Late Cenozoic climate indicators in marine sediments of southern Chile: Indications for the expansion of the circum-Antarctic cryosphere and impact on strength of the subduction zone

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Introduction

In the Southern Central Andes between 33°S and 40°S the Andean subduction orogeny as a result of upper-plate contraction is limited to the Middle and Late Miocene. Pliocene volcanics that cover the Miocene deformation structures south of the Juan Fernandez ridge (33°S) are either undeformed or only affected by transtensional structures. In contrast, north of the ridge, upper plate shortening has been continuous throughout the Neogene and Quaternary. These differences have been related to the variations in trench fill on either side of the ridge. To the north the trench is virtually empty, whereas the sediment fill exceeds 1.5 km south of it (Bangs & Cande, 1997). These sediments most likely reduce the strength of the plate interface and thus inhibit shortening of the upper plate (Lamb & Davies, 2003). The trench sediments are mainly derived from the North Patagonian Andes between 39°S and 46°S which have been repeatedly glaciated in the last 7 Ma (Mercer & Sutter, 1982) as a result of global cooling (Zachos et al., 2001). Hence, the climate history of Southern Chile may have played a key role in limiting the southward growth of the Andean subduction orogen. However, the timing of Late Cenozoic cooling in Southern Central Chile remains poorly documented.

Here we review the available Neogene climate indiactors for Southern Central Chile in an attempt to test the relation of climate change and upper plate shortening evolution.

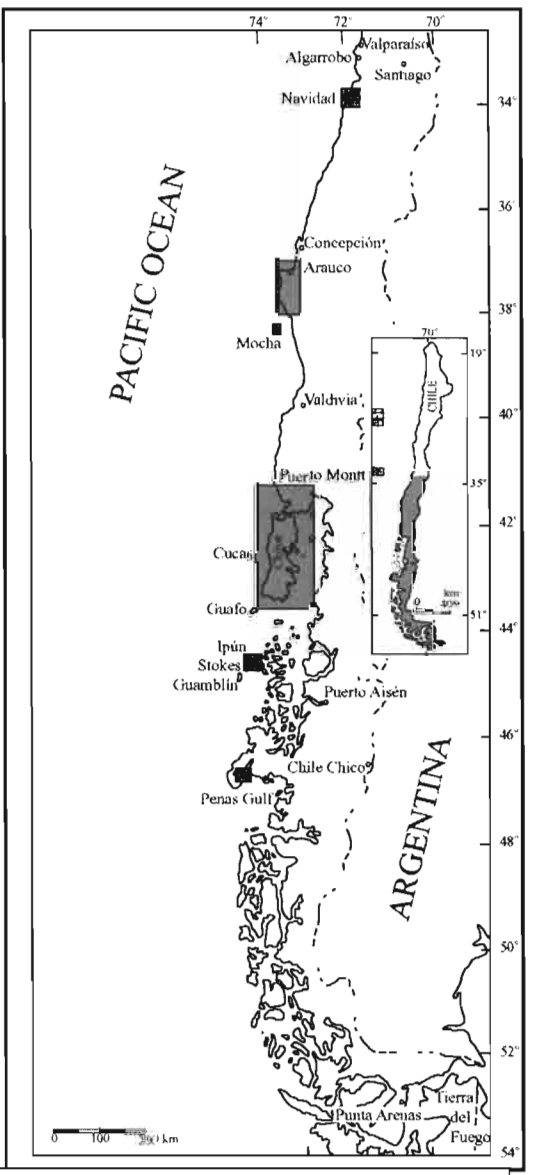

Figure 1. Cenozoic marine deposits in southern Chile (shaded boxes) containing the investigated faunas. Miocene deposits exist in Navidad, Arauco, Mocha, Cucao, Ipún,

Neogene climate in Southern Central Chile

The global cooling that started after the middle Miocene climatic optimum led to an expansion of the circum-Antarctic cryosphere driven by the northward migration of the westerlies, similar to the glacial-interglacial cycles of the Quaternary (Lamy et al., 2004).

Because of its geographic position, the South American continent offers the unique opportunity to study Cenozoic climate changes on-shore along a wide range of high latitudes. The here revised deposits are located between 33° and 47°S (Figure 1) and include several Miocene and Pliocene units and their respective faunas. Sedimentation is almost exclusively clastic and ranges from mudstones to granitoid boulders. The only detailed sedimentological study is that of Encinas et al. (2003) for the Navidad Formation, but due to its complex history (Finger et al., 2003; Nielsen et al., 2003) it includes the sediment types of the other deposits, although the depositional environment may vary significantly between units.

The early to middle Miocene molluscan fauna in the Navidad Formation and its southern equivalents (i.e., the Ranquil Formation of Arauco and the Lacui Formation of Chiloé Island) has affinities with that of Peru (DeVries & Frassinetti, 2003; Nielsen et al., 2003) and contains many tropical to subtropical taxa (Covacevich & Frassinetti, 1980; Frassinetti & Covacevich, 1981, 1982; Groves & Nielsen, 2003; Nielsen, 2004), although the indicators for warm climate become less frequent towards the south. However, most are shallow water taxa that have been reworked and displaced at greater depth during the latest Miocene or earliest Pliocene (Finger et al., 2003; Nielsen et al., 2004) when few warm water taxa were still living in central Chile (Nielsen & DeVries, 2002). The associated microfauna of foraminifers and ostracodes is typical of the transitional middle latitudes in the temperate zone. A warmer and more humid climate during the (late?) Miocene is evidenced by fossilized woods from the Ranquil Formation of Arauco (Schöning & Bandel, 2004). The deposits from Mocha Island contain a similar fauna to that of the Navidad Formation (Tavera & Veyl, 1958), but due to some differences are considered here to be slightly younger. The molluscan faunas from Ipún and Stokes Islands (Frassinetti, 2001, 2004) correlate closely with that of the Navidad Formation and an early to middle Miocene age has been inferred for the deposits accordingly. The age of the Chaicayán Group of the Penas Gulf has been given as late Miocene by Forsythe et al. (1985), but some groups of mollusks differ significantly from those of the more northern units.

The Pliocene La Cueva Formation (e.g., Herm, 1969) contains a shallow water molluscan fauna similar to that of today. The late Pliocene Tubul Formation of Arauco (Biro, 1979) contains a moderately shallow water molluscan fauna that is similar to the modern fauna of the Magellan region, indicating cooler water temperatures then those of today (Valdovinos & Nielsen, in prep.). Frassinetti (1997, 2000) suggested a Pliocene age for the deposits of Guafo Island based on the gastropods and bivalves encountered, which correlate closely with the molluscan fauna from Guamblín Island (Frassinetti & Covacevich, 1995) and Tubul (Arauco Peninsula).

Preliminary results

Preliminary analysis of Cenozoic faunas from southern Chile leads to recognition of several climatic stages. (1) During the early to middle Miocene, shallow water temperatures were relatively high with a low latitudinal gradient from 33° to 47°S. (2) Temperatures around the Miocene-Pliocene boundary were temperate. (3) Late Pliocene faunas show cooler water temperatures than today.

Conclusions

Our preliminiary results indicate that the climatic evolution apparently reflects the northward migration of the westerlies zone. However, the chronology of the migration remains poorly constrained, much worse than the sedimentary record of upper plate contraction. Hence, at this stage we are unable reconstruct the sequence of events in sufficient detail to asses the impact of global cooling onto subduction orogeny.

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