Lithostratigraphy, depositional environments and tectonic setting of the Bahía Inglesa Formation west of Copiapó, north-central Chile

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Abstract. As yet unpublished stratigraphic sections were used to revise the lithostratigraphy and conduct a geohistory analysis of the Bahía Inglesa Formation south of Caldera. This indicates that the basin began to subside from more than 100 m above present sea-level at 15 Ma to reach 100 m below sea-level at around 9 Ma. It then experienced an uplift of 100 m until 7.7 Ma, and then subsided more than 300 m until 6 Ma, before being uplifted again by 200 m until 5 Ma. These tectonic events are ascribed to the southward migration of the Juan Fernández Ridge underneath the continental crust. Differences in the migration speed and intensity of uplift-subsidence cycles can possibly be attributed to oroclinal bending of the Juan Fernández Ridge due to friction with the overlying continental plate.

Keywords: Caldera Basin; Juan Fernández Ridge; oroclinal bending

1 Introduction

We present an interpretation of the stratigraphy, age and depositional environment of the Bahía Inglesa Formation in the Caldera Basin west of Copiapó, based on as yet unpublished stratigraphic sections. The basin, which stretches south along the coastal plain from Caldera to the mouth of the Copiapó River, is filled by a Neogene marine succession overlying Paleozoic metamorphic rocks and Mesozoic granitoids. The succession is subdivided into the Angostura Formation, dated at 15.3±0.6 Ma (Henriquez, 2006), Bahía Inglesa Formation, and the Caldera Beds. The Bahía Inglesa Formation is a semi-consolidated sequence of fossiliferous, clastic and phosphatic rocks characterized by numerous lateral and vertical facies change. It has been dated by different authors as middle Miocene to Pliocene in age, whereas the depositional environment has been interpreted as ranging from the littoral zone to the upper continental slope (Marquardt, 1999; Godoy et al., 2003; Achurra, 2004; Henriquez, 2006; Achurra et al., 2009, Carreño, 2012).

2 Stratigraphy

A total of 32 stratigraphic sections were measured in the Bahía Inglesa Formation since 2003, but they have only been informally recorded in unpublished Graduate and Masters Theses (Achurra, 2004; Henriquez, 2006; Carreño, 2012). Of these, one section (Le Roux, unpublished work) lies within a submarine canyon cutting through older strata of the Bahía Inglesa Formation, so that the canyon-fill deposits cannot be correlated directly with the rest of the Bahía Formation profiles, even though they are considered to belong to the same succession. Table 1 shows the proposed stratigraphic subdivision, depositional environments and approximate ages.

3 Metodology

The sedimentary facies and stratigraphic succession of the Bahía Inglesa Formation reflect sea-level oscillations that can be used, in conjunction with global sea-level curves (Hardenbol et al., 1998), to deduct relative tectonic movements affecting this part of the southeastern Pacific coastline during the Neogene. The methodology, known as geohistory analysis, consists of determining the age and depositional depths of the units composing a stratigraphic succession, relating the paleobathymetry to the global sea level at the time, and calculating the progressive elevation of a reference surface relative to the present sea level. Here, the cumulative thickness of the units must be employed, but in this case the thicknesses of the different members are variable from section to section and in some cases incomplete, e.g. where the base or top of the member was not exposed. Therefore, only the maximum measured thickness of each particular member, rounded to the nearest meter, was used. The cumulative thickness was measured upward from the reference surface (the contact between the Angostura Member and the Jurassic basement at Puerto Viejo) to the middle of each member, thus progressively adding half the maximum thickness of each member to those of the underlying members. As concerns the paleobathymetry, the following mean depositional depths were assigned to the different facies: supratidal flat – 1 m; foreshore – 0 m; estuary – -10 m; upper shoreface -, -20 m; middle shoreface – -50 m; lower – shoreface – -

80 m; inner shelf – -120 m; outer shelf – -170 m; upper continental slope – -500 m. Fig. 1 shows the results of this analysis.

4 Results and discussion

The absence of rocks with an age between 15.3 and about 10 Ma in the coastal sector between Puerto Viejo and Caldera indicates a major unconformity, suggesting that this part of the coastline was subjected to subaerial erosion during the Langhian to early Tortonian. The Angostura Formation was deposited in a shoreline environment, probably a paleo-estuary of the Copiapó River, but at an elevation of about 100 m above present sea level. Since 15.3 Ma, tectonic subsidence occurred simultaneously with a drop in sea-level, but no marine deposition took place until about 10 Ma. From 10 – 9.0 Ma, the basin subsided to 100 m below present sea level, rising about 70 m between 9.0 and 8.0 Ma. This was followed by dramatic subsidence of nearly 300 m, bringing the depositional depths to that of the upper continental slope. However, a similarly dramatic turn-around at about 7 Ma uplifted the coastal sector more than 200 m, succeeded by another subsidence of 70 m until 2.3 Ma.

The seaboard of around 100 m a.s.l. at 15 Ma can possibly be attributed to the presence of the NE-trending Juan Fernández Ridge underneath the continental crust during the Langhian. As the ridge migrated southward, the crust subsided strongly in its wake, before isostatic rebound caused renewed uplift during the Zanclean. These events mirror similar tectonic processes described further south at Carrizalillo and Tongoy (Le Roux et al., 2005). However, there was apparently a slower migration rate and more intense uplift-subsidence effects in the Caldera area than further south. This could be attributed to oroclinal bending of the Juan Fernández Ridge due to friction with the overlying continental plate, which diminished the angle of incidence and the intensity of the stress field, but increased the migration velocity of the ridge relative to the coastline.

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Table 1. Stratigraphic subdivision of the Bahía Inglesa Formation (A = Achurra, 2004; H = Henríquez, 2006; C = Carreño, 2012).

New subdivision (Members)	Correlation with older units	Lithological characteristics and maximum recorded thickness	Depositional environments	Age range Mdeian age): Ma
Quebrada Blanca	8, 9 (A); 11 (H)	Conglomerate, sandstone, (bio)calcirudite, diatomaceous shale (23)	Upper – lower shoreface, tsunami backflow	<2.3
Rocas Negras	6, 7 (A); 12 (H); 7 (C)	(Bio)calcirudite, (bio)calcarenite, minor tuff, conglomerate, sandstone, shale (30 m)	Upper – middle shoreface	4.2
Mina Fosforita	4, 5 (A); 8, 9, 10 (H); 4, 5, 6 (C)	Sandstone, siltstone, shale, minor phosphate-pebble conglomerate, biocalcarenite (22 m)	Upper shoreface – upper continental slope	7.6–6.0 (6.8)
Chorillos	4 (C)	Conglomerate with large rip-up clasts (8 m)	Submarine channel, tsunami backflow	8.1–6.8 (7.5)
La Higuera	4 (A); 8 (H); 2, 3, 4 (C)	Shale, sandstone, siltstone, gypsum veins (26 m)	Outer shelf – upper continental slope	9.2–7.0 (8.1)
Cerro Ballena	8 (C)	Sandstone, siltstone (9 m)	Supratidal flat	9.0–6.5 (8.4)
Punto Totoral	2, 3, 4 (A); 4, 7 (H): 2, 3 (C)	Biocalcarenite, biocalcirudite, conglomerate (23 m)	Upper – middle shoreface	9.9–8.5 (9.2)
Puerto Viejo	1, 2 (A); 6 (H); 1 (C)	Sandstone, siltstone, shale (11 m)	Middle – lower shoreface	9.7–9.2 (9.5)
El Pimiento	1, 2 (A); 3, 5, 6 (H)	Biocalcarenite, (bio)calcirudite, sandstone, minor conglomerate, shale, claystone (24 m)	Upper – lower shore-face	9.9–9.5 (9.7)

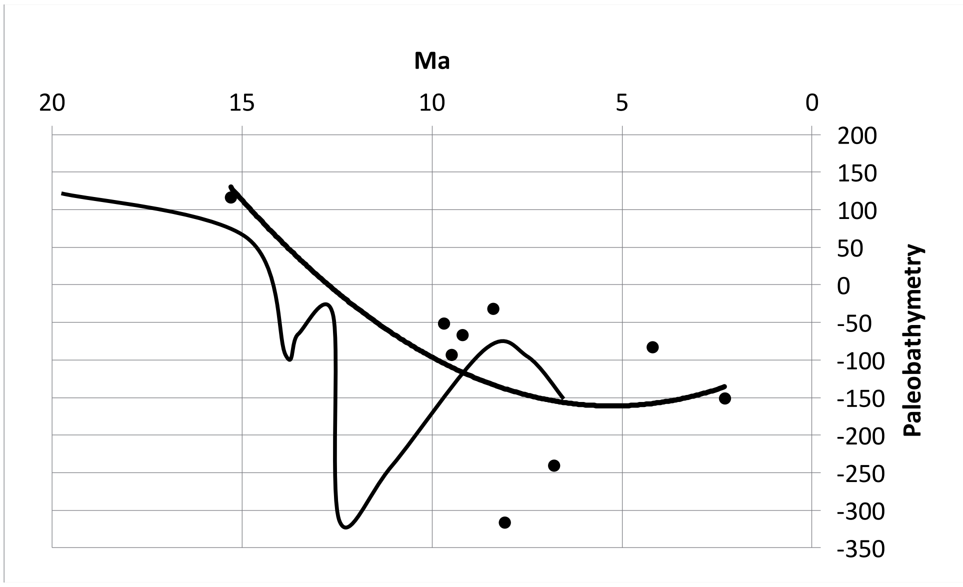

Figure 1. Tectonic uplift and subsidence in the Caldera basin as reflected in the Bahía Inglesa Formation.

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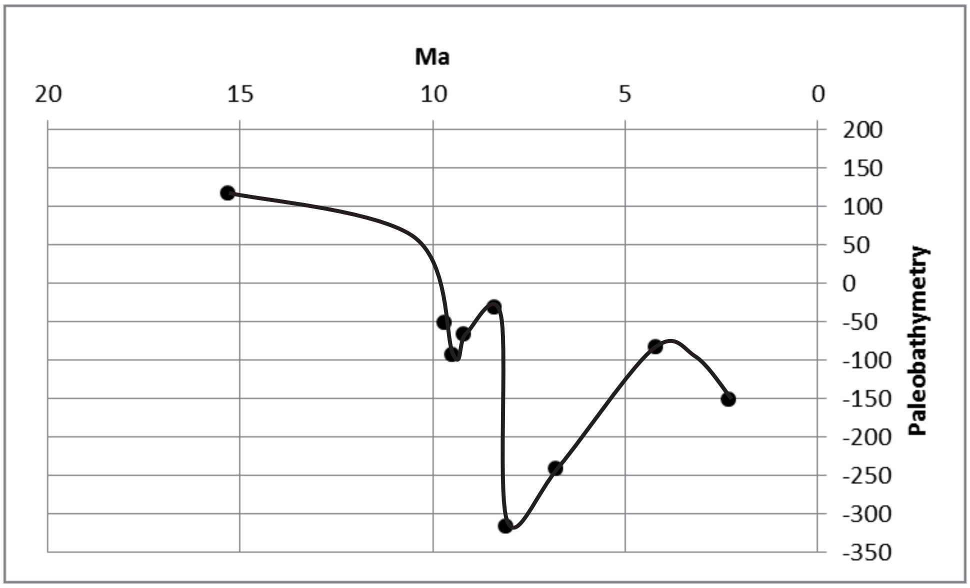

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