TECTONIC AND STRATIGRAPHY OF THE ISCHIGUALASTO-VILLA UNIÓN BASIN, ARGENTINE

Authors:
Christian C. Born[1], Farid Chemale Jr.[2]

Adresses:
[1]Estrada dos Alpes, 2091. Bairro Cascata, Porto Alegre, RS, Brazil. CEP 91720-120
[1]cristao_geo@yahoo.com.br; [2]farid.chemale@ufrgs.br

ABSTRACT

The integrated analyses of stratigraphic and sin-sedimentary deformational data of Ischigualasto Basin deposits, allowed us reconstruct its evolutive history during Triassic. Two regional scale stratigraphic sections were measured and correlated, one near the Valle Fertil Suture, the active basin border fault during Triassic, and one on the flexural margin.

Block rotation and half-*graben* development were influenced by tensional stress field with maximum extension axis oriented NE-SW. Due to this tectonic configuration, the depocenter is located over the NW trend of the preexistent structure (Valle Fertil Suture). The differential subsidence, caused by two main tectonic pulses, resulted in the deposition of two wedge-shaped rift Sequences (SEQ 1 and SEQ 2), composed of three tectonics system tracts each: (i) Rift Initiation Systems Tract (RIST), marked the initial movements of faults; (ii) Rift Climax Systems Tract (RCST), associated with maximum subsidence rates; and (iii) Rift Fill Systems Tract (RFST), characterized by decreasing in the subsidence rates (thermal subsidence).

The RIST of SEQ 1 is composed of alluvial and fluvial systems of the Talampaya/Tarjados Formation showing agradational stacking pattern. The increase in border fault activity generates a great subsidence in the adjacent region, recorded by the development of fan-delta systems of the Los Chañares Formation. Associated with this subsidence, due to the block rotation, the flexural margin is uplifted, causing a local base level fall, which induces broad erosion observed at the top of the Talampaya Formation in the east portion of the basin. During the RCST the lake gets broader and deeper. The basin is filled by retrogrational deltaic systems of the Ischichuca Formation. The stacking pattern of the deltaic parasequences becomes progradational (Los Rastros Formation) when fault activity decreases during the RFST.

The SEQ 2 is composed by the agradational alluvial system of the Água de La Peña Formation (RIST), that changes to the meandering fluvial system of the Ischigualasto Formation (RCST) and culminates with prograding fluvial systems of the Los Colorados Formation (RFST).

INTRODUCTION

The Ischigualasto-Villa Unión Basin, located in NW Argentine (figure 1), is a NW-SE elongated Triassic rift filled by terrigenous, volcanics and volcaniclastics. Its deposits overlie uncorformably over the Paleozoic granite-gneissic basement and the Paleozoic Pre-Rift sequence of Paganzo Basin. The complex thrust system developed during the Andean Orogeny and the absence of fossils in the lower deposits hinders stratigraphic correlations in a regional scale. The Argentina's Triassic basins are interpreted to be formed by an extensional process with the maximum extension axis oriented NE-SW (Tankard *et al.*, 1995). This regime reactivated the N-S and NW Paleozoic structures, as the Valle Fertil Suture, formed by the collision of the Cuyania microcontinent against the Gondwanides' west margin and which is believed to be the active border fault of Ischigualasto Basin during Triassic.

In our work we have used structural and stratigraphic sequence methods to propose a tectonic-sedimentary model for the Ischigualasto Basin. To build up this model we have analyzed the sin-sedimentary deformation structures of Ischigualasto Basin units in order to characterize its structural style. The definitions of the tectonic stages, stratigraphic correlations and sedimentary provenance of

the different areas were based on two detailed stratigraphic sections at the Ischigualasto and Talampaya Park's regions.

PREVIOUS WORKS

The Ischigualasto Basin has been extensively studied and has been traditionally subdivided in litho formations, cited below from the base to the top:
I – Talampaya e Tarjados formations (Romer & Jensen, 1966), Lower Triassic and,
II – Água de La Peña Group (Bossi, 1971), composed by Ischichuca-Los Chañares Formation (Frenguelli, 1944), Los Rastros Formation (Frenguelli, 1944), Middle Triassic, and Ischigualasto (Frenguelli, 1944) and Los Colorados formations (Bossi, 1971), Upper Triassic.

Kokogian *et al*. (1987) presented a palaeoenvironmental analysis of the basin. Spalletti (2001) and Casselli *et al*. (2001) have studied Ischigualasto and Los Colorados formations, respectively.

Milana & Alcober (1995) presented the first tectonic-sedimentary model, with two rift sequences subdivided in sin- and post-rift stages. Their Sin-Rift I stage comprises the Talampaya, Tarjados and Ischichuca/Los Chañares formations. Their Post-Rift I stage comprises the Los Rastros Formation. The second sequence, the Sin-Rift II stage, comprises the Água de La Peña and Ischigualasto formations. Los Colorados Formation represents the Post-Rift II stage. These same authors based on the isopach data, concluded that the Ischigualasto Basin has half-graben geometry.

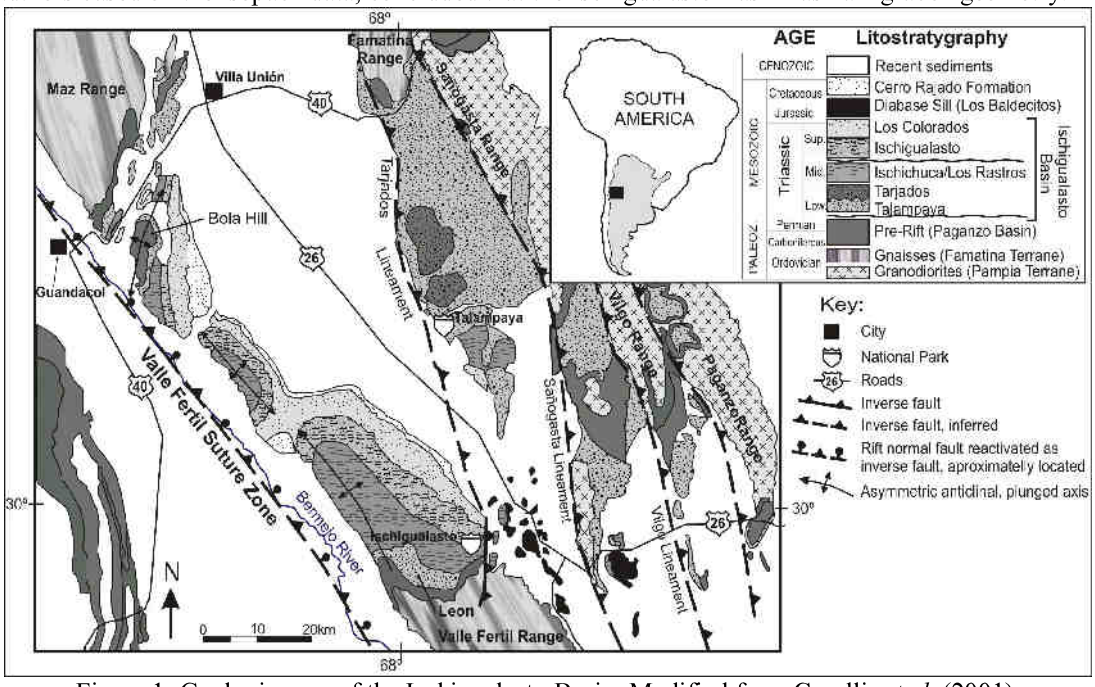

Figure 1: Geologic map of the Ischigualasto Basin. Modified from Caselli *et al.* (2001).

RESULTS

SIN-SEDIMENTARY FAULTS

Were measured 23 sin-sedimentary normal faults on the Talampaya Formation, resulting on a mean N-S, east and west dipping plane. There is also NW and NE planes (figure 2).

Figure 2: Left: sin-sedimentary fault in conglomerates of Talampaya Formation. Right: lower hemisphere stereogram showing the poles of sin-sedimentary fault planes.

STRATIGRAPHY

Leon/Ischigualasto Park Profile

The Talampaya Formation comprises facies associations of alluvial fans, fluvial channel (figure 3a), longitudinal bars and flood plain (figure 3c). These facies associations characterize a braided fluvial system with shallow gravel bed channels and a poorly developed flood plain. Palaeocurrents shows a NE trend. This system has high sediment supply from the Pre-Rift Sequence, evidenced by few conglomerate blocks observed in some sandstones (figure 3b).

The Los Chañares Formation is characterized by fan delta facies association (figure3d). It is characterized by coarsening-upward cycles that begins with 4-6m thick packages composed by tuffaceous mudstones intercalated with some thin massive sandstone beds, overlain abruptly by a 3-4m thick package of lenses-shaped, amalgamated tuffaceous conglomerates with trough cross stratification. The tuffaceous mudstones represent shallow lacustrine deposits that receive constant ash falls. The massive sandstones are hyper-concentrated turbiditic flows, and the conglomerates represent the braided fluvial system that enters into the lake.

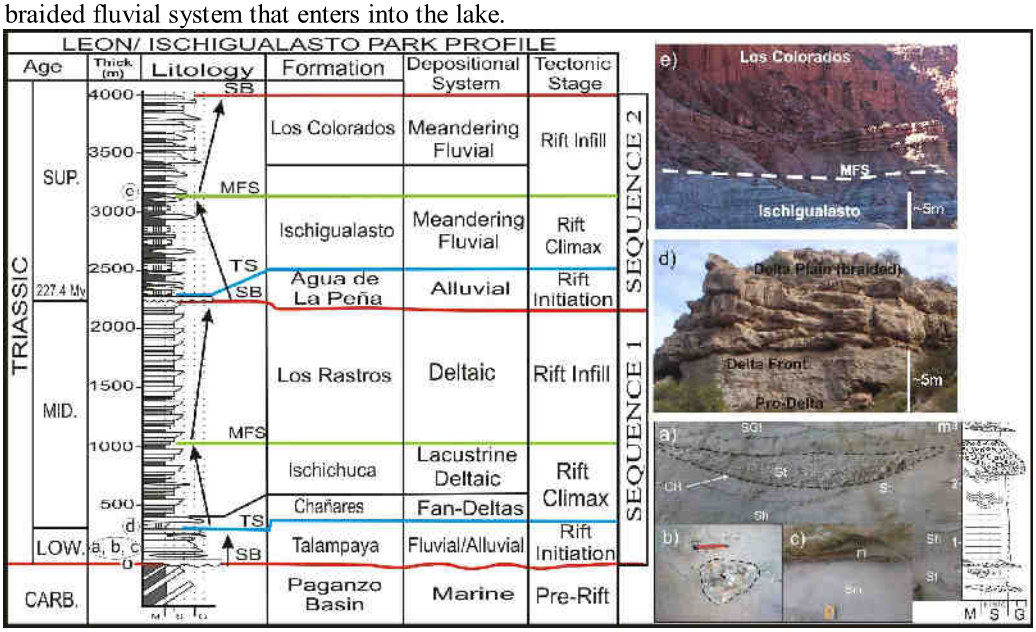

Figure 3: Composed columnar profile of Leon/ Ischigualasto Park region.

The Ischichuca Formation is composed of coarsening upward parasequences, each one of them composed by carbonaceous shales at the base (lacustrine association facies) overlain by siltstones and fine sandstones with ripples (pro-delta facies association) that grades to medium sandstones with trough cross stratification (delta-front facies association), ending the cycle there are lenses-shaped sandbodies filled by cross stratified sandstones; enclosed by mudstones with very thin coal beds (delta plain facies association-distributary channels and flood plains). This formation shows a retrogradational stacking pattern. The overlying Los Rastros Formation is composed by the same facies associations, but has upward less-developed lacustrine deposits, which characterize a progradational stacking pattern.

The Agua de La Peña Formation comprises trough cross stratified conglomerates; composed mainly by quartz pebbles. This facies association characterizes a braided fluvial system; which is related to medial alluvial fan portions.

These conglomerates are overlain by the Ischigualasto Formation, characterized by a meandering fluvial system composed by channel facies association (ribbon sandbodies filled by coarse to medium-grained trough cross stratified sandstones with basal conglomeratic lag), and overbank facies association (flood plain mudstones and thin sheet sandbodies showing normal gradation, wich represents crevasse splay deposits). This fluvial system grades upward to a more coarse fluvial system with less developed flood plain (Los Colorados Formation), which has the same facies associations of the Ischigualasto Formation.

Talampaya/Gualo Profile

This profile begins with Talampaya Fm. The basal portion of this formation is not exposed. This unit is composed of amalgamated sheet sandbodies composed by conglomeratic basal lags and coarse- to medium-grained sandstones with trough and planar cross stratifications, compounding fining-upward cycles. This facies association is interpreted to be the record of an ephemeral fluvial system. The dominance of dune-scale cross beddings and the absence of macroforms sugest shallow fluvial channels. Some rare thin mudstone lenses with mudcracks that rarely occur at the top of the cycles represent the overbank deposits. The stacking pattern is agradational. The top of this unit is a marked erosive surface (figure 4b).

The Tarjados Formation (figure 4b) is composed of ribbon sandbodies filled by coarse to medium sandstones with thin basal conglomeratic lags. These facies are interpreted as fluvial channels. Intercalated with this macroforms, there are massive mudstones with mudcracks and thin fine-grained sandstone beds with ripples, which are interpreted to represent the overbank deposits. This set of facies association compounds a braided fluvial system with a more developed flood plain when compared to the underlying Talampaya Formation.

The Tarjados Formation is overlain by the Los Chañares Formation. This formation shows at its base a 2m thick conglomerate, suggesting a progradation of alluvial fans. This conglomerate is overlain by incomplete deltaic parasequences (without lacustrine facies association) that shows a progradational stacking pattern, with the sigmoidal macroforms migrating to W (figure 4a).

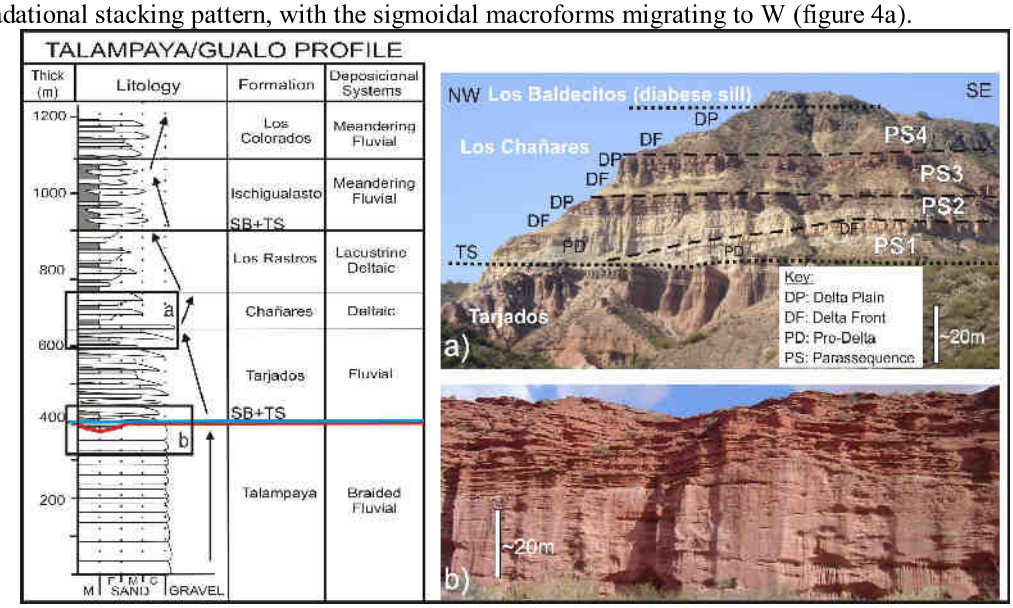

Figure 4: Columnar profile of Talampaya-Gualo region; a) Contact between Tarjados and Los Chañares Formation; b) Erosive unconformity between Talampaya and Tarjados formations.

This formation grades upward to the lacustrine/deltaic deposits of the Ischichuca/Los Rastros Formation, which in this region comprises black shales (lake association facies), siltstones and fine sandstones with ripples (pro-delta association facies), fine to medium sandstones with trough cross

stratification (delta-front facies association) and trough cross stratified fine to medium sandstones (delta-plain facies association). The stacking of the parassequences marks a retrogradational pattern.

The Ischigualasto Formation comprises isolated ribbon sandbodies enclosed within thick mudstone packages with some tuffaceous mudstones and thin fine to medium-grained sandstone beds intercalated. Sometimes the base of the macroforms has a conglomeratic lag. The profile ends with the Los Colorados Formation, which is composed by sandstone lenses and overbank mudstones. The top of this formation was eroded.

DISCUSSION

Sequence 1

This sequence begins with the structural rearrangement of the pre-rift units, which generates the basal sin-rift unconformity. The abundant presence of N-S sin-sedimentary normal faults in Talampaya Formation suggests an E-W direction for the extension. However, the stratigraphic analysis indicates that the greatest subsidence is at the NW faults (border fault), so the maximum extension would be oriented perpendicular to these structures, so NE-SW, confirming the hypothesis of Tankard *et al.* (1995). On both cases, the NE faults would correspond to transfer or release faults.

In the rift initiation systems tract, the tectonic subsidence rates are low. The fulfilling is given by basalt flows (at the northern portion), alluvial and braided fluvial systems (Talampaya Fm.) in agradational stacking pattern. The palaeocurrents distribution indicates an axial and transversal sediment influx, part of it coming from the pre-rift sequence.

New border fault movements generates a great subsidence adjacent to the border fault, recorded by the development of fan-delta system that enters in a shallow lake with frequently ash falls (Los Chañares Fm.). Associated with this subsidence, due to the block rotation, the flexural margin (at Talampaya Park's region) is uplifted, causing a local base level fall, which induces broad erosion, with low fluvial incision at the top of Talampaya Formation. Bosence (1998) and Küchle *et al.* (2005) emphasize the importance of block rotation caused by fault activity, which causes subsidence in the hangingwall, synchronous with an uplift of the adjacent footwall (figure 5).

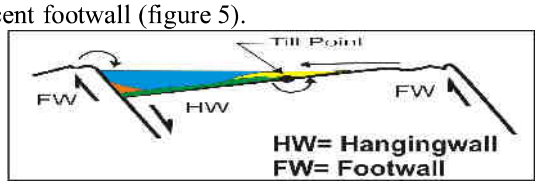

Figure 5: Synchronous relative uplift (and erosion) of the footwall and subsidence of the hangingwall. From Küchle *et al.* (2005).

This region thus experiments subsidence, registered by the deposition of a fluvial system of moderate sinuosity, with more developed flood plain (Tarjados Fm.). These deposits can be related to the initial lacustrine deposits of Ischichuca Formation on the west portion of the basin.

During the rift climax systems tract, there is a great expansion and deepening of the lake. The stacking pattern near the border fault is retrogradational (Ischichuca Fm.). After this, the tectonic activity stops, and the subsidence is only thermal, which decreases the subsidence rates. This is recorded by a progradation of the deltaic systems observed in Los Rastros Formation.

Sequence 2

The rift initiation systems tract begins with new movimentations in the border fault that causes base level fall adjacent to it. This base level fall induces a large progradation of the alluvial fans (Agua de La Peña Formation) over the deltaic systems. Milana and Alcober (1995) based on compositional maturity of these deposits suggest that they result from the reworking of previously deposited alluvial fans. In the regions away from the border faults, there is a low subsidence rate period, resulting on the restrict sedimentation of meandering fluvial systems (Ischigualasto Formation).

During the rift climax systems tract, there is an increase on the subsidence rates, which causes an inundation, recorded by meandering fluvial systems (Ischigualasto Formation) over the alluvial fans of Agua de La Peña Formation. The flood plains are frequently covered by ash falls. A tuff bed was dated by Rogers *et al.* (1993) using Ar^{40}/Ar^{39} method obtaining an age of 227, 8 ± 0, 3 My that corresponds to Middle Carnian.

The rift fill systems tract comprises the top of Ischigualasto Formation and the entire Los Colorados Formation. This stage is marked by a progradation of the fluvial systems. This

interpretation is based on the increase of the channel/overbank ratio and on the more oxiding conditions. Guadagnin (2004) argued that this change is due to the progressive relative lowering of the phreatic level during the eo-diagenetic stage, which makes the sediments that was before below the water table, and so in reduction conditions (Ischigualasto Formation), to be oxided. This is supposed to be caused by the basin silting.

CONCLUSIONS

The filling of Ischigualasto Basin can be divided in two wedge-shaped rift sequences, each one of them composed by three tectonic systems tract (*sensu* Küchle *et al.*, 2005): (i) Rift Initiation Systems Tract, agradational, marked by the initial movements of faults; (ii) Rift Climax Systems Tract, retrogradational, associated with maximum subsidence rates; and (iii) Rift Fill Systems Tract, progradational, characterized by low subsidence rates (thermal subsidence).

Besides the non-continuity between the outcrops (separated by a reverse fault), based on recent models for rifts, the erosional unconformity between Talampaya and Tarjados formations observed at Talampaya's Park can be correlated with the transgressive surface near the border fault.

The extensional stress field which generated the Ischigualasto Basin has a NE-SW maximum extension axis. This tectonic configuration reactivated the Valle Fertil Suture as the basin's border fault, as well as the N-S basement fabric.

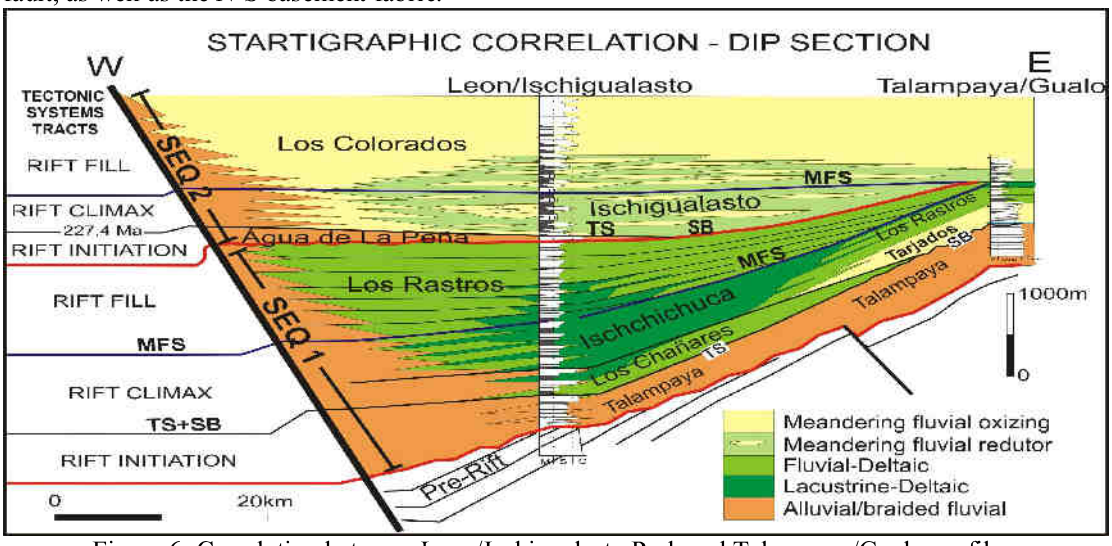

Figure 6: Correlation between Leon/Ischigualasto Park and Talampaya/Gualo profiles.

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