Marine Geology 395 (2018) 363–379

Contents lists available at ScienceDirect

Marine Geology

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

Seismic stratigraphy of the Central Basin in northwestern Ross Sea slope and rise, Antarctica: Clues to the late Cenozoic ice-sheet dynamics and bottom-current activity

Sookwan Kim[a,b], Laura De Santis[c], Jong Kuk Hong[a,b,*], Diego Cottlerle[c], Lorenzo Petronio[c], Ester Colizza[d], Young-Gyun Kim[a,e], Seung-Goo Kang[a], Hyoung Jun Kim[a], Suhwan Kim[a], Nigel Wardell[c], Riccardo Geletti[c], Andrea Bergamasco[f], Robert McKay[g], Young Keun Jin[a], Sung-Ho Kang[a]

[a] Korea Polar Research Institute, Incheon, South Korea
[b] University of Science and Technology-Korea, Daejeon, South Korea
[c] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale-OGS, Trieste, Italy
[d] University of Trieste, Trieste, Italy
[e] Research Institute of Oceanography, Seoul National University, Seoul, South Korea
[f] Institute of Marine Sciences-National Research Council (ISMAR-CNR), Venice, Italy
[g] Victoria University of Wellington, Wellington, New Zealand

ARTICLE INFO

Editor: G.J. de Lange

Keywords:
Antarctica
Ross Sea
Seismic stratigraphy
Contourites
Glacial sediments
Sedimentary process

ABSTRACT

Sedimentation processes influenced by late Cenozoic ice-sheet dynamics and bottom-current activity can be extracted from the seismic stratigraphic record of the Ross Sea continental slope and rise, where more continuous sedimentary successions are preserved compared to the continental shelf. In this study, we present a seismic stratigraphic analysis of the Central Basin that lies in the northwestern Ross Sea, using newly acquired and existing legacy seismic reflection data that are correlated to adjacent scientific drill sites. The chronostratigraphy of Ross Sea seismic sequences lying above the mid-Miocene sequence boundary (RSU4, ca. 16.5–15.5 Ma) is based on the former Antarctic Offshore Stratigraphy (ANTOSTRAT) project. Depth-contour and isopach maps of sedimentary sequences bounded by two major unconformities of RSU4 and RSU2 (the late Pliocene boundary, ca. 4.0–2.8 Ma) and the present-day seafloor were produced to illustrate the evolution of paleo-seafloor morphology, distribution of sediments and depocenter migration in the western Ross Sea outer margin.

The results of seismic stratigraphic analysis indicate that gravity sedimentation processes dominated the Central Basin infill up to the mid-Miocene, and then downslope sediment supply gradually diminished through the late Miocene and Quaternary, likely reflecting a shift toward a cooler, less erosive glacial regime change. Since the late Pliocene, a topset-truncated glacial prograding wedge developed in the upper continental slope at the mouth of the Joides Basin and the sediment depocenter was shifted from the basin floor to the upper slope, suggesting the more persistent occurrence of grounded ice sheets on the outer continental shelf. Meanwhile, persistent along-slope bottom-current processes formed contourites on the slope and over the crests of banks surrounding the Central Basin since the mid-Miocene. In the late Pliocene, the contourites that formed off the Joides Basin mouth were overlain by glaciogenic debris flows, while the growth of contourites continued over and along the flanks of banks, farther to the north. This suggests that along-slope bottom-current processes near the Joides Basin mouth were diminished or dominated by the glacial discharge to the continental shelf edge. The sediment stacking patterns differ between the Joides/Central Basins and the Drygalski/Adare Basins located on the westernmost Ross Sea margin, suggesting that distinctive glacial/interglacial behavior of the former grounded ice streams and sediment supplies in the troughs feeding these basins were largely controlled by the paleo-seafloor morphology of the western Ross Sea continental shelf.

* Corresponding author at: Korea Polar Research Institute, 26 Songdomirae-ro, Yeonsu-gu, Incheon 21990, South Korea.
E-mail address: jkhong@kopri.re.kr (J.K. Hong).

https://doi.org/10.1016/j.margeo.2017.10.013
Received 8 June 2017; Received in revised form 23 October 2017; Accepted 30 October 2017
Available online 14 November 2017

1. Introduction

Sedimentary processes in high-latitude continental margins are mainly controlled by ice-sheet advances and retreats on the continental shelves and by bottom-water current activity on the continental slopes and rises during glacial and interglacial periods (Anderson et al., 1979; Wright and Anderson, 1982; Rebesco et al., 1996; Alley et al., 1997; Camerlenghi et al., 1997). Reconstructing the glaciomarine sedimentary processes from geological and geophysical analysis could provide useful insight into the dynamics of Antarctic ice sheets since the onset of glaciation at ca. 34 million years ago and into the variability of bottom-water circulation (Rebesco et al., 1996, 2006; Barker et al., 1999; Uenzelmann-Neben, 2006; Cooper et al., 2009; Uenzelmann-Neben and Gohl, 2012; McKay et al., 2016).

Since the early 1970s, numerous seismic surveys and scientific drilling projects have been provided information on the crustal structures and on the stratigraphic framework of the Ross Sea, Antarctica (e.g. Houtz and Davey, 1973; Hayes and Frakes, 1975; Cape Roberts Science Team, 2000; Naish et al., 2006; Cooper et al., 2009). The sedimentary successions above the acoustic basement were divided into eight seismic sequences, termed Ross Sea Seismic Sequences (RSS-1 to RSS-8), with bounding unconformities, termed Ross Sea Unconformities (RSU6 to RSU1), defined by the Antarctic Offshore Stratigraphy project (ANTOSTRAT, 1995). Seismic stratigraphic and sediment core analyses on the continental shelf have revealed the occurrence of repetitive and frequent grounding events of the East and West Antarctic ice sheets (EAIS and WAIS) over the Ross Sea (e.g. Alonso et al., 1992; Anderson and Bartek, 1992; De Santis et al., 1999; Bart, 2003; Bart et al., 2011; Gasson et al., 2016; Levy et al., 2016) (Fig. 1) after the Middle Miocene Climatic Optimum (MMCO) at ca. 17–14.5 Ma (Zachos et al., 2001). Studies on Pleistocene and Holocene marine geological and geophysical data, including geomorphological mapping, highlighted the footprint of a large variety of subglacial erosional and depositional processes (e.g. Bart, 2004; Mosola and Anderson, 2006; McKay et al., 2012; Anderson et al., 2014; Halberstadt et al., 2016; Yokoyama et al., 2016; Lee et al., 2017) (Fig. 1a). These studies are crucial for past Antarctic ice sheet modeling and future sea-level change (e.g. Pollard and DeConto, 2009; Golledge et al., 2014; DeConto and Pollard, 2016). In contrast to the continental shelf, there have been less seismic stratigraphic studies for the Ross Sea slope and rise (e.g. Granot et al., 2010; Lindeque et al., 2016). In general, more continuous and detailed sedimentary records are preserved with minimum hiatus in this part of the Antarctic outer continental margin, but they provide a less direct signature of ice sheet advance than the less continuous continental shelf records (e.g. Barker and Camerlenghi, 2002; Cooper and O'Brien, 2004; Escutia et al., 2011). Therefore, an analysis of overall sedimentary architecture using the integration of the inner and outer continental margin sedimentary sequences could provide a better understanding of the glaciomarine sedimentary processes in the Ross Sea, and how these may relate to ice sheet expansion and contraction on the continental shelf, as well as linking to regional and global archives of late Cenozoic global climatic and oceanographic evolution.

In this study, we aim to fill a gap between the shallow- and deep-water depositional systems by analyzing the seismic sequences above the mid-Miocene glacial unconformity (RSU4, ca. 16.5–15.5 Ma) in the Central Basin, which lies in the northwestern Ross Sea continental slope and rise, using the newly acquired multichannel seismic (MCS) data and existing legacy MCS data from the Antarctic Seismic Data Library System (SDLS, Fig. 2) (Wardell et al., 2007). Four major unconformities (RSU4, RSU3-CB, RSU2 and RSU1-CB) were traced into the Central Basin, bounding the seismic sequences RSS-5 to RSS-8 (from the oldest to the youngest) as defined by previous seismic stratigraphic interpretations (Brancolini et al., 1995; De Santis et al., 1995; Bart et al., 2000; Granot et al., 2010) (Fig. 3). Seismic facies units were identified and used to infer the sedimentary processes occurring in the Central Basin since the mid-Miocene. The Ross Sea seismic sequences and their boundaries were mapped over the western Ross Sea outer margin and allow the evolution of paleo-seafloor and distribution of sedimentary sequences in the Central Basin region to be characterized, and the late Cenozoic local and regional ice sheet dynamics and bottom-current circulation in the western Ross Sea to be reconstructed. These results will guide the location of some alternate drill sites for the International Ocean Discovery Program (IODP) Expedition 374 in 2018 (McKay et al., 2017) to understand the WAIS evolution and oceanographic controls in the Ross Sea slopes and rises, which aims to refine the chronostratigraphic framework of the seismic sequences interpreted in this paper.

2. Regional setting

The Ross Sea, is one of the main glacial drainage outlets of the EAIS and WAIS (Denton et al., 1989; Shipp et al., 1999; Livingstone et al., 2012; Anderson et al., 2014; Halberstadt et al., 2016) (Fig. 1a,b) and it consists of a number of rift basins and half grabens formed through the evolution of the West Antarctic Rift System (WARS) (Cooper and Davey, 1985; Behrendt et al., 1991; Cooper et al., 1991; Davey and Brancolini, 1995). In contrast to low-latitude continental shelves, the Ross Sea shelf is characterized by water depths exceeding 500 m, and an overdeepend bathymetry resulting from isostatic depression and subglacial erosion by repeated advances and retreats of grounded EAIS and WAIS (Brancolini et al., 1995; De Santis et al., 1999). The Joides and Drygalski Basins, two cross-shelf glacial troughs in the western Ross Sea, occupy major tectonic depressions bounded by high-relief banks. The Joides Basin is inferred to have been one of the main drainage pathways of EAIS-sourced ice feeding into the Ross Sea during the Last Glacial Maximum (LGM) (Anderson et al., 1992, 2014; Shipp et al., 1999; Livingstone et al., 2012; Harris et al., 2014; Halberstadt et al., 2016). The Central Basin is located seaward of the Joides Basin and, unique to the other sectors of the Ross Sea and the Antarctic margin, is a semi-closed tectonic depression surrounded by high-relief banks. The Central Basin is thought to have widened to ca. 130 km between west of the Iselin Bank and the Hallett Ridge during the process of the WARS opening, at ca. 60 Ma (Cande et al., 2000; Cande and Stock, 2004; Wilson and Luyendyk, 2009). However, due to a limited number of cross-basin geophysical data such as deep seismic, magnetic and gravity survey data in the vicinity of the Central Basin, the nature and opening history of this rifting basin remains unknown (Wilson and Luyendyk, 2009).

The Central Basin is characterized by four different morphological sectors, each presenting a unique stratigraphic evolution: (1) the Joides Basin mouth and continental slope, (2) a ponded basin in the southeastern upper slope, (3) the Central Basin floor, and (4) surrounding topographic highs such as the southern (Bank A) and northern (Bank B) basement highs, the Hallett Ridge, and the Iselin Bank (Fig. 2). The southwestern continental slope to the north of the Joides Basin mouth (Fig. 2) has a gentle gradient (ca. 1°) from 600 to 1800 m water depth. In contrast, the southeastern continental slope has an initial ca. 2° dip, from 400 to 600 m, and then it becomes steeper (ca. 4.1–6.7°) from 1000 to 1600 m. At the change of dip, it is characterized by a small intraslope basin at a depth of about 600–1000 m below the shelf edge, with a circular shape and ca. 40 km wide. The small basin is confined to the north by a tectonic basement high, Bank A (Fig. 2). We name this small intraslope basin “ponded basin” in analogy to previously described similar features (e.g. Prather, 2003; Close, 2010). The floor of the Central Basin is up to 150 km wide and 2000 m and it is flanked to the east by the Iselin Bank and to the west by the Hallett Ridge with ca. 4.2–4.6° slope gradients. It is bounded to the north by Bank B and the Scott Canyon.