Marine Geology 265 (2009) 1–18

Contents lists available at ScienceDirect

Marine Geology

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

Clay mineral provenance of sediments in the southern Bellingshausen Sea reveals drainage changes of the West Antarctic Ice Sheet during the Late Quaternary

C.-D. Hillenbrand [a,*], W. Ehrmann [b], R.D. Larter [a], S. Benetti [a,1], J.A. Dowdeswell [c], C. Ó Cofaigh [d], A.G.C. Graham [a], H. Grobe [e]

[a] British Antarctic Survey, Madingley Road, Cambridge CB3 0ET, United Kingdom
[b] Institute for Geophysics and Geology, University of Leipzig, Talstrasse 35, D-04103 Leipzig, Germany
[c] Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge CB2 1ER, United Kingdom
[d] Department of Geography, Durham University, South Road, Durham DH1 3LE, United Kingdom
[e] Alfred Wegener Institute for Polar and Marine Research, Am Alten Hafen 26, D-27568 Bremerhaven, Germany

ARTICLE INFO

Article history:
Received 10 October 2008
Received in revised form 2 June 2009
Accepted 12 June 2009
Available online 23 June 2009

Communicated by J.T. Wells

Keywords:
Late Quaternary
West Antarctic Ice Sheet
ice stream
Bellingshausen Sea
clay mineralogy
continental margin
diamicton

ABSTRACT

The Belgica Trough and the adjacent Belgica Trough Mouth Fan in the southern Bellingshausen Sea (Pacific sector of the Southern Ocean) mark the location of a major outlet for the West Antarctic Ice Sheet during the Late Quaternary. The drainage basin of an ice stream that advanced through Belgica Trough across the shelf during the last glacial period comprised an area exceeding 200,000 km^2 in the West Antarctic hinterland. Previous studies, mainly based on marine-geophysical data from the continental shelf and slope, focused on the bathymetry and seafloor bedforms, and the reconstruction of associated depositional processes and ice-drainage patterns. In contrast, there was only sparse information from seabed sediments recovered by coring. In this paper, we present lithological and clay mineralogical data of 21 sediment cores collected from the shelf and slope of the southern Bellingshausen Sea. Most cores recovered three lithological units, which can be attributed to facies types deposited under glacial, transitional and seasonally open-marine conditions. The clay mineral assemblages document coinciding changes in provenance. The relationship between the clay mineral assemblages in the subglacial and proglacial sediments on the shelf and the glacial diamictons on the slope confirms that a grounded ice stream advanced through Belgica Trough to the shelf break during the past, thereby depositing detritus eroded in the West Antarctic hinterland as soft till on the shelf and as glaciogenic debris flows on the slope. The thinness of the overlying transitional and seasonally open-marine sediments in the cores suggests that this ice advance occurred during the last glacial period. Clay mineralogical, acoustic sub-bottom and seismic data furthermore demonstrate that the palaeo-ice stream probably reworked old sedimentary strata, including older tills, on the shelf and incorporated this debris into its till bed. The geographical heterogeneity of the clay mineral assemblages in the sub- and proglacial diamictons and gravelly deposits indicates that they were eroded from underlying sedimentary strata of different ages. These strata may have been deposited during either different phases of the last glacial period or different glacial and interglacial periods. Additionally, the clay mineralogical heterogeneity of the soft tills recovered on the shelf suggests that the drainage area of the palaeo-ice stream flowing through Belgica Trough changed through time.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

The southern Bellingshausen Sea (Fig. 1) is a poorly-studied area on the Pacific continental margin of Antarctica, but was a major outlet for ice drainage from West Antarctica during the past (Ó Cofaigh et al., 2005a). The area was investigated in detail during cruise JR104 on *RRS James Clark Ross* in 2004. Multibeam swath bathymetric data and sub-bottom acoustic profiles revealed the existence of a major glacial trough ("Belgica Trough") on the shelf and an associated trough mouth fan ("Belgica TMF") on the adjacent slope (Ó Cofaigh et al., 2005a; Dowdeswell et al., 2008; Noormets et al., 2009). Distinct seabed morphological features on the shelf, such as mega-scale glacial lineations, drumlins and grounding-zone wedges, indicate that Belgica Trough was the former pathway of a grounded ice stream, which had advanced onto the outer shelf and probably to the shelf break during the last glacial period (Ó Cofaigh et al., 2005a; cf. Wellner et al., 2001). Moreover, the orientation of the subglacial bedforms suggested that the ice stream was fed by grounded ice draining through Eltanin Bay, located directly to the south of Belgica Trough, and Ronne Entrance, located between southwestern Alexander Island and the English Coast (Fig. 1). These results implied that ice flow into

* Corresponding author. Tel.: +44 1223 221340; fax: +44 1223 221646.
E-mail address: hilc@bas.ac.uk (C.-D. Hillenbrand).
[1] Present address: School of Environmental Sciences, University of Ulster, Cromore Road, Coleraine, BT52 1SA, United Kingdom.

0025-3227/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.margeo.2009.06.009

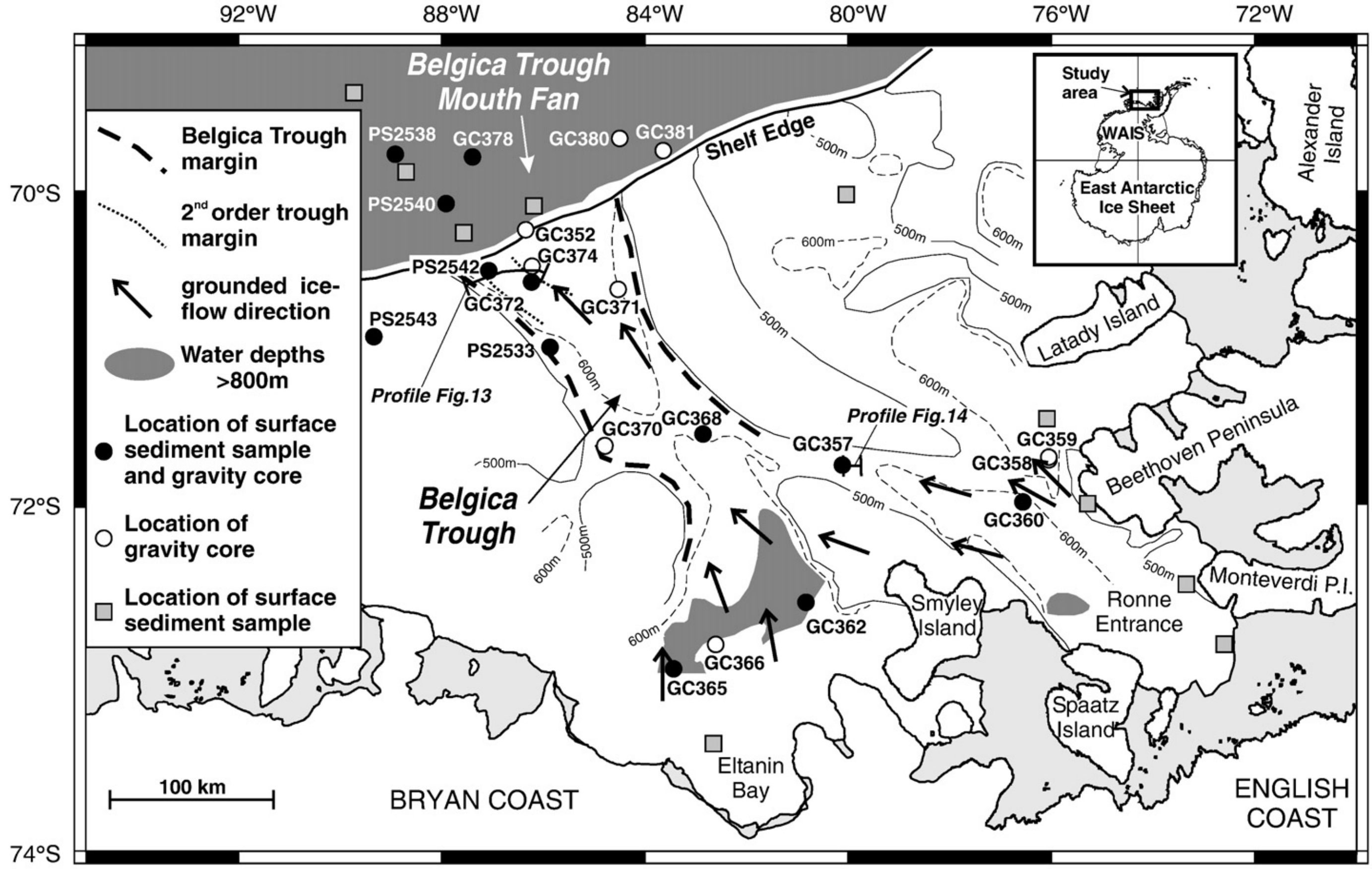

Fig. 1. Map of the southern Bellingshausen Sea with locations of sediment cores and surface sediment samples (note: only identifications of gravity core sites are given, for a summary of all locations see Supplementary Table). Grounded ice-flow directions according to Ó Cofaigh et al. (2005a).

the southern Bellingshausen Sea drained more than 200,000 km^2 of the West Antarctic hinterland and, in contrast to the present ice drainage pattern, played a significant role for ice drainage from the largely marine-based West Antarctic Ice Sheet (WAIS) during the Late Quaternary (Ó Cofaigh et al., 2005a).

First results of studies on three sediment cores collected from the continental margin in the southern Bellingshausen Sea during cruise ANT-XI/3 with *RV Polarstern* in 1994 confirmed grounded ice advance onto the outer shelf and deposition of diamictons interpreted as glaciogenic debris flows (GDFs) on the western part of the Belgica TMF (Hillenbrand et al., 2005). While the clay mineralogical composition of a glacial diamicton recovered from the shelf (site PS2533-2; location see Fig. 1) corroborated supply of glaciogenic detritus from Eltanin Bay, the clay mineralogical composition of the GDFs on the continental slope (sites PS2538-2 and PS2540-3; locations see Fig. 1) pointed to major supply of subglacial debris via Ronne Entrance (Hillenbrand et al., 2005). The latter finding is surprising, because the orientation of subglacial bedforms on the shelf indicates that ice flowing into Belgica Trough was mainly fed by ice draining the WAIS through Eltanin Bay with a smaller contribution from ice draining the Antarctic Peninsula Ice Sheet through Ronne Entrance (Ó Cofaigh et al., 2005a).

In this paper, we present a large clay mineralogical dataset compiled from surface seabed samples and 21 sediment cores recovered from the southern Bellingshausen Sea during cruises JR104 and ANT-XI/3 (Supplementary Table). We relate the clay mineralogical composition of the sediments to different environmental conditions affecting deposition on the shelf and slope since the last glacial period. Moreover, we infer variations in past ice-drainage patterns from changes in sediment provenance. Subglacial sediment dispersal reconstructed from provenance data has been studied in detail for palaeo-ice sheets on the Northern Hemisphere (for a review see Clark, 1987). These studies used mainly mineralogical, petrological or geochemical indicator concentrations in tills, for example erratics from a particular well-known rock source, to determine transport distances (e.g. Clark, 1987; Dyke and Morris, 1988; Klassen, 2001). The indicator concentrations usually decrease exponentially or linearly with distance from the source (Clark, 1987; Klassen, 2001), forming so-called dispersal trains (e.g. Dyke and Prest, 1987; Dyke and Morris, 1988). The length of these dispersal trains varies between a few kilometres and 1000 km (e.g. Clark, 1987; Dyke et al., 2002). Topography, basal ice velocity and initial concentration of englacial debris have been recognized as primary factors promoting subglacial sediment dispersal over long distances (Clark, 1987; Dyke and Prest, 1987; Dyke and Morris, 1988; Klassen, 2001). In our study area, mountain valleys are restricted to the Antarctic Peninsula, and thus we can assume that a palaeo-ice stream advancing across the shelf of the southern Bellingshausen Sea transported debris predominantly at its base. Given the topography of Belgica Trough and relatively high palaeo-ice flow speed, which is inferred from the mega-scale glacial lineations present within the trough, we can expect subglacial dispersal trains to be in the order of a hundred to hundreds of kilometres (cf. Clark, 1987; Dyke and Morris, 1988).

2. Materials and methods

Undisturbed sediments from the seafloor surface (recovered with box and multiple corers) and long sediment cores (recovered with a gravity corer) were collected during cruises JR104 with *RRS James Clark Ross* in 2004 and ANT-XI/3 with *RV Polarstern* in 1994 (Miller and Grobe, 1996; Fig. 1, Supplementary Table). The sediment cores were described visually and using X-radiographs. Shear strength was measured on the split cores using a hand-held shear vane and a shear vane HAAKE Rotovisco 1500 M, respectively.

Download English Version:

https://daneshyari.com/en/article/4719091

Download Persian Version:

https://daneshyari.com/article/4719091

Daneshyari.com