Coastal glacial valley system in the Wood Bay (western Ross Sea, Antarctica)

C. Sauli, M. Busetti, L. De Santis, L. Sormani, and N. Wardell

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS Borgo Grotta Gigante 42/c, 34010 Sgonico, TRIESTE, ITALY (csauli@ogs.trieste.it, mbusetti@ogs.trieste.it, ldesantis@ogs.trieste.it, lsormani@ogs.trieste.it, nwardell@ogs.trieste.it)

Summary In the context of the reinterpretation of marine seismic data in the Ross Sea being made for the Vilmap PNRA project, newly acquired higher resolution single channel seismic lines (IT02) allowed a detailed investigation of the Cenozoic glacial features present in the Wood Bay, coastal area of western Ross Sea between Cape Washington and Mariner/Borchgrevink Glaciers. The investigation focused on the dynamics of the East Antarctic Ice Sheet, and, in particular, the local coastal glaciers that extend into the sea as ice tongues, contributing to drainage the East Antarctic Ice Sheet through the Transantarctic Mountains. The dynamics of the group of three valley and outlet glaciers, the Tinker Glacier, Aviator Glacier and Parker Glacier, is clearly shown in the investigated depositional features that include subglacial and proglacial progradational deposits, grounding zone wedges, a possible morainal bank complex, and in the erosional evidence of glacial unconformities and troughs.

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Introduction

The project “Revision of the maps of the main interpreted seismic unconformities in the Victoria Land Basin” (VILMAP PNRA) has reinterpreted seismic multichannel and single channel data, acquired in the past twenty years in the Victoria Land Basin (Ross Sea, Antarctica), on the basis of the new well information of Cape Roberts and recently available seismic lines to give a revised seismo-stratigraphic analysis of the Cenozoic sedimentary cover of the region. This project provides revised digital stratigraphic and isopach maps of the principal regional unconformities and seismic sequences in the western Ross Sea made by the Ross Sea Regional Working Group of ANTOSTRAT (Brancolini et al., 1995). The basis of the present study (Figure 1) are the low and medium resolution multichannel seismic data (IT88-89-90, USGS, BGR, MAGE) and single channel seismic lines (PD90, IT02).

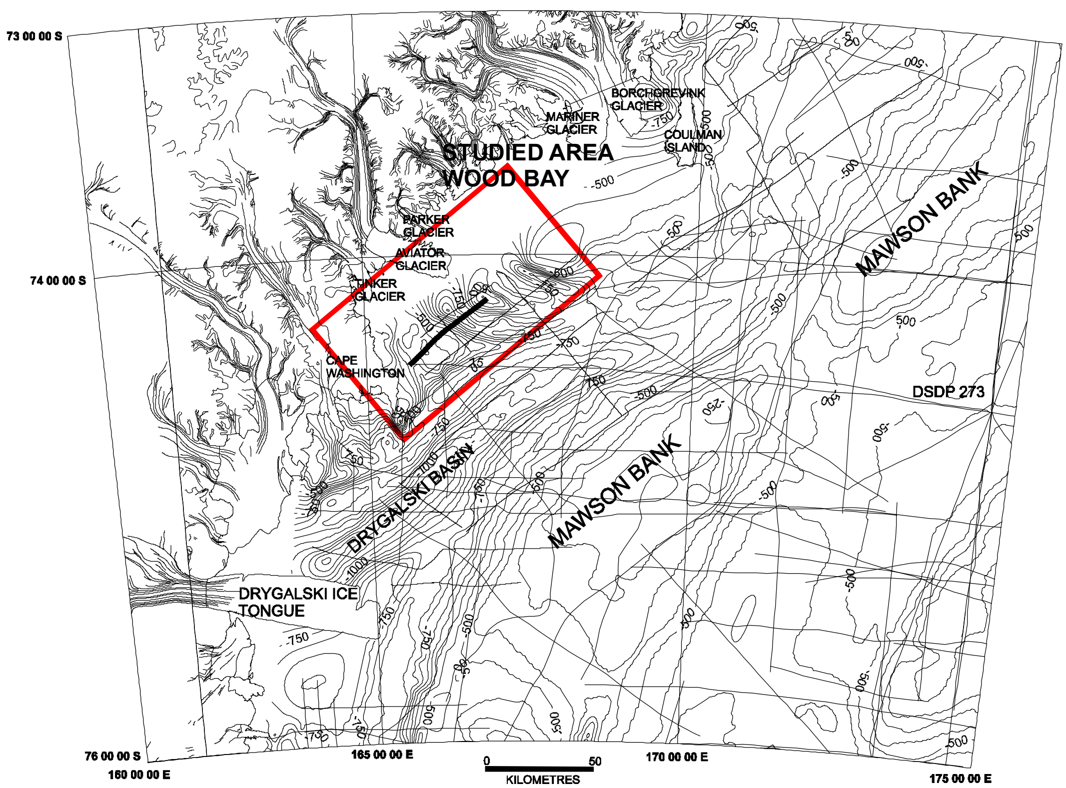

Figure 1. Location of the survey area showing the seismic tracks for the data used in this study. The seismic section in Figure 2 is shown by the heavy line. Bathymetry (annotated at 250 m intervals) after Davey (2004).

Extensive glaciation in Antarctica is inferred to have started at the beginning of the Oligocene (Barron et al., 1991), with the early ice sheet confined to East Antarctica (Denton et al.,1991; Hambrey et al., 1991). In the Miocene, the Antarctic Ice Sheets had a major expansion on both West and East Antarctica (Kennett, 1982; Hambrey et al., 1991; Anderson, 1999). The glaciomarine sediments, recovered in the drill sites on the Ross Sea continental shelf, record throughout the Miocene shifts from temperate to sub-polar or polar climates (Anderson, 1999). The recent CRP wells provide evidence for the expansion of polythermal glaciers from the Transantarctic Mountains (Powell et al., 1998), as well as subsequent ice recession during the Late Miocene. In the Plio-Pleistocene, the maximum glaciation occurred (Kennett, 1982).

The Ross Sea lies between the eastern and western parts of the Antarctic continent. Its morphology and sedimentary structures have been influenced by the West and East Antarctic Ice Sheets which have drained into the Ross Sea via the Ross Ice Shelf, and by drainage of the East Antarctic Ice Sheet through glaciers that cross the Transantarctic Mountains. The sea floor morphology in the Ross Sea displays a series of dominant northeast-southwest ridges and troughs and a characteristic foredeepened topography. The shallow morphological features and sedimentary deposits record the most recent glacial expansions and retreats. In the past, ice streams have crossed the region of the present Ross Sea and formed the distinctive ridge and trough morphology. In the western Ross Sea, the morphology of the sea floor and the thick sedimentary cover that has been deposited along the margin also provide evidence of the Neogene-Quaternary activity of the coastal glaciers.

The glaciers that are presently along the western Ross Sea margin are coastal valley and tidewater glaciers. This study focuses on the coastal area of the Victoria Land Basin north of Cape Washington and in front of the group of three glaciers - the Tinker Glacier, Aviator Glacier and Parker Glacier - and their associated glacier ice tongues (Figure 1). Most of these glaciers are “cold” glaciers that are generally dry-based and less erosive of the underlying morphology than in the past when the glaciers were warmer, temperate, and subjected to major fluctuations in extent. The sedimentary cover, the geometry of the sediment deposits within it, and the morphology of the sea bottom that record the history, evolution, and dynamic movements of the Antarctic Ice Sheet were analyzed to derive the past dominant glacial environments and the climatic changes which the glaciers have undergone.

The East Antarctic Ice Sheet is considered to have existed for approximately 35 Ma, but age control is limited in the Ross Sea region and a sediment record going back to Late Eocene, 36 Ma, was only recovered at one site, CIROS-1 in McMurdo Sound (southern Victoria Land Basin), and no other drill sites record the onset of the glaciation.

Data

During the Vild (acronym of Importance of Cenozoic tectonic and glacial events in the evolution of the Victoria Land landscape) PNRA 2001-2002 survey, 1520 kilometres of new single channel seismic lines (IT02) were recorded by M/N Italica Research vessel using a single 105 cu in G.I. Gun with a working pressure of 140 bar. These data were processed at Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (INOGS) and gave good high resolution seismic information close to the coast. In order to study the area of Wood Bay, off the Tinker Glacier, Aviator Glacier and Parker Glacier, a heterogeneous set of multichannel seismic data (IT88-89-90, USGS, BGR, MAGE) and single channel seismic lines (PD90, IT02) was assembled and analyzed. The heterogeneity of the data is demonstrated by the differences in depth of penetration that varies from 2 to 6 seconds two way travel time (TWTT) and in vertical resolution for seismic features of 5 to 60 meters. To reduce this heterogeneity and make the various data sets more comparable, near trace seismic sections of the available Italian multichannel seismic sections were prepared. Limited data coverage and the lack of well site information close to the studied area have prevented the possibility of dating confidently the subglacial and glacial proximal records older than Miocene. Drill-site stratigraphic control of the interpreted unconformities and seismic units is based on well site DSDP 273 (Hayes and Frakes, 1975; Hambrey and Barrett, 1993), east of the study area.

Discussion

The IT02 seismic data, particularly the strike lines, display a glacial valley system, showing the 400-480 meters ($v = 1600$ m/s) deep, and 6-8 km wide, carved glacial troughs. The seismic acoustic analysis of the IT02 profiles identifies two main acoustic units (Unit 1, Unit 2), and a younger infilling sequence with reflectors onlapping on the lateral walls of the infilled U-shaped valleys. Four seismic facies are recognized, H, M, N and P. Two dated unconformities of Late Pleistocene and Mid-Miocene age, 4 Ma and 16.2 Ma, and the well bottom time line of 18.34 Ma (in glaciomarine mudstone), have been identified in well DSDP 273, but only the well bottom time line has been continuously correlated to the IT02 VILD seismic profiles. The lower unit (Unit 1) is limited by two major regional unconformities, the lower one of which lies just above the 18.34 Ma event. It is best shown in the dip seismic sections where it displays an almost 400-500 msec thickness of seaward prograding laminated, frequently spaced, oblique-tangential clinoforms (Facies P) (Alley et al., 1989; Howat and Domack, 2003). On the strike lines, Facies P displays a more massive and slightly hummocky character. Unit 2 is separated from Unit 1 by an unconformity characterized by toplap. It forms the top

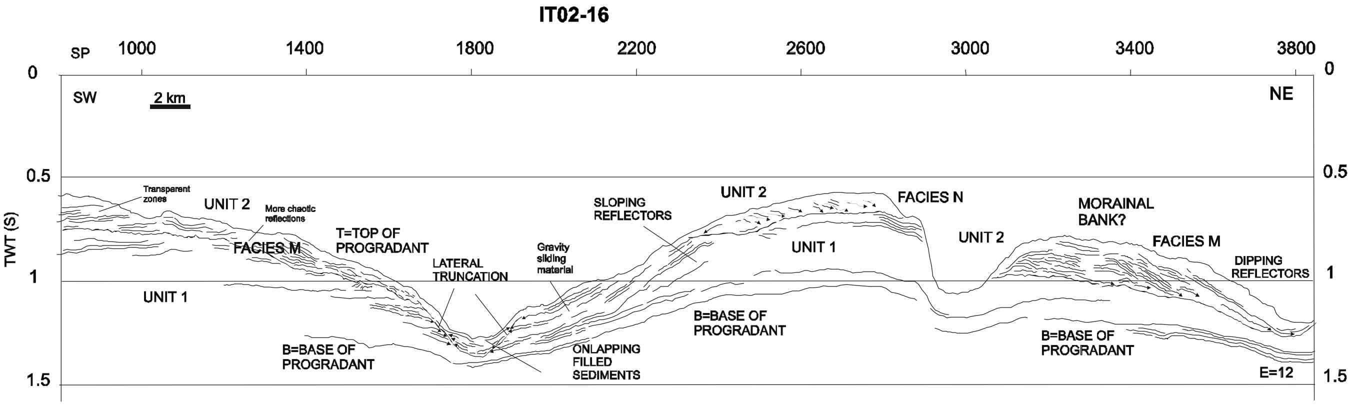

Figure 2. Interpreted seismic line IT02-16, showing seismic units 1 and 2 and seismic facies, H, M, N, P discussed in the text.

part of the ridges and contains three main facies M, H, N, the boundaries to which are not well defined on the available seismic data. Seismic Facies M consists of discontinuous irregular-sub horizontal and chaotic variously curved internal reflectors. The presence of hummocky discontinuous reflectors in the facies could be interpreted as a high content of ice rafted debris in the glacimarine sediment. Seismic Facies H consists of medium-high amplitude, more or less regularly spaced horizontal/sub horizontal reflectors. Facies N is defined by prograding features that are not in the dominant ice-flow direction, and it is tentatively interpreted as deposition along the lateral margin of a glacier. On one ridge, Facies M in Unit 2 has an external mounded shape with internal reflectors verging towards the trough floor that may be interpreted as lateral or end moraines (morainal banks). (Hambrey, 1994; Powell and Domack, 1995).

The IT02 lines show that subglacial/proglacial sediments deposition has mainly occurred in the ice-flow direction, more or less perpendicular to the coast line. In the more recent overlying sediments (Unit 2), the presence of grounding zone wedges (Bart and Anderson, 1995) documents the stepwise retreat of the ice front towards the coast. The seismic profiles parallel to the coastline define the major erosional processes that the coastal glaciers have exerted in the area showing the glacial unconformities and the troughs. The intervening troughs prevented the unique correlation of the seismic units that collectively form Unit 2 and were deposited on the top of the ridges above the main glacial prograding unit (Unit 1).

Summary

During the Cenozoic, the valley and outlet glaciers that pass through the Transantarctic Mountains along the Victoria Land coast have dominated the marine sedimentation processes, building possible morainal deposits, fans and/or subglacial/proximal deltas, locally separated by troughs. The single channel seismic lines, IT02, that run parallel to the coast in front of the ice tongues show a glacial valley system, younger than 18.34 Ma, with an intervening series of ridges and carved troughs whose deflection north-eastward probably results from the influence of the major glacial system of the David Glacier/Drygalski Ice Tongue. Subglacial/proximal glacial and more ice-distal seismic acoustic facies, linked to the activities of the coastal glaciers tongues, have been recognized in the sedimentary sequence. A system of U-shaped troughs forming the western Ross Sea floor is the result of the glacial erosion activity and suggests that in the past more extensive glaciers through the Transantarctic Mountains contributed to enhanced drainage of the Antarctic Ice Sheet. These glaciers, flowing parallel to the trough axis, eroded the trough base and truncated the previous deposited proglacial sediments. The identified seismic facies demonstrate that deposition occurred along the ice-flow direction, which was generally perpendicular to the coast, in two environments i) a close to the ice flow margin environment (at the front or along the margin of the glacier) and ii) in a more ice-distal environment, when the glacier was retreating.

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