GENESIS AND KINEMATIC OF THE NORTHERN BOLIVIAN ALTIPLANO

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INTRODUCTION

The Altiplano is an enigmatic high plateau of the Central Andes, characterized by a thick crust about 70 Km (Wigger et al., 1994, Beck et al. 1996). Recent seismologic data show that magmatic accretion did not cause this crustal thickening (Dorbath et al., 1992), and numerous authors have emphasized the importance of horizontal shortening in the Altiplano structuration (Roeder 1988; Baby et al., 1992; Hérail et al., 1993). New seismic data available in YPFB as well as recent field works allow us to present a new geometrical model of the northern Altiplano, and to discuss its sedimentary evolution characterized by thick accumulations of Tertiary continental sediments (10.000 m).

STRUCTURAL SETTING

Recent field's works and analyses of seismic perfiles reflexions available in YPFB permit us to propose a new tectonic setting.
The northern Bolivian Altiplano can be divided in three structural domains (fig. 1 § 2)

- domain 1: At the eastern edge, the La Joya-Toledo plain forms the northern extremity of the Poopo basin, where late Tertairy and Quaternary deposits overlay the SW verging thrusts system of the Cordillera Oriental (Coniri Fault system). This plain is limited to the west by the Chuquichambi thrust, which forms the oriental flank of the Corque syncline. More to the north, in the Corocoro area where the Coniri limit is outcropping, synsedimentary structures prove a compressionnal activity of the Coniri fault as a thrust west verging system. This generation of structures is fold latter with a transpresionnal geometry showing a strike slip movement along this limit.
- domain 2: In the central area, the Corque syncline (2A) corresponds to the eastern part of an inverted half-graben. In the central part of the syncline, reflexion siesmic data show a thickness of 10 000 meters of Tertiary deposits, whithin which no erosionnal surfaces are observed. Its oriental flank represents the hanging wall of the Chuquichambi thrust, whereas its occidental flank is carried on the Turco thrust. The sole thrust is located in the base of the Tertiary series characterized by evaporitic layers. Little lenght wawe of structures located in the western flank are compatible with a thin skin tectonic and show that the basement is not impliquated in the compressive structures. In the central part of the northern altiplano, at the Andamarca latitude, the eastern edge of the Corque hemi-graben (not inverted) is N-S oriented, and reactived with a dextral strike-slip movement. More to the south at the east of the continuation of the Chuquichambi trend fault, Salinas de Garcia Mendoza area, oblique and sygmoide folds developped into Cretaceous deposits provide a transpresionnal regime induced by the dextral movement along the Chuquichambi limit.
- domain 3: The western edge is characterized by undeformed Pliocene and Pleistocene formations. These sediments seal: to the east, the preserved part of the Corque basin (2B), and to the west, a hemi-graben

(3), limited at its eastern edge by the Villa Flor fault, which is the continuation of the Mauri basin outcropping to the North in the Berenguela area. Tectonic style is reactivation of vertical faults well constrained by seismic perfiles.

TERTIARY SEDIMENTARY SEQUENCES

Using recent new datations (Swanson et al., 1987; Lavenu et al., 1989; Marshall et al., 1992, Kennan and al, 1995), we characterize five major depositional sequences which regroup all the previously sedimentary formations defined on the Altiplano (Hochstatter 1972; Cheroni, 1968 for example):

- Sequence 1 (Eocene-Oligocene: Tihuanacu Fm., Berenguela Fm., Turco Fm.), is formed by an alternance of red sandstones and argilites, characterized in its upper part by lenses of west-proceeding fluvial conglomerates (Sempere et al., 1990). This sequence does not outcrop in the Cordillera Oriental; it is 3000 m thick in the domain 2 and 2200 m thick in the domain 1.
- Sequence 2 (basal Upper Oligocene - Lower Miocene: Coniri Fm., Kollu Kollu Fm., Azurita and Huayllapucara Fm., Mauri 1-5 Fm.) is characterized by coarse conglomeratic layers, which are composed of Paleozoic rocks pebbles coming from the East (Coniri Fm), in domain 1, and red granites and gneiss pebbles coming from the West, in domain 3. In the Corque syncline (domain 2), the sequence consists of sandy sediments. Near the Coniri fault (domain 1), the sediments show progressive unconformities recording the uplift of the Cordillera Oriental. The base of the Coniri Fm has been dated at 25,5±1,7 My (Sempere et al., 1990) and the base of the Mauri Fm at 25,2±1 My (Lavenu, 1989).

- Sequence 3 (Middle Miocene) overlies the Oligo-Miocene on the domain 2, and an erosional surface on domains 1 and 3. It is 5000 meters thick in the center of the Corque syncline and thinner to the west. The base is characterized by sandstones, thin conglomerates and argillite (Caquiaviri Fm.), and the top by argillites and local evaporites (Rosapata Fm.). In the Mauri basin, the sediments (base of Mauri 6 Fm) are volcano-detritic and pinch out to the West. In domain 1, the sediments are thinner and pinch out to the East.

-Sequence 4 (Upper Miocene: Pomata Fm.) shows progressive unconformities and overlies the Middle Miocene with the Callapa tuff dated at 9,03±0,007 My (Marshall et al.,1992). This sequence is composed of argillites and lenses of conglomerates with Paleozoic rocks pebbles in domains 1 and 2, with some volcano-detritic sediments to the West. The domain 3B is characterized by greywackes.

- Sequence 5 (Pliocene) dated at its base at 5,34±0,003 My (Marshall et al., 1992), unconformably overlies the Upper Miocene. This sequence is composed of lacustrine sandy loam with lenses of east-prograding conglomerates, in domain 1, and volcano-detritic sediments, in domains 2 and 3.

BALANCED CROSS SECTIONS

Four sections have been constructed using the kink method. For each one's, structures are built with hypothesis of a mimimun shortening. The main detachments are located in the base of the Ordovician, base of the Silurian, base of the Devonian and base of the Tertiary rocks; In Salinas de Garcia Mendoza area, base of the Cretaceous is a decollement surface permitting the expulsion of an cretaceous basin. The thrust system geometry is characterized by fault progation folds of 1° generation (sometimes reactivacted), fault bend folds and duplex structures. The eastern limit of the Corque basin was built as a normal fault reactivacted in the north and creation of short cut (deformation of the footwall) in the south. These mecanisms of inversion are well imaged by tomographic images resulting of analog sand box experiments realised and analysed by tomography in IFP.

In our balanced cross section,the value of shortening ranges between 25 km to 60 km. Shortening is bigger in the south where the Poopo basin is well developped.

CONCLUSIONS: KINEMATIC MODEL AND CRUSTAL GEOMETRICAL MODEL

A combined study of the structural geometry and depositional sequences allow us to propose a tectonosedimentary evolution :

During Eocene-Lower Oligocene times, the Altiplano corresponded to a basin filled up by a low detritism coming from the West. The Chuquichambi trend could control the sedimentation during this period, and induce the difference of thickness between domains 1 and 2 and the depot center of evaporitic layers present at the base of the first sequence.

During the Oligo-Miocene, the Altiplano started to structure and corresponded to a compressional basin thrusted by the Eastern Cordillera. Erosive surfaces in domains 1, 2B and 3 show that the basin boundaries were deformed and eroded, while the central part of the basin (2A) was undeformed and filled by sediments, due to the erosion of the Eastern Cordillera and the western Precambrian basement.

The Middle Miocene is characterized by very high rates of sedimentation in two north-south elongated hemi-graben: the Mauri basin and the Corque basin. This period corresponded with a gentle tectonic activity along the thrusts of the Coniri system (Hérail et al. 1993). Geometry of the synsedimentary deformation, recorded within the upper Miocene sequence in the Corque syncline and Poopo basin, show that the Corque hemi-graben suffered the tectonic inversion and that in the same time Coniri system was reactivacted with a strike slip component.

During the Lower Pliocene, in domains 3 and 2, the Upper Miocene structures were peneplaned and sealed by volcano-detritic sediments. The Poopo basin (1) corresponded to a terrigene basin controlled by the development of the Chuquichambi thrust, which becomè a ridge between two Pliocene basins. At the same time, the Subandean zone was structured (Baby et al., 1989); crustal shortening increased and produced an uplift of the Cordillera and the Altiplano.

Combinning our regional studies of the Altiplano and Subandean zone and surface mapping of the Eastern Cordillera provided by the Bolivian Oil Company YPFB, we purpose two crustal balanced cross sections with a shortening of 191 km for the 18° transect and 231 km for the 22° transect (Baby and al, this issue). At this crustal scale the Altiplano take characteristics of a piggyback basin and corresponds to the bigest detritic basin of the andean chain.

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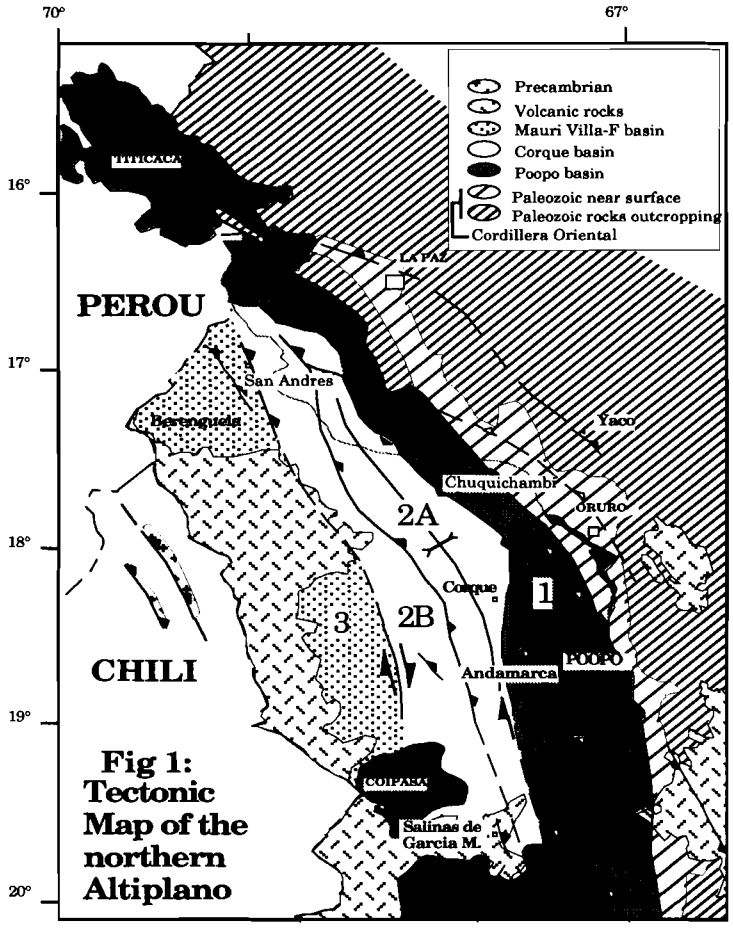

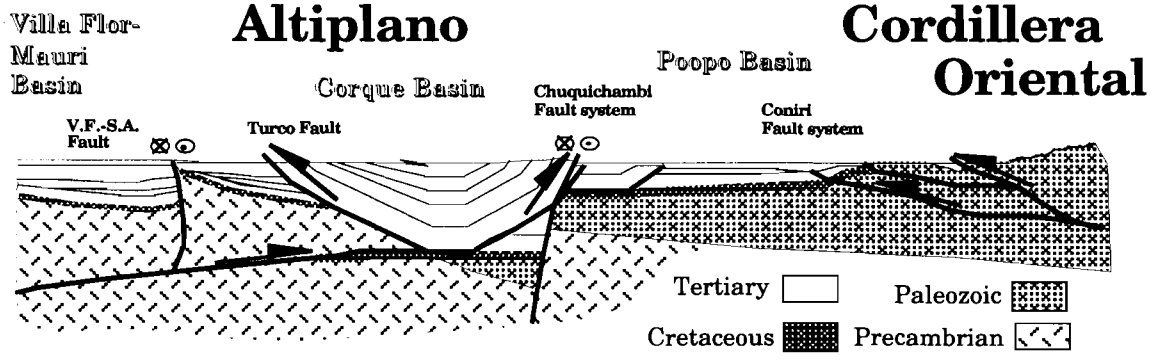

Fig 2: Schematic section of the northern Altiplano