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The problem of the progressive unconformity in the continental red beds of the southern region of Cusco, Peru

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ABSTRACT

The Upper Cretaceous-Tertiary continental red beds series of Cusco region are source of controversy on their origin, age and divisions. This is manifested mainly by the involved units continuous denomination and age changes. Certain incompatibilities also exist about the thickness and the attributed age of certain units, because it is not convincing how a so potent series could be accumulated in a relatively short period.

Of another side, diverse studies admit the existence of a progressive unconformity in different Central Andean basins. It is mentioned, for example, a unconformity of this type (active flank syntectonic unconformity) in Lircay, Central Peru (Mégard et al., 1983). In the southern Cusco region those structures are mentioned for San Jerónimo group and Paruro formation (Córdova, 1986; López & Córdova, 1988; Carlotto et al., 1992; Jaimes & Romero, 1996).

The field detailed analyses carried out in several points of the southern region of Cusco demonstrate that this structural accident is in fact a well defined angular Unconformity, which would discard the existence of a progressive Unconformity, at least for this region. This forces to revise some existent stratigraphic classifications, which that, in turn, would induce to analyze from another perspective the sedimentation and tectonic mechanisms and the correlations with other similar units of the region.

The progressive unconformity in southern Cusco was defined using the models proposed by Duee et al. (1976), Artaud et al. (1977), following that outlined by Riba (1973, 1974; mentioned by Mégard et al., 1983). According to these models, in the distal areas of the sedimentation basins it should have a gradual variation in the strike of the strata. The variation should only be possible in the strike but not in the direction, whereas it is assumed that the feeding area doesn't change. Of another side, two criteria must be respected: sedimentary continuity and parallelism of the strata (Semperé, 2004).

THE TWO SEDIMENTATION EVENTS

Waiting for a redefinition of the stratigraphic units as a result of this new verification, we consider, for this work, two categories or sedimentary events instead of well-known stratigraphic units (San Jerónimo group and Paruro formation):

First event deposits: mainly red fine grain formations, of lacustrine and flood plains environments, with wide channels and presence of conglomerates in sandy bars, in some cases with erosive base, indicating a basin with not very significant subsidence. These deposits have steep strikes and a reddish visual aspect. Puquín, Quilque, Chilca formations or Chitapampa super group (Mendívil & Burga, 1994) would belong to this event.

Second event deposits: grizzly coloration and abundance of feldsparic sandstones, the fine sediments representing a low percentage. The inclination of the strata doesn't overcome 35°. Those deposits remain on the

red folded deposits of the first event. According to this new proposal, the Kayra, and Soncco formations of San Jerónimo group would belong to this event.

Structurally this would also indicate that there were two different tectonic events: the first one (with a NNE-SSO shortening direction) produced folding and inverse faults whose azimuth varies among 110° and 140° NE, and strikes of 40° to 90°. The second one (with a shortening direction next to E-W) reactivated the inverse faults transforming them into direction faults, tilting the Oqopata northern and southern compartments. In these structures the azimuth varies between 90° and 100° NE and the strikes between 15° at 35°.

This also remits us to the problem of the red reds thickness. After some interpretations the compressive régime originated folding with short wavelengths, giving a continuous sedimentary complex impression (which seems to increasing or duplicating the thickness of these sedimentary unit), when in fact we are in face of anticlines or synclines flanks; that becomes evident at northern of Cusco city, and in the structural profile of the Arahuay-Checoperqa-Anqaschaka syncline. This outline would have induced to duplicate, in some cases, the thickness of the sedimentary packets. Our detailed studies have put in evidence these duplications when carrying out the Anqaschaka column, where the anticline is evidenced in rocks of the first event.

EVIDENCES OF ANGULAR UNCONFORMITY

The detailed field studies and the established correlations for different stratigraphic columns allow to ensuring the progressive unconformity consigned by several authors for southern region of Cusco is, in fact, a well defined angular unconformity. They are three main evidences confirming this theory: the well marked direction differences between the underlying and overlying units, certain tectonic-structural characteristics and the proved existence of combined processes of Toppling-landslide.

Evidence of differentiated direction

The most convincing evidence is given by the differences of the strata directions, something that the visual exam can even prove easily. The analyzed columns correspond to Anqaschaka, Socsohuaylla and Oqopata places:

Place	Underlying unit (first event)		Overlying unit (second event)	
	Azimuth	Strike	Azimuth	Strike
Anqaschaka (fig. 1)	110° NE	Subvertical to vertical	25° NE	25°-30° NE
Socsohuaylla (fig. 2	100° NE	Vertical to subvertical	20° NE	20° NW
Oqopata (fig. 3)	140° NE	45° NE	15° NE	15° SE

For the Anqaschaka case, when making the rotation to an horizontal projection of the second event sedimentary group (something that anyway should happen in some moment), the first sedimentary group had an orientation of 130° NE and a strike of 85°NE, so very different direction and strike; this implies that the mentioned sedimentary continuity condition (a indispensable requisite for a progressive unconformity) didn't exist.

Tectonic-structural evidences

In the units corresponding to the first event, a NW-SE folds system exists, with wavelengths of 5-6 km. toward the south of the area (Anqaschaka-Checoperqa), and of 2 km. toward the north area (Oqopata), thanks apparently

to the faults confluence or to the faults deadening, whose vergencies varies from the south in the southern area, to vertical in the middle and northern area in Tankarpata and northwestern of Oqopata (fig. 4). According to the paradigmatic pattern of the progressive unconformity a pre or synsedimentary inverse fault must exist in the mobile front, something that in our study area cannot evidence cartographic neither structurally.

Evidence of Toppling-complex landslide processes

For the Anqaschaka case we have also verified that the apparent angular progressive unconformity corresponds to a case of Toppling associated to a slow evolution giant landslide. Here the stratification has a fan configuration. From certain angles of vision this disposition seems a progressive unconformity. In fact, the development of the large scale neighboring landslides generated a Toppling process for haulage and progressive loss of basal support; that process opens the way to a gradual change in the inclination of the strata. Therefore, the fan feature doesn't respond to a tectonic cause but to an evident and very well defined process of external geodynamic combining the Toppling and giant and complex landslide mechanisms. This would have happened after the first event and before the second. This Toppling-Landslide association, is, on the other hand, frequent in these continental red series. We know the confirmed cases of Huaynapicol and Saylla-Ch'akiqocha, at northeastern and southeastern of Cusco city, respectively (Carreño & López, 1997a; 1997b; Carreño, 1998).

CONCLUSION: TOWARD A NEW VISION OF THE CUSCO REGIONAL STRATIGRAPHY

The results of the detailed work demonstrate the existence of an angular unconformity instead of a progressive unconformity in the southern region of Cusco. This induces to outline a revision of the regional existent approaches related to the tectonic and litho-stratigraphic setting, and their correlations with similar units in other regions.

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Fig. 1 Anqaschaka

Fig. 2 Soqsohuaylla

Fig. 3 Oqopata

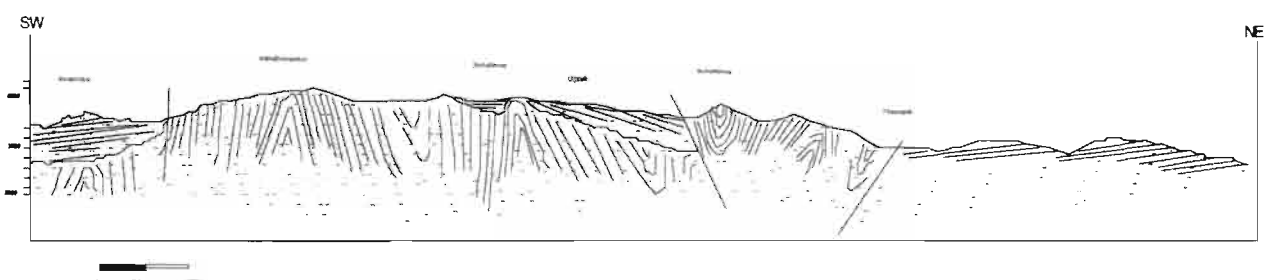

Fig. 4 Structural section of southern Cusco (Red: first event unities; black: second event deposits)