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Stratigraphic evolution of a submarine channel–lobe complex system in a narrow fairway within the Magallanes foreland basin, Cerro Toro Formation, southern Chile

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ABSTRACT

This study integrates newly acquired stratigraphic data, geologic mapping, and paleocurrent data to constrain the stratigraphic evolution of the oldest channel–lobe complex in the Upper Cretaceous Cerro Toro Formation in the Silla Syncline area of the Magallanes Basin, termed the Pehoe member. The Pehoe member ranges in thickness from 60 m in the north to at least 410 m farther down system and comprises three separate divisions (A, B, and C). A lower conglomerate unit and an upper one, termed Pehoe A and C divisions respectively, represent the fill of major incised submarine channels or channel complexes. These are separated by stratified sandstone of the Pehoe B division, representing a weakly confined lobe complex, either transient or terminal.

The integration of new data with observations from previous studies reveal that the three main coarse-grained conglomerate and sandstone members in the Cerro Toro Formation in the Silla Syncline include at least seven distinct submarine channels or channel complexes and two major lobe complexes. The thinning and disappearance of these units along the eastern limb of the syncline reflect confinement of the flows to a narrow trough or mini-basin bounded to the east by a topographic high. This confinement resulted in unidirectional paleocurrents to the south and southeast in all deposits. Changes in depositional geometries are interpreted as reflecting changes in sediment supply and relative confinement. Submarine channels were from 700 m to 3.5 km wide and occupied a fairway that was 4–5 km wide. Flows moving south and southeast in this mini-basin probably crossed the eastern topographic high south of the present exposures and joined those moving southward along the axis of the foreland basin at least 16 km to the east.

1. Introduction

Slope mini-basins are well documented features in continental margin settings (eg., Bouma, 1982; Satterfield and Behrens, 1990; Pratson and Ryan, 1994; Prather et al., 1998; Beaubouef and Friedmann, 2000; Booth et al., 2000; Badalini et al., 2000; Adeogba et al., 2005; Mallarino et al., 2006; Madof et al., 2009). However, submarine mini-basins along the margins of foreland basins are considerably less well known. Outcrop examples include several Grès d'Annot mini-basins of the French Alpine foreland basin (Sinclair, 2000; McCaffrey and Kneller, 2001; Amy et al., 2007); the Taveyannaz sandstone in the "Inner" sub-basin of the North Alpine Foreland Basin, Eastern Switzerland (Sinclair, 1992); the intra-slope mini-basin in the Tres Pasos Formation in the Magallanes foreland Basin, southern Chile (Shultz and Hubbard, 2005); the Apennine satellite basins (Ricci Lucchi, 1986, 1990), such as the Deruta wedge top basin (Conti et al., 2008) in Northern Italy; and the sub-basins in the Southern Pyrenean foreland basin, Spain (Ardèvol et al., 2000). Subsurface examples include piggyback basins of the Upper Puchkirchen Formation in the Upper Austrian Molasse Basin (Covault et al., 2009). These mini-basins are often enclosed, generally crescent to elliptical shaped, and initially filled with relatively unconfined turbidite lobes developed on the basin floor. Some show a ponded-to-bypass succession (fill and spill), recording the initial basin filling by aggradation and a subsequent spilling of sediment further downstream into another basin (Sinclair, 2000; Amy et al., 2007).

Fewer open, trough-shaped mini-basins within foreland basins have been documented. Two examples include the Mesohellenic piggyback basin (Doutsos et al., 1994; Zelilidis, 2003), and parts of the Langhe sub-basin in the Tertiary Piedmont Basin (Gelati and Gnaccolini, 1998). A modern seafloor example of a relatively small,

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structurally confined trough of about 2 km length and 1 km width is present within the Levant deep-water fold- and thrust belt (Clark and Cartwright, 2009; their Fig. 11), which is not directly related to a foreland basin. Basin configuration clearly plays a major role in controlling the stratigraphic evolution and architecture of the deep-water basins. In order to better understand these relationships, detailed, bed-scale observations need to be tied into a larger, depositional system-scale context (see also Flint et al., 2011; Gagnon and Waldon, 2011; Pyles et al., 2011; Romans et al., 2011; Tinterri and Muzzi-Magalhaes, 2011).

The present study presents an outcrop analysis of a confined, submarine depositional system in the Magallanes foreland basin, southern Chile. This system is unusual because it developed within a trough-like mini-basin that acted as a fairway for sediment gravity flows on the arc side of the larger Magallanes foreland basin. Termed the Silla Syncline mini-basin, the basin fill consists of at least 1100 m of strata composed largely of mudstone and thin-bedded sandstone but includes three major coarse-grained conglomerate and sandstone units. From base to top, these coarse units have been named the Pehoe, Paine, and Nordenskjöld members (Crane and Lowe, 2008). Previous studies have described and interpreted the Paine (DeVries and Lindholm, 1994; Coleman, 2000; Beaubouef, 2004; Crane and Lowe, 2008; Campion et al., 2011) and Nordenskjöld (Barton et al., 2007a; O'Byrne et al., 2007) members.

The objectives of this study are to explore the lithology, stratigraphic architecture, sedimentology, and evolution of the Pehoe member in the Silla Syncline mini-basin. These results are combined with previous studies of the overlying Paine and Nordenskjöld members to develop a model of the origin and filling of the mini-basin as a whole.

2. Geologic background

2.1. Geologic setting of the Magallanes Basin

The Magallanes Basin is an elongate, north-south oriented retroarc foreland basin located east of the Cordillera de los Andes on the southwestern edge of the South American plate (Fig. 1). Its predecessor basin, the Rocas Verdes backarc basin, originated as a rift basin from a Middle to Late Jurassic extensional episode associated with the initial breakup of Gondwanaland (Gust et al., 1985; Biddle et al., 1986; Pankhurst et al., 2000; Fildani and Hessler, 2005; Calderón et al., 2007). Deposits of the Zapata Formation draped the structurally partitioned, sediment starved Rocas Verdes backarc basin with a thick (>600 m), mud-rich cover (Fig. 1; Fildani and Hessler, 2005). The inversion of the Rocas Verdes backarc basin into a foreland basin was associated with the onset of the Andean orogeny in Late Cretaceous time. Compression caused flexural loading, which created a narrow, elongate foredeep, the Magallanes Basin, that subsided to bathyal water depths (Natland et al., 1974; Dalziel, 1986; Wilson, 1991).

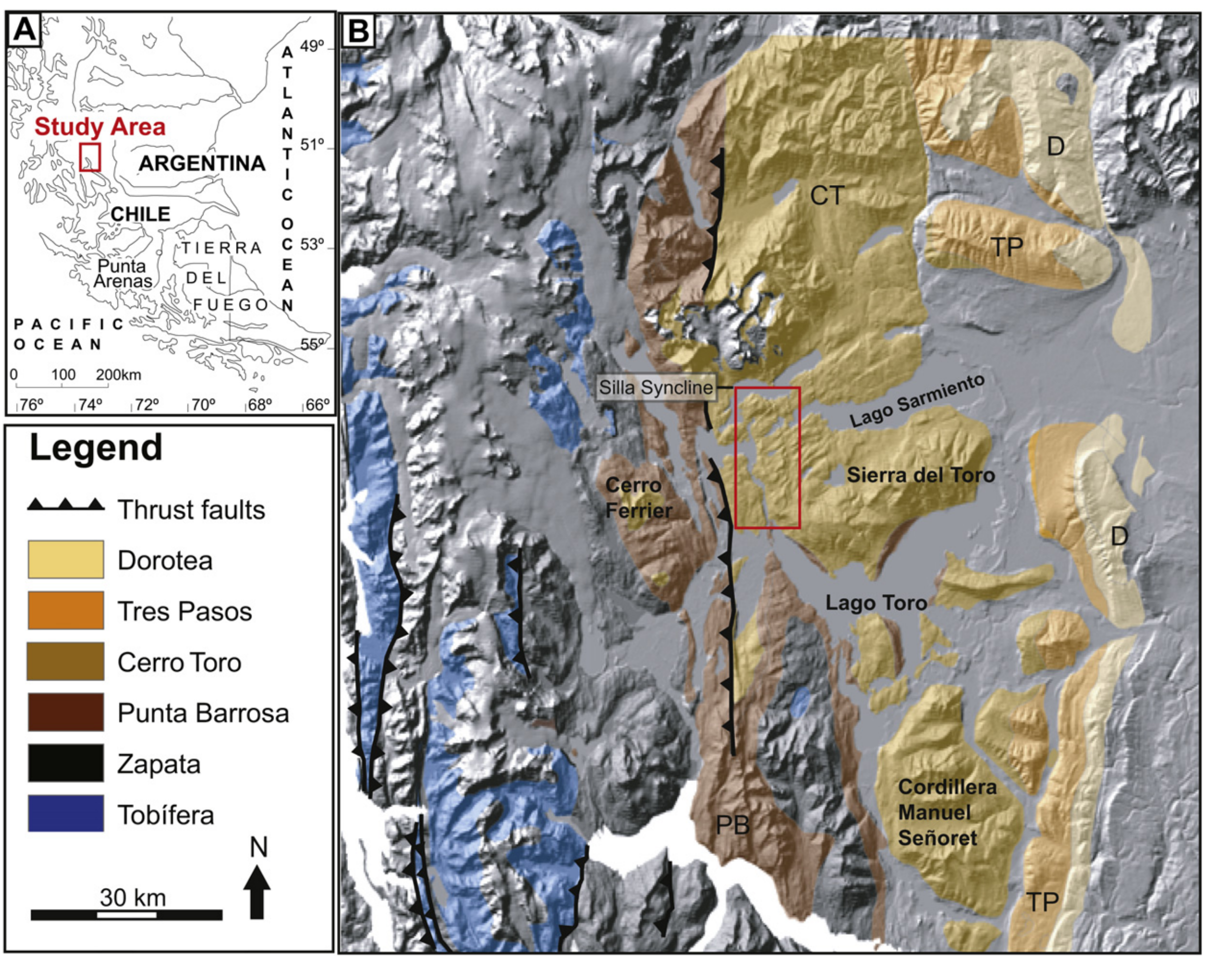

Fig. 1. (A) Overview map of southernmost South America showing the location of the study area. (B) Geologic map of the Ultima Esperanza district showing the Zapata and Tobífera Formation of the predecessor backarc basin (Rocas Verdes) and the deep- to shallow-water basin fill of the marine Magallanes foreland basin, the Cerro Toro, Tres Pasos and Dorotea formations (modified from Fosdick et al., in press).