New insights into submarine geomorphology and depositional processes along the George V Land continental slope and upper rise (East Antarctica)

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Summary The PNRA/MOGAM (MOrphology and Geology of Antarctic Margins) project collected swath bathymetric and subbottom acoustic data from the slope and rise of the George Vth Land in 2006 from R/V OGS Explora. Previous studies demonstrated that thick shelf margin prograding sedimentary wedge buried rugged glacial morphology, as in most of the Antarctic margin. The new survey shows that the continental slope and rise is actually incised by a complex network of converging submarine canyons, some of which directly connected to main shelf depressions. Along the slope, canyon erosion by turbiditic flows and by cold dense bottom currents likely prevented the burial of, or exhumed, relict features of the previous glacial topography Further coordinated multidisciplinary investigations of this margin are planned for the International Polar Year.

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Introduction

Regional studies across the George V Land margin based on multichannel seismic profiles (e.g. Eittreim et al., 1987; Escutia et al., 2005; Donda et al., 2007; Close et al., 2007) and more detailed studies (De Santis et al., 2003; Donda et al., 2003), show a buried rugged morphology and seismic facies (e.g channel-levee) under the continental slope and rise, suggesting a more dynamic setting in the past when the glacial environment was dominated by meltwater processes and deposition by temperate or polythermal glacial systems.

Thick shelf margin sedimentary wedges, with high angle slope-foreset beds, filled and buried the previous morphology suggesting a major change in the ice sheet configuration, possibly from highly dynamic, polythermal to more stable polar environmental conditions. No stratigraphic control is available for this sector of the Antarctic margin. Indirect correlation with DSDP site 269 would suggest that the transition in the acoustic facies configuration and in the inferred environmental condition occurred in the late Miocene (De Santis et al., 2003; Donda et al., 2007).

The modern sea bed of the Antarctic continental slope generally shows no significant evidence of meltwater processes, apart from gullies and small channels, that are interpreted as formed at the base of grounded ice sheet expanded over the shelf (Anderson, 1999, Shipp et al., 1999; Evans et al., 2005; Dowdeswell et al., 2004). In most cases the channel systems incising the upper rise do not have canyon-related feature on the slope.

The Italian PNRA/MOGAM (Morphology and geology of Antarctic Margins) project was set up to investigate the relationship between the modern and recent sea bed depositional processes, in particular in relationship to the inferred downslope cascade pathways of the High Salinity Shelf Water produced along the coast today (Gordon and Tchernia, 1972; Rintoul, 1998; Bindoff et al., 2000, 2001) and during the late Quaternary (Presti et al., 2005; Harris and Beaman, 2003). To achieve this objective, in 2006 the MOGAM project used the R/V OGS Explora to collect swath bathymetric and subbottom chirp data, from the slope and rise of the George Vth Land.

Here we present preliminary results of the MOGAM cruise and in particular we focus on the morphology of the slope seaward of the mouth of the Mertz-Ninnis trough, where buried features, formed during early phase of the margin development, partially outcrop above the sea floor and are clearly imaged by detailed swath bathymetry and high resolution acoustic data.

The MOGAM swath bathymetry data cover an area of about 10,000 km^2, across the slope and rise of the George V Land (Figure 1) in 600-3500 meters of water depth. The investigated area is between 145° and 143°E of longitude and 64°45’ and 65°50’S of latitude. The swath data were collected using Reson SeaBat 8150 multibeam system, with 234 beams and frequency of 12 kHz. PDS2000 has been used as processing software.1500 km of subbottom chirp II acoustic data were also collected during the MOGAM cruise with sweep of 2-7 kHz. These data have been analysed and combined with previously collected PNRA/WEGA (WilkEs basin GlAcial history, Brancolini et al., 2000) and other French, Japanese, US multichannel seismic data, and available through the Seismic Data Library System. The WEGA multichannel data were collected with 2X150 GI Airgun (6.8 liters), a 500 m analog streamer with 40 channels, group interval of 12.5 m, shot interval of 10 seconds (25 m at 5 knot survey speed). Radex Pro software, distributed by the DECO Geophysical Co. Ltd., is used for multibeam, chirp and seismic data interpretation and display.

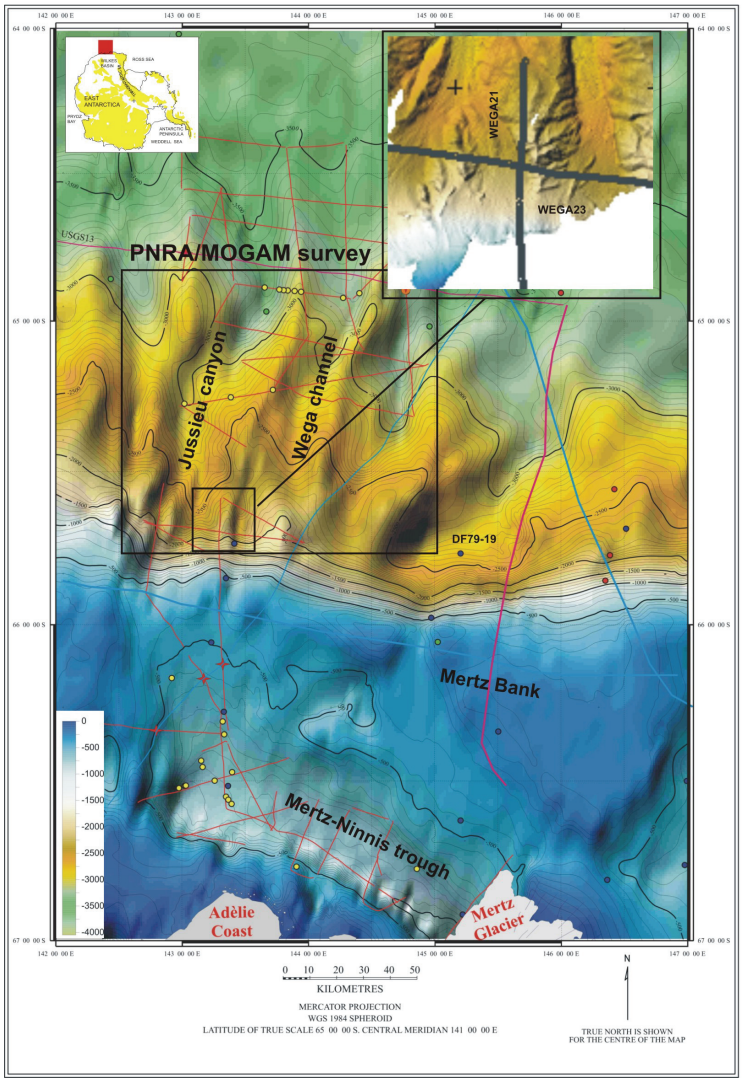

Figure 1. Bathymetric map of the George Vth Land margin (Caburlotto et al., 2006, modified). The upper right inset shows a detail of the upper slope as imaged by swath bathymetric data collected by the PNRA/MOGAM cruise in 2006 by OGS Explora. The red, blue and pink thin lines show the location of existing multichannel seismic data and the yellow and blue dots show sediment core location. The red stars are the proposed IODP proposal 482 Rev. sites (Escutia et al., 1997).

The regional trend of main morphologic features of the margin is provided by the bathymetric map between 142°E and 147°E and 67°S and 64°S compiled by Caburlotto et al. (2006, fig. 1). The map shows that the continental shelf, with an average water depth of 450-500 m is overdeepened with a landward sloping profile. The inner shelf is occupied by a deep basin, the Mertz-Ninnis Trough, extending north-westward, sub-parallel to the coastline. On the outer shelf the glacial trough shallows toward the shelf edge to less than 500 m water depth, where it turns toward north-northwest confined between two sedimentary banks (Adelie and Mertz Banks). The continental slope extends from the shelf break down to about 2000 m water depth. The slope facing the shelf troughs is steeper (6°-11°) than elsewhere. The slope seaward of the shelf banks shows a gradient of 2.6°-4° and 4°-6° respectively in front of the Adèlie Bank and the Mertz Bank. Large and deeply incised channels cut the slope in front of the trough mouths. Some of these channels heads reach the shelf edge and are connected with the inner shelf depressions, like at ca. 143°E of longitude, up slope of the Jussieu channel, and at 145°E, in correspondence of the minor shelf depression within the Mertz Bank. None of the channel heads located seaward of the shelf banks reach the upper slope and shelf edge. The continental rise is dissected by numerous dendritic deep-sea channels converging to form main feeder channels that develop into channel-levee complexes across the lower rise. The channel orientations in the proximal area is generally toward the north, roughly perpendicular to the continental slope.

Preliminary results and interpretation

The new swath and chirp data document a geomorphological setting of the floor of the upper slope much more complex than expected, on the basis of interpretation of lower resolution data collected previously (Fig 1). The new data show that the continental slope and rise seaward of the Mertz-Ninnis Glacial valley sill appears to be incised by a complex network of converging submarine canyons (the upper slope branches of the Jussieu Canyon system), some of which directly connect to the Mertz-Ninnis shelf depression.

The floor of the upper slope branches of the Jussieu canyon system is about 5 km wide and is smooth and flat. The low acoustic penetration and high amplitude of the sea floor reflector suggest a compacted sea bed.

Multichannel seismic profiles perpendicular to the shelf edge show that the strata filling the upper slope branches of the Jussieu canyon system are forest beds belonging to a shelf prograding wedge, up to 1 second (twt) thick, that pinches out at the base of the continental slope.

Multichannel seismic profiles parallel to the shelf edge, from the mid and lower slope, show that the modern canyons are superimposed on old, V-shaped depressions, that today are partially filled with sedimentary strata (fig. 2).

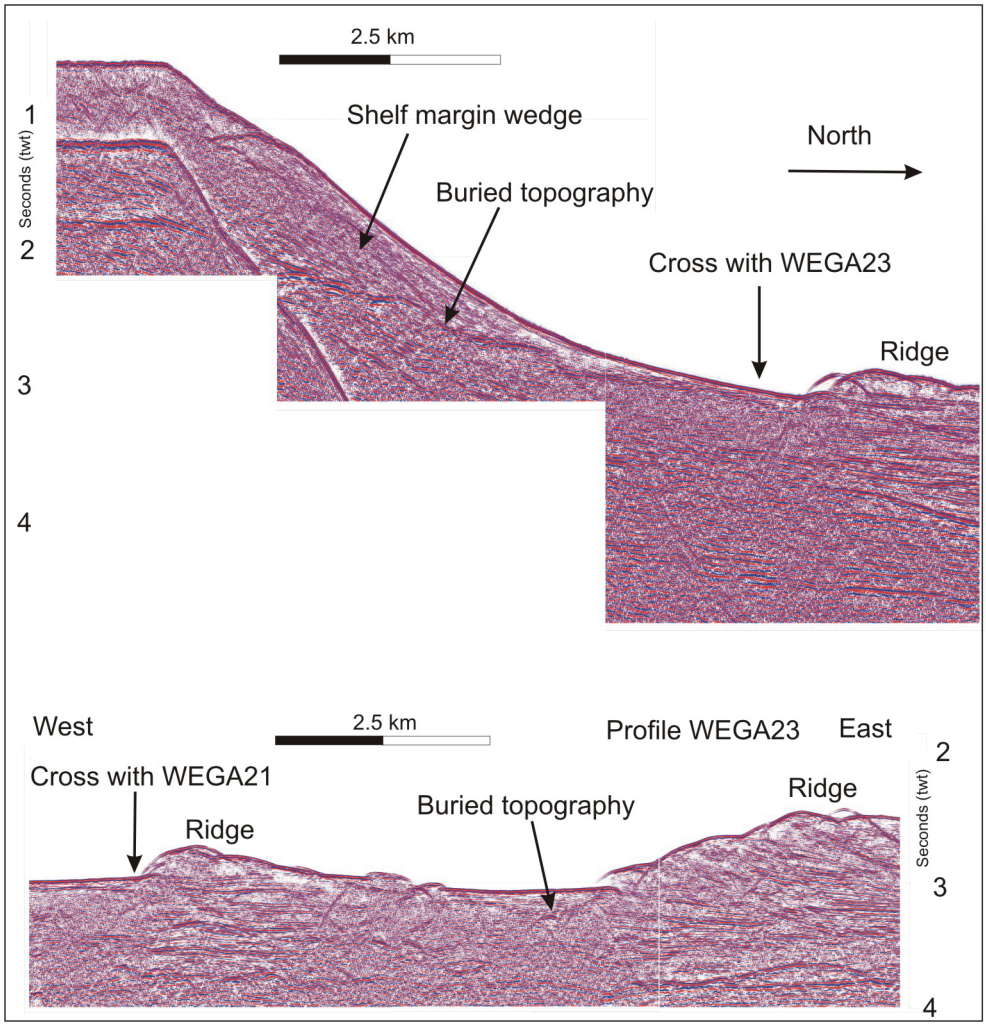

Figure 2. Multichannel seismic profiles WEGA21 and WEGA23. The data were collected under the frame of the joint Italian-Australian WEGA (Wilkes basin GlAcial history) scientific expedition in 1999-2000 (Brancolini et al., 2000). See inset in figure 1 for profiles location

The upper slope branches of the Jussieu canyon system are bound by ridges, that have a rugged surface and high amplitude sea bed character. Multichannel seismic data show that the ridges are internally stratified with a geometry suggesting a channel-levee type deposition. Downfaulted sedimentary blocks and strata truncation at the sea floor along the sides of the ridges, would suggest recent flank collapse and erosion.

The combination of swath bathymetry and seismic data seaward of the Mertz-Ninnis trough shows that a shelf margin prograding wedge is blanking the old glacial morphology of the George Vth Land continental slope (Fig 2), like in other sector of the Antarctic margin (e.g. Donda et al., 2007; Rebesco et al., 2006). However the surface of the shelf margin wedge appears incised by canyons and the shelf edge has a concave rather than the typical convex shape shown by glacial trough-mouth fan. These differences in the slope configuration of the George Vth Land margin can be explained by either: 1) a lesser capacity of the Mertz-Ninnis glacial system to transport and built a well developed shelf margin wedge during the most recent glacial maximum advances over the shelf or 2) intense erosion of the slope fan during and/or after the deposition of the glacial prograding wedge.

The cause of the present margin configuration and the age of its evolutionary phases is unknown due to a lack of stratigraphic information, which also prevented determination of sediment rates of the shelf prograding wedge and buried strata. One short core (only 2 meters in length) was collected from a the levee of one branch of the Jussieu canyon. The ongoing analysis of this core may help in understanding the age and type of sedimentary processes that formed the slope ridges. The sediment core DF79-19 (Anderson et al., 1981), just to the east of the MOGAM survey area (Fig 1), recovered Pliocene and late Miocene strata from the slope in water depth of 2598 m (Escutia et al., 2003). It is located on the flank of another main slope canyon, seaward of a shelf margin depression along the edge of the Mertz bank. The core location projected 5 km to the west on a multichannel seismic profile suggests it likely penetrated a stratified ridge similar to those observed along the flanks of the Jussieu canyons.

Previous studies on seismic facies demonstrated that down-slope flows deeply incised the margin and turbidity currents were the main process for sediment supply to the rise during most of the Paleogene and Neogene (Escutia et al., 2004; De Santis et al., 2003; Donda et al., 2007). Thick turbidites (up to 1 m) recovered from the Jussieu Canyon levees on the rise (Busetti et al., 2003) would suggest that quite significant turbiditic flow are still occurring along the slope in this sector of the Antarctic margin. On the other hand, current-controlled sediment drift features and sediment waves fields are well developed on the sheltered flanks of canyon levees, suggesting a strong and continuous influence of bottom contour current on the deep water sedimentation. Sediment cores from the WEGA channel, to the east of the Jussieu canyon, document a constant downslope bottom current traction activity rather than episodic turbiditic processes, during the Quaternary (Caburlotto et al., 2006).

The flat floor of the modern slope canyons versus their former V-shape would suggest that non depositional or more widespread erosional processes rather than strong erosive canyon axis downflow are acting today within the canyons.

Oceanographic data documents that dense water is produced along the coast and frequently spills off the shelf and flows down the continental slope, probably channelled within the canyons (Gordon and Tchernia, 1972; Rintoul, 1998; Bindoff et al., 2000, 2001).

In analogy with other areas of dense water production, we believe that along the George Vth Land margin, shelf water cascading currents driven by salinity contrast and also entraining fine organic and terrigenous particles, might have the capacity for reshaping submarine canyon floors and carrying sediment to the deep sea environment. This is also supported by the direct observation of nepheloid layer off the George Vth Land margin (Eittreim et al., 1971). During the present polar interglacial we believe that this may represent the main process for sediment erosion, transport and supply to the rise in this sector of the East Antarctic margin. An outcome of this work is that detailed swath bathymetric investigation across the Antarctic slope might be used to identify a particular morphological proxy for recognizing other potential areas of dense water spilling off and downslope flow.

Summary

A swath bathymetry survey on the George Vth Land (East Antarctica) continental slope conducted under the PNRA/MOGAM project in 2006 provides new insights into morphological expression of process for sediment erosion and deposition related to bottom water flow across the continental shelf edge.

Along the slope canyons, erosion by turbiditic flows and by cold dense bottom currents likely prevented the burial or exhuming of relict features of the previous glacial topography. Sediment waves, sediment drift and moat features demonstrate a continuous bottom current flow across the continental rise. Sediment core document the bottom current activity since the mid Quaternary.

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