SCREE BENCHES AROUND ICE-DAMMED LAKES IN SOUTH GEORGIA

By D. BROOK

ABSTRACT. Scree benches around two lakes dammed by Neumayer Glacier are described and compared. They are considered to be raised beaches formed during periods of higher lake level, when Neumayer Glacier was thicker and in a more advanced state than at present. They were probably formed during the historical past but there is no evidence as to the time interval between individual benches.

DURING a geological survey of the area between Cumberland West Bay and Fortuna Bay, three ice-dammed lakes were found along the northern edge of Neumayer Glacier (Fig. 1). The smaller central one is surrounded by rocky crags and was not closely approached but the shores of Gulbrandsen Lake and the lake at the southern end of Olsen Valley are formed on

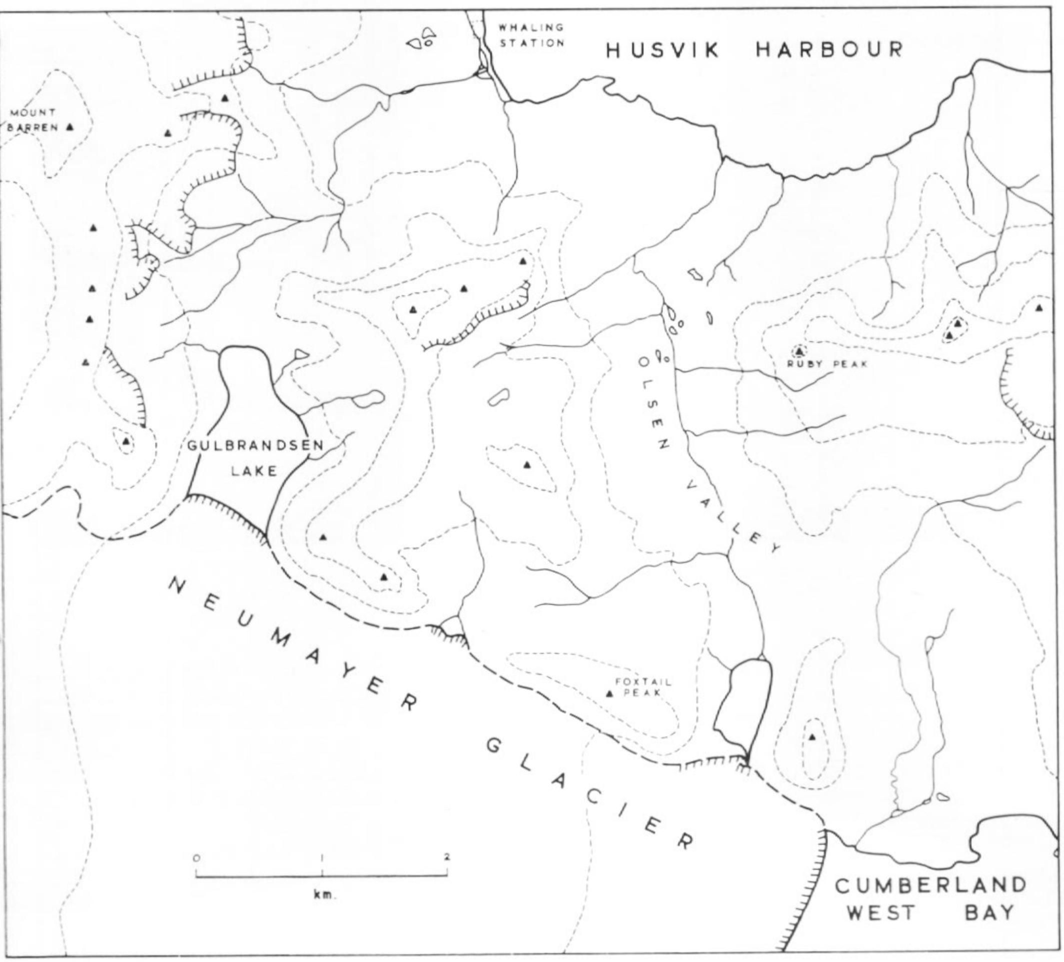

Fig. 1. Sketch map of the area between Husvik Harbour and Neumayer Glacier, showing the location of the ice-dammed lakes discussed in the text. The form lines are at *c*. 150 m. intervals.

scree slopes at an angle of 20–30°. These screes are interrupted by a number of distinct benches with a slope of <1° towards the lake.

The heights of the benches above the lake shore were measured by means of a linen tape and Abney level, and the altitudes of the lakes were obtained by aneroid barometer (corrected to mean sea-level at Husvik whaling station). Mapping was done from field sketches and prismatic compass measurements using as a base map a 1:12,500 enlargement of the published 1:100,000 map of South Georgia.

Description of the Lakes

Gulbrandsen Lake

Situated about 6·4 km. south-west of the Husvik whaling station at an altitude of 215 m. a.s.l. (November 1965), this is a small lake about 1·5 km. long and 1 km. wide. It is dammed at the southern end by ice cliffs of Neumayer Glacier (Fig. 2), ranging from 3 m. in height at

Fig. 2. Gulbrandsen Lake viewed from the north, 15 November 1965. The nature of the dam of Neumayer Glacier and the almost complete ice cover are well seen. Scree benches on the eastern side of the lake can be vaguely seen. (Photograph by A. Bottomley.)

the margins to 9–12 m. in the centre. Lateral moraine covers the edge of the glacier near the lake shore and extends onto the adjacent screes. The lake appears to be fairly deep, for glacier icebergs about 5 m. high were floating on its surface. No outlet stream was seen but the distinct crevasse just below the moraine at the south-eastern end of the ice front (Figs. 2 and 3) may be due to a weakness in the glacier caused by the partial collapse of a subglacial tunnel, the exit of an outlet stream. Alternatively, it may have been caused by run-off of melt water from the moraine or possibly a combination of the two.

Six distinct benches ranging from 5·09 to 21·23 m. above the lake surface (Table I) cut across the screes. Possible higher benches were noticed but not measured as they tended to be masked by recent scree falls; this is also true of one or two intermediate and minor benches. The benches are quite discrete (Fig. 3), though in places the uppermost one splits into four smaller benches with steps of about 0·2 m. There is a distinct increase in width of the benches (0·38–6·10 m.) from the lowest to the highest. At lake level, the scree shelves down fairly steeply into the water with no sign of any beach development.

Fig. 3. Gulbrandsen Lake viewed from the north, 31 December 1965. The Lake is still largely ice-covered, though the snow cover of rock and scree slopes has disappeared except in the gullies. Scree benches are very distinct on the western side of the lake. (Photograph by A. Bottomley.)

TABLE I. SCREE BENCHES AROUND GULBRANDSEN LAKE ALONG TRAVERSE a–a (FIG. 4)

Level	*Width of bench* (m.)	*Height above lake* (m.)	*Horizontal distance from lake shore* (m.)
1	0·38	5·09	10·41
2	0·61	6·16	12·09
3	3·07	8·84	17·73
4	3·66	15·20	32·41
5	3·20	18·69	40·91
6	6·10	21·23	44·93

Away from the glacier, all of the benches are present in varying degrees (Fig. 4) and each one shows a marked parallelism to the present lake shore. A number of streams flow into the lake in gorges up to 9 m. deep but, because of the extensive snow cover (even as late as 31 December 1965), it is not known whether the benches extend into them.

The material on the benches is similar to the rest of the scree with no noticeable difference in roundness, but it is apparently more compacted and solid, the interstices between the larger blocks being packed tight with smaller pebbles and sand. No vegetation was seen on any of the benches.

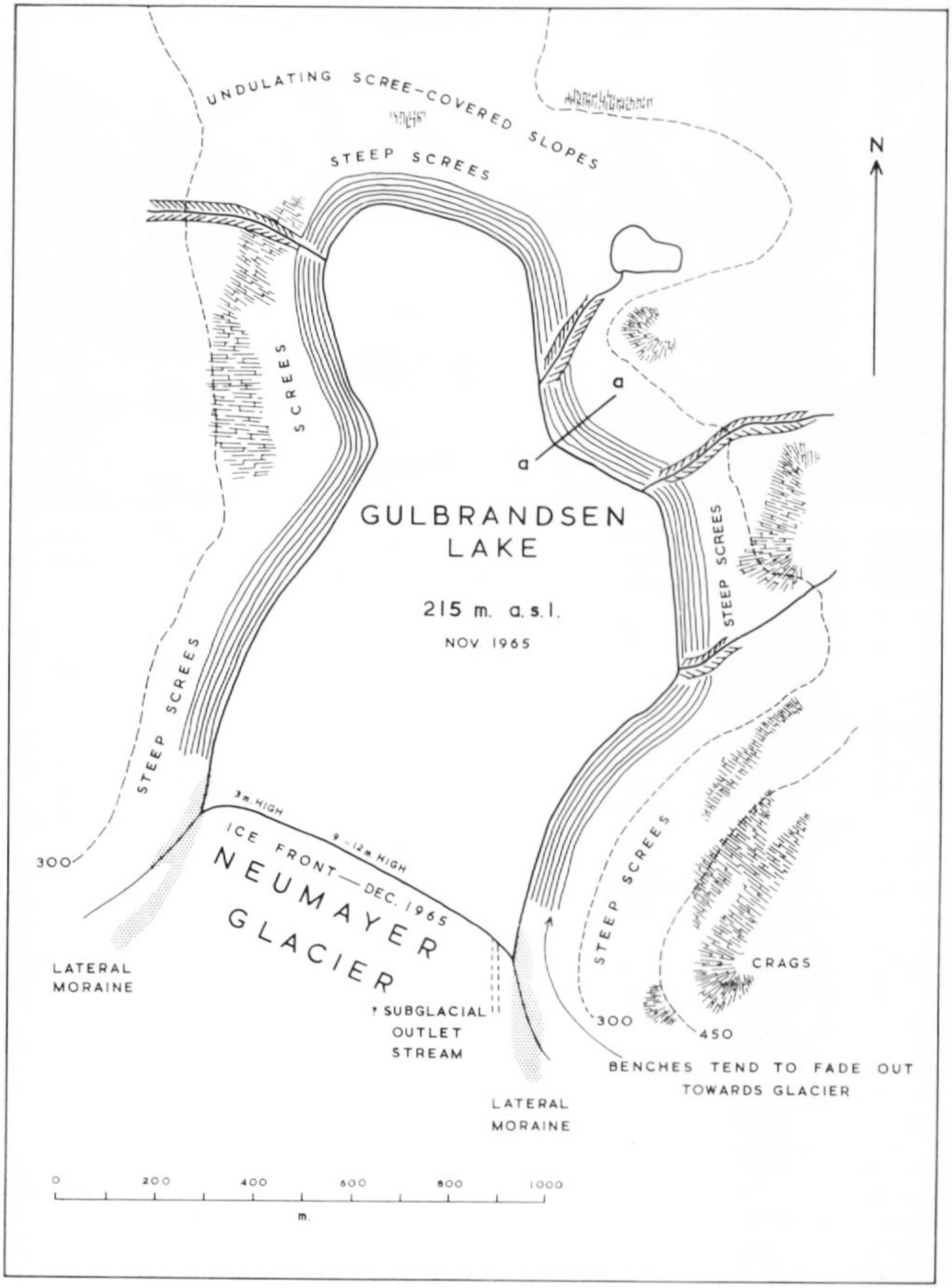

Fig. 4. Sketch map of the area around Gulbrandsen Lake, showing the scree benches and the location of the measured section a—a. The contours are at *c*. 150 m. intervals.

Lake at the southern end of Olsen Valley

Situated about 9·6 km. south-south-east of the Husvik whaling station at an altitude of 9·1 m. a.s.l. (November 1965), this lake is about 1 km. long and 0·5 km. wide. At its southern end it is blocked by the ice-cored lateral moraine of Neumayer Glacier (Fig. 5), and its outlet is by way of a subglacial tunnel which can be seen emerging from the glacier snout about 0·7 km. to the east-south-east.

There is a beach 1·22 m. wide around the lake shore and beyond this the scree shelves steeply into the water. Large flat expanses of gravel are developed at both the northern and southern ends of the lake. 16 distinct benches, ranging from 2·27 to 28·65 m. above the surface of the lake (Table II), cut across the screes. Although they are quite discrete (Fig. 6), they are not as well developed as those around Gulbrandsen Lake. They show no systematic variation in width.

TABLE II. SCREE BENCHES AROUND THE LAKE AT THE SOUTHERN END OF OLSEN VALLEY ALONG TRAVERSE b–b (FIG. 7)

Level	*Width of bench* (m.)	*Height above lake* (m.)	*Horizontal distance from lake shore* (m.)
Beach	1·22		
1	0·46	2·27	5·66
2	1·07	2·87	6·73
3	1·22	4·24	9·46
4	0·51	4·71	10·67
5	0·71	6·19	13·59
6	0·56	7·54	15·58
7	0·46	8·48	17·06
8	0·46	9·14	18·27
9	0·61	10·86	21·32
10	1·47	14·23	27·13
11	0·66	18·52	35·21
12	0·81	19·27	36·63
13	1·78	20·88	39·58
14	0·66	25·23	47·01
15	1·37	27·77	51·06
16	0·53	28·65	53·20

The benches are best developed on the eastern side of the lake (Fig. 7), where the full complement of 16 parallel the lake shore and flat gravel area. Elsewhere, not all the benches are present and different ones are developed in different areas and not all of them are parallel to the present shoreline. The main stream enters the lake at its northern end, where it debouches from a small ravine, spreads out and splits up over the flat gravel area. The benches can be traced along the sides of the valley almost to the mouth of this ravine.

Fig. 5. Lake at the southern end of Olsen Valley viewed from the north, 27 November 1965, showing the moraine dam and the glacier beyond. Neumayer Glacier is heavily crevassed with abundant seracs. Scree benches on the eastern side of the lake can be vaguely seen. (Photograph by A. Bottomley.)

Fig. 6. Lake at the southern end of Olsen Valley viewed from the west, 27 November 1965. Scree benches parallel the lake shore and the large flat gravel area north of it.

The material on the benches is similar to the scree, except that the material covering the lower two or three benches and the present-day beach tends to be more rounded. The benches are compacted in a similar way to those around Gulbrandsen Lake. The flat gravel area at the northern end of the lake and several of the lower benches on its eastern side have a sparse vegetation of grasses and moss.

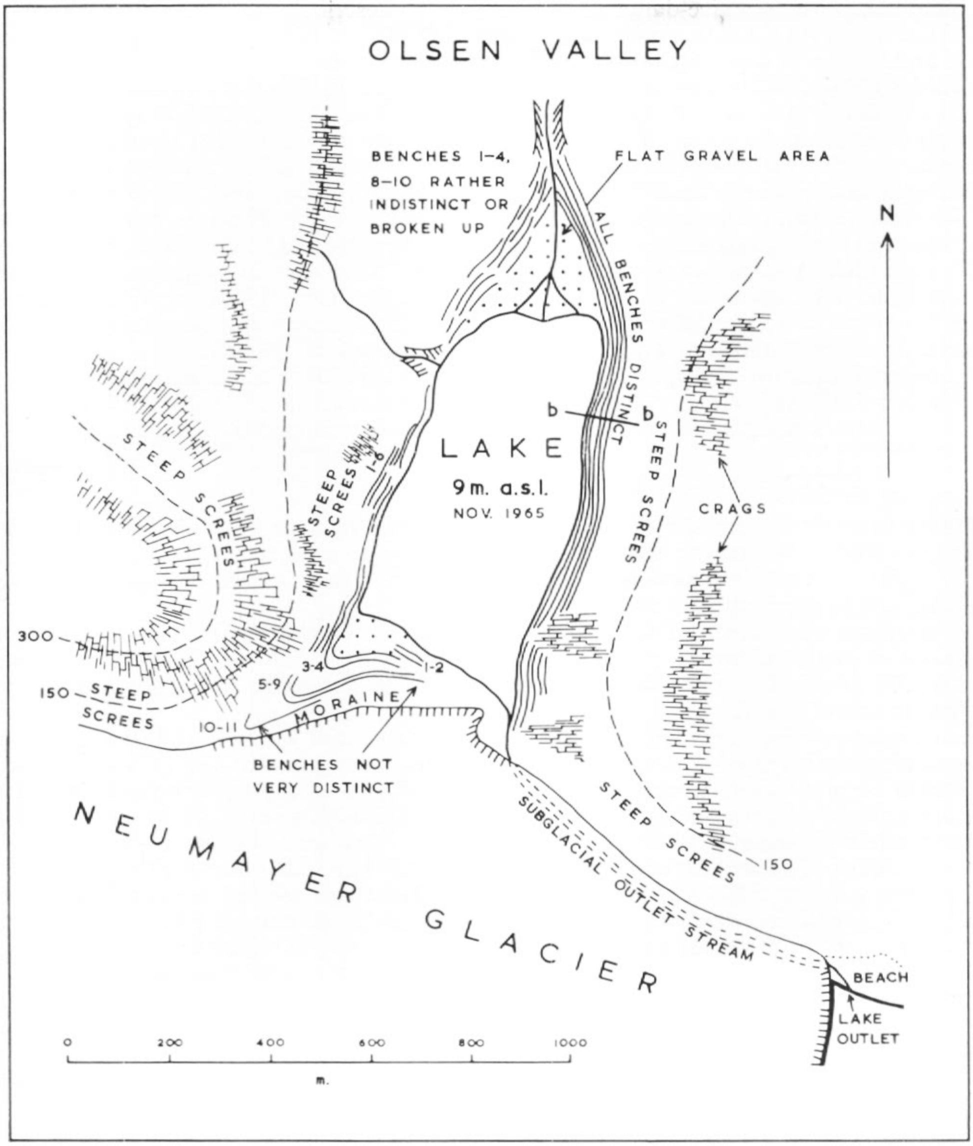

Fig. 7. Sketch map of the lake at the southern end of Olsen Valley, showing the scree benches and the location of the measured section b—b. The contours are at *c*. 150 m. intervals.

Discussion

Origin of the benches

The scree benches are believed to be "raised beaches" formed during periods of a higher lake level. The present-day beach and the lower benches around the lake at the southern end of Olsen Valley are believed to be water-formed. The general angularity of the material on the upper benches around this lake and on all the benches around Gulbrandsen Lake, together with the largely ice-covered nature of the latter, is assumed to be evidence of their probable formation by the grinding action of floating ice.

Raised beaches around ice-dammed lakes have been described from North America (Carter and Atherton, 1961), South America (Nichols and Miller, 1952) and Europe (Aitkenhead, 1960), and they show some similarities to those discussed here.

Hopkins (1959), in his discussion of the history of Imuruk Lake in Alaska, suggested that the lake level fell as a result of an increase in water loss due to increased evaporation during a period when summers were considerably warmer. Recent raised beaches around the ice-dammed lake south of the main Eldridge Glacier in the Mount McKinley Range were attributed to seasonal changes in lake level (Carter and Atherton, 1961); they considered that one high-level beach formed in winter and several beaches as much as 50 m. lower in elevation in summer. In the Lago Argentino area of Patagonia (Nichols and Miller, 1952), lakes dammed by Moreno Glacier lasted less than 1 year and formed wave-washed ledges and small clifflets in unconsolidated sediments around their shores. Aitkenhead (1960) described terraces in screes 30–80 m. above a glacier-dammed lake in arctic Norway and he attributed these to periodic drainage of the lake with successively lower levels of stability.

A situation similar to that postulated by Aitkenhead (1960) is envisaged in South Georgia but whether drainage is equally sudden and periodic is not certain. Lowering of the lake level may have been accomplished gradually with periods of pronounced stillstand.

Drainage of the lakes

The lake at the southern end of Olsen Valley is drained by a stream which cuts through the lateral moraine of Neumayer Glacier and then follows a subglacial tunnel to the sea at the glacier snout. This may not have been so in the past, when the lake was blocked by the glacier itself and not by its moraine alone.

The drainage mechanism of Gulbrandsen Lake is not known but it may be by a similar subglacial or englacial tunnel, possibly along the line of the crevasse at one end of the ice front (p. 32). It could also be drained by elevation of the glacier from the lake bottom by the buoyant action of water.

Thorarinsson (1953) suggested that floating of the ice barrier would lead to the catastrophic and complete drainage of Graenalón and Grímsvötn in Iceland, but Glen (1954) considered this would be more likely to lead to the maintenance of a steady level in the lake and that drainage was caused by the enlargement of the water-filled hollow in the glacier due to variation of strain-rate with shear stress. A floating mechanism was postulated by Aitkenhead (1963) for the drainage of an ice caldera in north-east Graham Land, and also for the lake dammed by Strupbreen in arctic Norway (Aitkenhead, 1960). He suggested that drainage was probably initiated by a rapid increase in the lake level due to partial or complete blocking of outflow channels as a result of exceptional weather conditions during the preceding winter.

The extent to which drainage of the lakes is seasonal (cf. Carter and Atherton, 1961) is unknown but no significant change in the level of Gulbrandsen Lake between visits of 15 November and 31 December 1965 was noticed. The lake at the southern end of Olsen Valley was only visited once, but the presence of vegetation on the gravel area north of the lake and on the lower benches east of the lake, and the nest of an Antarctic tern on the gravel area south of the lake, suggest this area is not regularly flooded.

When the two lakes in South Georgia had a higher level, they may have been drained by different mechanisms to those operating at present; floating of the ice barrier is a strong possibility, the drainage channel being kept open by erosion of the underlying sediments or of the glacier itself. The most important factor determining the lake levels would therefore be the thickness of the glacier, and any changes in level would be related to its state of advance or recession.

Increased evaporation during a period of warmer summers (Hopkins, 1959) may have had some influence on lake level but increased ablation of the glacier under similar circumstances would probably have been more significant. If there is a direct relationship between height above the lake and age of the benches (i.e. if higher benches are older), the increase in width of benches with height above Gulbrandsen Lake may indicate an increase in the rate of recession of Neumayer Glacier, correspondingly shorter periods of stability being represented by the narrower lower benches. If, however, the benches are related to periods of stillstand during both advance and recession of the glacier, this direct relationship is invalid and the progressive increase in width of the benches is of no significance.

Comparison of the two lakes and its significance

Benches at the same height as all those around Gulbrandsen Lake also occur around the lake at the southern end of Olsen Valley (Tables I and II; Fig. 8). In some cases, they are

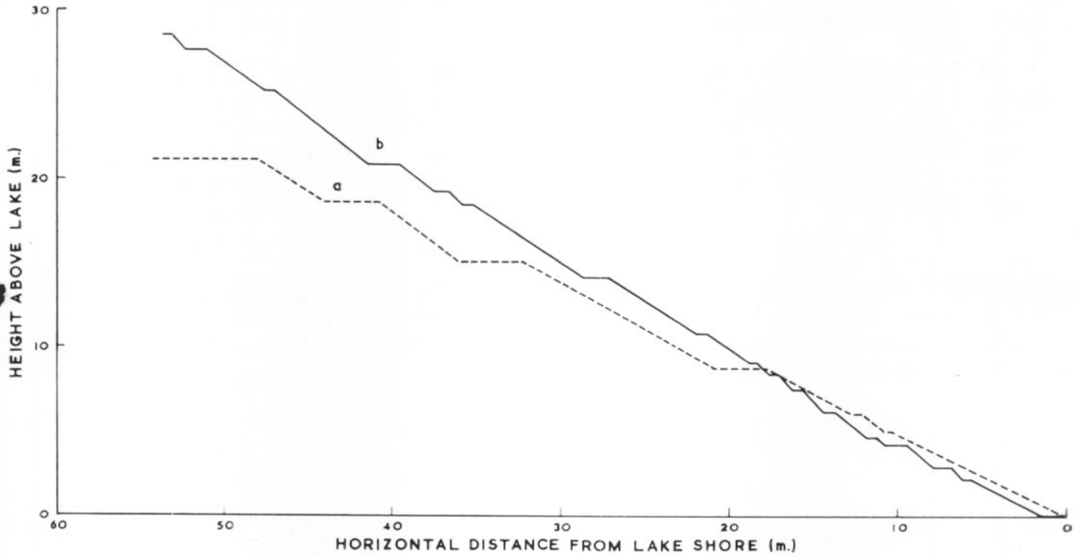

Fig. 8. Diagrammatic representation of the scree benches around Gulbrandsen Lake (a) and the lake at the southern end of Olsen Valley (b) showing their correspondence in heights above the lake surfaces.

represented by groups of benches rather than by individual benches, and there is also a tendency towards intermediate benches around the lake at the southern end of Olsen Valley.

The two lakes are widely separated in altitude and in position with respect to Neumayer Glacier. The relatively good correspondence between the heights of benches around the two lakes seems to imply that the magnitude of changes at high and low levels in the glacier was essentially the same, and also possibly implies contemporaneity of these changes. The intermediate benches around the lake at the southern end of Olsen Valley apparently indicate that major fluctuations in Neumayer Glacier occurred in a series of minor stages, some of which were reflected only near its snout, though the cumulative effect was the same. The absence of a present-day beach around Gulbrandsen Lake is probably not significant.

Age of the benches

Smith (1960) suggested that glacial advances in South Georgia in 1875 and 1926–29 were preceded by long periods when the climate was at least as warm as it is at present. Ives (1962) used the differential growth of lichens above and below the shoreline to date drainage of former ice-dammed lakes in the upper valley of the Isortoq River, Baffin Island, at 200–250 yr. ago. Lichens were not observed around either of the lakes in South Georgia, the only vegetation seen being grasses and mosses around the lake at the southern end of Olsen Valley. A comparison with the lake alongside Eldridge Glacier (Carter and Atherton, 1961) suggests that this vegetation could have formed since the most recent advance suggested by Smith (1960). The absence of vegetation around Gulbrandsen Lake is probably the effect of altitude rather than time.

The benches may well be associated with the advances suggested by Smith (1960) but there is no evidence as to the time interval between them.

SUMMARY

Gulbrandsen Lake and the lake at the southern end of Olsen Valley are small lakes dammed by Neumayer Glacier. Both show striking evidence, in the form of "raised beaches" up to almost 30 m. above the lake surfaces, of Recent changes in Neumayer Glacier, separated by periods of stability. The correlation of bench heights between the two lakes is reasonably good and this reflects a similar effect of changes both adjacent to and at a distance from the glacier snout. A comparison with the work of Smith (1960) and Carter and Atherton (1961) suggests that the benches could have formed in the historical past, and possibly within the last 100 years.

N. Aitkenhead (personal communication) found an ice-dammed lake alongside Lyell Glacier in South Georgia but he did not approach it closely enough to observe whether there were any scree benches. If they are present, they may give more general information as to changes in the glacierization of South Georgia. For the same reason correlation with the moraines of the area may be significant but this cannot be attempted on the basis of the present work.

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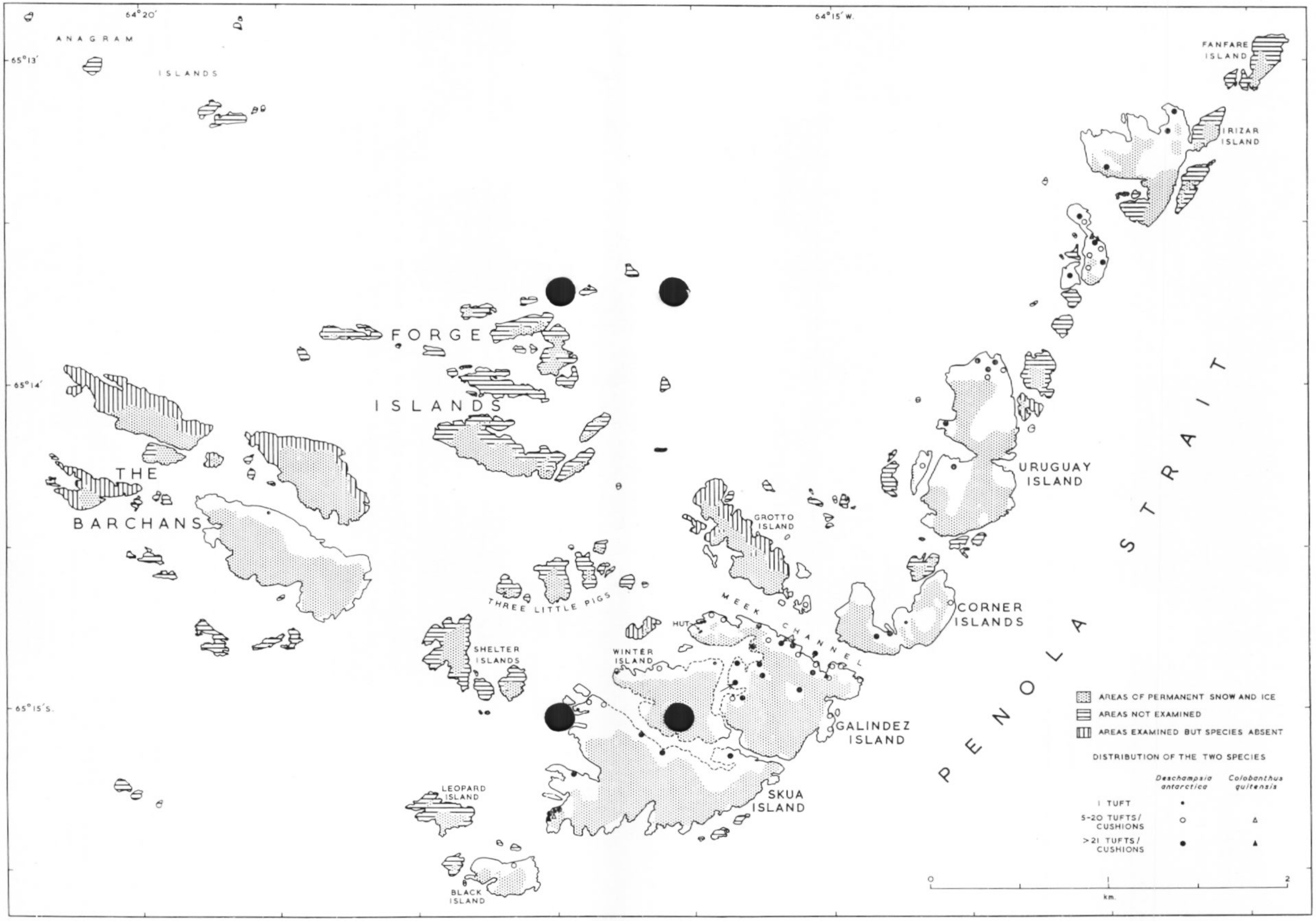

Fig. 1. Distribution of *Deschampsia antarctica* and *Colobanthus quitensis* in the Argentine Islands between December 1963 and April 1965. The positions of the Stella Creek and Meek Channel *D. antarctica* sites on Galindez Island are indicated by arrows.

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