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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

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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 ~18 m.y. (<21 to >2.7 Ma). Contractional 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°) 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 ~600 m thick Chucal Formation (between the 21.7±0.8 Ma old uppermost Lupica Formation and the 17.5±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 ~200 m thick Quebrada Macusa Formation (between the 17.5±0.4 Ma age of its basal deposits and the ~11 Ma age of its uppermost levels, a 7 m.y. period) and (2) the lower Lauca Formation (between the ~11 Ma age of the upper Quebrada Macusa Formation and the 2.3±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.

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Resumen

La actividad del sistema estructural de Chucal, con vergencia al este, ubicado al este del Cordón Chapiquiña-Belén en la Cordillera Occidental, fue continua o casi continua durante ~18 m.a. (entre <21 Ma y >2,7 Ma). La contracción deformó depósitos tobáceos y fluviales o aluviales distales del Oligoceno Superior pertenecientes a la parte superior de la Formación Lupica, depósitos fluviales y lacustres del Mioceno de la Formación Chucal, y depósitos esencialmente lacustres del Mioceno?—Plioceno de la parte inferior y más occidental de la Formación Lauca. Controló también las condiciones paleogeográficas y paleoambientales en las que estas unidades se depositaron. Condiciones más húmedas al lado oriental del Cordón Chapiquiña-Belén favorecieron el desarrollo de flora y de abundantes mamíferos. La deformación se asocia a la falla inversa de Jaropilla y al Anticlinal Chucal, al este de la falla. La deformación en el Anticlinal Chucal comenzó antes del inicio de la depositación de la Formación Chucal y estuvo controlada por una falla inversa ciega. Los estratos del flanco occidental tienen un manteo casi constante de 45–50° al oeste y la serie estratificada es contínua, en cambio, en el flanco oriental el manteo disminuye alejándose del eje del pliegue y la serie es discontínua; el crecimiento del anticlinal determinó en este flanco el desarrollo de tres discordancias progresivas observables. La deformación fue particularmente rápida durante la depositación de los ~600 m de espesor de la Formación Chucal (entre los 21,7±0,8 Ma de la parte superior de la Formación Lupica y los 17,5±0,4 Ma de la base de la suprayacente Formación Quebrada Macusa, un periodo de 4 m.a.). La velocidad de deformación disminuyó durante (1) El periodo de 7 m.a. que tardó la depositación de los ~200 m de espesor de la Formación Quebrada Macusa, entre los 17,5±0,4 Ma obtenidos en su base y los ~11 Ma obtenidos en su parte superior y (2) el periodo de 7 m.a. que tardó la depositación de la parte inferior de la Formación Lauca, entre los ~11 Ma de la parte superior de la Formación Quebrada Macusa y los 2,3±0,7 Ma obtenidos en la Ignimbrita Lauca, intercalada en su parte media. Asociamos esta deformación con la actividad tectónica que causó el alzamiento del Altiplano, sin embargo, evidencia paleobotánica previa no indica cambios altitudinales mayores en el periodo aquí considerado y sugiere, más bien, que el rápido alzamiento se habría producido después de la depositación de la Formación Quebrada Macusa.

1. Introduction

The Andean Cordillera is the typical example of a subduction-related mountain belt (cordilleran-type mountain belts sensu Dewey and Bird, 1970), formed through crustal shortening and thickening and magmatic additions along the border of the overriding plate. In this case, the mountain range formed along the western continental margin of South America above the subducting Nazca plate (Jordan et al., 1983; Allmendinger, 1986; Isacks, 1988; Ramos, 1988; Kono et al., 1989; Kay and Abbruzzi, 1996; Allmendinger et al., 1997; Muñoz and Charrier, 1996). The tectonic evolution and resulting paleogeographic features of the southern central Andes therefore directly reflect subduction activity (Charrier, 1973; Frutos, 1981; Jordan et al., 1983, 1997; Ramos, 1988; Mpodozis and Ramos, 1989).

Although the convergence of the Nazca and the South American plates suggests a continuous, long-term compressive strain regime along the active continental margin, the resulting tectonic style suggests that the stress regime underwent a series of major changes during Andean evolution. Along the northern and central Chilean Andes, there is growing evidence of a late Cenozoic extensional event followed by a long episode of contraction (for the region discussed herein, see García, 1996; García et al., 1996; for farther south at 27°S, see Mpodozis et al., 1995; for localities between 33 and 36°S, see Charrier et al., 1994a, 1999, 2002; Godoy and Lara, 1994; Godoy et al., 1999; Jordan et al., 2001). The tectonic style that results from a contractional episode generally is characterized by high-angle thrust faults with variable vergence, which strongly suggests that they are inverted normal faults (Muñoz and Charrier, 1996; García, 1996, 2001; Farías et al., 2002). In the altiplano of northern Chile, the contractional episode began in the early Miocene and seems to have continued until the Pliocene (Muñoz and Charrier, 1996; García, 1996, 2001; García et al., 1996; Riquelme, 1998). The plant and palynologic content of the early Miocene deposits described subsequently strongly indicate that they were deposited at a rather low altitude above sea level (Charrier et al., 1994b). A similar conclusion has been derived from somewhat younger deposits located only 100 km away in Bolivia (Gregory-Wodzicki et al., 1998).

We present evidence of rapid east-vergent contractional deformation during the Miocene in the Western, or Volcanic, Cordillera of the Chilean altiplano in the Arica region (18–19°S), following a probable extensional episode. This deformation episode is associated with important local topographic changes.

We describe the early Miocene–Pliocene syntectonic evolution of a series of fluvial and lacustrine deposits, associated with a well-exposed, east-vergent, anticlinal structure in the Cerro Chucal region, next to Salar de Surire (Fig. 1). The excellent exposures, numerous fossil-bearing horizons, and frequent occurrence of abundant datable volcanic material provide a detailed chronology of the evolution of the east-vergent structural system that developed on the east side of a contemporaneously uplifted block: the Chapiquiña-Belén ridge (Charrier et al., 2000) (Fig. 2). The uplift of this block probably caused major modifications in the drainage pattern of the Arica region, as well as rapid paleogeographic variations on the eastern side of the Chapiquiña-Belén ridge. These rapid paleogeographic