Tectonophysics 594 (2013) 80–90

Contents lists available at SciVerse ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Tectonic and climatic signals from apatite detrital fission track analysis of the Cape Roberts Project core records, South Victoria Land, Antarctica

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ARTICLE INFO

Article history:
Received 10 July 2012
Received in revised form 8 March 2013
Accepted 14 March 2013
Available online 21 March 2013

Keywords:
Detrital thermochronology
Climate/tectonics interaction
Cenozoic tectonics
Antarctica

ABSTRACT

The Cenozoic tectonic reorganization of the West Antarctic Rift System in the Ross Sea region occurred concurrently with a major change in the global climate system and a global reorganization of plate motions. This region thus provides the opportunity to study in detail a range of geological issues dealing with tectonic and climate feedbacks during the late Eocene/early Oligocene greenhouse/icehouse transition at high latitudes. With the aim to decipher tectonic vs. climatic forcing in the ice sheet drainage evolution, a detrital apatite fission track study was carried out throughout the Cenozoic drill-cored stratigraphic succession of the Cape Roberts Project (McMurdo Sound, Victoria Land Basin). Apatite fission-track ages of detrital samples, with depositional ages between 34 Ma and 17 Ma, were decomposed into statistically significant age populations. Three age peaks were detected, reflecting different bedrock provenance areas: (i) a young peak (P1 between 34 Ma and 26 Ma) recording the signal of a source area exhumed with a constant denudation rate, but absent in the proximal continental area; and (ii) two peaks, older than 40 Ma, that are instead compatible with thermochronological data available from the onshore bedrock. P1 peak testifies a late Oligocene–early Miocene denudation event and traces a southern provenance of a fraction of the sediments filling the Cape Roberts Basin. We propose that this denudation event might have been triggered by renewed N–S transtensional shearing along the western shoulder of Victoria Land Basin, controlling glacial flow pattern and the associated sediment transport.

1. Introduction

The greenhouse/icehouse climatic transition at the Eocene–Oligocene boundary defines one of the most important changes of the Cenozoic climate evolution at the global scale (Zachos et al., 2001). It is still debated whether this transition was bipolar and, in particular, whether regional tectonics contributed or not to global climate changes (tectonic forcing vs. climate forcing; Blythe and Kleinspehn, 1998; DeConto and Pollard, 2003; DeConto et al., 2008; Molnar and England, 1990; Thomas, 2008; Tripati et al., 2008).

During the Cenozoic times, a major geodynamic re-organization occurred in the southern hemisphere, with the rifting of the Southern Ocean that caused the tectonic and climatic isolation of the Antarctic plate (Kennett, 1977; Müller et al., 2008). The Antarctic isolation was completed by the formation of the Drake Passage (Scher and Martin, 2006), which was responsible for (i) the deep water connection between the Pacific and Atlantic oceans, (ii) formation of the Antarctic circumpolar current, and (iii) development of the icecap at about 34 Ma (DeConto and Pollard, 2003). In this context, the Cenozoic (Eocene–Oligocene boundary) tectonic re-organization of the West Antarctic Rift System (WARS) in the Ross Sea region occurred (Hamilton et al., 2001; Rossetti et al., 2006; Salvini et al., 1997; Storti et al., 2007; Wilson, 1995) (Fig. 1). The continental rifting started in the Early Cretaceous (cfr. Fitzgerald, 2002) and during Cenozoic times underwent a renewed tectonic activity, mostly recorded in the transition from orthogonal to oblique rifting along the Transantarctic Mountains (TAM) front (Storti et al., 2007).

Tectonic and climate datasets from drilling projects in syn-tectonic basins on the continental shelf along the western margin of the WARS (projects MSSTS, DVDP, CIROS, Cape Roberts and ANDRILL; Fig. 1) provided essential information for the reconstruction of the climate/tectonics interaction during the Cenozoic times. Long-term subsidence/erosion processes (Zattin et al., 2010) and short-term glacial fluctuation related to astronomic cycles (Dunbar et al., 2008; Naish et al., 2001; Roberts et al., 2003) have been reconstructed. Moreover, the detrital thermochronology and sedimentary petrographic records of core samples and well logs from the ANDRILL project (Passchier et al., 2011; Talarico and Sandroni, 2009; Zattin et al., 2010) documented that source areas for sediment supply were dominantly located far to the south. From these recent data it arises that glacial drainage was dominantly parallel to the N–S tectonic structures that formed the

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0040-1951/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.tecto.2013.03.017

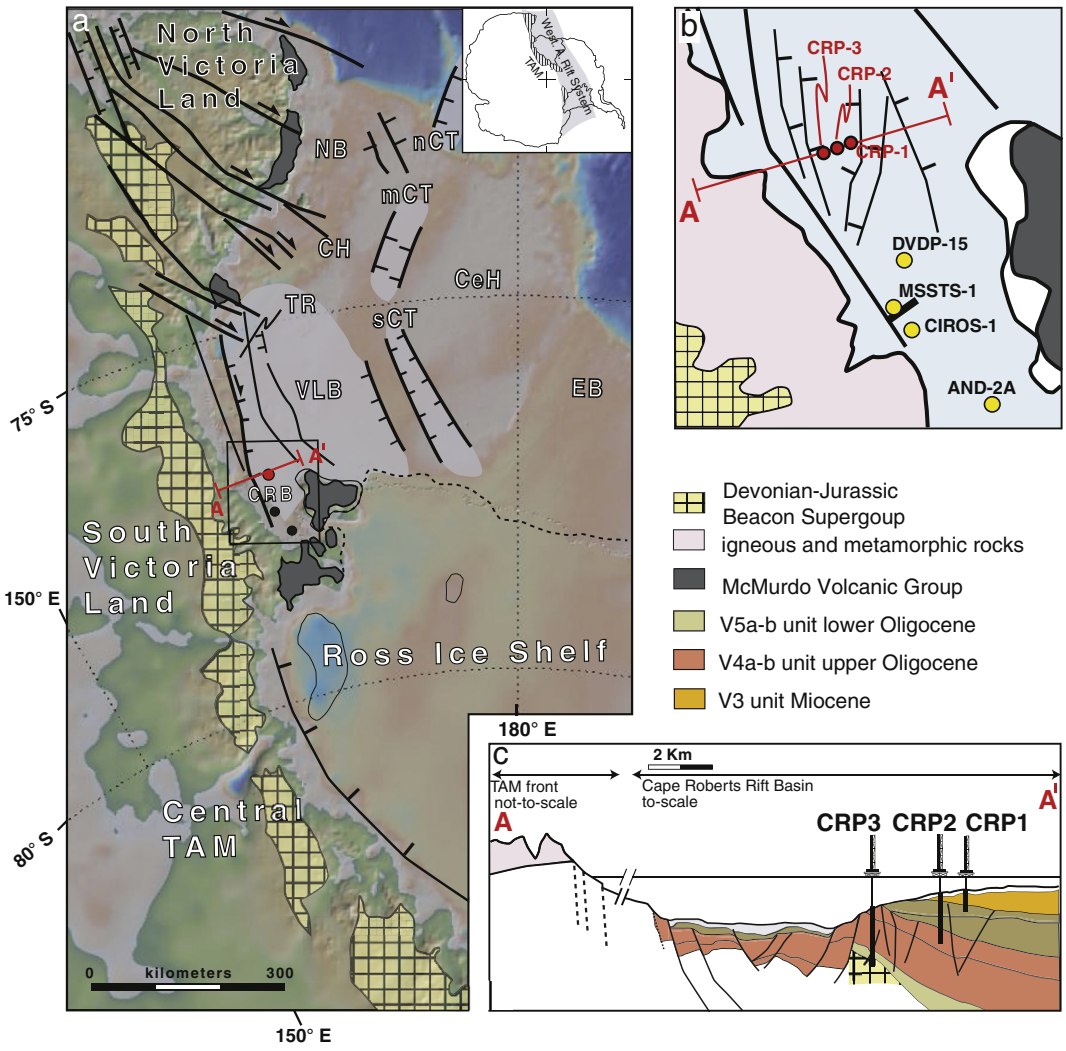

Fig. 1. (a) Map of the Ross Sea region showing the main lithotectonic units of the Transantarctic Mountains (TAM) and principal Cenozoic structural elements, with location of the Cape Roberts Project drill holes. (b) Map of the Cape Roberts Rift Basin showing main tectonic features on top of V4 unit from seismic lines of Hamilton et al. (2001). NB = Northern Basin, nCT = Northern Central Trough, mCT = Mid Central Trough, sCT = Southern Central Trough, CH = Coulman High, CeH = Central High, TR = Terror Rift, VLB = Victoria Land Basin, EB = Eastern Basin, CRB = Cape Roberts Basin. Location of ANDRILL Program drill sites and previous programs (DVDP, CIROS, MSSTS) are also indicated. (c) Land drawing of seismic lines 97 with projected location of CRP drill holes.
Modified from Hamilton et al. (2001).

Terror Rift, the westernmost portion of the Victoria Land Basin (VLB), where the post-Oligocene tectonic activity of the WARS was located (Fielding et al., 2008; Hamilton et al., 2001; Salvini et al., 1997; Storti et al., 2007). These tectonic structures might have controlled the glacial drainage, modulating the proximal and distal sedimentary supplies in the offshore basins placed at the front of the icecap. The importance of the effects on the tectonic evolution on the glacial activity has been shown in numerous studies (see Hamilton et al., 2001; Van der Wateren and Cloething, 1999; Wilson et al., 2011). In addition, an increasing number of papers describes the occurrence of neo-tectonics in the Victoria Land region, along the western Ross Sea margin (e.g., Dubbini et al., 2010; Faccenna et al., 2008; Paulsen and Wilson, 2009; Rossetti et al., 2006; Storti et al., 2007), suggesting an interplay between climate and tectonics for the space-time cryosphere evolution in the region (Fielding et al., 2008; Wilson et al., 2011).

With the aim to elucidate how Cenozoic tectonics have interfered with the ice sheet flow patterns in the Ross Sea region, in this study we carried out detrital fission track analysis of apatite (AFT) within the drill-core records of the Cape Roberts Project (CRP) (Fig. 1). The CRP cumulative stratigraphy (composed by three separate drill-cores, CRP-1, CRP-2, and CRP-3) covers a time span from the Devonian to Pleistocene and it is unique among the VLB cores to have recovered the basin substratum and the first Oligocene deposits, constraining onset of tectonic subsidence of the Cape Roberts Basin at ca. 34 Ma (Cape Roberts Science Team, 2000; Galeotti et al., 2011) (Fig. 2). After initial rift opening, CRP succession records a nearly continuous Oligocene to Early Miocene (34 Ma to 17 Ma) sedimentation history providing an invaluable tool to investigate the processes of denudation acting on the TAM and mechanism of sediment transport at Oligocene/Miocene transition. Our results document occurrence of young detrital apatite thermochronological ages (between 34 Ma and 26 Ma), not compatible with the AFT ages available from the proximal continental area. The CRP AFT data set is complementary to and completes information obtained from the ANDRILL drill cores (Zattin et al., 2010, 2012), because it covers a larger time window, detecting the first deposition of young AFT age-bearing sediments and revealing its episodic occurrence. This evidence supports a common bedrock source area for the sediment supply along the western shoulder of the Victoria Land Basin, located away to the south. These results impose revision of the current understanding on the paleo-glacial drainage network, emphasizing the control operated by Cenozoic tectonic structures in the glacio-fluvial sediment supply.