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Relative sea level curves for the South Shetland Islands and Marguerite Bay, Antarctic Peninsula

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Abstract

This paper presents preliminary relative sea level curves for the Marguerite Bay region and for the South Shetland Islands. The Marguerite Bay curve is constrained by both new and previously published ^{14}C dates on penguin remains and shells, and on two isolation basins dating back to 6500 ^{14}C yr BP. Extrapolation back to the marine limit yields a minimum deglaciation date for Marguerite Bay of ca 9000 ^{14}C yr BP. Analysis of beach clasts suggests that there was a period of increased wave activity, perhaps related to a reduction in summer sea-ice extent, between ca 3500 and ca 2400 ^{14}C yr BP. The curve for the South Shetland Islands is derived entirely from published ^{14}C dates from isolation basins and on whalebone, penguin bone and seal bone. The curve shows an initial relative sea level fall, which was interrupted by a period in the mid-Holocene when relative sea level rose to a highstand of between 14.5 and 16 m above mean sea level (amsl), before falling again.

1. Introduction

Relative sea level (RSL) variation records the interplay between eustatic sea level change and local isostatic changes. Global eustatic sea level change is reasonably well known (e.g. Fleming et al., 1998) and so RSL variation is an important source of information on former maximum ice thicknesses, the timing of deglaciation, and subsequent changes in ice cover. Where there are good field data on former RSL, combined studies of RSL curves and modelled glacial-isostatic adjustment (GIA) provide a powerful tool for determining past ice sheet history. In Antarctica there is poor coverage of RSL data, due largely to the lack of coastal ice-free areas where coastal deposits can accumulate, and to a paucity of organic material for radiocarbon dating. A small number of areas where robust RSL curves have been determined include the Scott Coast (Hall and Denton, 1999) and the Vestfold and Larsemann Hills, East Antarctica (Zwartz et al., 1998; Verleyen et al., 2004).

This paper provides preliminary RSL curves for the northern Antarctic Peninsula (South Shetland Islands) and south-central Antarctic Peninsula (Marguerite Bay) (Fig. 1), and thus helps us to infer the timing of deglaciation, former ice volumes and to provide field constraints for glacial-isostatic modelling of Antarctic deglaciation.

2. Derivation of RSL curves

There are two main sources of the elevation and age data necessary for RSL curves. The first, and more common, source is morphological evidence such as raised shorelines, deltas, etc., that have been dated using embedded organic material such as shells. The second source is to use isolation basins to determine past sea level change (Sundelin, 1919). These are former marine basins or inlets that have been isostatically raised above

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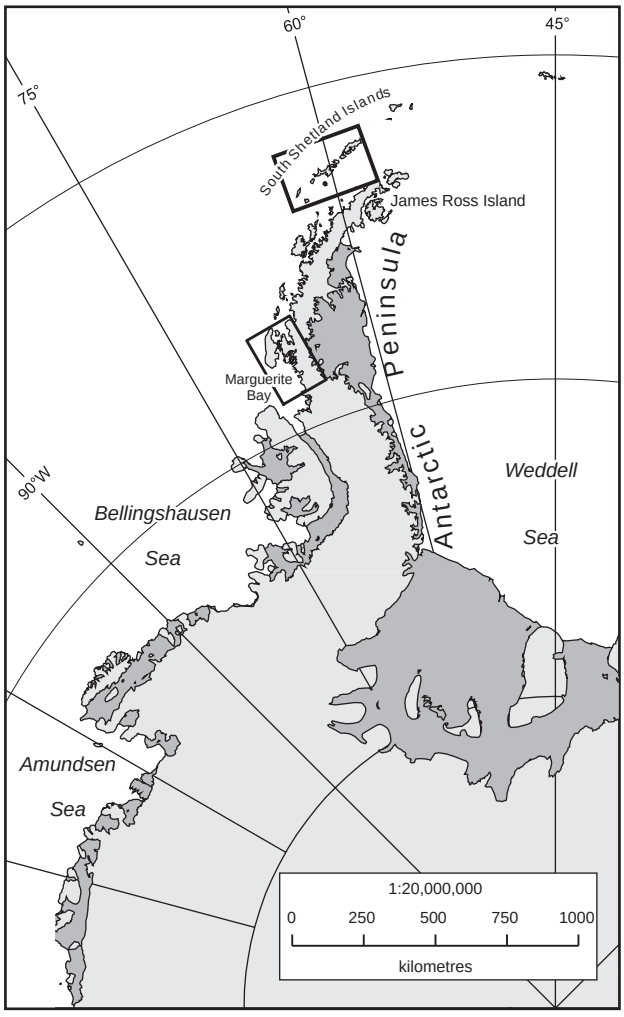

Fig. 1. Location map of Antarctic Peninsula. The two study areas are boxed. Ice shelves are shown by dark shading.

contemporary sea level and become freshwater basins. The timing of the marine–freshwater transition (derived from ^{14}C dating) can be used to determine when the inlet sill or threshold of the basin was raised above sea level. This approach can yield more precise age and elevation data than morphological evidence and has been used to good effect to produce RSL curves for northwest Europe and parts of the Arctic. It is also less subject to errors such as reworking of the organic material in beaches, and because the freshwater sediment (or macrofossils within it) is usually dated directly above the marine–freshwater transition marine reservoir corrections are not usually a problem.

The curves presented in this paper have been determined by a combined approach. Dates from isolation basins have been used wherever possible, but where lakes do not exist close to the coast a variety of types of morphological data have been used. In the case of the Marguerite Bay curve the majority of dates are on material from abandoned penguin colonies (Emslie and McDaniel, 2002), shells or seal hair. In the South Shetlands dates come from whalebone, penguin bone, seal bone, wood and seaweed. Penguin bones provide only minimum limiting dates as penguin rookeries may be located tens of metres above sea level, depending on species and local geography. Conventional ^{14}C dates are reported throughout this paper and are presented as in the original publications. However, instead of using the original authors' reservoir corrections we have applied systematic reservoir corrections for each type of material, namely penguin bone (1130 ± 134 yr, Berkman and Forman, 1996), whalebone and sealbone (1424 ± 200 yr, Berkman and Forman, 1996) and marine sediment (1300 ± 100 yr, Berkman et al., 1998). Thus, any changes in the reservoir corrections would affect equally all those dates on a particular type of material.

3. Site descriptions and beach surveys

3.1. Marguerite Bay

The RSL curve for Marguerite Bay uses data from seven sites, spread over an area of approximately 60 km × 30 km in the northern part of the bay (Fig. 2a, Table 1). The sites are Horseshoe Island, Pourquoi Pas Island, and Calmette Bay in the northeast of the bay, and Ginger Islands, Lagoon Island, Anchorage Island and Rothera Point in the north and west of the bay. We have combined the data from these sites because they are sufficiently close together (< 100 km) that there are unlikely to be major local differences in RSL history.

The sites were used to determine the elevation of the marine limit (using Autoset Level), minimum and maximum dates for raised beach formation, the timing of isolation, and variations in the roundness of beach material through time.

3.1.1. Marine limit

The highest known occurrences of wave-cut platforms and raised beaches in the region, reported here for the first time, are on Pourquoi Pas Island and Calmette Bay, where we surveyed the marine limit at 41 m above mean sea level (amsl). In Gaul Cove, an inlet on the northeast side of Horseshoe Island, the highest beach level is 22 m amsl. A knoll rising to 31 m close to the main UK base at Rothera Point has rare occurrences of rounded beach material wedged in crevices near its summit, implying that this is a minimum value for the marine limit. There is also a report of a marine limit at 50–55 m elsewhere on Horseshoe Island (C. Hjort, pers. comm. 2003), measured with an altimeter.

3.1.2. Timing of isolation

The sediment of "Skua Lake" (67°48′40″S, 067°18′50″W, 3.5 m amsl) was cored by Wassell and