TECTONIC INSTABILITY RELATED WITH THE DEVELOPMENT OF THE PALEOZOIC FORELAND BASIN OF THE BOLIVIAN CENTRAL ANDES (14-22°S)

Enrique DIAZ[1], Rodrigo LIMACHI[2], Víctor Hugo GOITIA[2], Daniel SARMIENTO[2], Oscar ARISPE[3] and Rubén MONTESINOS[4]

(1) ORSTOM, Casilla 9214, La Paz, Bolivia
(2) YPFB, Casilla 1659, Santa Cruz, Bolivia
(3) UMSA, La Paz, Bolivia
(4) UATF, Potosí, Bolivia

KEYWORDS : Gravity flows, Paleozoic, foreland basin, tectonic instability, Bolivia.

INTRODUCTION

The revision of many type stratigraphic sections of the Bolivian Paleozoic Cordilleran cycle in the Altiplano, Eastern Cordillera and Subandean region revealed frequent gravity-flow deposits within the sequence. While their presence is not new, their revision and interpretation is of interest in order to corroborate the latest interpretations of the Paleozoic evolution of the Bolivian Central Andes. This work summarises the principal findings with respect to gravity-flow deposits of a 7-month-long revision of most of the type stratigraphic sections of the Silurian through Mid-Carboniferous of Bolivia, and draws conclusions on their relation with the tectonic setting during that time.

STRATIGRAPHY AND TECTONICS

Basic stratigraphy for the Paleozoic of Bolivia has been recently revised and published under the YPFB-ORSTOM scientific cooperation agreement (Sempere, 1995; Oller, 1992). The Lower Paleozoic (Cambro-Ordovician) Tacsarian sequence mostly reflects the development of a backarc basin, which was followed by a Silurian to mid Carboniferous foreland successor basin (Sempere, 1989, 1995; Isaacson and Díaz, 1995). The Cordilleran cycle (Suárez, 1989) represents the infill of this basin (see figure 1 for reference).

1. Initiation of the foreland successor basin: the Cancañiri Fm.

This unit has been dated as Early Silurian (Llandovery) based on the latest (more recent) non-resedimented fauna present in it (Suárez, 1995). The Cancañiri Fm. presents all types of evidence for submarine sediment instability, including mass slides, rafted beds, slumps, debris flows, mud flows and turbidites. Slided and rafted beds may reach thicknesses exceeding 50 m and widths exceeding several kms. Grain-size of the resedimented material varies greatly, leading to many different lithologies depending on the degree of mixture. Evidence for glaciation of the source area is indicated by the presence of large outsized granitoid clasts, and faceted and striated clasts found within the debris flow deposits. However, there is no evidence for subglacial deposits (tillites, pavements), and it is here suggested that glaciation was local and temporarily reached the basin margins as tidewater glaciers. The thickness of this unit varies greatly from a few meters or absent, to more than 1 km in western areas. Several

different events of catastrophic resedimentation can be identified, together with intermediate phases of "normal" deposition. It is probable that these events affected different areas at different times, beginning in the late Ashgillian and ending in the Wenlockian. To the west, the Cancañiri Fm. lies within two deep-marine shaly units: the Tokochi and Huanuni Fms. The overlying Llallagua Fm. consists of turbidites with a western source area, and the common depocenter area hosting the Tokochi, Cancañiri, Huanuni and Llallagua Fms. probably corresponds to the foredeep of the basin in response to tectonic deformation and piling of thrusted blocks to the west and south.

2. The Siluro-Devonian shallow-marine sedimentary fill of the foreland basin

Beginning in the Wenlockian with the Uncía and Kirusillas Fms., and ending in the Famennian with the Colpacucho and Iquiri Fms., the filling of the mid-Paleozoic retroarc foreland basin of the Bolivian Central Andes took place as a wave- and storm-dominated shallow-marine platform (epeiric sea). The high subsidence rates and sediment-supply rates kept pace with global sea-level changes, allowing for the recognition of at least three third-order cycles with variably-developed systems tracts. The depocenters and areas of maximum subsidence progressively shifted to the east and north from the Ordovician to the Carboniferous (Montemurro, 1994). This trends are related with an active deformational front located to the south and west. Higher degrees of erosion and wider pre-Cretaceous gaps in the same direction corroborate this inference. Evidence for sediment instability can be found in all the units, specially towards the southern and western areas (Figure 2). As with the Cancañiri Fm., all the different stages of submarine gravity flows are present in the Siluro-Devonian sequence, from massive slides, rafted slabs, slumps, debris flows, mudflows and turbidites. Figure 2 summarises the geographic location and the distribution in the stratigraphic column of the most important events.

3. End of the foreland setting and change of tectonic regime in the Carboniferous

The gradual shallowing-upwards and regressive tendency of the Late Devonian units is abruptly cut by a marked deepening and the initiation of resedimentation in the latest Famennian (Strunian). The Cumaná and Itacua Fms. overlie a short and poorly-preserved deepening event, followed by high clastic influx and deposition of the Ambo Group in the northern Altiplano, and the Macharetí and Mandiyutí groups in the central and southern Sub-Andes and Chaco. As with the Cancañiri Fm., evidence for a glaciated source area is indicated by the presence of large outsized granitoid clasts and frequent faceted and striated clasts found within the debris flow deposits or as dropstones. However, there is no evidence for subglacial deposits (tillites, pavements) in Bolivia, and it is suggested that glaciation was only local and temporarily reached the basin margins as tidewater glaciers (Díaz and Isaacson, 1994). Displacement of the region to lower latitudes during the Carboniferous led to important climatic changes (Sempere, 1995; Isaacson and Díaz, 1995). Serpukhovian regression set the end of the foreland basin development and the beginning of a new tecto-sedimentary cycle with erosion of relict reliefs and deposition of the Titicaca and Cuevo Groups in a different tectonic setting.

CONCLUSIONS

Two major periods of instability events and resedimentation initiate and terminate respectively the development of the Cordilleran cycle. These two periods (latest Ordovician-Early Silurian and latest Devonian-Early Carboniferous) are characterized by resedimented units locally exceeding 1-km thickness each, which provide evidence for a tectonic imprint on the global eustatic cycles affecting the Central Andean basin. Widening of stratigraphic gaps to the south and west, and progressive displacement of the foredeep (maximum subsidence areas) and depocenters towards the east and north, are probably related with propagation of the deformational front in this latter direction. Variable-sized gravity-flow deposits throughout the sequence evidence tectonic instability during the whole Cordilleran cycle (Figure 2). Tectonic piling in the deformational front was the probable cause for the increased subsidence, sediment supply and tectonic instability which facilitated sediment failure, as well as for the development of reliefs leading to local glaciation during periods of cold climate and favourable orientation (late Ashgill-Llandovery and late Famennian-Tournaisian).

REFERENCES

Díaz E. and P.E. Isaacson 1994. Late Devonian glacially-influenced marine sedimentation in western Gondwana: the Cumaná Formation, Altiplano, Bolivia. *CSPG Memoir*, 17, 511-522.

Isaacson P.E. and E. Díaz 1995. Evidence for a Middle-Late Paleozoic foreland basin and significant latitudinal shift, Central Andes. *AAPG Memoir*, 62, 231-249.

Montemurro G. 1994. Estratigrafía y ambiente sedimentario del Silúrico y Devónico en la cuenca del Chaco boliviano. 11° Congr. Geol. Boliviano. *Memorias*, 151-160.

Oller J. 1992. Cuadro cronoestratigráfico de Bolivia. YPFB internal document.

Sempere T. 1989. Paleozoic evolution of the Central Andes (10-26°S). 28th Int. Geol. Congr., Washington D.C.. *Abstracts*, 3, 73.

Sempere T. 1995. Phanerozoic evolution of Bolivia and adjacent regions. *AAPG Memoir*, 62, 207-230.

Suárez R. 1989. El Ciclo Cordillerano (Silúrico-Carbonífero inferior) en Bolivia y su relación con países limítrofes. *Revista Técnica YPFB*, 10 (3/4), 233-243.

Suárez R. 1995. Comentarios sobre la edad de la Formación Cancañiri. *Revista Técnica YPFB*, 16 (1-2), 51-54.

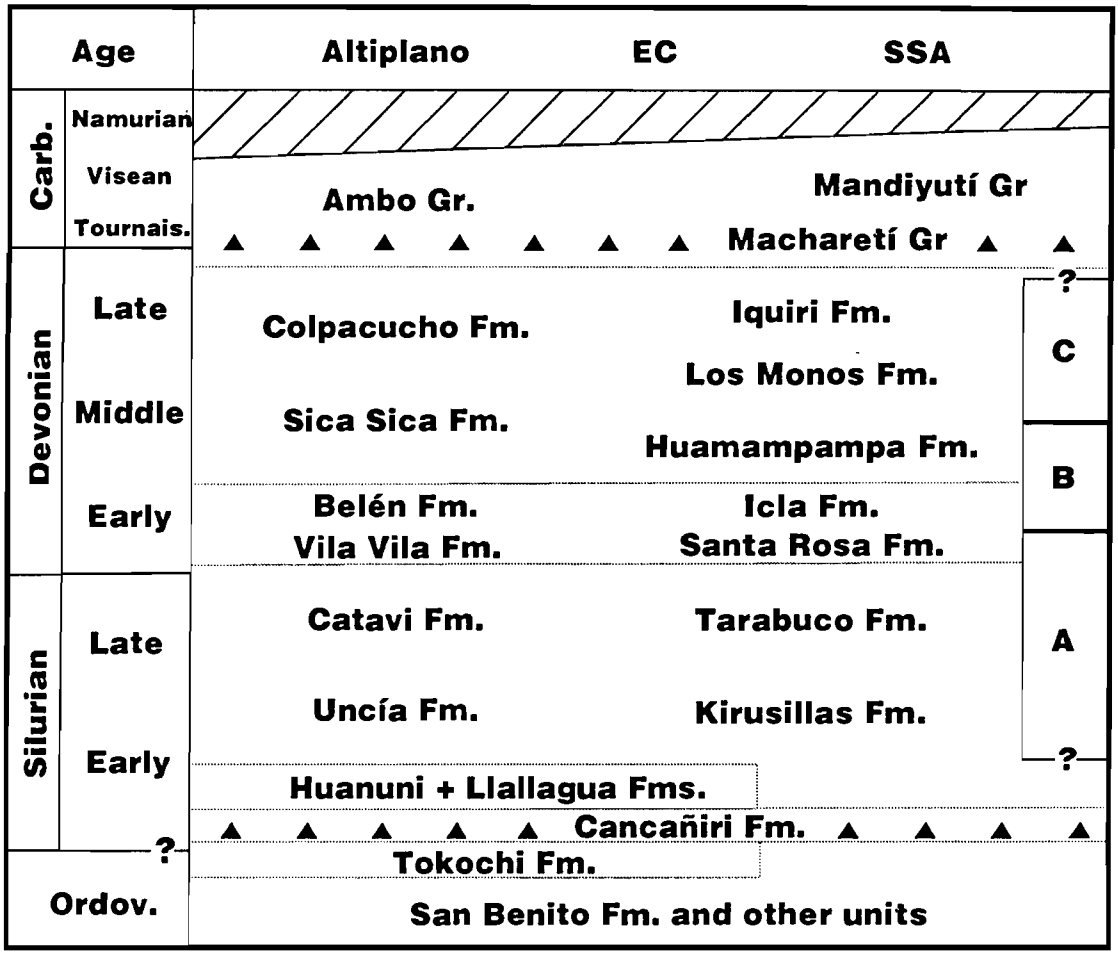

Figure 1: Simplified stratigraphy and correlation of the Paleozoic Cordilleran cycle (Silurian-early Carboniferous) of the Bolivian Central Andes. Triangles indicate the two major events of tectonic instability and resedimentation. A, B, C: main third-order cycles. EC: Eastern Cordillera, SSA: southern Sub-Andes.

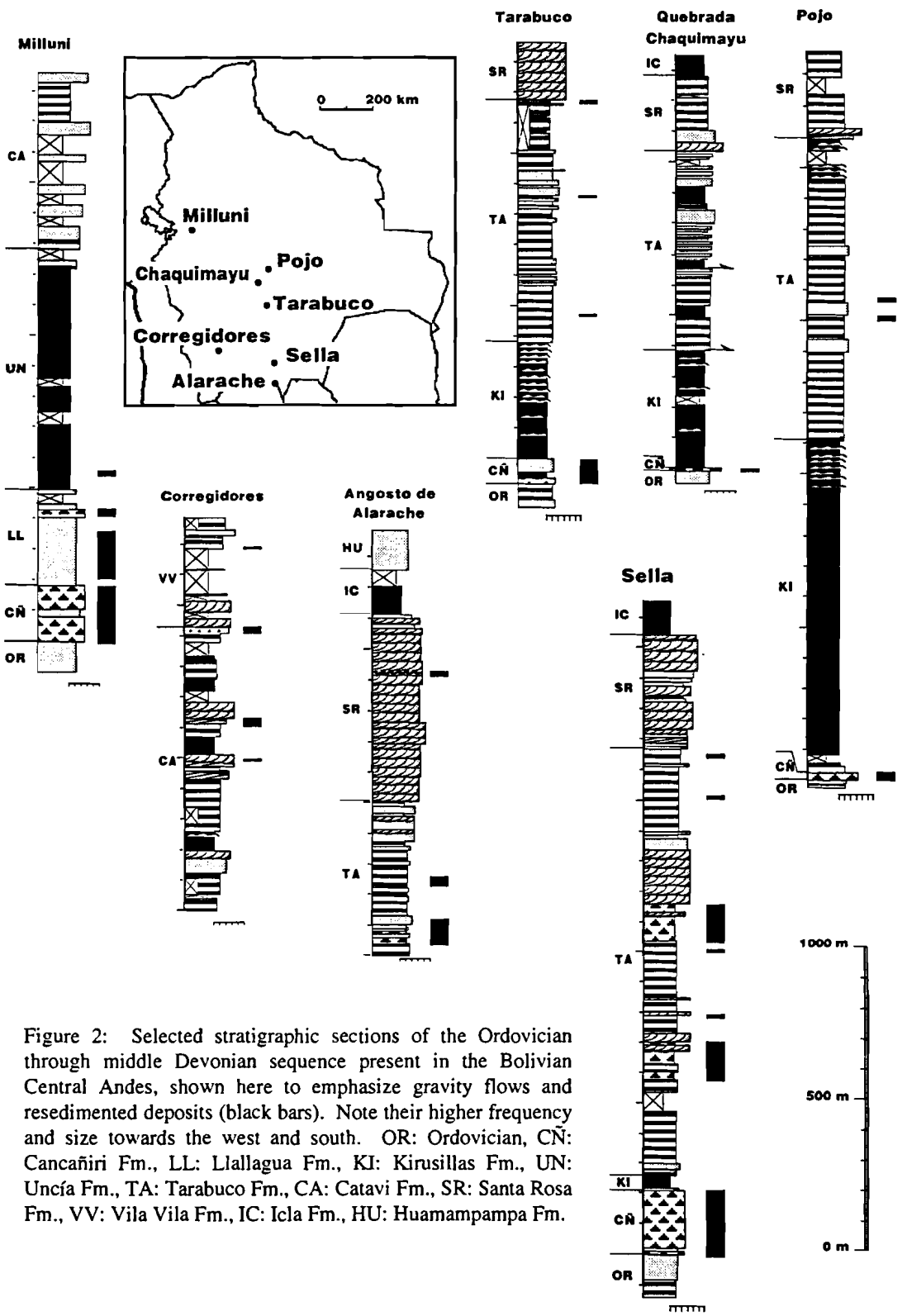

Figure 2: Selected stratigraphic sections of the Ordovician through middle Devonian sequence present in the Bolivian Central Andes, shown here to emphasize gravity flows and resedimented deposits (black bars). Note their higher frequency and size towards the west and south. OR: Ordovician, CÑ: Cancañiri Fm., LL: Llallagua Fm., KI: Kirusillas Fm., UN: Uncía Fm., TA: Tarabuco Fm., CA: Catavi Fm., SR: Santa Rosa Fm., VV: Vila Vila Fm., IC: Icla Fm., HU: Huamampampa Fm.