Marine Geology 355 (2014) 297–309

Contents lists available at ScienceDirect

Marine Geology

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

Late Neogene geomorphological and glacial reconstruction of the northern Victoria Land coast, western Ross Sea (Antarctica)

Chiara Sauli *, Martina Busetti, Laura De Santis, Nigel Wardell

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Borgo Grotta Gigante 42/c, 34010 Sgonico, Trieste, Italy

ARTICLE INFO

Article history:
Received 26 June 2013
Received in revised form 16 June 2014
Accepted 19 June 2014
Available online 27 June 2014

Keywords:
Antarctica
western Ross Sea
Neogene
seismic stratigraphy

ABSTRACT

This study is a contribution to the reconstruction of the geomorphology and the glacial history of the northern Victoria Land coastal glaciers. High-resolution single-channel reflection seismic lines were collected in 2002 within the framework of the Italian Antarctic programme (PNRA), in Wood Bay and Lady Newnes Bay, north to Cape Washington (western Ross Sea, Antarctica). The data provide evidence of overdeepened marine subglacial valleys, more than 1 km deep and 1–2 km wide, formed along the seaward extension of the Tinker, Aviator, Fitzgerald and Icebreaker glaciers and converging into the major SW–NE ice stream system. The spatial distribution and the geometry of the seismic facies, as well as the direct correlation with the seismic sequences in the Northern Basin, are interpreted to document 1) the depositional activity of a coastal glacial system seaward of northern Victoria Land (NVL) after 18 Ma (based on the seismic correlation with the base of DSDP 273) and possibly in the early Pliocene, in coalescence with expanded ice streams coming from the south along the Drygalski Basin, possibly draining from the WAIS as documented at AND-1B in the McMurdo Sound (Naish et al., 2007, 2008, 2009), followed by 2) the development of TAM tidewater glaciers that carved sea valleys near the Victoria Land coast, onto the shelf. The transition from a dynamic thick ice sheet covering the coastal area of NVL to the NVL valley glaciers advancing and retreating up to about 100 km from the coast in the middle Pliocene would represent a significant environmental change, possibly from interglacial conditions more temperate than today and gradually cooling to a cold and dry coastal regime.

1. Introduction

The Ross Sea is one of the key areas where the response of past Antarctic Ice Sheets to climate, tectonic and sea level change can be directly extracted from the thick sedimentary record. It is one of the largest embayments of the present Antarctic margin into which both the marine-based West Antarctic Ice Sheet (WAIS) and the terrestrial East Antarctic Ice Sheet (EAIS) waxed and waned since the onset of glaciations (Barron et al., 1991; Bartek et al., 1991; Denton et al., 1991; Hambrey and Barrett, 1993).

Geophysical data document the evidence of ice streams crossing the Ross Sea continental shelf since the mid to late Miocene times (Brancolini et al., 1995a; De Santis et al., 1995; Anderson, 1999). Recurrent episodes of ice grounding up to the shelf edge, with widespread erosion, subglacial deposition and the deposition of trough mouth fans (TMFs), occurred in the late Miocene–early Pliocene in the eastern Ross Sea (Alonso et al., 1992; De Santis et al., 1995) and in the north western Ross Sea (Brancolini et al., 1995a; Bart et al., 2000, 2011).

A general cooling trend is documented by the Cenozoic sedimentary and biostratigraphic record collected in the central and eastern Ross Sea by DSDP leg 28 sites and near the Victoria Land coast by CRP and ANDRILL drill sites (Cape Robert Science Team, 1998, 1999, 2000; Naish et al., 2007, 2008, 2009). The late Cenozoic record is discontinuous, and its interpretation provides controversial hypotheses: one is suggesting that polar and dry condition were established in Antarctica since the mid Miocene (Denton et al., 1991; Sugden et al., 1993; Lewis et al., 2006), the other suggests that temperate, wet glaciers persisted up to the mid Pleistocene, at least in some coastal areas (Webb and Harwood, 1991; Hambrey and McKelvey, 2000; Rebesco et al., 2006).

Glacial marine but still temperate conditions were well documented by the Oligocene and early Miocene sections in the Ross Sea (Hayes and Frakes, 1975). Open marine conditions, with limited sea ice and marine water much warmer than today characterised interglacial intervals, in the Pliocene, as indicated by diatom associations in drill core AND-1B in the Southern McMurdo Sound (Naish et al., 2007, 2008, 2009).

In the northern Victoria Land (NVL) and in the Terra Nova Bay region, onshore geologic and geomorphological investigations record the occurrence of a predominant polar glacial regime in the mid to late-Miocene (Baroni et al., 2005, 2008; Baroni and Fasano, 2006; Di Nicola et al., 2009). The persistence of dynamic conditions in the

* Corresponding author.
E-mail address: csauli@inogs.it (C. Sauli).

http://dx.doi.org/10.1016/j.margeo.2014.06.008
0025-3227/

Miocene is found within the volcanic eruptions (c. 13–5 Ma), of sedimentary sequences of both wet and dry-based glaciers (Smellie et al., 2011a,b). At present the NVL is characterised by a network of sinuous valleys with a dendritic pattern of coastal and outlet glaciers (Baroni et al., 2008).

Onshore studies concluded that the Tinker, Aviator, Parker, Fitzgerald and Icebreaker, Mariner and Borchgrevink valley glaciers were isolated from the EAIS by the Transantarctic Mountains until the late Miocene (Baroni et al., 2005), and they have preserved typical polar geomorphological features with negligible erosional power, since 8.2–7.5 Ma (Armienti and Baroni, 1999).

A grid of high-resolution reflection seismic data, collected by the Italian programme PNRA/VILD in 2002, provides for the first time new insights into the morphological setting and the record of depositional systems of glacial sea valleys and ridges in the offshore Wood Bay and Lady Newnes Bay (Fig. 1).

The results of this work contribute to the reconstruction of the evolution of the NVL valley glaciers in their offshore area during the Neogene and show how they responded to coastal conditions rather than to the EAIS volume changes.

The scope of this work is to identify the most suitable sites for future shallow and deep sediment drilling in the two coastal bays in order to date the evolution of the highly dynamic, small NVL valley glaciers and their interactions with the WAIS.

2. Regional setting

The Ross Embayment and the Transantarctic Mountain (TAM) are the result of the continental crustal extension and rift shoulder uplift (Fitzgerald et al., 1986; Fitzgerald and Stump, 1997), which occurred during the Late Cretaceous and Cenozoic West Antarctic Rift System (Behrendt et al., 1991; Rocchi et al., 2002, 2005). As a consequence, in the Ross Sea several rift basins were formed, the westernmost of which, close to the Victoria Land coast, are the Victoria Land and Northern basins. The extensional tectonics, together with fluvial, marine and glacial processes, favoured the deposition in these basins of several kilometres of sediments (Brancolini et al., 1995b,c; Cooper et al., 1987). Since the Eocene, right-lateral strike-slip tectonics overprinted both the extensional basins offshore and the NE–SW fault systems in the northern Victoria Land (Salvini et al., 1997), and a pervasive magmatic activity affected the western Ross Sea/northern Victoria Land area (Kyle, 1990; Armienti and Baroni, 1999; Rocchi et al., 2002; Rossetti et al., 2006).

Glacial processes shaped the physiography of the Ross Sea: the loading of the ice caps on the continent and the glacial erosion overdeepened and foredeepened the continental shelf (ten Brink et al., 1995), and the erosion of the north-directed ice streams produced a basin and bank topography. In the western Ross Sea, the morphology is dominated by troughs parallel to the coast, specifically the N–S Nordenskjöld Basin, from McMurdo to the Drygalski Ice Tongue, limited eastward by a series of volcanic islands (Ross, Beaufort and Franklin islands) and submarine volcanoes, and the NE–SW Drygalski Basin, north of the Drygalski Ice Tongue up to the continental margin and limited eastward by the Crary and Mawson banks (Fig. 1). Water depths of almost 1 km are often present in the sea-valleys perpendicular to the coast offshore of the Victoria Land glaciers, for example in front of the Mackay Glacier in the south western Ross Sea and in the Wood and Lady Newnes bays, and exceed 1.5 km north of the Drygalski Ice Tongue (Fig. 1).

The drainage basin of the NVL glaciers lies onshore and in the coastal area where mountain peaks exceeding 3500 m are present less than 80 km away from the coast. The NVL dendritic valley network are thought to be shaped by fluvial erosion after the TAM uplift, since at least 55 Ma, and developed along the main NW–SE regional fault systems (Baroni et al., 2005). A significant portion of the valley system trends N–S to NNW–SSE following transtensional faults that developed in post Eocene time (Salvini et al., 1997; Baroni et al., 2005). The glacial morphology is superimposed on the previous fluvial valley network (Baroni et al., 2005).

In the northern Victoria Land the magmatic activity has been almost continuous since middle Eocene, with the emplacement of alkaline rift-related plutons, dikes, swarms and volcanoes of the McMurdo Volcanic Group (Rocchi et al., 2002 and references therein). The last

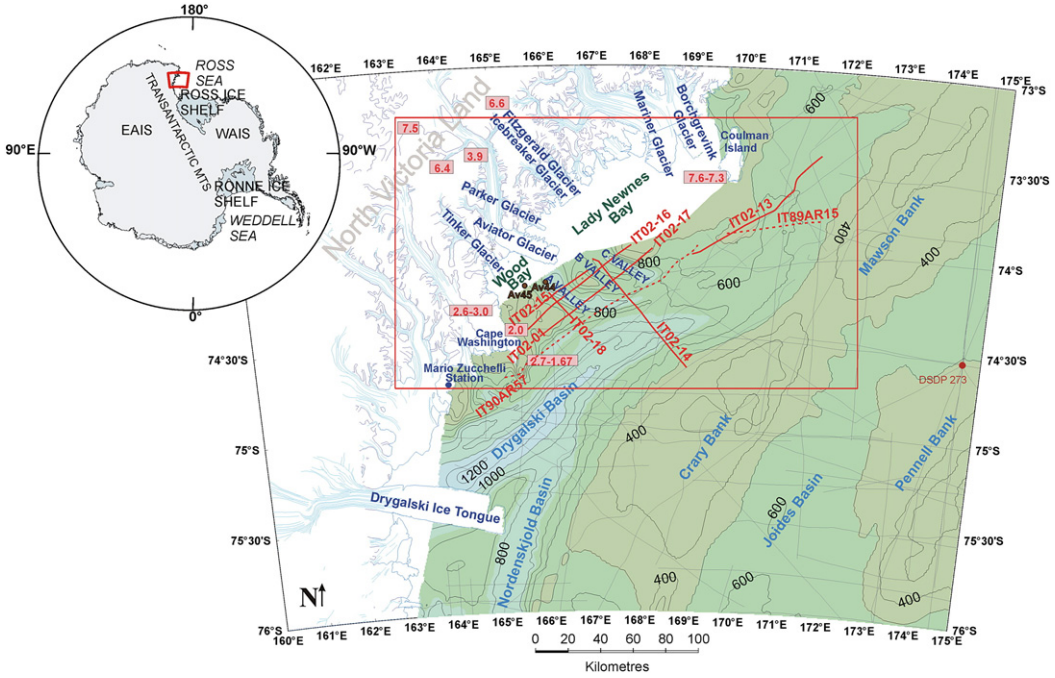

Fig. 1. North-western Ross Sea location map with present bathymetry (contour lines every 100 m) (Davey, 2004), track lines of interpreted seismic lines (multichannel cruises from SDLS: IT88, IT90, USGS, and single channel cruises IT02 and PD90 profiles). The well DSDP 273 site is also shown. The single-channel seismic lines IT02 (Figs. 3–7, 11a), discussed in the text, are indicated with the red bold lines. The IT90AR57 and IT89AR15 multichannel profiles are displayed with dotted red lines. The ages of the volcanic rocks in NVL are displayed in the red boxes (Armienti et al., 1991; Wörner et al., 1989).