the Arequipa Massif. The resulting heterogeneous lithosphere later formed the basement of the Western Altiplano and Eastern Altiplano. The boundaries of the lithospheric blocks still constitute weakness zones along which more recent deformations (lateral displacement, overthrusts…) are concentrated. Thus, during the Cenozoic times, lithospheric microblocks composing the Southern Peru are apparently displaced by NE-trending and E-trending transform fault systems (Patacancha-Tamburco and Puyentimari-Rancahua faults and E-W segment of the C-L-M fault system, Figure 1). Some of these structures like the Abancay-Andahuaylas Fault System extends towards the coast and separate the Arequipa and Paracas massifs.

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