Antarctic Science 17 (1): 29–32 (2005) © Antarctic Science Ltd Printed in the UK DOI: 10.1017/S0954102005002397

The onset of deglaciation of Cumberland Bay and Stromness Bay, South Georgia

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Abstract: Carbon dating of basal peat deposits in Cumberland Bay and Stromness Bay and sediments from a lake in Stromness Bay, South Georgia indicates deglaciation at the very beginning of the Holocene before *c.* 9500 ^{14}C yr BP. This post-dates the deglaciation of one local lake which has been ice-free since at least 15 700 ^{14}C yr BP on account of its atypical geomorphological location. The latter indicates the likely presence of floristic refugia on South Georgia during the Last Glacial Maximum from which newly exposed terrestrial and aquatic habitats were rapidly colonized.

Received 20 July 2004, accepted 19 September 2004

Key words: Early Holocene deglaciation, geomorphology, glacial refugia, palaeoecology, radiocarbon dates, sub-Antarctic

Introduction

Geomorphological (Clapperton 1971, 1990, Clapperton *et al*. 1978, 1989), palaeoecological (Barrow 1977, 1983, Barrow & Smith 1983, Clapperton *et al*. 1989, Van der Putten *et al*. 2004) and lithological-chemical investigation (Rosqvist *et al*. 1999, Rosqvist & Schuber 2003) of organic lake and terrestrial sediments around Stromness Bay and Cumberland Bay (Fig. 1) provides conflicting models of deglaciation. In this paper we review the existing evidence from radiocarbon dates collected at the base of the peat cover and from lake sediments, and present new data that better constrain the minimum onset of deglaciation in this region.

The site investigated

South Georgia (54°30'–55°00'S, 35°30'–38°30'W) is a large sub-Antarctic island, lying with the Polar Front. The cold oceanic climate induces exstensive snow and ice cover. However, the lower coastal zones are snow free in summer and covered by tundra-like vegetation, varying between tussock, grass heath, marsh and bog, and cryptogamic communities.

This study is limited to Husdal and the "Tønsberg Peninsula" (unofficial name) in Stromness Bay (Fig. 1). The latter peninsula and the northern part of Husdal, known as Karrakkatta Valley, are characterized by the presence of many small lakes, situated in glacial hollows. These are located in the most sheltered zone of the island and it is generally assumed that deglaciation made early progress here (Smith 1981). To date, research has included sediment coring in Parochlus Lake, Block Lake and Lake 1 (Wassell 1993, Rosqvist *et al*. 1999, Rosqvist & Schuber 2003) and Lake 10 (this paper) together with peat cover surveys (Van der Putten *et al*. 2004).

Review of the existing data on deglaciation

Based on research in Cumberland East Bay, Cumberland West Bay and Stromness Bay Clapperton (1971, 1990) and Clapperton *et al*. (1978, 1989), presented a model of environmental and climate changes that can be summarized as follows:

- Ice cap maximum extent before 18 000 BP, to the edge of the continental shelf.
- Withdrawal of the ice cap to a short distance beyond the present shore between 18 000 and 14 000 BP.
- Further glacier recession to within fjords and bays between 14 000 and 10 000 BP.

This model is based on evidence from trimlines, lateral and terminal moraines. In addition, radiocarbon dates of peat deposits (Table I, no. 1, 2, 3) were used to show that the lower zone (< 50 m) of the north-east coast of South Georgia was ice-free after *c.* 9700 BP. Later Holocene moraines were formed *c.* 2200 BP and between *c.* 800 and 100 BP.

The onset of terrestrial organic accumulation on the north-east coast was studied by Smith (1979, 1981) based on carbon dating of peat deposits (Table I, n.s 4, 5 & 6). These gave minimum ages for deglaciation ranging from 8657 ± 45 to 9433 ± 120 BP.

Wasell (1993) and Rosqvist *et al*. (1999) dated basal sediments of lakes in the northern part of Husdal and on the "Tønsberg Peninsula". For Lake 1 a sample near the base of a 4.8 m sediment core yielded an age of 15 715 ± 150 BP. Wasell concluded that the drainage area of Lake 1 seems not

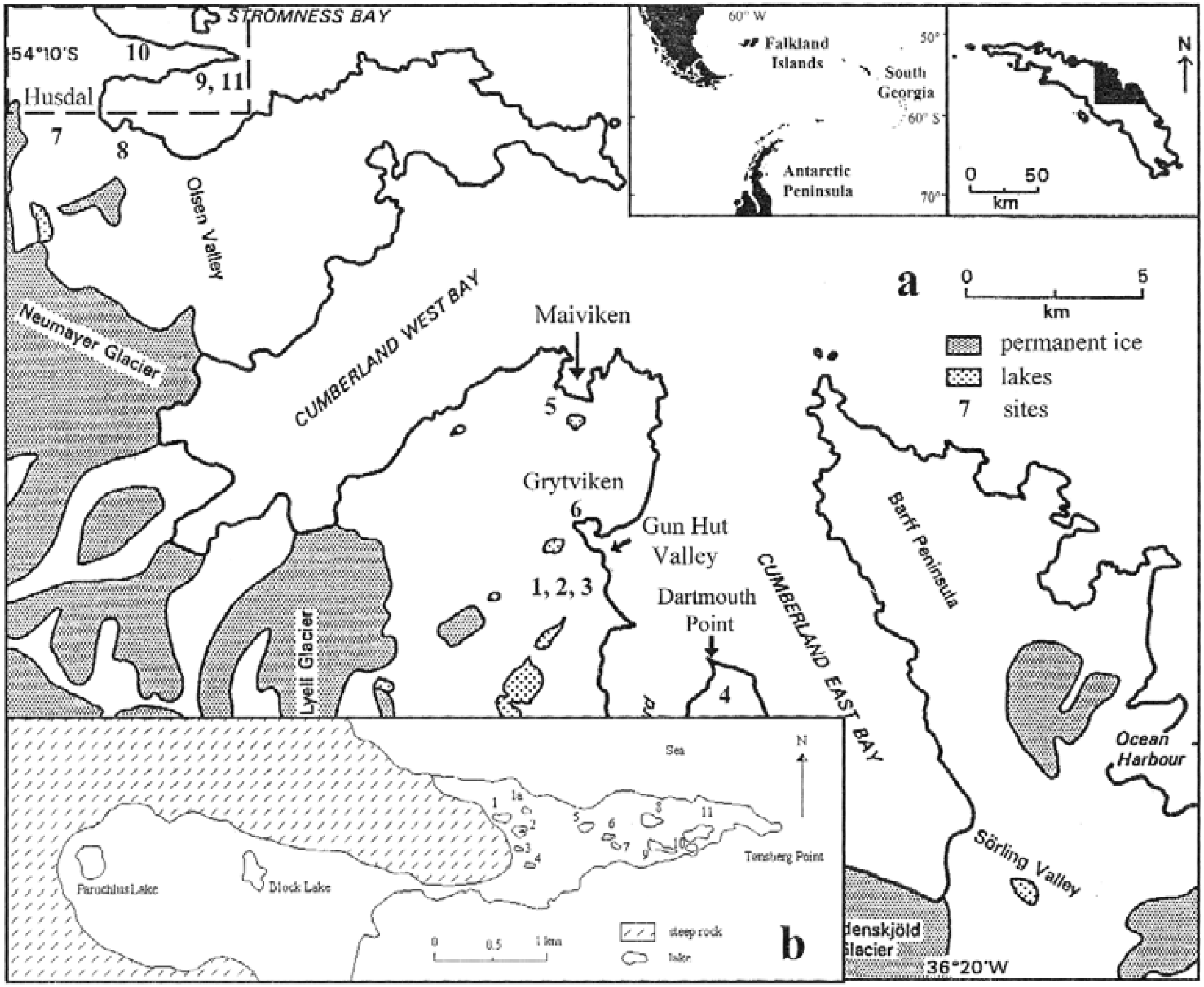

Fig. 1. a. Location of South Georgia and the study area in Cumberland and Stromness Bay (after Barrow & Smith 1983). Numbers on the map show the sites of radiocarbon dates of peat bases and lake sediments presented in Table I. The area in dotted line shows the location of inset b. **b.** Location of the lakes in Husdal and on the "Tønsberg Penisula" (numbering of the lakes follows H. MacAlister).

to have been directly affected by glaciers for at least the last 14 000 years on account of its location on a ridge about 70 m a.s.l. and its protection from glacial action by a peak on this ridge. Glacial streams were channelled down the major valleys, and Lake 1 was located in between two major glaciers during the late Pleistocene and the early Holocene ice retreat (Wasell 1993, p. 14).

New radiocarbon dates

The data derived from samples collected in 1992–93 and 1995–96 can be summarized as follows.

Peat sequences

Two peat sequences in Husdal, Kanin point sequence (0–3.20 m) and Sinkhole sequence (0–4.65 m) were radiocarbon dated at their base (Table I and Fig. 1). On the "Tønsberg Peninsula" dating of peat accumulation in a small oval shaped hollow found aside Lake 11 (Fig. 1b) near the eastern extremity of the peninsula revealed a sequence of 3.20 m thick covering nearly the whole Holocene (Van der Putten *et al.* 2004). The lowermost sediments in this depression consist of alternating peaty and silty layers, pointing to shallow pool conditions at the start of the infilling. The two radiocarbon dates of these layers (Table I, Tønsberg Point), indicate that the pool came into existence soon after the beginning of the Holocene. The most striking fact concerning the vegetation is the presence. at the base of the sequence. of nearly all the species of vascular plants and mosses, occurring in later phases and at present.

Lake sequence

Lake 10 (eastern extremity of the "Tønsberg Peninsula") had a sediment depth of 4.90 m consisting mainly of organic gyttja with visible plant remains, mostly mosses.

https://doi.org/10.1017/S0954102005002397 Published online by Cambridge University Press

Table I.

Location	Author	Depth below surface	Laboratory no.	Date (^{14}C yr BP)	Age range (cal yr BP)	No. Fig. 1a
Radiocarbon dates of peat bases in the Cumberland- and Stromness Bay area						
"Gun Hut Valley" Cumberland East Bay	Clapperton *et al.* (1978)	160 cm	SRR-582	8537 ± 65	1σ 9555–9470 2σ 9690–9420	1
		255 cm	SRR-736	9493 ± 370	1σ 11350–10150 2σ 12150–9650	2
	Barrow (1983) Clapperton *et al.* (1989)	350 cm	SRR-1979?	9700 ± 150	1σ 11230–10750 2σ 11600–10550	3
Dartmouth Point, Cumberland East Bay	Smith (1981)	280 cm	SRR-1165	9417 ± 35	1σ 10700–10570 2σ 11050–10500	4
		300 cm	SRR-1166	9433 ± 120	1σ 11100–10400 2σ 11200–10250	
Maiviken, Cumberland West Bay	Smith (1981)	180 cm	SRR-1162	8657 ± 45	1σ 9680–9540 2σ 9760–9530	5
Grytviken, Cumberland East Bay	Smith (1981)	460 cm	SRR-1168	8737 ± 50	1σ 9890–9600 2σ 9920–9550	6
Husdal, Stromness Bay	This paper	460 cm	UtC-3307*	9160 ± 110	1σ 10480–10210 2σ 10700–9900	7
Husdal, Kanin Point, Stromness Bay	This paper	315 cm	UtC-6866*	8225 ± 45	1σ 9400–9030 2σ 9410–9030	8
Husdal, Tønsberg Point, Stromness Bay	Van der Putten *et al.* (2004)	303 cm	UtC-3186*	9220 ± 60	1σ 10480–10240 2σ 10560–10230	9
		308 cm	UtC-4179*	9520 ± 80	1σ 11070–10640 2σ 11200–10550	
Radiocarbon dates of lake sediments in Stromness Bay area						
Husdal, Tønsberg Point, Lake 1, Stromness Bay	Rosqvist *et al.* (1999)	497–501 cm	Ua-2991*	15715 ± 150	1σ 19100–18400 2σ 19550–18050	10
Husdal, Tønsberg Point, Lake 10, Stromess Bay	This paper	436 cm	UtC-6532*	8350 ± 50	1σ 9470–9290 2σ 9500–9140	11
		447 cm	UtC-6232*	9060 ± 50	1σ 10245–10180 2σ 10400–9970	

* Measured by AMS

All samples are bulk peat samples, except for Ua-2991, UtC-6532 and UtC-6232 which are bulk dates of organic lake sediments. All UtC-samples were pre-treated by routine AAA-method at the Royal Institute for Cultural Heritage (Brussels, Belgium) and measured at the Van de Graaff laboratory (Utrecht, The Netherlands). Calibration of the radiocarbon dates was performed using the OxCal program (Ramsey 1995). Probability method was used. A southern hemisphere correction was not applied and no reservoir effects (Moreton *et al.* 2004) were taken into account. All ages in the paper are ^{14}C years BP.

Below a depth of 4.55 m, there is an abrupt change from the organic gyttja to an underlying grey inorganic silt. This kind of silt is also described by Rosqvist *et al.* (1999) as the bottom layer of Lake 1 and interpreted as a proglacial lake deposit. Six levels of the core were radiocarbon dated; the lowermost two, respectively at 8 and 19 cm above the sediment change, yielded ages of 9060 ± 50 BP and 8350 ± 50 BP, indicating a Holocene onset of organic infilling of the lake. From these data we conclude that the site of Lake 10 became ice free after the beginning of the Holocene.

Discussion and conclusions

From the existing and new radiocarbon dates from both lake sediments and peat deposits in the Cumberland – Stromness area (Table I) we conclude, in agreement with Clapperton *et al.* (1989) and Smith (1979, 1981), that the deglaciation of the lower zones (< 50 m) of this area took place in the first centuries of the Holocene between *c.* 9000 and 9600 BP. This conclusion is based on the assumption that vegetation rapidly colonised ice-free zones after ice retreat and that peat growth started at the same time (Smith 1981, Björck *et al.* 1991, Rosqvist *et al.* 1999). However, based on radiocarbon dates from Lake 1, Rosqvist *et al.* (1999, p. 968) concluded that ice pulled away from Tønsberg Peninsula at *c.* 15 700 BP.

Our interpretation is that this pre-dates deglaciation of the rest of the Cumberland–Stromness area on account of its atypical location (described above) which may have become ice free soon after the initial warming around 15 700 BP and therefore it provides a remarkable record of postglacial climate change. The fact that all or nearly all plant species were present in the peat deposits at the beginning of the Holocene soon after the deglaciation, can be considered as an indication that some areas remained ice-free with plants surviving the glacial period in refugia on South Georgia and its adjacent archipelago. Barrow (1977) also came to this conclusion based on his palynological research. In the light of this assumption the discovery of one possible ice-free catchment by Rosqvist is very important and endorses our conclusion that a correct understanding of the deglaciation history of South Georgia can provide a valuable link in palaeoenvironmental and palaeoclimatological reconstructions of the Antarctic and sub-Antarctic regions.

Acknowledgements

British Antarctic Survey, Cambridge, UK (Professor D. Walton) provided the facilities for the field campaigns on South Georgia. The technical and practical help in the field of Ash Morton and Rod Arnold was indispensable. Also Dr L. Beyens is thanked for his assistance with the fieldwork. We also thank P. Cleveringa (TNO NITG, The Netherlands) for interesting discussions and suggestions. Dr D. Hodgson and an unknown referee are thanked for their detailed comments. Funding was provided by the Scientific Research Foundation (FWO) Flanders (Programs 1.5.655-94 and G.0203-97) and Ghent University, Belgium.

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https://doi.org/10.1017/S0954102005002397 Published online by Cambridge University Press