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Correlation and paleoenvironments of middle Paleogene marine beds based on dinoflagellate cysts in southwestern Patagonia, Argentina

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ABSTRACT

An understanding of paleonvironmental and paleoceanographic evolution of the Southwestern Atlantic Ocean during the Palaeogene is prevented by the lack of precise tools to date and correlate the sedimentary units. Palynological samples collected in the upper portion of the Man Aike Formation, which crops out southern Lago Argentino area, in the southwest of the Austral Basin (50°21′45″S–72°14′30″W), contain well preserved marine organic dinoflagellate cysts, which are potentially important biostratigraphic and paleoenvironmental indicators. Herein we describe the composition of the Man Aike Formation's dinoflagellate cyst assemblages and compare them to similar assemblages collected in the same basin in the upper member of the Río Turbio Formation using Compositional Statistical Analysis. The dinoflagellate cyst assemblages from the upper part of the Man Aike Formation are highly correlated to the assemblages from the upper member of the Río Turbio Formation from outcropping sections (51°31′13″S–72°15′11″W) and with the lower part of sediment cores drilled by Yacimientos Carboníferos Fiscales in the Río Turbio Formation area. These dinoflagellate cyst assemblages show a very low correlation with the assemblages from the upper part of the Yacimientos Carboníferos Fiscales's cores. The comparison of our results with the high-resolution Southern Pacific Ocean dinoflagellate cyst zonation for the late Palaeocene to late Eocene allow us to date some of the dinoflagellate events recorded in formations of southwestern Patagonia. The assemblages from the Man Aike Formation and the lower part of the upper member of the Río Turbio Formation relate to the zones SPDZ11 and SPDZ12 and are assigned to the mid-middle Eocene (late Lutetian to early Bartonian). The biostratigraphy proposed herein constrains the age of the Man Aike Formation and equivalent units based on calcareous microfossil data, mollusks affinities and $^{87}Sr/^{86}Sr$ isotopic values to an age ranging between ~42 and 39 Ma. The assemblages from the upper part of the upper member of the Río Turbio Formation relate to the SPDZ13 Zone, which corresponds to the late Eocene (early Priabonian). The dinoflagellate cyst assemblages indicate that they were under the influence of relatively warm, marine open waters in an inner-shelf environment for the lower part of the sections. In the upper part of the sections, the assemblages suggest shallow marine waters associated with coastal areas and high trophic levels, possibly as a result of freshwater inputs.

1. Introduction

Early Paleogene climates were considerably warmer than present climate, with higher CO_2 atmospheric concentrations and substantially smaller latitudinal temperature gradients (Greenwood and Wing, 1995; Sexton et al., 2006; Sluijs et al., 2006; Zachos et al., 2008; Bijl et al., 2009). The transition from the early Eocene (greenhouse) to the Oligocene (icehouse) climatic regimes began about 50 Ma, when the Southern Ocean started cooling (Zachos et al., 2001, 2008; Bijl et al., 2009, 2013a). Accelerated global cooling during the late middle Eocene led to the onset of large ice sheets on Antarctica by the end of the Eocene, ~34 Ma (Zachos et al., 1994; Barker et al., 2007). The increasing interest on the climatic evolution during the early Paleogene greenhouse

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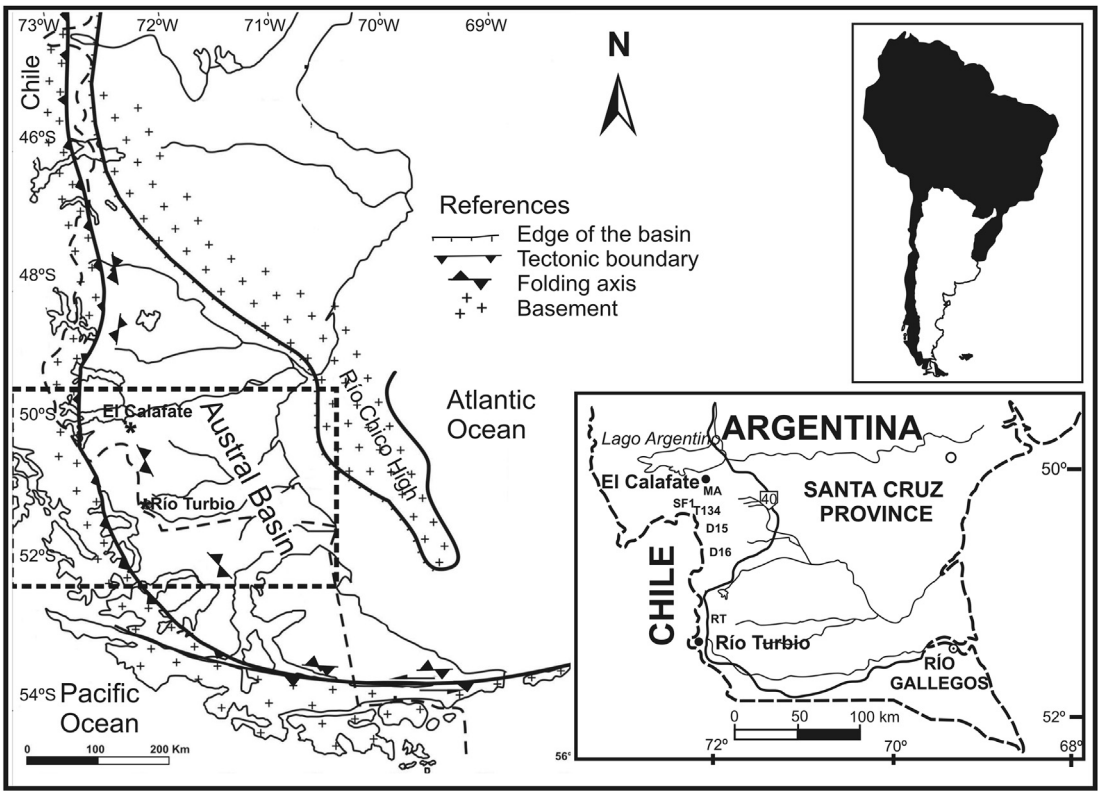

Fig. 1. Map of the south of Patagonia indicating the extension of the Austral Basin. Detail of southern part of Santa Cruz Province showing the location of the studied localities.

interval has promoted numerous multidisciplinary studies in southern high-latitude regions (Bijl et al., 2011 and references therein). However, while much information is now available on the opening of the Tasmanian Gateway and its resulting oceanographic changes, the time of the opening of the Drake Passage is still ambiguous, because only few sections cover the Paleogene in this area. On top of that, lack of biostratigraphic tools to date and correlate the stratigraphic units has hampered paleoenvironmental and paleoceanographic reconstructions during the Eocene.

Planktonic calcareous microfossils, e.g., foraminifera and nannofossils, which are well calibrated for mid-latitude reconstructions are largely absent or poorly preserved at high latitudes (Florindo et al., 2003; Barker et al., 2007). However, based on foraminifera Malumián and Nañez (2011) noted that Patagonian Shelf extended considerably towards the west during the Cenozoic Atlantic transgressions. The development of extensive shallow seas controlled the distribution of planktonic foraminifera by limiting the access of deep-sea species and adult forms. These conditions favored the endemism of the benthic foraminifera. Diatoms and other siliceous microfossils are also rarely preserved in lower Paleogene sediments from the Southern Ocean (Bijl et al., 2013b), particularly in sections cropping out in southwestern Atlantic basins (González Estebenet et al., 2012).

The fossil record of dinoflagellates is composed largely of organic walled dinoflagellate cysts (dinocysts). In distinction to forams and diatoms, the dinocysts are preferentially preserved in settings with high sedimentation rates and low oxygen concentration levels such as the Paleogene marine marginal sediments and the shelf environments of circum-Antarctic areas (Wrenn and Hart., 1988; Brinkhuis et al., 2003a,b; Guerstein et al., 2010a; Bijl et al., 2011). Around 50 Ma the circum-Antarctic dinocyst assemblages shifted from cosmopolitan, being dominated by low-latitude species, to endemic, being dominated by high-latitude species (Bijl et al., 2011, 2013a). The endemic Antarctic assemblage was originally named "Trasantarctic Flora" (Wrenn and Beckman, 1982). Further studies found the species belonging to this Antarctic community in many Southern Ocean sites (Wrenn and Hart, 1988; Cocozza and Clarke, 1992; Mao and Mohr, 1995; Truswell, 1997; Levy and Hardwood, 2000; Brinkhuis et al., 2003a,b; MacPhail and Truswell, 2004; Guerstein et al., 2008; Sluijs et al., 2009; Escutia et al., 2011; Bijl et al., 2011, 2013a,b).

Cores drilled at high latitudes of the Southern Ocean have been calibrated with magnetoestratigraphy (Stickley et al., 2004a; Bijl et al., 2013b). In contrast, the early Paleogene sections exposed in the southern tip of South America are patchy and lack independent age control. Bijl et al. (2011) posited that a species of Paleogene dinoflagellates is endemic to the Southern Ocean when its distribution pattern is restricted to Eocene latitudes south of 45°S. Because of the latitudinal endemism, several dinocyst species are good biostratigraphic markers (Bijl et al., 2013b) and allow the correlation of stratigraphic units from different parts of the Austral Basin (Fig. 1).

Sea-level changes during the Cenozoic caused major transgressions along the South American margin. Particularly, the Austral Basin was almost completely flooded during the middle Eocene. This transgression deposited the Man Aike Formation (MAF) (Furque, 1973) and the upper member of the Río Turbio Formation in the southwestern part of the Santa Cruz Province, Argentina (Malumián, 1999). Due to their proximity to the Drake Passage, whose opening led to major ocean circulation and climate changes during the Paleogene, the marine sediments of the MAF and the Río Turbio Formation (RTF) (Leanza, 1972) are a highly valuable source of information for the assessment of paleoenvironmental and paleoclimate change (Huber et al., 2004; Lagabrielle et al., 2009). The dinocyst assemblages recovered in the MAF and the RTF hold many species endemic to the Southern Ocean, thus