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Recent retreat of ice cliffs, King George Island, South Shetland Islands, Antarctic Peninsula

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ABSTRACT. Comparison of aerial photos shows that the ice cliff in Marian Cove, Maxwell Bay, southwestern King George Island, retreated approximately 250 m between 1956 and 1986, but advanced about 40 m between December 1986 and January 1989. The advance in the late 1980s seems to be related to the cold austral winters of 1986–88. A topographic survey in January 1994 revealed that the ice cliff in Marian Cove had again retreated around 270 m since January 1989; approximately the same as from December 1956 to December 1986. In Potter Cove, the ice cliff retreated approximately 400 m from 1956–89. The more pronounced retreat here may be attributable to shallower water depths (<30 m). These ice cliffs retreats are discussed as a possible consequence of recent regional warming.

INTRODUCTION

Changes in the Antarctic ice shelf are likely results of atmospheric warming. They include the melting of glacier margins and retreat of ice shelves. Melting and the disappearance of ice shelves have already been observed around the Antarctic Peninsula (Doake and Vaughan, 1991; Skvarca, 1993; Ward, 1995; Vaughan and Doake, 1996), including deglaciation in East Antarctica (Burgess and others, 1994) and glacier fluctuations in South Georgia (Gordon and Timmis, 1992).

Marian and Potter Coves are fjords in Maxwell Bay, southwestern King George Island, South Shetland Islands, off the northern tip of the Antarctic Peninsula (Fig. 1). Marian Cove lies northeast–southwest and is 1.3 km wide and 3 km long. Potter Cove is 1.4 km wide and 3.5 km long. The inner parts of the coves are rimmed with ice cliffs 5 to 30 m high and 15 to 40 m high, respectively.

This paper describes ice-cliff retreat in these small fjords over the past few decades based on evidence from aerial photographs and topographic surveys.

MATERIALS AND METHODS

Aerial photographs were obtained from the Royal Navy which surveyed Marian and Potter Coves on 20 December 1956 and 4 January 1989. Marian Cove was also photographed by the Chilean Air Force on 21 December 1986.

The Marian Cove ice cliffs were investigated in January 1994 by the Korea Ocean Research and Development Institute (KORDI) during a topographic survey of Barton Peninsula (Kim and Baek, 1995; KORDI, 1996). King Sejong station is located on Barton Peninsula, a promontory 8.5 km by 9.5 km between Marian and Potter Coves. These surveys allowed a detailed mapping of the ice cliffs.

The ice cliffs in the aerial photographs and figure 3 of Kim and Baek (1995) were digitized for image analysis. Changes in the ice-covered area and the amount of ice-wall retreat were obtained with reference to the topographic map.

RESULTS AND DISCUSSION

Comparison of the aerial photographs of Marian Cove showed the ice-covered area reduced by about 280 000 m^2 from December 1956 to December 1986 but increased by 45 000 m^2 from December 1986 to January 1989. The January 1994 topographic survey revealed that the ice front in the cove had retreated again since January 1989, and an area of 290 000 m^2 had been lost (Table 1). Overall, the ice cliff (around 1100 m long) retreated up to 680 m with a mean of 480 m from December 1956 to January 1994 (Fig. 2).

In Potter Cove, the ice cliff (around 1000 m long) retreated up to 490 m with a mean of 400 m and an area of

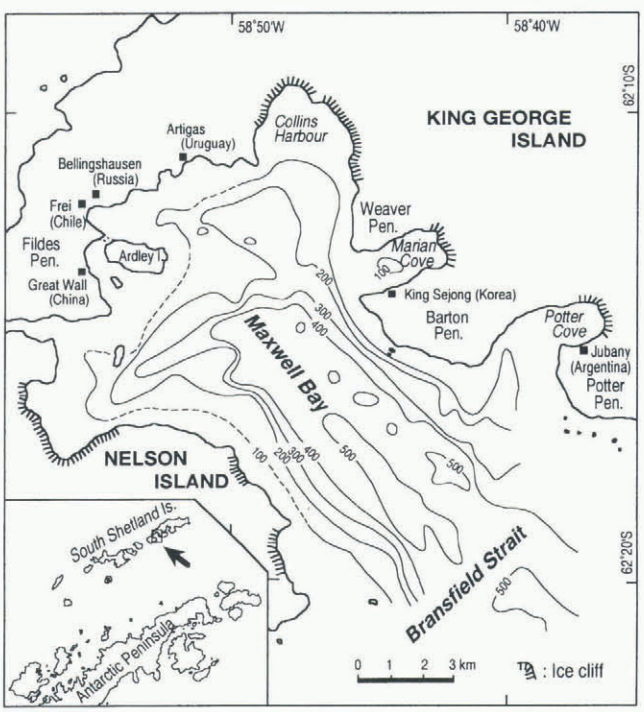

Fig. 1. Study area on King George Island.

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Table 1. Recent retreat of ice cliffs from air photo image analysis and topographic survey, King George Island

	Period	Areal reduction	Mean length change	Max. length change
		m^2	m	m
Marian Cove	Dec 1956–Dec 1986	278 669	253	378
	Dec 1986–Jan 1989	−44 699	−41	−100
	Jan 1989–Jan 1994	292 965	266	389
	Total	526 935	478	683
Potter Cove	Dec 1956–Jan 1989	360 600	398	488

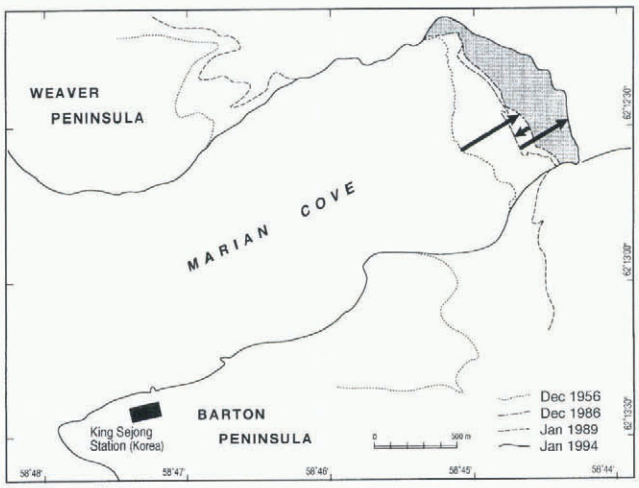

Fig. 2. Retreat of Marian Cove ice cliff. Note the advance nearly equivalent to the retreat over 30 years (December 1956 and December 1986) and during 5 years (January 1989 and January 1994).

360 000 m^2 was lost from December 1956 to January 1989 (Fig. 3). The ice retreats were likely related to cyclic changes, and advances would have been possible during cold spells.

The mean annual air temperature at Presidente Eduardo Frei base (Chile), on Fildes Bay about 13 km from Marian Cove, showed that 1989 was the warmest year since 1970 (Fig. 4). Air temperatures at King Sejong station (Korea), measured since February 1988, also showed the same characteristics (Table 2). Recently, 1989 seems to have been the warmest year, at least in the western part of the Antarctic Peninsula, according to records from King George Island as well as Faraday (1957–89) and Marguerite Bay (1962–89) (Morrison, 1990).

On the other hand, the advance of the Marian Cove ice cliff by 10–100 m from December 1986 to January 1989 (Table 1), with a likely mean value of 41 m, may be related to the cold spell between 1986 and 1988 (Fig. 4). Until 1996, 1988 was one of the coldest years at King Sejong station, with a yearly mean temperature of −2.5°C (Table 2).

Marian and Potter Coves have nearly the same surface area. However, the area of ice loss in Potter Cove (around 360 000 m^2) is about one-and-a-half times larger than that in Marian Cove (around 230 000 m^2) from December 1956 to January 1989 (Table 1). The catchment basin area of Marian Cove at 9.5 km^2 is close to that of Potter Cove at 9.4 km^2, as shown by the 1:200 000 scale map published by the Defense Mapping Agency Hydrographic/Topographic Center (1980). Thus, catchment basin area cannot be the

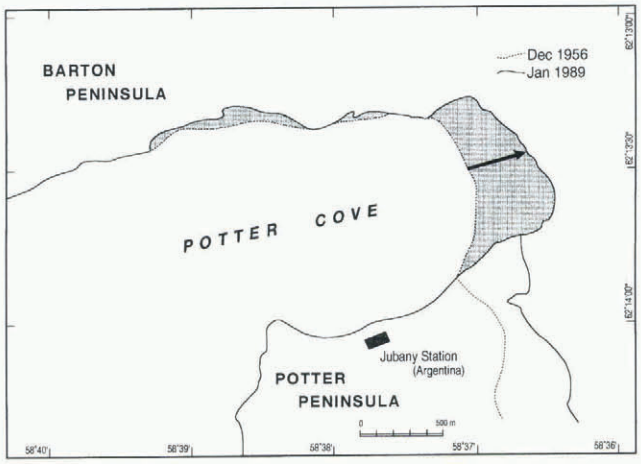

Fig. 3. Retreat of Potter Cove ice cliff from December 1956 to January 1989.

main cause of the greater retreat in Potter Cove. An alternative factor may be the difference in depth of the two fjords. Marian Cove is more than 130 m deep (Kim and Baek, 1995) while Potter Cove is only about 30 m deep (IHA, 1980). Due to the shallower depth, the ice cliff in Potter Cove may be grounded while that in Marian Cove may be floating or less firmly aground. This difference in thickness may be responsible for the larger area retreat in Potter Cove.

The monthly mean air temperatures from December to March at King Sejong station are above zero and the breakups of the ice cliff presumably occur mainly in that season. Infrequent rain from October to April might produce icemelt water which could trigger the breakup of the glacier (Doake and Vaughan, 1991).

The freezing of Marian Cove is unlikely to hamper the disappearance of ice cliffs as the ice calving is independent of the sea ice around the cliffs. The water around them is not frozen except in full winter, even if Maxwell Bay and Marian Cove may be frozen from May or June to September, and they do not freeze every year. For example, the bay and the cove were not frozen in the austral winters of 1989, 1994 and 1996 since 1988. Duration of freezing of the cove varies from <1 month to 4 months with ice thickness varying from 60 cm or less according to the meteorological measurements and observation of sea ice at King Sejong

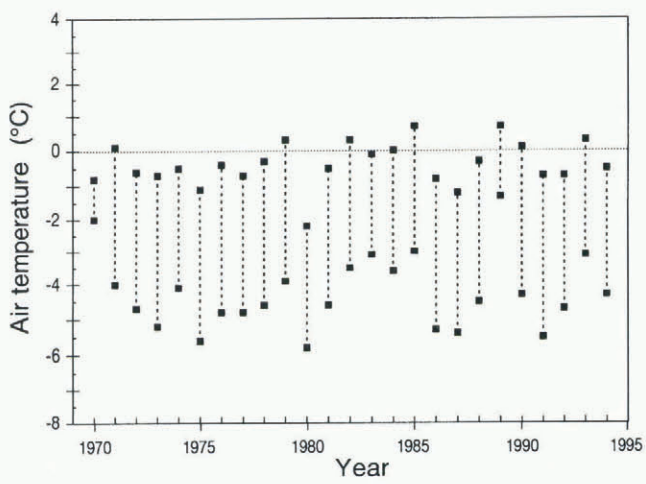

Fig. 4. Mean annual maximum and minimum air temperatures at Presidente Eduardo Frei Base, King George Island, 1970–94.

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Table 2. Monthly mean air temperature (°C) and freezing of sea, King Sejong station, Barton Peninsula, King George Island

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1988	–	2.3	−0.1	−1.1	−1.9	−7.6 MC[a]	−4.8 MC[c] MB[c]	−8.4 MC[c] MB[b]	−3.2 MC[b] MB[b]	−2.6	−1.1	0.5	−2.5
1989	1.5	2.4	2.3	−4.8	−0.9	−2.0	−0.7 MC[a]	−2.1	−3.0	−0.6	0.2	1.4	−0.5
1990	2.3	2.7	1.2	−4.8 MC[a]	−4.9 MC[a]	−4.2 MC[a]	−5.3 MC[a]	−5.3 MC[a]	−2.7	−1.9	−0.8	0.7	−1.9
1991	2.2	0.8	−0.2	−2.3	−7.2	−8.8 MC[a] MB[a]	−6.5 MC[b] MB[b]	−6.6 MC[c] MB[c]	−2.9 MC[b] MB[a]	−3.5 MC[a]	−0.8	−0.2	−3.0
1992	1.8	0.8	−1.1	−0.7	−8.0 MC[a] MB[a]	−7.7 MC[b] MB[b]	−7.2 MC[c] MB[c]	−4.1 MC[c] MB[c]	−2.1 MC[a] MB[a]	−2.5	−0.1	2.6	−2.3
1993	2.0	2.2	0.4	−0.8	−2.1	−3.6	−2.8	−3.2 MC[a]	−3.0 MC[a]	−1.4	0.2	0.8	−0.9
1994	2.2	1.6	1.1	−1.0	−3.6	−3.4	−10.3 MC[a]	−3.3 MC[a] MB[a]	−2.9 MC[a]	−5.0	1.0	1.5	−1.8
1995	2.6	2.3	0.3	−1.2	−2.1	−6.2 MC[a]	−12.0 MC[b] MB[b]	−10.3 MC[c] MB[c]	−5.6 MC[c] MB[c]	−0.8 MC[a] MB[a]	−0.5	1.3	−2.7
1996	2.0	2.7	1.5	1.0	−2.1	−4.8	−3.4	−3.6	−1.4	−1.3	−0.1	1.1	−0.7

MC, Marian Cove MB, Maxwell Bay a, Partial and (few days) freezing b, Nearly full freezing c, Full freezing

station (Table 2). It seems that the sea is not frozen when the yearly mean air temperature is above −2.0°C.

We suggest that the retreat of ice tongues in these small Antarctic fjords may be related to the recent regional warming. Indeed, surface air temperatures measured on the west coast of the Antarctic Peninsula have shown long-term warming trends (King, 1994). One location on the Antarctic Peninsula has shown an increase of around 1.5°C over the past 30 years (Morrison, 1990). A mechanism that may explain this behaviour is that the fracture toughness of ice is reduced at higher temperatures and in the presence of meltwater (Sabol and Schulson, 1989). The meltwater percolates through the crevasses on the surface of the ice tongues down to the basal zone, opening them up (Doake and Vaughan, 1991).

CONCLUSIONS

This investigation shows that the ice cliffs are retreating possibly in response to the atmospheric warming in the area. The higher rate of retreat of ice cliffs in recent years may be the result of more rapid warming during this period.

The advance of the ice cliff observed in January 1989 suggests that the glaciers and ice flow around King George Island respond quickly to small temperature variations.

It is necessary to survey the ice cliffs around the fjords on King George Island periodically to confirm their temporal variations.

Further studies are necessary to confirm the hypothesis suggested for the disappearance of large areas of ice in Potter Cove in comparison to Marian Cove from December 1956 to January 1989.

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