The Proterozoic basement of the Arequipa massif, southern Peru: Lithologic domains and tectonics

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Introduction

The Proterozoic rocks outcrops along the southern coast of Peru, on the margin of the Pacific Ocean and extends in the Western Cordillera of the Andes, forming a major exhibition of pre-Andean rocks where tectonothermal activity has been recognized preliminarily throughout Proterozoic history; being Grenville ages (~1000-1200 Ma) well documented. There are many gaps in knowledge of the Arequipa massif, for example, in lithological and tectonic part, there are so many authors taking the massif as an undifferentiated complex. We show in this paper a new Proterozoic basement mapping supported by field works. In addition we raised a discussion of the tectonic evolution of this massif.

Regional geological setting

The Arequipa Massif is the main basement of central Andes (Wasteneys *et al.*, 1995), displays a magmatic and metamorphic evolution complex. This massif is mainly made of migmatitic gneiss rocks, thus between Camana and Mollendo, the occurrence of the mineralogical joint: orthopyroxene-sillimanite-quartz is common in gneiss, migmatite and granulite rocks, so that they are described as ultra-high-temperature rocks (Martignole *et al.*, 2003), that apparently is extending through all Proterozoic basement of central Andes between the southern Peru and northern Chile. The oldest rocks displays ages between 2000-1900 Ma (Wasteneys el al., 1995; Dalmayrac *et al.*, 1977; Ries, 1976). Preliminary Rb-Sr and U-Pb geochronology implies granulites-amphibolites metamorphic facies between ~1900 to 1800 Ma (Cobbing *et al.*, 1977; Shacklenton *et al.*, 1979), but recently U-Pb geochronology analysis in zircons from gneisses near the Mollendo, Quilca and Camaná areas indicates a high-degree metamorphism between 1200 and 970 Ma, whose ages put in evidence the orogenic-metamorphic event named Grenville (Wasteneys *et al.*, 1995), alternatively Dalmayrac *et al.*, (1977), proposes that those rocks underwent two metamorphic events, during the Paleoproterozoic (1950 Ma) and Neoproterozoic (600 Ma) times. In the Southernmost part of Arequipa massif in Ilo, to the north of the environs of the Arica elbow, there are outcrops one of the few Proterozoic anorthosite rocks occurrences (it is showing an Sm-Nd model age at 1150 Ma) [(Martignole *et al.*, 2005)] documented in the Andes basement, also demonstrating the orogenic-metamorphic Grenville belt indicated above. Whereas in the north part of the Arequipa massif, in the locality of San Juan, there outcrops diamictites, interpreted as glaciers deposits (tillites) of Chiquerio Formation, probably Neoproterozoico age (Caldas, 1979). Recent analyses of zircons and ^{13}C isotopes from Chiquerío and San Juan formations that showing an age of deposition for these glaciers deposits (unique in the proto-Andes belt) between 635-750 Ma (Chew *et al.*, 2007b). At the moment it is thought that Arequipa massif accreted to the

main Amazonia craton during Sunsas orogeny (~1000 Ma, equivalent in South America to Grenville event) [Loewy *et al.*, (2004), on the basis of U-Pb geochronology in zircons].

Lithologic domains

The mapping of the metamorphic rocks outcrops was based on domains, and was supported on field works, where it has been possible to differentiate ten litologic domains showed in the margin from the South coast of Peru (I) and in the western margin of the Western Cordillera (II) (Figure 1). The predominance of the migmatitic gneisses and granulites of greater antiquity are observed, as well as metamorphic rocks from sedimentary protolite, evidenced by first time in the western margin of the Western Cordillera (e.g. in Condesuyos and Pampacolca, see Figure 1). Also structural alignments were identified, which they are removing the main basement from the central Andes.

Discussion

Ries *et al.*, (1976) was the first that indicates metamorphism in gneiss rocks of Mollendo in granulites facies with an age of 1960 ± 33 Ma then Dalmayrac *et al.*, (1977), indicates two orogenic-metamorphic events: (1) the first prograde event, produces gneisses, characterized by biotite-estaurolite, garnet-kyanite-sillimanite-potassium feldspar from relicts associations of a type of average pressure with cordierite in catazonal paragenesis on granulites facies, dated at 1950 Ma to age same that Ries *et al.*; but Dalmayrac *et al.* mentioned a metamorphism second more (2) pressure low, characterized by chlorite-muscovite-epidote-cordierite, that corresponds to a epizonal retrograde metamorphism dated at 600 Ma, whereas Cobbing *et al.*, (1977), indicates three metamorphic events: (1) the first event in granulites facies, produced an extensive area of undifferentiated gneiss rocks

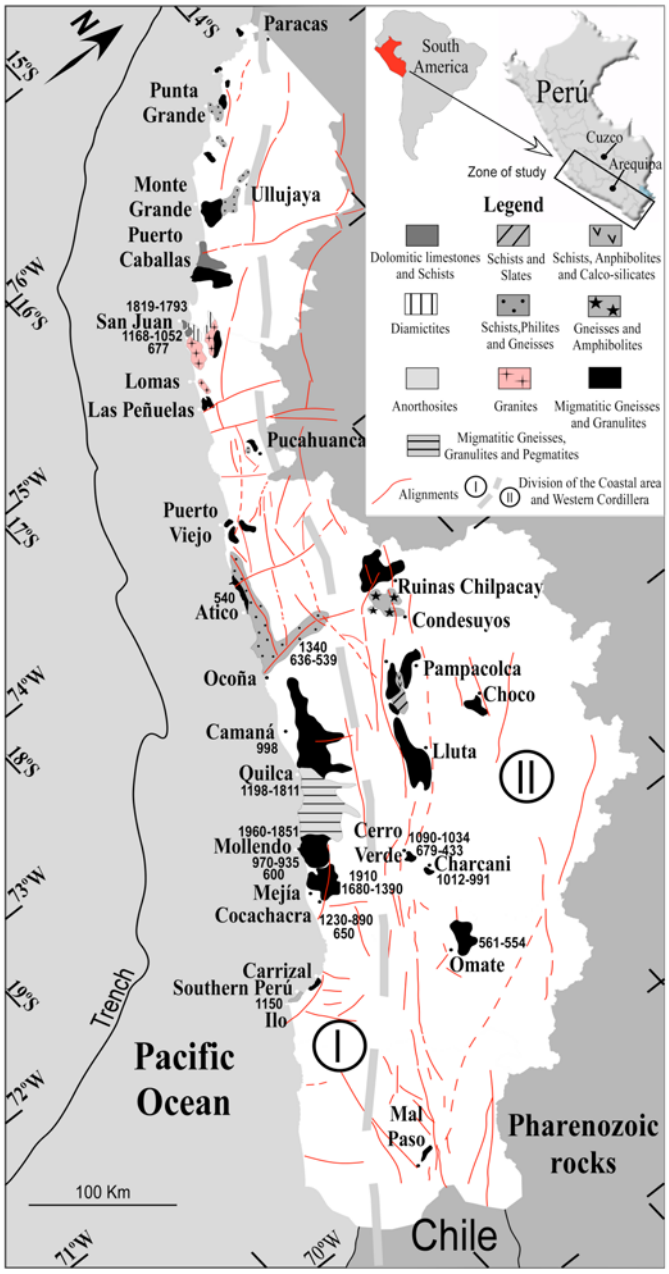

Figure 1. Map of lithologic domains of the Proterozoic of the Arequipa massif, supported by unpublished field works and completed with INGEMMET maps. Numbers are range of ages at Ma taken from authors mencioned in text.

dated at 1811 Ma, (2) the second event of sedimentary deposition and subsequent metamorphism produced schist and gneiss rocks in amphibolites facies dated at 1340 Ma, (3) and the third, a migmatization event that probably affected to gneiss and schist rocks, and that could be contemporary with the mentioned metamorphic event in amphibolites facies or it could taken place in later Precambrian or Cambrian times?. The same way Shacklenton *et al.*, (1979), mentions three metamorphic events: (1) the first denominated Mollendo event in the sillimanite-gneiss rocks of Mollendo in granulites facies, dated at 1918 Ma, also producing, probably a estaurolite-andalusite schist rock, (2) followed by a metamorphism denominated Atico event where a series of basic and acid igneous rocks were intruded and deformed in amphibolites facies, having begun in 679 ± 12 Ma (Stewart *et al.*, 1974, in the Charcani gneiss) and ending in 440 Ma, (3) and a third event denominated Marcona, it happened previous erosion of the Atico complex, depositing discordantly to the sediments of the Marcona Formation, with slight deformation, associated to a metamorphism in green schists facies, dated at 392 Ma.

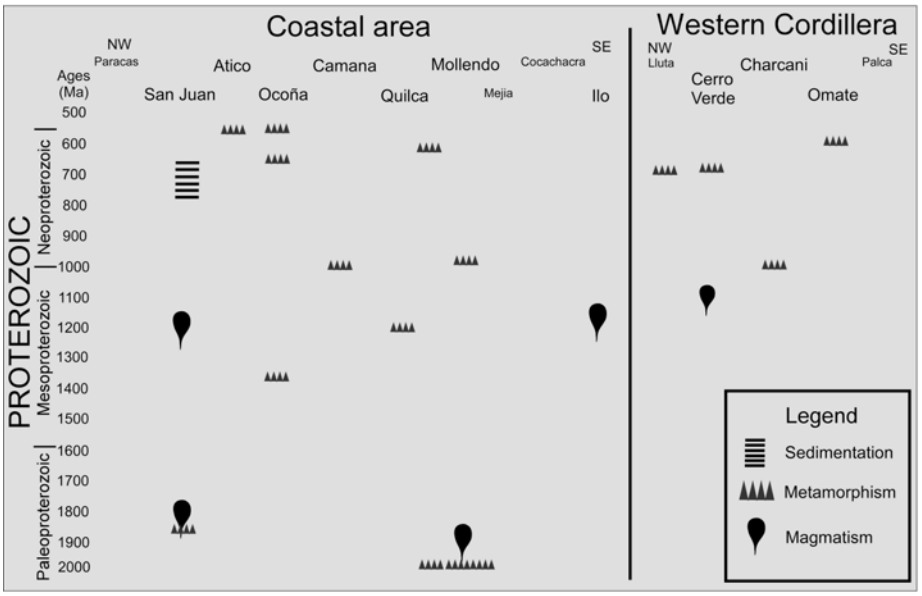

Figure 2. Summary of the tectonic of the Arequipa massif. Data taken from authors mentioned in text.

But Wasteneys *et al.*, (1995), discusse the age of metamorphism at granulites facies, and it indicated a younger age, and this is prevailed to the previous metamorphism mentioned before, thus, in Quilca gave an age of 1198 +6/-4 Ma and 970 ± 23 Ma in the Mollendo area [these ages are according with preliminary ages of James & Brooks, (1976), in Dalmayrac *et al.*, (1977) that were the firsts that mencioned a Grenville age indicate a metamorphism in Charcani gneiss at 1012 ± 52 Ma] concluding that the isochronal ones published of 1900 Ma of Rb-Sr for the gneiss rocks of the Arequipa massif register ages of metagranitoid protolite and were not affected by the high metamorphism degree, relating them to orogeny of Grenville, furthermore Martignole *et al.*, (2003), indicates recently an age of metamorphism at 998 ± 11 Ma for a migmatitic gneiss rock from Camana that reinforce the presence of Grenville ages on the south coastal of Peru. Protolites of the gneissitic basement in San Juan and Mollendo crystallized between 1851-1819 Ma and the age of crystallization of the granite of San Juan was dated at 1793 Ma by U-Pb in zircons (Loewy *et al.*, 2004). This would preliminarily indicate us that a Paleoproterozoic metamorphic event existed (Figure 2) associated to a magmatism, that affected deepest meta-sedimentary sequences of the Arequipa massif, producing gneisses in granulites facies, thus it is demonstrated

that intrusive ones which cut to the Precambrian gneiss rocks of the San Juan from Marcona. Loewy *et al.*, (2004), indicate that the Arequipa massif underwent three different pulses from metamorphism and deformation: (1) 1820-1800 Ma, (2) 1200-940 Ma and (3) 440 Ma.

Conclusions

Analysis of the evolution of the northern part of Central Andes, in southern Peru and northern Chile shows a magmatic and metamorphic polycyclic evolution in Proterozoic time, with a magmatism-metamorphism event at ~1000 Ma (Mesoproterozoic later) associate to metamorphism in granulites facies demonstrated in San Juan and Mollendo, and an acid magmatism in San Juan and metamorphism in Camana-Mollendo and San Juan in the Mesoproterozoic time, these evidences would be according to the accretion of the massif to the Amazonia craton. The radiometric analyses carried out in Arequipa massif indicate three groups of well differentiated ages in all the Proterozoic (Figure 2). The lithologic domains (Figure 1) show the first mapping and lithologic division of the Arequipa massif and variety of the rocks from this massif as well as its relation with the metamorphic degrees.

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