

## Rapid tectonic and paleogeographic evolution associated with the development of the Chucal anticline and the Chucal-Lauca Basin in the Altiplano of Arica, northern Chile

Reynaldo Charrier<sup>a,i,\*</sup>, Alvaro N. Chávez<sup>b</sup>, Sara Elgueta<sup>b</sup>, Gérard Hérail<sup>a,c,i</sup>, John J. Flynn<sup>d,1</sup>, Darin A. Croft<sup>e,2</sup>, André R. Wyss<sup>f</sup>, Rodrigo Riquelme<sup>a,h,i</sup>, Marcelo García<sup>g,3</sup>

<sup>a</sup>Departamento de Geología, Universidad de Chile, Casilla 13518, Correo 21, Santiago, Chile

<sup>b</sup>SIPETROL S.A., Vitacura 2736, 8 Piso, Providencia, Santiago, Chile

<sup>c</sup>IRD, LMTG, 38 Rue des 36 Ponts, 31400 Toulouse, France

<sup>d</sup>Department of Geology, Field Museum of Natural History, 1400 S. Lake Shore Drive, Chicago, IL 60605, USA

<sup>e</sup>Department of Organismal Biology and Anatomy, University of Chicago, 1025 E. 57th Street, Chicago, IL 60637, USA

<sup>f</sup>Department of Geological Sciences, University of California, Santa Barbara, CA 93106, USA

<sup>g</sup>Servicio Nacional de Geología y Minería, Avda. Santa María 0104, Santiago, Chile

<sup>h</sup>Departamento de Ciencias Geológicas, Universidad Católica del norte, Castilla 1280, Antofagasta, Chile

<sup>i</sup>Convenio Universidad de Chile-IRD, France

Received 1 March 2003; accepted 1 June 2004

### Abstract

The east-vergent Chucal thrust system, on the east side of the Chapiquiña-Belén ridge in the Western Cordillera, was continuously or almost continuously active for  $\sim 18$  m.y. ( $<21$  to  $>2.7$  Ma). Contractual activity deformed late Oligocene tuffaceous, fluvial, or distal alluvial deposits of the uppermost Lupica Formation; fluvial and lacustrine deposits of the Miocene Chucal Formation; tuffaceous and coarse fluvial deposits of the Quebrada Macusa Formation; and the lower part of the westernmost, latest Miocene?—Pliocene, essentially lacustrine Lauca Formation. It controlled the paleogeographic and paleoenvironmental conditions in which these units were deposited. More humid conditions on the east side of the Chapiquiña-Belén ridge favored the development of an abundant mammal fauna and flora. The deformation is characterized by the Jaropilla thrust fault and the Chucal anticline, which is east of the fault. Deformation on the Chucal anticline began before the deposition of the Chucal Formation and was controlled by a blind thrust fault. The west flank has a nearly constant dip ( $45$ – $50^\circ$ ) to the west and nearly continuous stratigraphic units, whereas on the east flank, the dip angle is variable, diminishing away from the axis, and the stratigraphic units are discontinuous. The anticline growth on this flank caused the development of three observable progressive unconformities. Deformation was particularly rapid during the deposition of the  $\sim 600$  m thick Chucal Formation (between the  $21.7 \pm 0.8$  Ma old uppermost Lupica Formation and the  $17.5 \pm 0.4$  Ma old base of the Quebrada Macusa Formation, a 4 m.y. period). The deformation rate decreased during the deposition of both (1) the  $\sim 200$  m thick Quebrada Macusa Formation (between the  $17.5 \pm 0.4$  Ma age of its basal deposits and the  $\sim 11$  Ma age of its uppermost levels, a 7 m.y. period) and (2) the lower Lauca Formation (between the  $\sim 11$  Ma age of the upper Quebrada Macusa Formation and the  $2.3 \pm 0.7$  Ma old Lauca ignimbrite, which is intercalated within its middle part). We interpret the contractional deformation to be associated with tectonic activity that led to the uplift of the Altiplano; however, paleobotanical evidence does not indicate any major altitude changes during the time period considered here but rather suggests that rapid uplift took place after the deposition of the Quebrada Macusa Formation.

© 2005 Elsevier Ltd. All rights reserved.

\* Corresponding author. Tel.: +56 678 4109; fax: +56 6963050.

E-mail addresses: rcharrie@cec.uchile.cl (R. Charrier), achavez@sipetrol.cl (A.N. Chávez), sara.elgueta@sipetrol.cl (S. Elgueta), gherail@paris.ird.fr (G. Hérail), jflynn@amnh.org (J.J. Flynn), dcroft@case.edu (D.A. Croft), wyss@magic.geol.ucsb.edu (A.R. Wyss), rodrigue@cec.uchile.cl (R. Riquelme), mgarc016@odelco.cl (M. García).

<sup>1</sup> Present address: Division of Paleontology, American Museum of Natural History, Central Park west at 79th street, New York, NY 10024, U.S.A.

<sup>2</sup> Present address: Department of Anatomy, Case Western Reserve University School of Medicine, 10900 Euclid Avenue, Cleveland, OH 44106, U.S.A.

<sup>3</sup> Present address: Exploraciones Mineras S.A., CODELCO, Avda. Nueva Oriente 2696, Calama, Chile.