Quaternary Science Reviews 30 (2011) 1583–1601

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

The marine record of deglaciation of the South Shetland Islands, Antarctica since the Last Glacial Maximum

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ARTICLE INFO

Article history:
Received 20 June 2010
Received in revised form
8 February 2011
Accepted 29 March 2011
Available online 29 April 2011

Keywords:
Antarctic Peninsula
Late Pleistocene
Holocene
Shelf
Fjords
King George Island
Bransfield Basin
Glaciation

ABSTRACT

The marine geological record of the glacial-retreat history of the South Shetland Islands is derived from the integration of seismic data, core lithofacies, radiocarbon ages and geomorphological data from two study areas. On the northern shelf, we present one of the first published multibeam bathymetric images of the seafloor. This new image combined with descriptions of new and existing short sediment cores and high-resolution seismic data from the continental shelf north of King George Island are used to map a grounding zone wedge that marks the minimum seaward extent of the South Shetland Ice Cap during the Last Glacial Maximum. Seismic data, multibeam bathymetry, and sediment cores from Maxwell Bay, on the opposite side of King George Island, are used to provide further spatial constrains on the history of grounding and retreat of the ice cap along the southern margin of the South Shetland Islands.

During the Last Glacial Maximum the South Shetland Ice Cap extended onto the outer continental shelf, some 50 km north of its present location. The ice grounded on the shelf in troughs in present water depths of almost 400 m. It had a minimum thickness of ~570 m and was also grounded in the deepest part of fjords and straits between the islands. To the south, the ice cap extended seaward of the mouths of fjords and straits to the steep northern boundary of the Bransfield Strait. Sediment eroded from the fjords and straits was deposited in prominent fans that extend into the Bransfield Strait and show evidence for an ice shelf that covered the Bransfield Strait during the Last Glacial Maximum. A long drill core (SHALDRIL) in Maxwell Bay and several jumbo piston cores yielded carbonate material used to constrain the timing and spatial extent of glacial retreat within Maxwell Bay. The oldest glacimarine sediments in the fjord date back to ~14.1 to ~14.8 ka and suggest an initial deglaciation earlier than most previous studies of the South Shetland Islands. Upper Maxwell Bay was ice free by 9.1 ka and most of Maxwell Bay proper was ice free by 5.9 ka except for the smaller tributary fjords of Maxwell Bay. These smaller tributary fjords were ice free by 1.7 ka, but may have been ice free earlier but reoccupied by a neoglacial advance that ended approximately 1.7 ka.

1. Introduction

The South Shetland Islands (SSI) are located at the northernmost tip of the Antarctic Peninsula (Fig. 1). The Antarctic Peninsula has experienced some of the most pronounced warming trends anywhere on Earth having warmed on average 3.4°C/century (Vaughan et al., 2003).Over the last 30–50 years several studies have documented the retreat of glaciers and the melting of ice throughout the region (Park et al., 1998; Simoes et al., 2004a; Cook et al., 2005). However, before drawing conclusions about the impact of warming on the ice sheets and glaciers of the region and their future fate it is important to put the current changes into context of the geologic record of ice retreat.

Glacio-isostatic models for the amount of ice that covered the SSI during the Last Glacial Maximum (LGM, ~20 ka) vary from as much as 500 m of additional ice cover to no significant additional ice (Tushingham and Peltier, 1991; Denton et al., 1991). To add to the confusion, the marine and terrestrial records of glaciation appear to oppose one another. Some recent reviews of the terrestrial glacial history of the SSI support little additional ice during the

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doi:10.1016/j.quascirev.2011.03.018

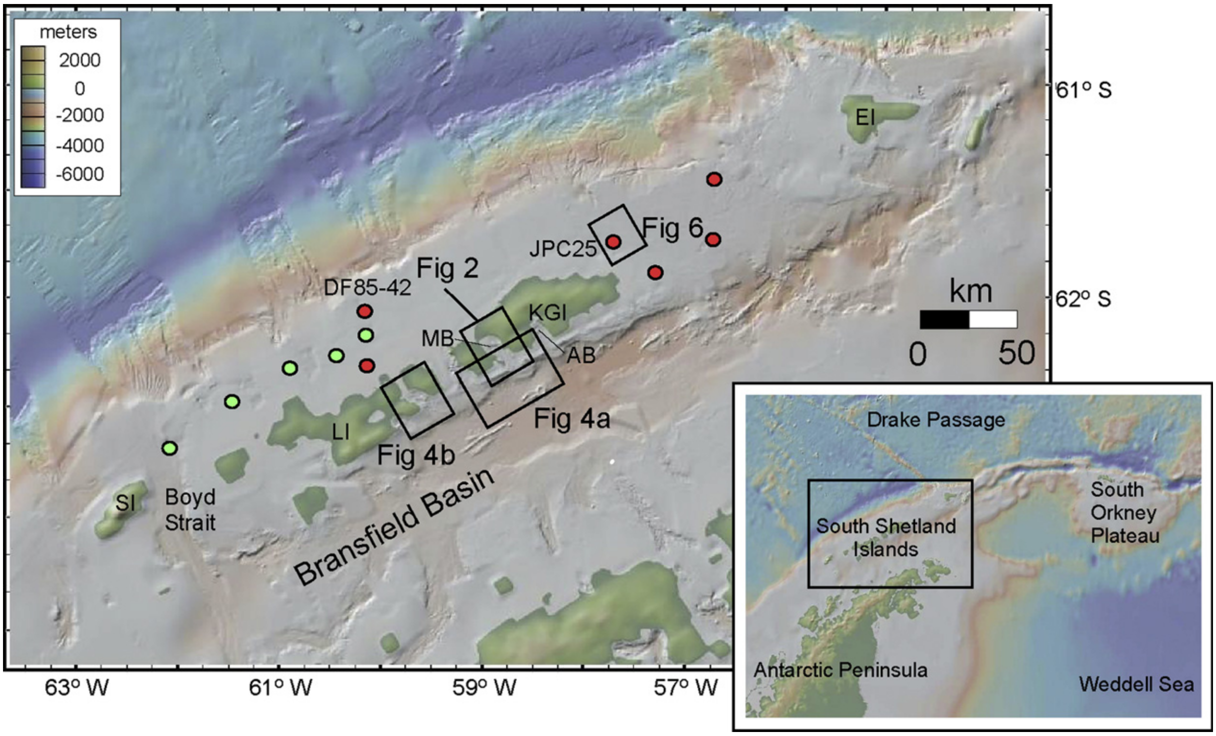

Fig. 1. Northern Antarctic Peninsula and South Shetland Islands region. Red circles represent cores with sandy surface sediments and green circles represent cores with muddy surface sediments. KGI = King George Island, LI = Livingston Island, SI = Smith Island, EI = Elephant Island, AB = Admiralty Bay, MB = Maxwell Bay. Basemap taken from www.geomapapp.org. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

LGM (e.g., Hall, 2003, 2009), while studies of the continental shelf south of the SSI indicate that the Antarctic Peninsula Ice Sheet extended to the shelf edge (e.g., Canals et al., 2000, 2002; Heroy and Anderson, 2005). However, both the terrestrial and marine records are incomplete. For example, few age constraints are available from the highest raised, presumably Pleistocene, beaches (greater than ~50 m) on the SSI and no moraines of LGM age have been documented on the islands. In addition, little work has been done to determine if the ice cap extended onto the northern and most extensive shelf of the SSI during the LGM.

This paper summarizes the existing marine work conducted on the shelves and fjords of the South Shetland Islands and incorporates new data from Maxwell Bay, the most widely studied sector of the SSI, and a portion of the continental shelf to the northeast of King George Island (KGI, Fig. 1) by providing some of the first multibeam bathymetric data from the northern shelf and new and existing seismic and core data. The objective of the continental shelf survey was to search for geomorphic features that might constrain the maximum extent of grounded ice during the LGM. In addition, cores were taken with the hopes of obtaining chronological constraints for the events recorded in the stratigraphy of the northern shelf. The objective of the study of Maxwell bay was to build upon the recent study of a 108.2 m SHALDRIL core (Milliken et al., 2009) and place the results of that work into a broader stratigraphic context with other studies and core data in order to summarize the marine record of deglaciation for the southern fjords of the South Shetland Islands. In particular, this paper aims at addressing three questions. First, did glacial ice extend onto the northern shelf of the South Shetland Islands? Second, if so, what constraints are available for the age of the advance? Third, what is the record of glacial retreat from Maxwell Bay? The new data presented in this study were collected as part of two recent (2005 and 2007) RV/IB *NB Palmer* cruises to the region.

2. Background

2.1. Setting

The SSI are an island arc situated off the northern coast of the Antarctic Peninsula and separated from the peninsula by Bransfield Strait, a back-arc basin (Fig. 1). To the south, the islands bound a steep fault-bound escarpment where the seafloor descends to just over 1000 m within 10 km of the coast. The islands are bounded on the north by a broad (average 60 km) shelf that slopes gently seaward. The relatively shallow (0–300 m), seaward dipping shelf is atypical of other portions of the Antarctic continental shelf that dip landward and have experienced more numerous episodes of glacial erosion (Anderson, 1999).

The SSI are currently covered by thin ice fields (<150–200 m thick; Curl, 1980) with peripheral rocky and gravel beaches (Sugden and John, 1973; Fig. 2). The maximum elevation on King George Island, the largest island in the chain, is ~700 m above sea level (asl) with a maximum ice cap thickness of 395–422 m (Simoes et al., 2004b; Blindow et al., 2010). According to John and Sugden (1971), the summer equilibrium line lies at 150 m asl on King George Island. Based on numerical models predicting its velocity, Ruckamp et al. (2010) suggest the ice cap on King George Island is partly temperate in nature with cold and temperate ice. A ground-penetrating radar (GPR) study of the internal character of the ice also found evidence for temperate ice below 400 m (Blindow et al., 2010).

On average, outlet and valley glaciers that terminate as tidewater glaciers are grounded at water depths between 80 and 120 m. The tidewater glaciers ablate mainly through iceberg calving during summer months when sea surface temperatures are above freezing (Khim et al., 2007). Modern ice flow velocities reach up to 120 m/y at the terminus of tidewater glaciers in Collins Harbor,