U.S. Geological Survey and The National Academies; USGS OF-2007-1047, Short Research Paper 026; doi:10.3133/of2007-1047.srp026

Extensive debris flow deposits on the eastern Wilkes Land margin: a key to changing glacial regimes

C. Escutia,[1] F. Donda,[2] F.J. Lobo,[1] and M. Tanahashi[3]

[1]Instituto Andaluz de Ciencias de la Tierra, CSIC-Universidad de Granada, Fuentenueva s/n, 18002-Granada, Spain (cescutia@ugr.es; pacolobo@ugr.es)
[2]Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Borgo Grotta Gigante 421c, Sgonico, Trieste 34010, Italy (fdonda@ogs.trieste.it)
[3]Research Institute of Geo-Resources and Environment, Site C-7, 1-1-1, Higashi, Tsukuba, 305-8567, Japan (tanahashi-m@aist.go.jp)

Abstract Glacial sequences deposited on the base-of-slope and upper continental rise off the eastern Wilkes Land margin show that depositional systems vary with time. During the early Oligocene to middle-late Miocene times glacial sequences are dominated by extensive glacigenic debris flow deposits (GDFs) that have lens or wedge shaped external geometries and internal chaotic seismic facies. Minimum runout distances are between 15 and 50 km with lateral extent between 5 and 13 km. Thicknesses vary between 170 and 380 m. We suggest that large volumes of melt-water production by a dynamic East Antarctic Ice Sheet (EAIS) define this glacial regime, which led to high sediment discharge onto the continental shelf and caused extensive sediment failures on the continental slope and rise. In contrast, during the Late Miocene-Pliocene transition there was an evolution to a more persistent cold-based EAIS characterized by decrease rates of glacial erosion and decrease production of melt-water resulting in mixed turbidite and debris flow deposition.

Citation: Escutia, C., F. Donda, F. J. Lobo and M. Tanahashi (2007), Extensive debris flow deposits on the eastern Wilkes Land margin: a key to changing glacial regimes-Online Proceedings of the 10th ISAES, edited by A. K., Cooper and C. R. Raymond et al., USGS Open-File Report 2007-xxx1047, Short Research Paper 026, 4 p.; doi:10.3133/of2007-1047.srp026.

Introduction

Glacial sequences deposited on the base-of-slope and upper continental rise off the eastern Wilkes Land margin (Fig. 1) show a shift with time in the dominant depositional systems. The earlier glacial sequences are dominated by extensive GDFs compared to the mixed turbidite and debris flow deposition that dominate later glacial deposition (Figs. 2, 3).

The aim of this paper is to report and describe massive debris flow deposits buried under the Wilkes Land continental slope and rise and to discuss, based on the varying stratigraphic evolution of the margin, their relevance as potential indicators for changes in the continental glacial regime. For this study we analyzed multichannel seismic reflection profiles collected by the Institute Français du Pétrole (IFP 1981-82), the United States Geological Survey (USGS 1984), the Japan National Oil Corporation (TH82-TH95; 1982-1995), and Australian-Italian Program WEGA 2000 (Fig. 1). The majority of these data were made available through the Scientific Committee for Antarctic Research (SCAR) Seismic Data Library System (SDLS).

Morphologic and acoustic character of the debris flow deposits

GDFs are identified at the base of the paleo-slopes based on their external geometry and internal reflection pattern. All of the GDFs in the Wilkes Land have irregular upper surfaces. In seismic profiles that are perpendicular to the margin, GDFs have commonly lens-shaped or wedge-shaped external geometries (Fig. 3A).

When wedge shaped, the GDFs decrease in thickness from the lower slope to the upper rise. In seismic profiles that are parallel to the continent, the debris flows are lens-shaped and the lateral pinch-out of the lenses is sharp (Fig. 3B). The internal acoustic character of the GDFs is mainly structureless characterized by chaotic seismic facies and hyperbolae (Fig. 3).

We differentiate between older and younger GDFs based on their stratigraphic position (i.e., unconformities bounding them). Older GDFs lie on top of a regional unconformity, WL-U3 (Figs. 2, 3), which on the continental shelf truncates 300 to 600 m of strata. WL-U3 has been interpreted to separate pre-glacial strata below from glacial strata above (Escutia et al., 1997; De Santis et al., 2003; Escutia et al., 2005). At the base of the slope the unconformity surface is smooth to irregular but no large erosion of the underlying seismic unit is observed (Fig. 3). The top of the older GDFs is onlapped by unconformity WL-U4 and/or an amalgamated surface representing WL-U4 and WL-U5. This implies that the older GDFs can involve sediments within seismic units WL-S4 and WL-S5, inferred to be of Late Oligocene-Early Miocene age (De Santis et al., 2003; Escutia et al., 2005). During this time the EAIS is believed to have a wet-based and dynamic glacial regime (Fig. 2). On the rise, units WL-S4 and WL-S5 are characterized by horizontally stratified reflectors and, within WL-S5, localized channel-levee complexes (Escutia et al., 1997; Escutia et al., 2000; Donda et al., 2007). Younger GDFs lie on top of unconformities WL-U4 or WL-U5, which exhibit an irregular surface caused by erosion of the underlying units. The upper boundary of these debris

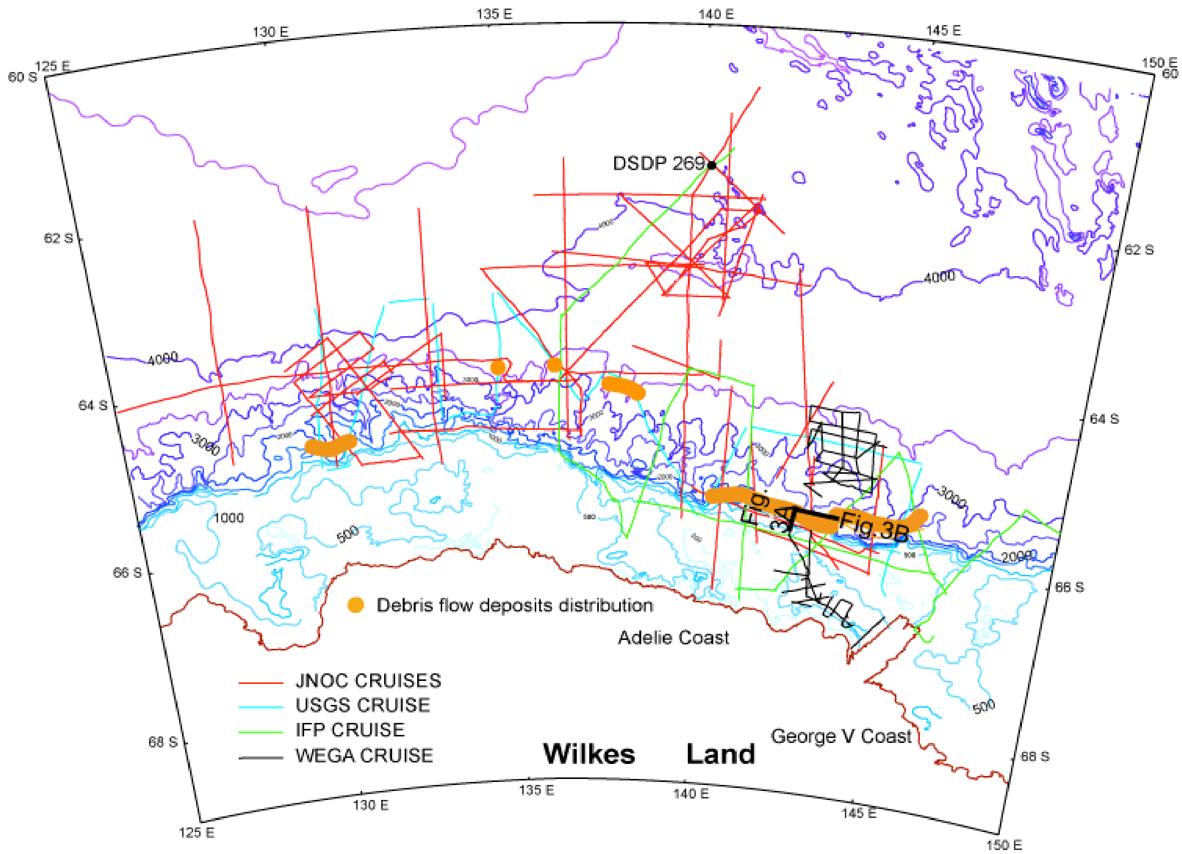

Figure 1. Location map with seismic reflection profiles analyzed for this study. Distribution of debris flow deposits and location of profiles in Figure 3 are also shown.

flows is less clear. At the base-of-slope, seismic units affected by the development of the debris flow could include WL-S4 to WL-S6 and could even involve WL-S7. In any case, seismic units above the WL-U7 unconformity are not involved in any of the GDFs as indicated by downlap of prograding slope wedge clinoforms (i.e., seismic units WL-S8 and WL-S9) in the proximal parts of the GDFs (Fig. 3A). At the seaward end of the debris flows however, irregularly stratified reflectors of unit WL-S6 and younger units overly the debris flow deposits. Unit WL-S6 on the continental rise is characterized by the initiation of widespread development of channel-levee complexes and sediment waves (Escutia et al., 1997; Escutia et al., 2002; Donda et al., 2007). The present hypothesis about the glacial evolution of this margin considers seismic units WL-S5 to WL-S6 to be of Early and Middle-Late Miocene in age, respectively, and to be deposited under a dynamic glacial regime of the EAIS (De Santis et al., 2003; Escutia et al., 2005, Donda et al., 2007) (Fig. 2). In profiles that are perpendicular to the margin, minimum runout distances are 15 km to 50 km for the older GDFs (Fig. 3A) and 35 km to 50 km for the younger GDFs. The width of the GDFs crossed by profiles that are parallel to the margin ranges from 5 km to 13 km (Fig. 3B). Maximum thickness ranges from 200 ms to 450 ms (about 170 to 380 m).

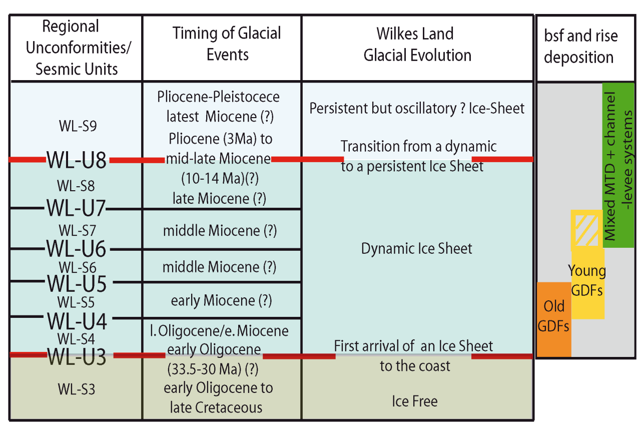

Figure 2. Current stratigraphic model for the Wilkes Land margin and inferred East Antarctic Ice Sheet evolution and timing of events. Shown are the changes in time of the dominant base-of-slope processes. Modified from Escutia et al. (2005).

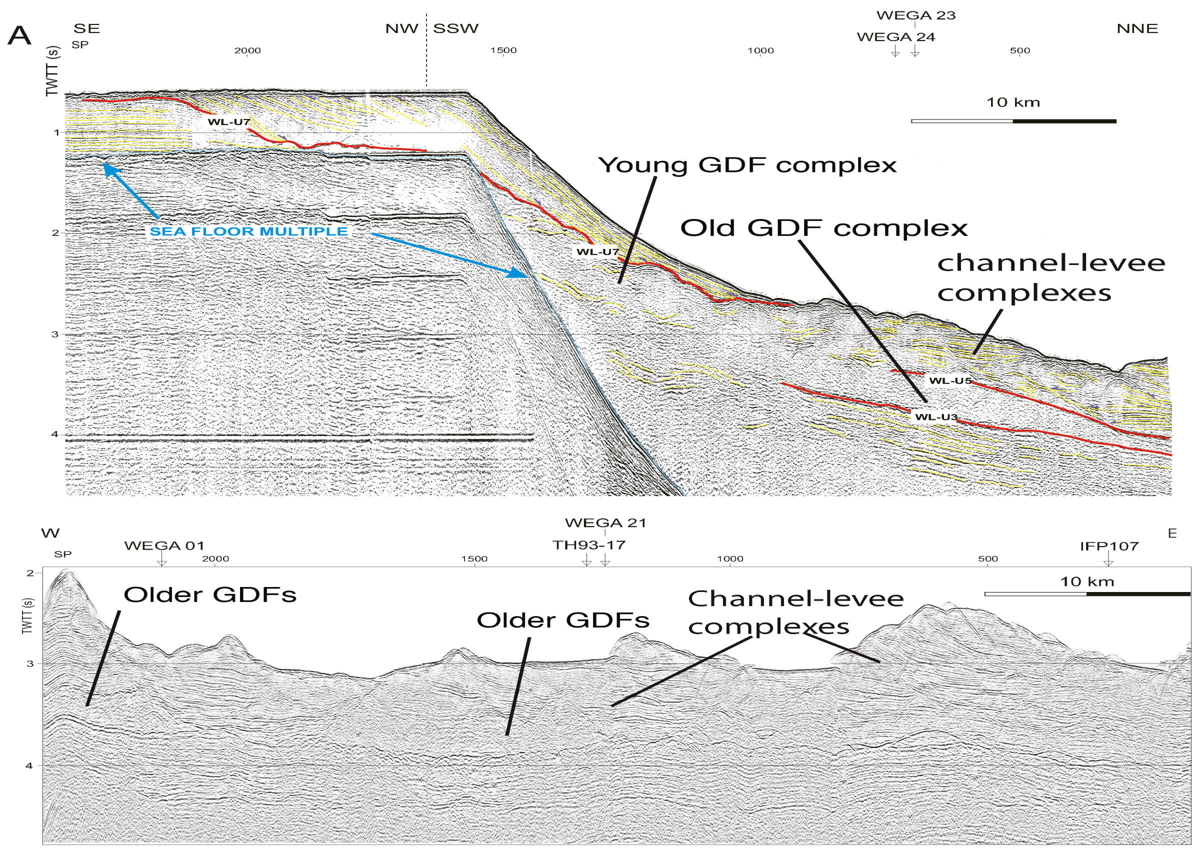

Figure 3. Multichannel seismic reflection profiles showing glacigenic debris flow deposits (GDFs) dominating early glacial deposition in the eastern Wilkes Land base-of-the-slope and upper continental rise. Channel-levee complexes of turbidite deposition dominate the upper glacial seismic units. See Figure 1 for location of profile.

Discussion

GDFs similar to those observed in the eastern Wilkes Land margin have been reported mainly from the North Atlantic glaciated margins, such as are the northeastern Canadian margin (Aksu and Hiscott, 1989, 1992), the Norwegian-Barents Sea margin (Laberg and Vorren, 1995, 1996; Elverhøi et al., 1997; Berg et al., 2005) and the Faeroe-Shetland Channel (Stoker et al., 1991). Glacigenic debrites have also been documented in several settings around Antarctica (Bart et al., 1999; Imbo et al., 2003; Passchier et al., 2003; O'Brien et al., 2004). The generation of that type of mass-movement processes is strongly related to the glaciation-deglaciation processes that have been dominant in such glaciated margins during a large part of the Pliocene-Pleistocene.

Current interpretations about the glacial evolution of the Wilkes Land margin with tentative ages for the Wilkes Land depositional units (De Santis et al., 2003; Escutia et al., 2005; Donda et al., 2007) (Fig. 2), suggest that GDFs were deposited during the Early Oligocene to Middle-Late Miocene times. GDFs were thus developed during times when temperate glaciers first and a wet-based and dynamic EAIS after advanced into the Wilkes Land continental shelf during times of glacial maxima. This dynamic glacial regime, characterized by large volumes of melt-water production, lead to high volumes of sediment discharge onto the continental margin. As a result, extensive sediment failures took place on the Wilkes Land continental slope and deposition of GDFs occurred on the base of the paleo-slope. In contrast, during the Late Miocene-Pliocene there was an evolution to a more persistent cold-based and stable EAIS characterized by decrease rates of glacial erosion and decrease production of melt-water. This resulted in variable terrigenous sediment supply through glacial troughs to submarine canyons that fed widespread channel-levee complexes of turbidite systems (Escutia et al., 2000) that characterize base of the slope and rise sedimentation starting with unit WL-S6 (Escutia et al., 1997; Escutia et al., 2000; Donda et al., 2003). Some mass transport sedimentation persisted at this time on the rise constrained, for the most part, to the base of the channel-levee deposits or interbedded within bottom contour-current deposits (Escutia et al., 2002; Donda et al., 2007).

Summary

Glacial sequences deposited on the lower slope and upper continental rise off the eastern Wilkes Land margin show significant variation of the dominant depositional systems with time. Extensive debris flow deposits dominate during the Early Oligocene to Middle–Late Miocene. During this time large volumes of melt-water produced by a dynamic East Antarctic Ice Sheet (EAIS) glacial regime led to high sediment discharge onto the continental margin and subsequent extensive sediment failures on the continental slope and rise. In contrast, during the Late Miocene–Pliocene there was an evolution to a more persistent, colder base EAIS that produced less melt-water leading to mixed turbidite and mass transport deposition.

Acknowledgments. The research presented in this paper was possible thanks to the Spanish Ministry of Science and Education Grant No. REN2003-0922-CO2-01. We thank the reviewers Sandra Passchier and German Leitchenkov and the co-editor Howard Stagg for their comments on this manuscript.

References

Aksu, A. E. and R. N. Hiscott (1989), Slides and debris flows on the high-latitude continental slopes of Baffin Bay, Geology, 17: 885–888.

Aksu, A. E. and R. N. Hiscott (1992), Shingled Quaternary debris flow lenses on the north-east Newfoundland Slope, Sedimentology, 39: 193–-206.

Bart, P. J., M. De Batist, and W. Jokat (1999), Interglacial collapse of Crary trough-mouth fan, Weddell Sea, Antarctica: Implications for Antarctic glacial history, Journal of Sedimentary Research, 69: 1276–1289.

Berg, K., A. Solheim and P. Bryn (2005), The Pleistocene to recent geological development of the Ormen Lange area. Marine and Petroleum Geology, 22: 45–56.

De Santis, L., G. Brancolini and F. Donda (2003), Seismic-stratigraphic analysis of the Wilkes Land continental margin (East Antarctica). Influence of glacially-driven processes on the Cenozoic deposition, Deep-Sea Research II, vol. 50, Nos. 8-9, 1563–1594.

Donda, F., Brancolini, G., De Santis, L., and Trincardi, F., 2003. Seismic facies and sedimentary processes on the continental rise off Wilkes Land (East Antarctica). Evidence of bottom current activity. Deep-Sea Research II, vol. 50, Nos. 8-9, 1509-1528.

Donda, F., G. Brancolini, P. O´Brien, L. De Santis and C. Escutia (2007), Sedimentary processes in the Wilkes Land margin: a record of Cenozoic Ice Sheet evolution, Journal of the Geological Society, London, v. 164: 243–256.

Elverhøi, A., H. Norem, E. S. Andersen, J. A. Dowdeswell, I. Fossen, H. Haflidason, N. H. Kenyon, J. S. Laberg, E. L. King, H. P. Sejrup, A. Solheim and T. Vorren (1997), On the origin and flow behaviour of submarine slides on deep-sea fans along the Norwegian-Barents Sea continental margin, Geo-Marine Letters, 17: 119–125.

Escutia, C., S. L. Eittreim and A. K. Cooper (1997), Cenozoic glaciomarine sequences on the Wilkes Land continental rise, Antarctica, Proceedings Volume-VII International Symposium on Antarctic Earth Sciences, 791–795.

Escutia, C., S. L. Eittreim, A. K. Cooper, and C.H. Nelson (2000), Morphology and acoustic character of the Antarctic Wilkes Land turbidite systems: ice-sheet sourced versus river-sourced fans, J. Sed. Res. 70 (1), 84–93.

Escutia C., L. De Santis, F. Donda, R. B. Dunbar, G. Brancolini, G., S. L. Eittreim and A. K. Cooper, (2005), Cenozoic ice sheet history from east Antarctic Wilkes Land continental margin sediments, Global and Planetary Change, 45 1-3: 51–81.

Escutia, C., C. H. Nelson, G. D. Acton, A. K. Cooper, S. L. Eittreim, D. A. Warnke and J. Jaramillo. (2002), Current controlled deposition on the Wilkes Land continental rise, in Deep-Water Contourite Systems: modern drifts and ancient series, seismic and sedimentary characteristics, edited by D. Stow et al., Geological Society, London, Memoirs, 22, 373–384.

Imbo, Y., M. De Batist, M. Canals, M. J. Prieto and J. Baraza, (2003), The Gebra Slide: a submarine slide on the Trinity Peninsula Margin, Antarctica. Marine Geology, 193: 235–252.

Laberg, J. S. and T. O. Vorren (1995), Late Weichselian submarine debris flow deposits on the Bear Island Trough Mouth Fan, Marine Geology, 127: 45–72.

Laberg, J. S. and T. O. Vorren (1996), The Middle and Late Pleistocene evolution of the Bear Island Trough Mouth Fan, Global and Planetary Change, 12: 309–330.

O'Brien, P. E., A. K. Cooper, P. Erwin, F. Florindo, D. Handwerger, M. Lavelle, S. Passchier, J. J. Pospichal, P. G. Quilty, C. Richter, K. M. Theissen and J. M. Whitehead (2004), Prydz Bay Channel Fan and the history of extreme ice advances in Prydz Bay, Proceedings Ocean Drilling Program, Scientific Results vol. 188, edited by A. K. Cooper, P. E. O'Brien and C. Richter, Ocean Drilling Program, College Station, TX.

Passchier, S., P. E. O'Brien, J. E. Damuth, N. Janusczak, D. A. Handwerger and J. M.Whitehead (2003), Pliocene–Pleistoncene glaciomarine sedimentation in eastern Prydz Bay and development of the Prydz trough-mouth fan, ODP Sites 1166 and 1167, East Antarctica, Mar. Geol., 199:279–305

Stoker, M. S., R. Harland and D. K. Graham, D.K. (1991), Glacially influenced basin plain sedimentation in the southern Faeroe-Shetland Channel, northwest United Kingdom continental margin, Marine Geology, 100: 185–199.