RAPID TECTONIC AND PALEOGEOGRAPHIC EVOLUTION: THE CHUCAL ANTICLINE, ALTIPLANO OF ARICA, NORTHERN CHILE

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INTRODUCTION

An east-vergent structural system composed of the Jaropilla Fault, and the Chucal Anticline (Riquelme, 1998; Riquelme and Hérail, 1997), is located on the S-E side of the fault-controlled Chapiquiña-Belén Ridge (Charrier et al., 2000), Altiplano of Arica (Fig. 1). This system deformed lower to upper Miocene rocks and caused the development of several progressive unconformities, located on the E-flank of the anticline (Riquelme, 1998; Riquelme and Hérail, 1997). The deformed stratigraphic series formed by the Lupica, Chucal, and Quebrada Macusa Fms. (Muñoz, 1991; Riquelme, 1998) ranges in age between 21.7±0.8 Ma and 10.4±0.7 Ma. The latter age corresponds to a less deformed lava covering the Quebrada Macusa Fm. (Riquelme, 1998).

New stratigraphic and structural studies, radioisotopic datings of tuff layers and discoveries of mammal fossils enable us to (1) better constrain the chronology of the tectonic evolution of the Chucal Anticline, and the development of the progressive intraformational unconformities, and (2) understand the effects of deformation on the stratigraphic sequence, sedimentation, and paleogeographic development of the Chucal-Lauca Basin.

STRATIGRAPHY AND CHRONOLOGY OF DEFORMATION

The core of the Chucal Anticline exposes the upper part of the Lupica Fm. formed by a >50 m thick, 21.7±0.8 Ma old, massive, white tuff (Riquelme, 1998) covered by a thin stratified series of white tuffaceous, lenticular, fluvial sandstones layers. On the W-flank it is 66 m thick and on the E-flank, 50 m thick. It is conformably covered with minor erosional discontinuities by the Chucal Fm. (Muñoz, 1991).

On the **western flank** of the anticline (Fig. 1), the Chucal Fm. (600 m thick) is a 35 to 40º west-dipping series, covered further west by the Quebrada Macusa Fm. It is composed by:

-Member W1 (60 m) begins with a lenticular, orange colored, channelizing paraconglomerate and is formed by three upwards-fining, fine grained sequences, ending with a 4-6 m thick calcareous series.

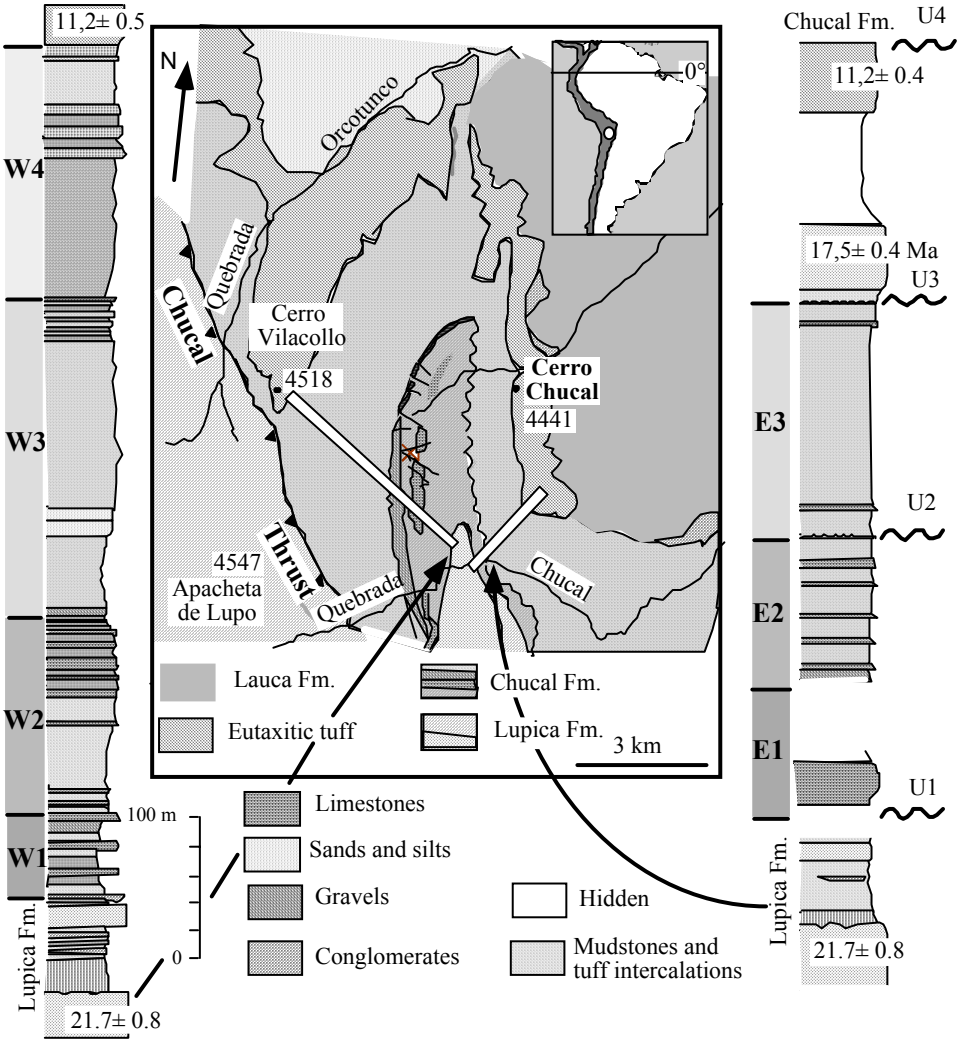

Fig. 1 - The Chucal Anticline: tectonic and stratigraphic columns.

-Member W2 (144 m) is white colored series composed of fine grained sandstones with intercalations of tuffaceous material, mudstones, and limestones. Limestones correspond to laminated marls (with plants remains), chert nodules, massive marls, fine calcareous sandstones, and micrites.

-Member W3 (225 m) corresponds to an alternation of green sandstones, mudstones, and a few, thin, external red in color, limestone intercalations. Plant remains are frequent in this member.

-Member W4 (172 m): This is the upper member of the Chucal Fm. and is characteristically comprised of brownish-grey mudstones. The upper part contains some conglomerate and tuff intercalations.

The W-flank series represents evolution from fluvial (Lupica Fm.) to lacustrine conditions (Member W2), lake filling and flood-plain development (Member W3), and new subsidence (Member W4). Mammal fossils were mainly found in the flood-plain facies, and some lacustrine-influenced strata.

On the **eastern flank**, the Chucal Fm. (<365 m) is a steeply E-dipping series, unconformably covered by the 17.5±0.4 Ma old lower tuff (Bond and García, 2002) of the Quebrada Macusa Fm. It is composed by:

-Member E1 (~100 m) is a white calcareous series deposited above the Lupica Fm.. Its exposed thickness is ~30 m. The gap between the Lupica Fm. and Member E2 is 100 m (its maximum possible thickness). Member E1 corresponds to the thicker Member W2 on the W-flank.

-Member E2 (100 m) is green in color, and corresponds to the thicker Member W3 on the W-flank. It contains limestone intercalations with an external red color. Its contact with Member E1 is not exposed.

-Member E3 (165 m) is a grey, massive, mammal-fossils bearing, fluvial sandstone series with hard, calcareous intercalations. The contact with the underlying member is slightly unconformable; it is less steeply dipping than Member E2. It has no equivalent on the W-flank. Considering its position between Member E2 and the Quebrada Macusa Fm., it can be chronologically correlated to all or to part of Member W3 on the W-flank.

The E-flank strata represent a series, interrupted by unconformities, of evolving paleoenvironmental conditions, from fluvial (Lupica Fm.), to lacustrine (Member E1), to lake filling and flood-plain systems with lacustrine influence (Member E2), and finally abruptly changing back to fluvial and flood-plain conditions, also with some lacustrine influences indicating continuing proximity to and persistence of a lake within the system.

Member W1 is not developed on the E-flank. The calcareous Member W2 is considerably thicker than its correlative Member E1, and the green sandstone Member W3 is thicker than its correlative Member E2. Member W4 has no equivalent on the E-flank. Considering its position between Member W3 and the lower white tuff of Quebrada Macusa Fm. it can be considered as a chronologic equivalent of Member E3 on the E-flank. Member E3 represents a major increase of transport energy not represented on the W-flank.

The W-flank column is relatively continuous. Interruptions in the sedimentation process in the E-flank have been interpreted as progressive unconformities (Riquelme, 1998; Riquelme and Hérail, 1997).

A major change in depositional regime occurred at the base of the Chucal Fm., with the deposition of the basal, orange colored conglomerates of Member W1, which is formed by upwards finning cycles, each one ending with lacustrine limestones. Deformation began after deposition of the orange colored member, and caused on the E-flank side: 1. Erosion of the orange colored member (U1), 2. reduction in thickness of Member E1 (U2), 3. reduction in thickness of Member E2 (U3), and 4. the progressive unconformity U4 on the E-flank.

FOSSIL MAMMALS

Abundant mammalian remains have been recovered from numerous horizons within the Chucal Fm. In the anticline's W-flank fossils generally occur in flood-plain facies and lacustrine-influenced intervals (i.e., in the lower parts of Members W3 and W4), whereas on the E-flank they predominantly occur in fluvial facies (i.e., Members E3 and E1), reflecting the distinctly different depositional systems on either side of the anticlinal.

The fauna (Flynn et al., 2002) appears to represent a single, short temporal interval, most likely Santacrucian or Friasian in age (e.g., between 14 and 17.5 Ma). The new date, from basal Quebrada Macusa Fm. strata overlying the mammal fossils, emphasizes that deposition and deformation of most of the Chucal Fm. was very rapid. It also suggests that this fauna more likely correlates to Santacrucian than any younger SALMA; additional work on the fauna and geochronology will clarify this point. At least eight fossil mammal taxa are currently identified from the Chucal Fm. (Flynn et al., 2002), including five notoungulates (*Nesodon imbricatus*, a toxodontid; three mesotheriid species; hegetotheriine), the litoptern *Theosodon*, a glyptodontoid, and the oldest known chinchilline rodent. Abundant new material and additional localities discovered in 2001 suggest that at least 6-7 additional species occur in this formation. Preliminary identifications include a notohippid notoungulate (supporting a Santacrucian age), a second (diminutive chinchilline, an armadillo, and several other interesting but as yet unstudied very small-bodied taxa. The large chinchilline, *Nesodon*, mesotheres, and hegetotheres are

known from multiple levels and on both flanks of the anticline. Bond and García (2002) report the existence of *Palyeidodon* in the upper levels of the Chucal Fm. on the E-flank.

CONCLUSIONS

Sedimentation of the 600 m thick Chucal Fm., pulses of development of the Chucal Anticline, development of progressive unconformities (U1 to U4), associated erosion, and development of at least partially isolated paleogeographies with abundant associated fauna (likely Santacrucian SALMA=17.5-16.3 Ma; Flynn and Swisher, 1995) and flora on both sides of the anticline occurred between about 21.7±0.8 Ma and 17.5±0.4 Ma. This rapid episode of deformation occurred within less than a 4 my interval. Further deformation affecting the Quebrada Macusa Fm. (U5) occurred after 11.2±0.5 Ma and before 10.4±0.7 Ma. The total time represented by this series, between the Basal Tuff (Lupica Fm.), and the upper tuff in the Quebrada Macusa Fm. is ~11 my.

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