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The origin of oriented lakes in the Andean foreland, Parque Nacional Torres del Paine (Chilean Patagonia)

Joseph Gonzales *, Atilla Aydin

Stanford University, Geological and Environmental Sciences, 450 Serra Mall, Braun Hall, Bldg 320, Stanford, CA 94305, USA

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Abstract

The Parque Nacional Torres Del Paine and surrounding area in the Magallanes foreland basin in Chilean Patagonia is the site for numerous lakes fed by glaciers and rivers in the Andean highlands to the west. The lakes are elongate and have conspicuously systematic orientations. We hypothesize that the origin of the oriented lakes lies in the fault system, composed of a right-lateral strike-slip fault set oriented 58° from north, a left-lateral strike-slip set oriented 87°, and a thrust fault set oriented 167°, that exists within the underlying rocks. To test this hypothesis quantitatively, we determined the shape and orientation of the lakes by fitting each lake with an ellipse of appropriate aspect ratio, and later with multiple ellipses consistent with the composite geometry of some lakes. We then examined the faults in the area in terms of their kinematics, orientation and distribution. The distribution of lake orientations showed three distinct groups which appear to correspond to the three main fault groups. For lakes fitted with multiple ellipses, the difference in means between the right-lateral, left-lateral, and thrust faults and their corresponding groups of lakes are 3.05°, 1.57°, and 5.17°. Using a Kolmogorov–Smirnov (K–S) statistical test to compare the orientations of faults with respect to the lakes suggests that there is not a strongly significant difference between the fault orientations and the corresponding lake groups. These results indicate that the faults have a profound control on the orientation, shape, and distribution of the lakes. We attribute this to faults and their damage zones being weaker and therefore prone to a faster rate of erosion, and to stress perturbations associated with discontinuous faults resulting in localized high density fracturing and surface subsidence. These results have implications for lake and drainage system morphologies in other foreland basins along the Andes and other similar settings.
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Keywords: Lake morphology; Faults; Damage zone; Chile

1. Introduction

The Andean foreland, and particularly the Parque Nacional Torres Del Paine are the sites for numerous oriented lakes, ranging from 0.03 km^2 to 40 km^2 in size. The origins of these lakes and the reason for their alignment are not well known. The only relevant effort in this regard is that of Plafker (1964) who analyzed the orientation, shape, and distribution of the lakes in continental sediments in the Bolivian foreland, and suggested that aerial subsidence or sags in the surface of the sediments overlying fracture-bounded basement blocks may have been the cause for lake alignment.

* Corresponding author. Tel.: +1 650 725 8708; fax: +1 650 725 0979.
E-mail address: joeg1@pangea.stanford.edu (J. Gonzales).

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In this paper we begin with the premise that the structural and tectonic settings play a profound role in geomorphology through deformation, erosion, and weathering. We test this premise first at the small scale in the Parque Nacional Torres Del Paine by analyzing the geometry and distribution of the lakes, characterizing the structural elements of the area, and examining the interplay between structural elements, particularly faults and their damage zones. We use mechanical principles for stress distributions and damage zones associated with discontinuous faults to support our hypothesis for the oriented lakes in the detailed study area. We then examine a larger area surrounding the national park to see if the results from the detailed study are applicable to the greater area. Finally, we compare the conclusions from this study to the Bolivian foreland and propose that our results may be applicable to other regions with similar structural settings.

2. Geographic and geological settings

The study area is located in the Parque Nacional Torres Del Paine, centered about 51°S and 73°W in the eastern part of the N–S-trending Andean orogenic belt in Chilean Patagonia (Fig. 1A). Most of the field data in this study was collected from an area that includes a major syncline, the Silla Syncline, and bounding thrust cored anticlines. Also present are many lakes, including Lago Grey, Lago Nordenskjold, Lago Pehoe, Lago Sarmiento, and Lago Toro (Fig. 1B).

The Magallanes Basin has been characterized as a retro-arc foreland basin (Wilson, 1991), related to the Andean Orogeny (Fig. 1C). Prior to the orogeny, in the Late Jurassic to the Early Cretaceous, the area had undergone extension related to the breakup of Gondwana, which resulted in the development of a back arc basin (Bruhn et al., 1978, Gust et al., 1985, Fildani and Hessler, 2005). The change from extensional to compressive environments and the creation of the Magallanes Basin is believed to be the result of the eastward progression of Andean orogenic activity.

The Magallanes foreland basin was filled in the Late Cretaceous to early Tertiary, with approximately 7 km of sediments (Wilson 1991; Biddle et al., 1986; Crane, 2004). The sediments in the Silla Syncline are part of the Cerro Toro Formation, which is present throughout much of the Magallanes Basin (Fig. 2). The thickness of the Cerro Toro Formation is estimated at 2000–2500 m (Katz, 1963; Wilson, 1991). The age of the formation, based on fossil evidence, is middle to upper Senonian (Katz, 1963), but might be younger based on recent zircon analysis of the underlying Punta Barrosa Formation (Fildani et al., 2003). The lithology of the Cerro Toro Formation is dominantly mudstone and thin bedded fine sandstone turbidites containing several thick (at times greater than 200 m) sequences of conglomerate

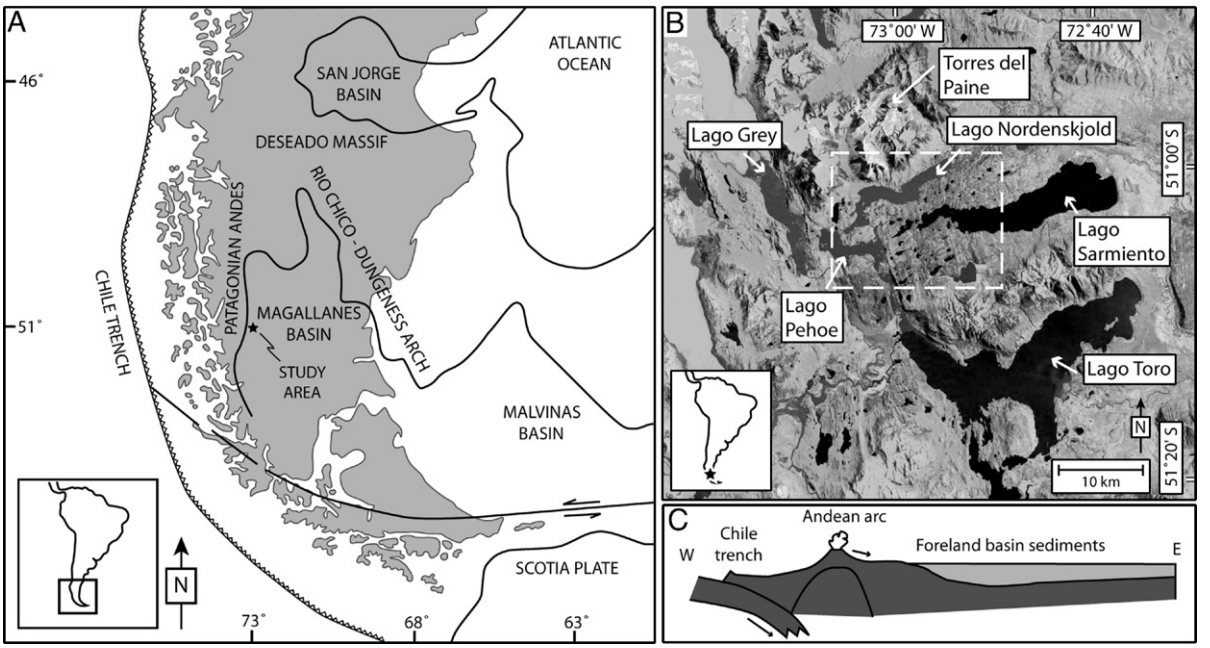

Fig. 1. A) Satellite image showing the location of major lakes in the study area. White box is the location of the detailed study area shown in Figs. 2 and 6. B) W–E section across the Andean subduction zone and the Magallanes foreland basin, adapted from Wilson (1991).

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