PALEOGEOGRAPHIC CONTROL ON THE EVOLUTION OF TERTIARY BASINS IN THE WESTERN CORDILLERA AND ALTIPLANO OF SOUTHERN PERU (CONDOROMA-CUSCO-AYAVIRI)

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INTRODUCTION

The lithosphere of the southern Peruvian Central Andes results from a long history of orogen superposition. The structures inherited during this process originate a high mechanical heterogeneity which controlled the deformation of the lithosphere each time it is subject to a new stress field. The evolution of the Andes of southern Peru offers a good example of the influence of lithospheric heterogeneity within a context of type-A subduction. Mesozoic paleogeography shows, from W to E, a Western Basin (Western Cordillera), a structural high called Cusco-Puno Swell (CPS, western Altiplano), and the Putina and Eastern Basin (eastern Altiplano and Eastern Cordillera) (Jaillard, 1994). This swell was limited from the western marine basin by the Cusco-Lagunillas-Mañazo (CML) fault system, and from the eastern marine and continental basin by the Urcos-Sicuani-Ayaviri (USA) fault system (Fig. 1) (Carlotto, 1998). These two systems formed during the Mesozoic. They are structures inherited from the Paleozoic or even older, and they separate two Proterozoic basements. During the Mesozoic, the CPS was covered by an average of 1 km thickness of sediments, mostly continental and occasionally restricted marine. However, during the Tertiary, it received continental sediments which may locally exceed 10 km thicknesses. Tertiary evolution was controlled by this paleogeographic feature, affecting not only the evolution of the basins, but also the deformation, the tectonic style, and the vergence of thrusting.

EVOLUTION OF TERTIARY BASINS

Andean deformation events began in southern Peru during the Late Cretaceous affecting the Western Cordillera, and continued during the Paleocene, migrating towards the NE. Thickening and loading of the crust beneath the Western Cordillera resulted in the development of a Paleocene foreland basin with continental deposits at the boundary zone between the Western Cordillera and the Altiplano (Quilque and Chilca Formations) (Fig. 2).

Early Eocene (approx. 50 to 42 Ma) sedimentary record is absent from the Western Cordillera and adjacent Altiplano, where younger deposits overlie Cretaceous and locally Paleocene units with strong unconformity, suggesting the erosion of the Western Cordillera during this period. We interpret this as a result of important uplift due to thickening of the crust, which became unstable and underwent delamination. At the same time, basic calc-alkaline magma (gabbro, cumulates and diorites) developed in the Western Cordillera, as exposed along its northern margin at the Andahuaylas-Yauri batholith. This magmatism probably resulted from fusion of the asthenosphere, which rose and was emplaced in the space left over by the lithosphere after sinking during delamination. Uplift and magmatism along the Western Cordillera resulted in its erosion, as well as feeding and filling of the San Jerónimo Red Beds Basin to the north, i.e., over the former structural high of the Cusco-Puno Swell (Western Altiplano). A thick alluvial and fluvial thickening-coarsening sedimentary pile exceeding 4 km (Kayra Formation) (Fig. 2) developed between approx. 50 and 42 Ma. The basin was bounded by the CLM and USA fault systems (Fig. 1), with right-lateral strike slip, and apparently corresponding to former faults separating the swell from the western and eastern basins. These faults did not lead to a classical pull-apart basin because the swell has an apparently thick substrate which behaves as a rigid massif which prevents thinning. Uplifted areas, located mainly to the south, are due both to delamination and right-lateral strike slip in relation with regional stress and plate kinematics taking place during that time.

Compressive deformation along the NE margin of the Western Cordillera and in the Altiplano took place around 44-40 Ma, initiating alluvial and fluvial coarse-grained deposits of the Pichu basin in the Western Cordillera, and in the Anta basin along its NE margin, with thicknesses exceeding 3 km. This coarsening sequence coincided with calc-alkaline andesitic and dacitic volcanism dated between 37 and 38 Ma towards the base, and alkaline towards the top, where it is dated in 29.9 Ma (Carlotto,1998). Meanwhile, sedimentation and deformation continued in the Altiplano, with the development of progressive unconformities within the San Jerónimo basin (Soncco Formation, 3 km thick, and dated at the top in 29.9 Ma) of the former CPS. This compressive event affected the delaminated zone, i.e., the Western Cordillera, which had a thin crust but still allowed the development of smaller calc-alkaline subvolcanic intrusive bodies (36-32 Ma). Compression also developed thrusting along the faults limiting the basin and the swell, particularly the northern margin of the Western Cordillera over the Altiplano. Within this context, the Pichu and Anta basins are interpreted as piggy-back basins located behind the CML fault system, with the San Jerónimo basin (Soncco Formation) in a foreland position (Fig. 1).

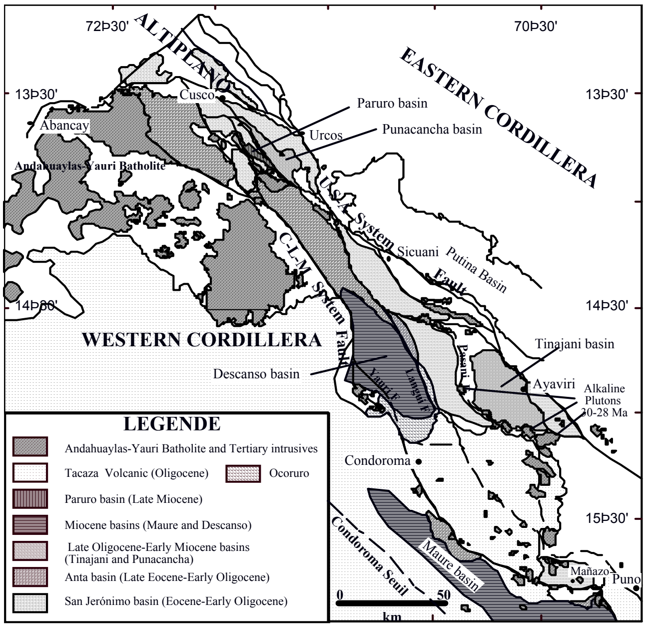

Fig. 1 Structural sketch-map of the Cusco-Ayaviri-Condoroma region showing the Tertiary basins, intrusives and volcanics rocks

The first potassic and shoshonitic alkaline magmatic events appear in the area between 30 and 28 Ma (Carlier et al., 1996). Potassic and ultrapotassic magmatism originated from fusion of rocks resulting from thermal re-equilibrium between a thick lithosphere (Altiplano) and a thinner lithosphere after delamination (Western Cordillera). The shoshonitic rock is originated from mixing of ultrapotassic and calc-alkaline magmas. This magmatism was also controlled by the CML and USA fault systems.

Around 30-28 Ma, and up to 20 Ma (late Oligocene-basal Miocene), an important volcanic activity took place in the Western Cordillera, and particularly along its NE margin (Tacaza volcanism). At the same time, the northern margin of the Western Cordillera locally received the Ocoruro conglomerates, indicating that the fault systems limiting the Western Cordillera and Altiplano were still active and served as conduits for the vulcanism (Figs. 1 and 2). Intermontane basins began to form in the Altiplano, in relation with the strike-slip faults of the CLM and USA fault systems (Fig. 1). Deposition in the Tinajani basin began around 28 Ma with a 600m, fluvial-lacustrine fining-upwards sequence controlled by the Pasani fault to the south, and Ayaviri fault to the north (Flores & Rodriguez, 1999). In Cusco, the Punacancha basin also developed during this period, with a 400m fluvial fining-upwards sequences controlled to the south by the Anyarate fault. The structures controlling these basins are part of the CML and USA fault systems, and had left-lateral strike-slip displacements, in agreement with the regional E-W tensors active at the time (Figs. 1 and 2).

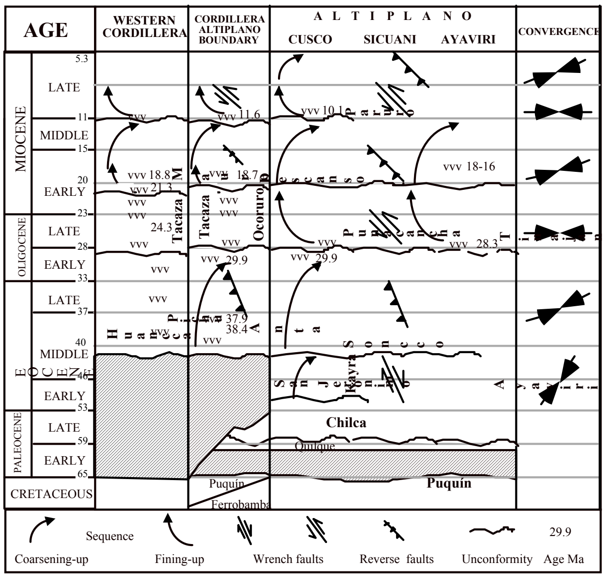

Fig. 2. Correlation chart of the main Tertiary stratigraphic formation of the Western Cordillera and Altiplano of Southern Peru

Between 22 and 12 Ma (Early-Middle Miocene) the Maure basin developed within the Western Cordillera (Fig. 1 and 2) and was filled with a 500 m coarsening sequence of lacustrine and fluvial deposits contemporaneous with explosive volcanism (21.39 and 18.82 Ma, Ar-Ar: Fornari, unpublished). This basin is located to the north of the Condoroma high, which apparently is a paleostructural high within the Western Cordillera, south of the CLM fault system, and continues into Bolivia (Fig. 1). At the boundary between the Western Cordillera and the Altiplano, the Descanso basin also developed during the same period as the Maure basin (Early-Middle Miocene), with a similar evolution of 800 m fluvial-lacustrine coarsening sequence and volcanism (Cerpa & Meza, 2001). The Langui and Yauri faults controling this basin are part of the CLM system (Fig. 1). In the Altiplano, continental sedimentation continued in the Tinajani (600m) and Punacancha (>1200m) basins during the Early-Middle Miocene, with a thickening-coarsening fluvial-alluvial sequence resulting from NE-SW compressive stress along the boundary thrust faults controling the basin.

Between 12 and 7 Ma (Middle-Late Miocene), sedimentation continued in the Maure basin of the Western Cordillera (Fig. 1 and 2), with a 500 m fining sequence unconformably overlain by volcanics dated in 4.92 Ma Ar-Ar (Fornari, unpublished). At the boundary between the Western Cordillera and the Altiplano, sedimentation also continued in the Descanso basin (Fig. 1 and 2) with a 200 m thinning-fining sequence mainly controled by the Langui fault (Cerpa & Meza, 2001). In the Altiplano, a new smaller basin began to develop, the Paruro basin, with a 500 m thinning-fining alluvial-fluvial-lacustrine sequence related with the Yaurisque fault located to the south (Jaimes & Romero, 1996; Carlotto, 1998). During this period, all the basins were subject to an almost E-W regional stress, with boundary faults undergoing left-lateral strike-slip (Fig. 2).

Between 7 and 5 Ma (Late Miocene) important deformation and volcanism took place in the Western Cordillera. The deposits of the Maure basin are unconformably overlain by volcanics dated in 4.92 Ma. However, at the Western Cordillera-Altiplano boundary the tectonic compression seems to be buffered, particularly south of the Descanso basin, where the lacustrine deposits at the top of the Descanso basin sequence grade into volcanic deposits dated between 7 and 5 Ma. Meanwhile, in the Altiplano of Cusco, the Paruro basin underwent important compressive tectonic activity, with deposition of alluvial-fan coarsening sequences (600m) prograding to the north, and displaying progressive unconformities controlled to the south by the Yaurisque fault, which now behaves as a thrust. The regional stress was compressive and NE-SW oriented, in accord with plate kinematics.

CONCLUSIONS

The mechanical heterogeneity of the Andes of southern Peru greatly conditioned the Mesozoic paleogeographic scheme, which in turn controlled the evolution of Andean deformation and Cenozoic basins. The Mesozoic normal and strike-slip fault systems of Cusco-Lagunillas-Mañazo (CLM) and Urcos-Sicuani-Ayaviri (USA) defined a structural high (Cusco-Puno Swell). During the Tertiary these faults acted mostly as strike-slip and reverse faults, and currently display an en echelon pattern. The CLM fault system controlled the uplift of the northern margin of the Western Cordillera, in relation with both Early Eocene delamination and right-lateral strike-slip leading to development of the San Jerónimo Red Beds (Kayra). Beginning at this time (42 Ma), the regional stress field changed first to NE-SW compression, and later to alternating E-W compression. This resulted in left-lateral strike-slip movements and NE-SW compression, with reverse displacements along the CLM and USA fault systems controlling the evolution of the basins. These faults also controlled the highly-potassic alkaline magmatism present from the Oligocene (30 Ma) and with a deep magmatic source.

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