Quaternary Science Reviews 89 (2014) 129–147

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

Glacial history of sub-Antarctic South Georgia based on the submarine geomorphology of its fjords☆

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ARTICLE INFO

Article history:
Received 4 March 2013
Received in revised form
2 December 2013
Accepted 6 December 2013
Available online 13 March 2014

Keywords:
Glacial history
Glaciation
Geomorphology
Swath bathymetry
Geochronology

ABSTRACT

We present multibeam swath bathymetric surveys of the major fjords surrounding the sub-Antarctic island of South Georgia to characterise the glacial geomorphology and to identify the relative timings and extent of past glacial advance and retreat. Bathymetry data revealed a range of glacial features including terminal, retreat and truncated moraines, deep (distal) outer and shallow (proximal) inner basins and cross shelf troughs. These provide evidence of glacial advance and retreat through several glacial cycles. A near consistent pattern of large scale submarine geomorphological features was observed in the different fjords suggesting a similar response of margins of the island ice cap to past climate forcing. A relative chronology based on the relationships between the submarine features with their radiocarbon and cosmogenic isotope dated terrestrial counterparts suggests that widely observed inner basin moraines date from the last major glacial advance or Last Glacial Maximum, while deep basin moraines may date from an earlier (pre-LGM) more extensive glaciation, which we speculate corresponds to MIS6. On the sides of the deep basins a series of truncated moraines show ice advance positions from preceding glacial periods. The cross shelf troughs, and mid-trough moraines are interpreted as the product of much more extensive glaciations that predate the fjord geomorphology mapped here, thus possibly older than MIS6. This hypothesis would suggest that South Georgia followed a glacial history similar to that of central Patagonia (46°S) where a series of Pleistocene glaciations (of MIS 20 and younger) extended beyond LGM limits, with the most extensive glacial advance occurring at *c.* 1.1 Ma.

1. Introduction

South Georgia is situated between the Antarctic Peninsula and southernmost South America. Its glacial history has been studied for nearly a century (Gregory, 1915). The main research questions have focused on whether its glaciations are in phase or out of phase with the South American, Antarctic and northern hemisphere glaciations, defining the maximum ice extent during the Last Glacial cycle, and establishing a chronology for deglaciation and glacier fluctuations during the Holocene. All of these questions have the wider goal of improving our understanding of the mechanisms of climate change, both regionally and with respect to the phasing of climate changes between the hemispheres (Broecker, 1998), as well as improving understanding of the mechanisms of ice sheet decay and its impact on global sea levels (Sugden, 2009).

To date, glacial geomorphological research on South Georgia has focused on the terrestrial geomorphology which has established that an independent ice cap glaciated the island during the local Last Glacial Maximum (referred to hereafter simply as 'LGM') (Clapperton, 1971; Sugden and Clapperton, 1977; Clapperton and Sugden, 1988; Clapperton et al., 1989; Bentley et al., 2007). Most of the effort has been focussed on interpreting the glacial features in specific, and logistically more accessible, locations on the basis of comparative geomorphology and geomorphological mapping (Clapperton, 1971; Stone, 1974; Clapperton et al., 1989), radiocarbon-based geochronological models of glacial sediments (Gordon, 1987), combined radiocarbon and cosmogenic isotope dating of moraines (Bentley et al., 2007), the onset of sedimentation in lakes and peat bogs (Clapperton et al., 1989; Wasell, 1993; Rosqvist et al., 1999; Rosqvist and Schuber, 2003; Van der Putten

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http://dx.doi.org/10.1016/j.quascirev.2013.12.005

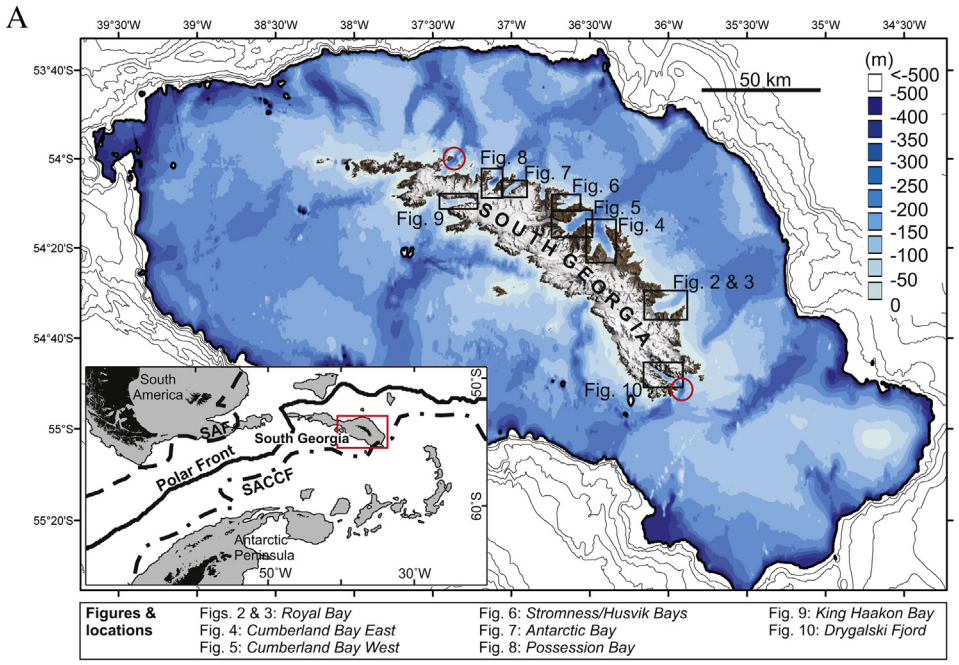

Fig. 1. (A) Topographic and bathymetric compilation of South Georgia and its continental shelf (223 m cell size grid, UTM Zone 24S projection) compiled from a variety of data sources including, multibeam swath and single-beam bathymetry data (Graham et al., 2008; Fretwell et al., 2009). Note the aligned trough systems widening from the fjords towards the outer shelf, converging tributaries, banked shelf edge features, well-defined shape of the continental margin, and radial distribution of troughs north and south of the island. Hillshade of DEM of South Georgia supplied by P. Fretwell, BAS. Locations of Figs. 2–9 are shown as inset boxes. Circles highlight the deep basins at Bay of Isles (northwest coast) and Drygalski Fjord (east coast). Inset map shows the wider regional location of South Georgia with grey shading indicating water depths <500 m. Oceanographic boundaries indicated are the Polar Front, the Sub-Antarctic Front (SAF) and the southern Antarctic Circumpolar Current Front (SACCF). Fig. 1 (B) Oblique aerial photograph along the heavily glaciated south coast of South Georgia facing west from near the head of Drygalski Fjord.

et al., 2004; Van der Putten, 2008), and lichenometric studies (Roberts et al., 2010). More recently the remarkable maximum extent of past glaciations around South Georgia has been revealed by a new compilation of bathymetric soundings from the continental shelf and surrounding waters. This has revealed large cross shelf glacial troughs, moraines and trough mouth fans on the shelf and slope at an unprecedented level of detail (Graham et al., 2008; Fretwell et al., 2009). These suggest that one or more glaciations have extended to the continental shelf break. Collectively, these studies have considerably advanced our understanding of the glacial history, but it is still not known whether at the LGM the ice cap extended to the edge of the continental shelf around South Georgia (Clapperton et al., 1989), or if the LGM was limited to the inner fjords as suggested both by the more recent mapping and dating of the