TYPES OF PEAT AND PEAT-FORMING VEGETATION ON SOUTH GEORGIA

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ABSTRACT. The principal peat-forming plant communities of South Georgia are described and the types of organic deposit, generally exceeding 0.5 m in depth, which they accumulate, are categorized into a broad basic classification. None of the South Georgian soils possesses a permafrost and five major peat types are recognized:

1. *Mire peats* developed on gentle seepage slopes on valley sides and hillsides. These are formed mainly by communities of rushes *(Rostkovia magellanica* and *Juncus scheuchzerioides),* a deciduous woody herb *(Acaena magellanica)* and the moss *Tortula robusta,* although other bryophytes, including *Sphagnum fimbriatum,* may be locally abundant. *Acaena* and *Tortula* also form a distinctive mire community in similar situations. Mire peats may reach 2–3 m in depth and are characterized by a permanently high water-table and exceptionally high exchangeable calcium concentrations (commonly exceeding 1 000 mg 100 g dry weight $^{-1}$); they are considered here as a form of soligenous eutrophic bog.
2. *Bog peats* with impeded drainage are formed by two distinct community types. One is dominated by *Rostkovia* which, in wetter sites on fluvio-glacial plains and lake margins, has a bryophyte understorey of carpet-forming mosses, especially *Calliergon sarmentosum* and *Drepanocladus uncinatus,* and various liverworts; drier sites on rock and in moraine basins with a lower water-table have an understorey of the tall turf-forming mosses *Chorisodontium aciphyllum* and *Polytrichum* spp. These deposits may reach 3 m in depth and are considered here as ombrogenous mesotrophic bogs.
   The other is dominated by *Deschampsia antarctica* which locally forms pure stands on raised beaches but in wetter depressions *Callitriche antarctica, Colobanthus quitensis* and various bryophytes are associated. These meso- to eutrophic ombrogenous bogs are often enriched by bird excrement and may exceed 2 m in depth.
3. *Moss peat* is developed mainly by deep banks of *Polytrichum alpestre,* with associated lichens and tussock grass *(Poa flabellata)* to form an acid peat up to 3 m in depth. In wetter parts of the island, shallower banks of *Chorisodontium aciphyllum* are commonly associated with stands of tussock grass on hillsides. These deposits have no water-table and are considered here as ombrogenous mesotrophic peats.
4. *Tussock peat* is formed by the tall pedestalled grass *Poa flabellata* on hillsides and coastal flats. The peat is usually less than 2 m in depth but one exceptional instance of almost 5 m is known. Non-biotically enriched stands develop a type of ombrogenous oligotrophic acid peat low in nutrients but they often grade into a more mesotrophic peat where the vegetation is inhabited by seals and sea birds.
5. A *ranker* type of peat occasionally develops beneath *Acaena magellanica–Tortula robusta* herbfield stands on well-drained hillsides or gullies. As with the mire communities composed of the same species, it is considered here as a soligenous eutrophic peat with high calcium levels but with a low water-table. It is a biologically rich substratum with high decomposition rates and consequently a slow rate of peat accumulation.

The development of peat in relation to deglaciation and plant-community development and distribution is discussed. Radiocarbon dating of organic deposits at various depths in several different community types indicates that peat formation has proceeded at a comparatively constant rate since the last major glaciation about 10 000 years ago (the oldest dates for basal peat layers are 9 493 ± 370 years B.P. and 9 433 ± 120 years B.P.). This suggests that no great changes in the climate have occurred during this period, since the vegetation does not appear to have been removed or its development arrested by resurgences of ice over the land, although there is geomorphological evidence of frequent advances and retreats of valley glaciers.

DURING the botanical survey of South Georgia (Fig. 1) between 1969 and 1974, the occurrence of peat deposits was recorded and in the 1972–73 summer several sites were examined critically in a palynological study. These were mainly in the Cumberland Bay area with one site on Annenkov Island. This paper reports on the characteristics and distribution of the more widespread and extensive peat-forming plant communities and attempts to classify the various organic deposits they produce. The results of the palynological investigations have been reported by Barrow (1977, 1978, in press *a, b*).

Will (1890) and Skottsberg (1902, 1912) provided brief descriptions of the island's vegetation and were the first to comment on the presence of peat deposits; other brief accounts of peat-forming vegetation have been given by Wace (1960), Greene (1964), Kats (1966) and Smith and Walton (1975). Limited and largely unpublished palynological investigations were made by Cranwell (1963, 1969, unpublished notes), who examined samples collected by the late J. Smith; samples of tussock peat also provided by him were examined for sub-fossil arthropods (Coope,

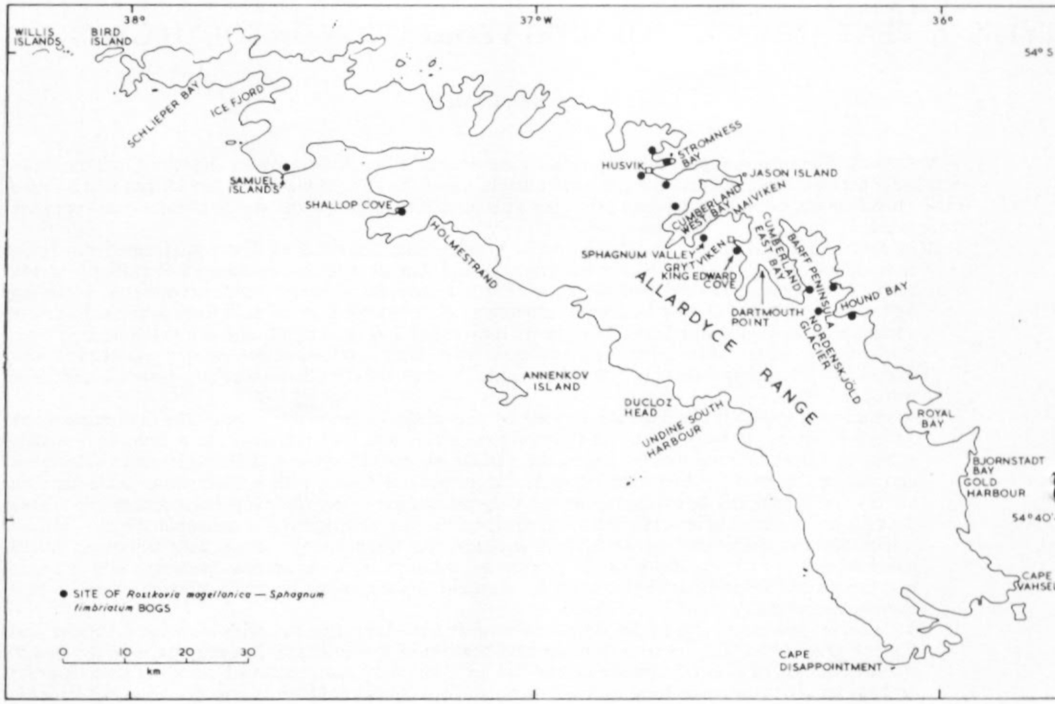

Fig. 1. Map of South Georgia showing place-names referred to in the text. The distribution of all known *Rostkovia magellanica–Sphagnum fimbriatum* bogs is also indicated.

1963). It was these studies which first indicated the potential of South Georgian organic deposits as a valuable source of palaeoecological information.

Floristic Composition of the Peat-forming Vegetation and General Characteristics of the Organic Deposits

Because of the alpine topography, low summer temperatures and considerable extent of permanent ice (58% of the island according to Smith (1960*a*)) with many glaciers reaching the sea at the heads of fjords, the amount of snow-free ground in summer with habitats suitable for extensive closed vegetation to develop and for organic deposits to accumulate is severely restricted. It is limited mainly to the coastal lowlands well below the summer snow line, which is about 500 m in the Stromness Bay–Cumberland Bay–Hound Bay area of the north-east coast in the lee of the high Allardyce Range but at about 400 m on the exposed south-west coast (Greene, 1964; Smith and Walton, 1975). The former area has probably been deglaciated longer than any other part of the island and it is here where most vegetational and pedological studies have been undertaken. Most of the large stands of vegetation with underlying peat deposits occur below 100 m altitude and are seldom far from the coast. The highest record for a bog peat is that of a layer of *Polytrichum alpestre* peat with *Juncus scheuchzerioides* rhizomes, up to 1 m thick but buried by 25–50 cm of fine mineral soil, gravel and stones, occurring at *c.*175 m altitude 2 km east of Hound Bay. All peat-forming communities are covered by deep snow (1–2 m) for much of the winter.

Although the mean monthly air temperature is near or below 0°C for 5 months of the year and the annual mean is only 1.8°C (the warmest month averages 5.3°C, based on 68 years' records (Smith and Walton, 1975)), South Georgian soils lack a permafrost, except perhaps above 500 m altitude (but here the mineral soils are very shallow and devoid of organic matter). Neither are there any palsa or ice-lens formations within the island's peats at present. However, the existence of periglacial phenomena in the form of networks of earth mounds, ridge-and-trough systems, solifluction lobes and patterned ground (Smith, 1960*b*; Clapperton, 1971; Stone, 1974) suggests that permafrost may have existed in comparatively recent times.

The soils of South Georgia have not been investigated in detail and there has been no attempt to classify them accurately. Smith and Walton (1975) have, however, recognized four principal soil groups within the Cumberland Bay area but their distribution is widespread over the island. They described organic soils exceeding 25 cm in depth developed by four main types of vegetation, all of which are strongly acid. In fact, some of the more soligenous mires are only mildly acid.

The following account attempts to categorize the deeper organic deposits on South Georgia based on a combination of criteria commonly used in the classification of organic soils (e.g. topography, morphology, chemical properties and surface vegetation) (see Farnham and Finney, 1965). In common with the relatively small-scale pattern of plant communities, which themselves are correlated largely with topographical, drainage and exposure factors, the distribution of peat-forming communities is consequently patchy and their size often small so that very seldom does any one category of peat cover more than one hectare. All peat-forming communities are subjected to the same overall climatic conditions, although those on the south-west coast probably receive more rainfall than those on the north-east coast (Richards and Tickell, 1968).

South Georgian peat deposits may be classified generally as intrazonal or topogenous bogs, as defined by Fraser (1954). Most of the deeper organic deposits are formed by bog communities and have been referred to by Kats (1966) as soligenic peat beds. Two broad categories of bog may be distinguished (see Ratcliffe, 1964). Soligenous or flush bogs (referred to here as mires) occur on wet gentle sloping valley or hill slopes, where a high water-table is maintained by the seepage of water through the substratum, enriching it with nutrients (especially calcium). Ombrogenous bogs (referred to here as bogs) occur in wet rock and moraine depressions and on fluvioglacial outwash plains, particularly adjacent to lakes and pools. Run-off is retarded due to the lack of slope and the water-table often remains at the surface throughout the year, except for the "raised bogs" which have built up well above the water-table.

There are two other categories of organic soils, of which that formed by tussock grass is the most widespread on South Georgia, covering great expanses of raised beaches and hillsides in most coastal areas. The peat formed by this grass has been referred to by Kats (1966) as grass hillocks. The fourth category develops beneath closed stands of the deciduous suffruticose herb *Acaena magellanica* in moist gullies, where it forms a peaty soil. The floristic composition of these major peat-forming communities is given in Table I and a comparison of the chemistry of the peats is given in Table II.

South Georgian peats are probably very similar to those developed on other sub-Antarctic islands, where the floristic diversity is low with only a few species contributing towards the accumulation of peat, the vegetation is subjected to low temperatures and high rainfall, and the soils have no permafrost (Kats, 1966). However, the calcium-rich mires of South Georgia do not appear to be represented on the other islands, even those of volcanic origin. Taylor (1955), in his account of Macquarie Island vegetation and soils, described the moss-dominated nutrient-poor peats with a high water-table and anaerobic decomposition as bog peats, and the more nutrient-rich peats with a high water-table beneath herbfield and *Juncus* communities as rich or poor fen peats depending on their nutrient status. Both bog and fen peats reach 6 m in depth. He referred to peat formed beneath tussock grass (*Poa foliosa*) and herbfield communities (*Pleurophyllum hookeri* and *Stilbocarpa polaris*) on slopes with no water-table and aerobic decomposition as highmoor peat. However, the author considers this term to be inappropriate when applied to tussock peat (see Kubiëna, 1953).

Huntley (1971) described the nutrient-poor tussock (*Poa cookii*) and herbfield (*Azorella *selago, Cotula plumosa,* etc.) peats of well-drained slopes on Marion Island as highmoor peat, and the poorly drained waterlogged mires (*Agrostis magellanica*) and bogs (*Blepharidophyllum densifolium* with *A. magellanica*) as lowmoor peat. More detailed accounts of the latter peats have been given by Smith (1977, in press). Mire peats of up to 3.5 m in depth have been recorded from both Marion and Prince Edward Islands (Schalke and van Zinderen Bakker, 1971). The peat-forming communities of *A. selago, Acaena magellanica, Pringlea antiscorbutica,* etc. produce a type of raised bog resembling "hochmoor" on Iles Kerguelen (Chastain, 1958), where peat deposits 5–6 m deep are frequent (Aubert de la Rüe, 1962) and in one locality may reach 10 m in depth (Aubert de la Rüe, 1966).

Mire Peat

On gentle seepage slopes, where there is some degree of water movement through the peaty substratum but where the water-table generally remains close to the surface throughout the year, a soligenous eutropic mire develops and this is equivalent to the valley and flush bogs referred to by Fraser (1954). Here, *Rostkovia magellanica* and *Juncus scheuchzerioides* are sparse and scattered small plants of *Acaena magellanica* are frequently present, occasionally achieving quite high cover; there is complete cover afforded by mosses, predominantly *Tortula robusta* (Fig. 2) and probably, to some extent, by the morphologically identical *T. serrata,* with small compact turf-like hummocks of *Bryum* spp., *Brachythecium* spp., *Bartramia subsymmetrica* and *Dicranella hookeri* where flushing is more evident. Liverworts are not usually abundant. In a few localities, circular or crescentic hummocks of *Sphagnum fimbriatum* also occur and occasionally may be the dominant moss, but it has a very restricted distribution on South Georgia (see Fig. 1). A typical feature of many of these mires on gentle slopes is the occurrence of "sink-

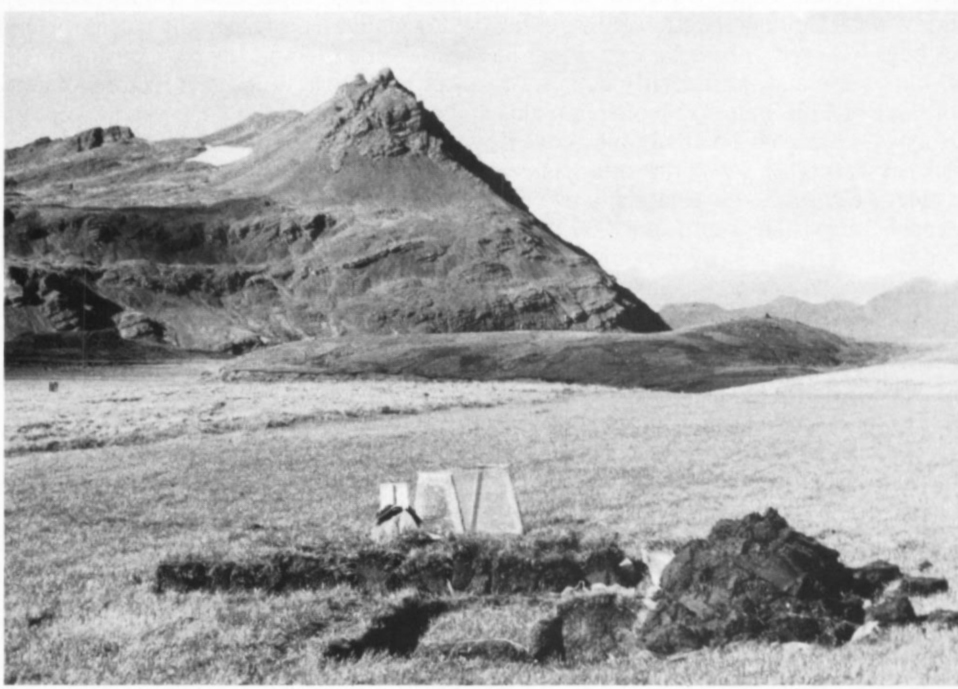

Fig. 2. *Rostkovia magellanica–Tortula robusta* mire on a gentle seepage slope. Peat depth *c.* 2 m. *Festuca contracta* grassland occurs on the slightly raised stony ground at the middle left and right. East side of Gull Lake, King Edward Cove.

Table I. Mean percentage cover and percentage frequency of occurrence of species in principal peat-forming plant communities on South Georgia

Plant community	*Rostkovia–Juncus–Acaena–Tortula mire*	*Rostkovia–Sphagnum mire*	*Acaena–Tortula mire*	*Rostkovia–Dicranoloma–liverwort, etc. bog*	*Rostkovia–Chorisodontium–Polytrichum bog*	*Deschampsia–Calliergon–Drepanocladus–liverwort bog*	*Deschampsia meadow*	*Calliergon swamp*	*Acaena–Tortula herbfield*	*Polytrichum alpestre bank*	*Chorisodontium bank*	*Poa tussock grassland (slopes)*	*Poa tussock grassland (wallows)*
Number of sites/quadrats* analysed	9/180	1/20	3/60	4/80	5/100	6/120	2/40	2/40	2/40	6/120	2/40	3/60	4/80
Acaena magellanica	23 : 99 (10–52)	6 : 90	59 : 100 (22–97)	< 1 : 15	< 1 : 5	3 : 14	< 1 : 8	2 : 45	92 : 100	< 1 : 2	2 : 45	2 : 28	< 1 : 14
Acaena tenera		3 : 75			3 : 45					< 1 : 2	< 1 : 20	< 1 : 20	
Callitriche antarctica												< 1 : 2	10 : 91
Colobanthus quitensis													< 1 : 10
Deschampsia antarctica	< 1 : 18		< 1 : 27	5 : 46	< 1 : 1	76 : 100 (45–93)	99 : 100	< 1 : 40				< 1 : 2	< 1 : 38
Festuca contracta	1 : 36	< 1 : 4	2 : 60	< 1 : 14	4 : 51				< 1 : 4	3 : 28		2 : 28	
Galium antarcticum	1 : 31		< 1 : 5										
Juncus scheuchzerioides	14 : 92 (2–34)	2 : 55	2 : 35	1 : 18	< 1 : 18			5 : 70		14 : 60 (1–23)			
Phleum alpinum	2 : 49	< 1 : 15	6 : 77	3 : 35	< 1 : 28	2 : 28						< 1 : 3	
Poa annua													< 1 : 9
Poa flabellata			< 1 : 3							< 1 : 6	2 : 20	78 : 100 (69–85)	41 : 100 (35–60)
Ranunculus biternatus	< 1 : 12		3 : 13	< 1 : 1									
Rostkovia magellanica	12 : 99 (4–14)	21 : 100	< 1 : 5	76 : 100 (69–79)	62 : 100 (35–78)	3 : 20		1 : 45					
Uncinia meridensis	< 1 : 14		< 1 : 2										
Bartramia patens	< 1 : 1			< 1 : 1	< 1 : 4				< 1 : 8	< 1 : 1			
Bartramia subsymmetrica	6 : 23 (0–53)		< 1 : 10										
Brachythecium austro-salebrosum	< 1 : 12											< 1 : 8	
Brachythecium sp.	< 1 : 1						< 1 : 2			< 1 : 2	< 1 : 15	< 1 : 33	< 1 : 4
Bryum spp.	< 1 : 12		3 : 33									< 1 : 6	
Calliergidium austro-stramineum				< 1 : 5		1 : 17							
Calliergon sarmentosum	< 1 : 6			< 1 : 10		9 : 43 (< 1–35)	< 1 : 10	100 : 100					
Chorisodontium aciphyllum	1 : 9	2 : 15	< 1 : 13		44 : 100 (19–96)	< 1 : 2				10 : 100 (2–22)	96 : 100	14 : 82	
Conostomum pentastichum					< 1 : 11					< 1 : 2	1 : 25		
Dicranoloma subimponens	2 : 19	< 1 : 5		17 : 53 (0–51)	3 : 31								
Drepanocladus cf. *revolvens*	< 1 : 6												
Drepanocladus uncinatus	7 : 58 (0–21)		< 1 : 2	9 : 38 (0–25)	< 1 : 12	16 : 22 (<1–97)	< 1 : 6				< 1 : 15		
Pohlia nutans										< 1 : 2	< 1 : 40	< 1 : 2	< 1 : 12
Polytrichum alpestre		< 1 : 5	2 : 18	< 1 : 5	13 : 59 (0–34)	< 1 : 2				86 : 100 (71–100)	2 : 30	12 : 48 (2–35)	
Polytrichum alpinum	< 1 : 1	< 1 : 15		< 1 : 23	3 : 64	< 1 : 7			< 1 : 2	< 1 : 7	5 : 60	2 : 48	
Polytrichum juniperinum	< 1 : 1				< 1 : 9							1 : 15	
Sphagnum fimbriatum		97 : 100											
Tortula robusta (possibly including *T. serrata*)	80 : 100 (26–100)		87:100 (67–100)	< 1 : 8		< 1 : 1			82 : 100	< 1 : 2	< 1 : 10	3 : 62	
Tortula spp.			< 1 : 13							< 1 : 1			
Blepharidophyllum densifolium				33 : 80 (3–75)	8 : 63	< 1 : 2				1 : 17			
Other foliose liverworts	< 1 : 20	< 1 : 15	4 : 33	11 : 100 (5–21)	20 : 100 (8–28)	33 : 72 (< 1–95)	< 1 : 16	< 1 : 50	< 1 : 16	9 : 100	1 : 100	2 : 94	< 1 : 14
Riccardia georgiensis	5 : 43	1 : 25	< 1 : 2	11 : 81 (2–24)	2 : 43	4 : 17					< 1 : 10		
Cetraria islandica					< 1 : 1					< 1 : 19			
Cladonia bellidiflora										< 1 : 35	< 1 : 60	< 1 : 24	
Cladonia rangiferina					6 : 53					7 : 64	2 : 80	2 : 23	
Cladonia balfourii + *C. pyxidata*			< 1 : 30			< 1 : 2				< 1 : 22	< 1 : 30	< 1 : 5	< 1 : 2
Cladonia carneola + *C. pleurota*										< 1 : 26	< 1 : 25	< 1 : 8	
Cladonia furcata + *C. gracilis*			< 1 : 7		4 : 49					2 : 66	4 : 85	2 : 27	
Cladonia phyllophora + *C. squamosa*					3 : 54					3 : 62	1 : 40	1 : 23	
Leptogium menziesii			< 1 : 7										
Lopadium willianum											< 1 : 25		
Ochrolechia frigida										< 1 : 5			
Peltigera canina			< 1 : 20										
Pseudocyphellaria endochrysea											3 : 30		
Pseudocyphellaria freycinetii					< 1 : 1						8 : 45	< 1 : 10	
Psoroma hypnorum											< 1 : 20	< 1 : 3	
Stereocaulon alpinum											< 1 : 10		
Lecanora/*Lecidea* spp. (muscicolous)										< 1 : 10			
Prasiola crispa						< 1 : 12		< 1 : 18				< 1 : 2	< 1 : 56
Basidiomycete spp.	< 1 : 1			< 1 : 2						< 1 : 2			< 1 : 10

Figures before colon are mean percentage cover per site; figures after colon are mean percentage frequency of occurrence per site; figures in brackets are range of mean percentage cover data where there is a large difference between sites.
* Quadrat size 50 cm by 50 cm except for tussock grass stands where 1 m^2 quadrats were used.

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TABLE II. CHARACTERISTICS AND CHEMICAL ANALYSES (AT 5–15 cm DEPTH) OF PRINCIPAL ORGANIC SOIL TYPES

Type of vegetation	*Habitat*	*Type of organic deposit*	*Maximum depth* (m)	*Number of sites sampled*	*Number of samples analysed*	*Field moisture content* (% dry wt)	*pH*	*Total N* (% dry wt)	*Extractable* (mg 100 g^{-1} dry wt) Na	K	Ca	Mg	P
Rostkovia–Juncus–Acaena–Tortula mire	Seepage slopes	Soligenous eutrophic peat	2.5	9	42	670 (±179)	5.60 (±0.26)	2.49 (±0.40)	32.1 (±11.1)	61.7 (±42.8)	1 053.1 (±205.0)	67.8 (±18.4)	9.1 (±7.1)
Rostkovia–Sphagnum mire	Seepage slopes	Soligenous mesotrophic peat	2.5	1	5	1 360 (±254)	4.52 (±0.13)	1.32 (±0.37)	30.6 (±6.9)	35.8 (±10.6)	200.0 (±93.0)	110.8 (±29.2)	6.4 (±2.1)
Acaena–Tortula mire	Seepage slopes, valley floors, stream margins	Soligenous mesotrophic peat	2	3	10	551 (±115)	4.79 (±0.45)	2.67 (±0.41)	49.5 (±22.1)	58.1 (±25.0)	352.0 (±149.4)	82.4 (±10.7)	20.7 (±10.9)
*Rostkovia–Dicranoloma–*liverwort, etc. bog	Level ground with impeded drainage	Ombrogenous mesotrophic peat	3	5	13	693 (±123)	4.32 (±0.26)	2.34 (±0.21)	25.5 (±7.0)	26.0 (±13.6)	139.4 (±82.6)	63.7 (±14.9)	6.7 (±3.0)
Rostkovia–Chorisodontium–Polytrichum bog	Rock and moraine basins with impeded drainage	Ombrogenous mesotrophic peat	3	5	25	408 (±55)	4.13 (±0.11)	2.23 (±0.41)	23.2 (±4.9)	25.0 (±9.2)	142.0 (±71.9)	52.6 (±11.0)	3.8 (±2.0)
Deschampsia–Calliergon–Drepanocladus–liverwort bog	Rock and moraine basins with impeded drainage; depressions at foot of slopes	Ombrogenous oligotrophic peat	2	5	10	639 (±73)	4.25 (±0.23)	2.98 (±0.79)	26.2 (±12.0)	36.5 (±30.5)	73.3 (±35.1)	54.2 (±37.5)	9.0 (±6.8)
Deschampsia meadow	Level to gently sloping ground especially adjacent to bird colonies	Ombrogenous oligotrophic peat	2.5	2	8	340 (±68)	4.33 (±0.17)	3.40 (±0.36)	19.0 (±9.2)	40.5 (±21.8)	69.7 (±30.2)	52.0 (±27.9)	10.2 (±5.4)
Acaena–Tortula herbfield	Moist sheltered gullies or slopes	Soligenous eutrophic ranker	0.75	2	6	285 (±32)	5.60 (±0.13)	2.66 (±0.64)	18.6 (±4.7)	10.4 (±6.3)	666.8 (±119.8)	48.6 (±18.4)	1.8 (±0.9)
Polytrichum moss bank	Level to gently sloping hillsides; depressions amongst hillocks	Ombrogenous mesotrophic peat	3	8	25	405 (±141)	3.82 (±0.20)	1.57 (±0.68)	31.8 (±14.8)	35.1 (±16.1)	124.1 (±107.6)	84.5 (±47.6)	9.2 (±5.3)
Chorisodontium moss bank	Gently to moderately sloping hillsides	Ombrogenous mesotrophic–oligotrophic peat	1	1	1	551	3.79	2.50	13.0	12.0	52.0	19.0	14.3
Poa tussock grassland	Raised beaches with seal wallows	Ombrogenous mesotrophic peat	2	2	5	205 (±62)	4.63 (±0.15)	2.70 (±0.38)	51.3 (±18.6)	98.4 (±32.6)	120.2 (±62.3)	60.0 (±12.2)	10.8 (±8.7)
Poa tussock grassland	Hillsides with seal and bird colonies	Ombrogenous mesotrophic–oligotrophic peat	2.5	1	3	n.d.	n.d.	2.97 (±0.32)	69.7 (±24.0)	39.3 (±24.0)	82.0 (±25.1)	84.7 (±68.9)	22.7 (±10.6)
Poa tussock grassland	Hillsides without seal and bird influence	Ombrogenous oligotrophic peat	2.5 (–5)	3	8	384 (±73)	3.99 (±0.21)	3.24 (±1.02)	17.8 (±6.7)	18.3 (±6.0)	41.1 (±21.1)	24.3 (±9.3)	9.4 (±3.4)

n.d. = No data.
All analytical data are mean values ± standard deviations.

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holes" penetrating from the surface to a small underground stream flowing in a runnel cut through the base of the peat deposit. These holes may be several metres in diameter and much of the surrounding surface water is diverted into them (Fig. 3a). The depth of peat may occasionally exceed 2 m beneath these stands; a profile through a typical *Rostkovia–Juncus–Acaena–Tortula* mire is shown diagrammatically in Fig. 4a, while Fig. 5 illustrates the peat depths throughout a mire.

These mire peats are generally less acid than the more oligotrophic bog peats and their nutrient status is typified by high concentrations of most elements, especially calcium and magnesium (Table II). Since the parent rock of the area (i.e. Cumberland Bay, where the vegetation and soil analyses were undertaken) is predominantly greywacke and of relatively low calcium content, the ion-retention capacity of the peat mosses must be very high. On steeper seepage slopes, where drainage is more rapid, the peat is less wet and is much shallower, seldom exceeding about 20 cm. The vegetation is essentially the same, although *Juncus* is often more abundant than *Rostkovia* and *Acaena* may be absent. The soil type is similar to the meadow tundra soils of Arctic regions but it lacks a permafrost (Tedrow, 1977). The underlying clayey soil has high nutrient concentrations, especially calcium and magnesium, and a pH of 5.5–6.5.

A similar type of soligenous eutrophic mire and peat develops where the slope is almost level or on the floor of a broad valley flanking a stream. The rushes decrease in abundance at the expense of *Acaena,* which locally may afford almost complete cover; the bryophyte understorey is again *Tortula robusta* with occasional patches of *Bryum* spp. and *Brachythecium* spp. The peat depth may reach 2 m. Although these stands are wet with a high water-table, drainage channels usually traverse the mire (Fig. 3b) and the run-off results in lower nutrient levels than in the richer mire peat up-slope.

Profiles cut through seepage-slope peats usually reveal thin layers of clay or fine sandy material, probably derived by down-washing during times of snow melt or exceptional rainfall, from barren mineral soils on the ridges or slopes above the sites. Wind-blown material must also accumulate in narrow bands. Where broader horizons of grey or grey-blue gley occur, the waterlogged anaerobic conditions produce narrow bands of iron and occasionally the mineral soil is stained reddish brown by hydrated ferric oxides oxidized from the ferrous compounds. Ferric staining, however, is perhaps best seen in horizons of the tundra brown soil beneath *Festuca contracta* grassland. Another feature frequently occurring in seepage-slope mires is the accumulation of iron bacteria concentrated below small springs and sometimes seen staining the melting spring snow in small gullies. These aggregations of reddish brown mud may cover several square metres to a depth of at least 10 cm. Shortly after the spring melt, they are dispersed by water and rain but these bacteria must play a significant role in the iron status of some of these mires (analysis of a sample of "iron bacteria" mud gave a concentration of 75 mg 100 g^{-1} dry weight extractable Fe, four times greater than that yielded by any other South Georgian organic soil).

Bog Peat

On level ground, where water movement is negligible and drainage is impeded, communities resembling a type of small-scale ombrogenous mesotrophic blanket bog form peat up to 3 m deep. There are two distinct types of bog, in one of which the dominant vascular plant is the rush, *Rostkovia magellanica,* and in the other the grass *Deschampsia antarctica. Rostkovia* bogs are differentiated on the basis of their water regime and consequently on their respective bryophyte understorey. On level ground, where the water-table is at or just below the surface on fluvio-glacial plains and adjacent to lakes and pools, the bryophyte cover comprises high cover of numerous species of liverworts, particularly *Blepharidophyllum densifolium* and *Riccardia georgiensis,* the carpet-forming mosses *Calliergon sarmentosum, Drepanocladus uncinatus* and with turf-forming *Dicranoloma* spp. in the less wet areas (Fig. 6). The cover afforded by these species, however, varies considerably between stands. Similar habitats liable to flooding in spring

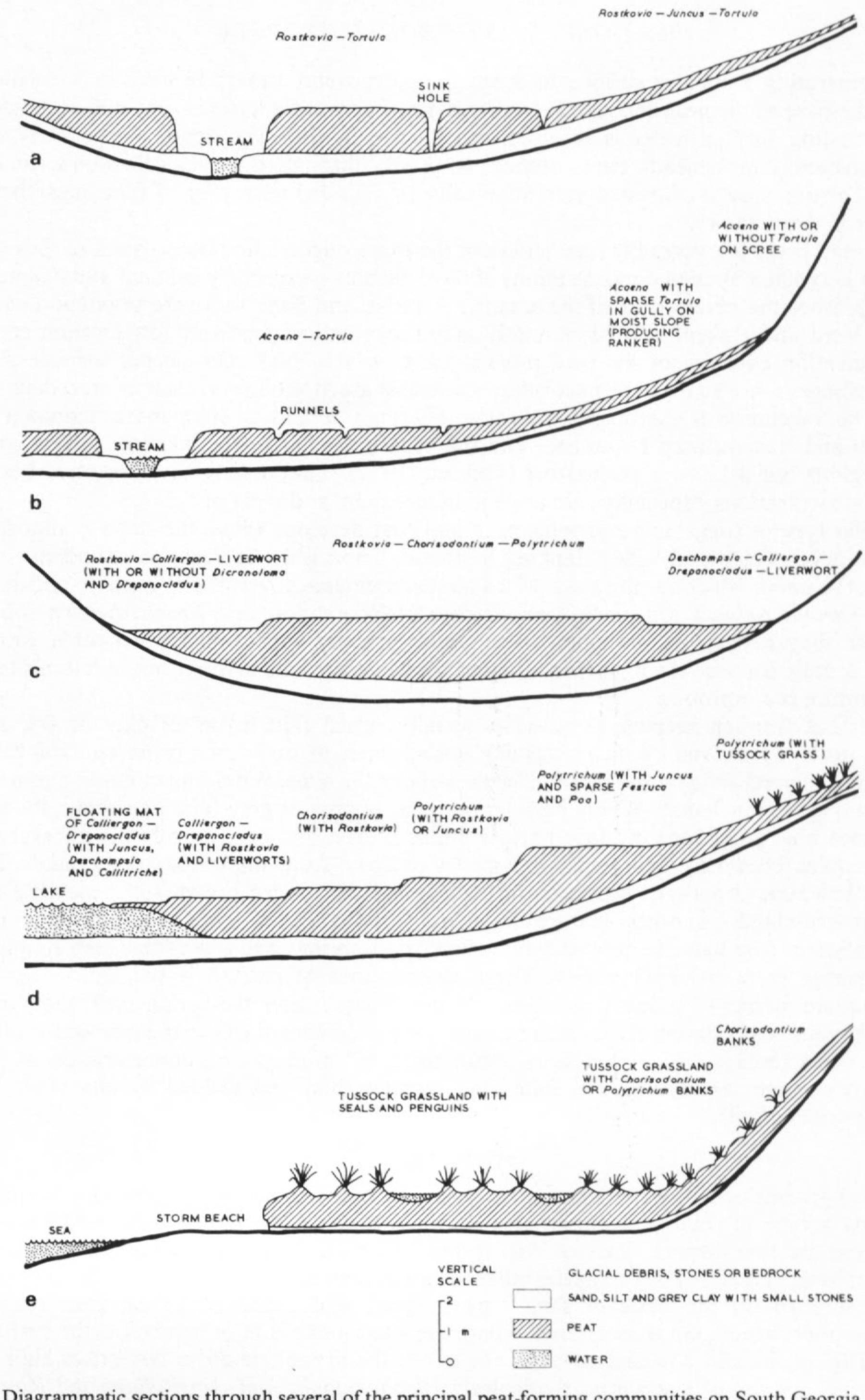

Fig. 3. Diagrammatic sections through several of the principal peat-forming communities on South Georgia.
a. *Rostkovia–Juncus–Acaena–Tortula* seepage-slope mire.
b. *Acaena–Tortula* seepage-slope mire.
c. *Rostkovia–Chorisodontium–Polytrichum* basin bog with *Rostkovia–Juncus*–hydrophytic bryophyte carpet or *Deschampsia*–hydrophytic bryophyte carpet bog in marginal "lagg".
d. Hydrosere sequence from floating vegetation to *Polytrichum alpestre* "raised bog".
e. Tussock (*Poa flabellata*) grassland, ranging from vegetation disturbed by seals, penguins or petrels to stands without biotic disturbance and with associated *Chorisodontium aciphyllum* moss-turf banks.

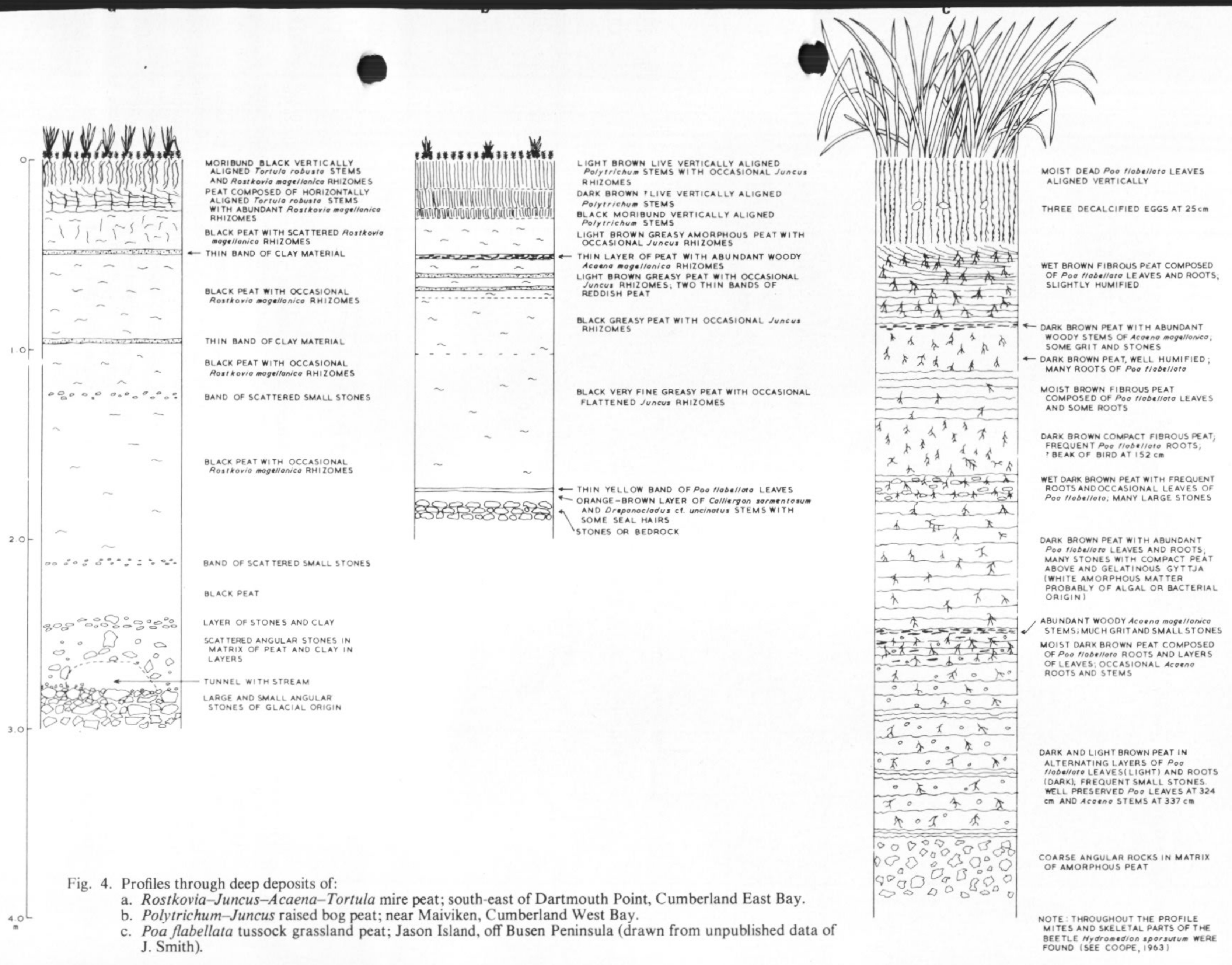

Fig. 4. Profiles through deep deposits of:
a. *Rostkovia–Juncus–Acaena–Tortula* mire peat; south-east of Dartmouth Point, Cumberland East Bay.
b. *Polytrichum–Juncus* raised bog peat; near Maiviken, Cumberland West Bay.
c. *Poa flabellata* tussock grassland peat; Jason Island, off Busen Peninsula (drawn from unpublished data of J. Smith).

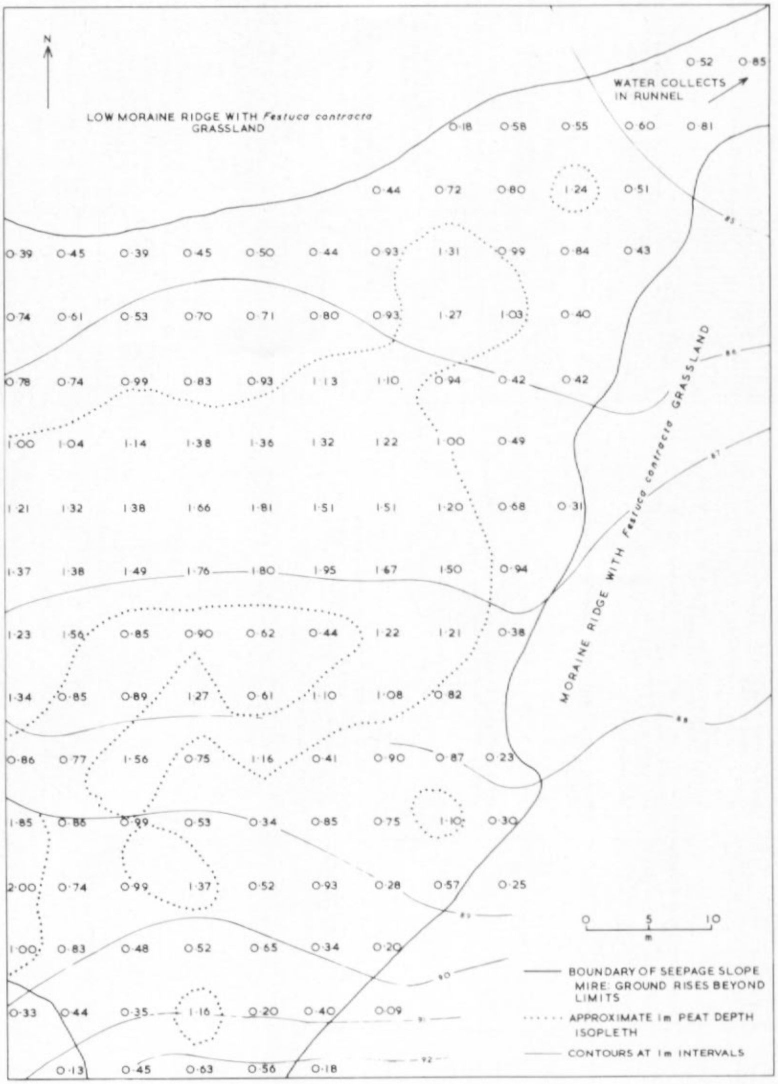

Fig. 5. Diagrammatic map of *Rostkovia–Juncus–Acaena–Tortula* mire on seepage slope to the east of Gull Lake, King Edward Cove, showing peat depths (unpublished data of G. J. Lawson).

and consequently receiving periodic input of sediment and nutrients support more mire-like stands of *Calliergon* and *Juncus* (Fig. 7), but the peat depth is usually less than 1 m and interspersed with bands of clay.

In rock and moraine basins with restricted drainage, where the water-table falls to below 15 cm from the moss surface in summer, there is often an understorey of the tall turf-forming mosses *Chorisodontium aciphyllum, Polytrichum alpestre* and *P. alpinum* with the former species usually predominating; various fruticose lichens, mainly *Cladonia* spp., occur on the drier moss turves and small widely scattered plants of *Acaena magellanica, A. tenera, Deschampsia antarctica, Festuca contracta* and *Phleum alpinum* may be present where there is some degree of drainage. Sink-holes such as those in *Rostkovia–Tortula* mire may occur (Fig. 8).

Fig. 6. *Rostkovia magellanica–Calliergon sarmentosum* bog with several other mosses and liverworts locally abundant. Peat depth 1.5-2 m. South-west Hestesletten, adjacent to Hamburg Lakes, Cumberland West Bay.

The wetter peripheral zone of such basin bogs often resembles a small-scale lagg (see Tansley, 1939, p. 675; Moore and Bellamy, 1974), serving as a water course and supports the hydrophytic carpet- and turf-forming mosses and liverworts with the rushes and occasionally *Deschampsia antarctica* (Fig. 3c). The central *Rostkovia–Chorisodontium–Polytrichum* turf community is raised slightly above this marginal vegetation. Peat depths in a typical *Rostkovia–Chorisodontium–Polytrichum* basin bog are illustrated in Fig. 9.

Both *Rostkovia* bog communities produce a fairly acid peat yet the calcium concentration is relatively high; they are therefore more characteristic of mesotrophic than oligotrophic bogs.

Occasionally, wet rock basins and depressions at the bases of slopes support stands of carpet-forming bryophytes (mainly *Calliergon sarmentosum, Calliergidium Austro-stramineum, Drepanocladus uncinatus* and *Cephaloziella* sp.). *Deschampsia antarctica* is frequently present as scattered plants but it may be quite abundant (see Fig. 11). These species accumulate an acid peat up to 1 m deep with comparatively low calcium levels and are perhaps the most oligotrophic of the ombrogenous bogs. Where the water-table is well below the surface for most of the year, as, for example, on raised beaches, the grass often forms a closed sward with negligible bryophyte cover, producing a peat seldom exceeding 1 m in depth. Such stands usually occur in drier situations adjacent to or in spaces amongst tussock grass and often close to gentoo penguin rookeries. Consequently, their nutrient status is raised, especially the levels of nitrogen and phosphorus.

In contrast, in parts of the island where rainfall is higher, particularly on Bird Island off the north-western tip of South Georgia, extensive stands of *Deschampsia antarctica* occur on wet level ground often adjacent to pools and surrounded by tussock grass (Fig. 10). *Colobanthus quitensis* is often abundant in this community together with *Callitriche antarctica* and scattered

Fig. 7. *Juncus scheuchzerioides–Calliergon sarmentosum* bog (darker area in centre) on level fluvio-glacial outwash plain subject to periodic flooding by melt water from Nordenskjöld Glacier. This grades into a *Rostkovia magellanica–Tortula robusta* mire (light area to left) on a seepage slope. Note "Swiss-roll" moraines of living vegetation at the edge of ice-covered moraine at right. Cumberland East Bay.

patches of *Conostomum pentastichum, Drepanocladus uncinatus, Polytrichum alpinum* and *Tortula robusta.* A physiognomically similar "meadow" bog occurs on Macquarie Island but with *Agrostis magellanica* replacing *Deschampsia antarctica* (Taylor, 1955). These meadows appear to be a hydroseral community, which has developed by the in-filling of depressions once occupied by larger pools and accumulating an anaerobic peat often exceeding 2 m in depth. On Bird Island the nutrient status of these meadows is raised considerably by the input of nitrogen and phosphorus from bird excrement; at certain times of the year large groups of brown skuas and wandering albatrosses congregate at these sites which are strongly influenced by their trampling and deposition of guano. This second category of *Deschampsia* grassland may be considered as an ornithogenically influenced meso- to eutrophic ombrogenous bog.

Moss Peat

A type of moss peat is formed by the tall turf-forming mosses *Polytrichum alpestre* and to a lesser extent *Chorisodontium aciphyllum.* It differs from the true tundra moss peat of Arctic regions in its absence of *Sphagnum* spp. and of a permafrost (Kubiëna, 1953). These mosses build up banks on relatively exposed levels to gently sloping hillsides close to the shore (Fig. 11) but the same type of "raised bog" also develops as a pre-climax community in depressions amongst low hillocks (notably at Maiviken, Cumberland West Bay), where they appear to represent an advanced stage in a hydrosere (Figs 3d and 12). The peat depth in such situations occasionally reaches 3 m but the water-table remains well below the surface. A profile through a *Polytrichum* raised bog is illustrated in Fig. 4b.

Fig. 8. Low hillocks dominated by short *Poa flabellata* tussock grassland with associated moss banks of *Chorisodontium aciphyllum* and *Polytrichum alpestre*. Peat depth *c.* 1 m. The darker vegetation in the broad valley in the centre foreground is a *Rostkovia magellanica–Polytrichum–Chorisodontium* bog with two deep "sink-holes" (blackish spots); peat depth is *c.* 1.5 m. The light-coloured vegetation on either side is *Festuca contracta* grassland. Maiviken, Cumberland West Bay.

The compact surface of *P. alpestre* is commonly colonized by epiphytic lichens (mainly species of *Cladonia*) and locally by *Cetraria islandica, Sphaerophorus globosus* and *Stereocaulon alpinum,* and occasional crustose species; *Usnea antarctica, Alectoria* spp. and *Cornicularia* spp., which are so abundant on identical moss banks in the northern maritime Antarctic (Fenton and Smith, 1981), are rare associates. The short rush *Juncus scheuchzerioides* is common and locally abundant, while scattered plants of *Festuca contracta* and *Poa flabellata* are often present. In wetter sites, *Chorisodontium* becomes the dominant moss and *Rostkovia* is the dominant rush with scattered *Festuca* and other grasses, and the community develops towards a type of "dry bog" closely related to the *Rostkovia–Chorisodontium–Polytrichum* bog described above (see Fig. 8).

Where there is a higher rainfall, especially on the south-west coast of the island, extensive spongy banks of *Chorisodontium* occur on moderately steep moist but well-drained slopes (Fig. 3e); small banks are common amongst tussock grass throughout the island. Unlike the *Chorisodontium* banks of the maritime Antarctic, which reach 3 m in depth and possess a permafrost (Fenton and Smith, 1981), those on South Georgia seldom reach 1 m. Epiphytic lichens, especially species of *Cladonia* and *Pseudocyphellaria,* are frequent and often reach exceptionally large dimensions (Lindsay, 1974). The banks may be broken by tussocks of *Poa flabellata* and *Acaena magellanica* is often present on the moss.

Both *P. alpestre* and *C. aciphyllum* peat accumulations have a low water-table but a comparatively high water content due to the high retention capacity of the moss, particularly the dense tomentum of rhizoids of *Polytrichum*. They are strongly acid and their nutrient status is quite

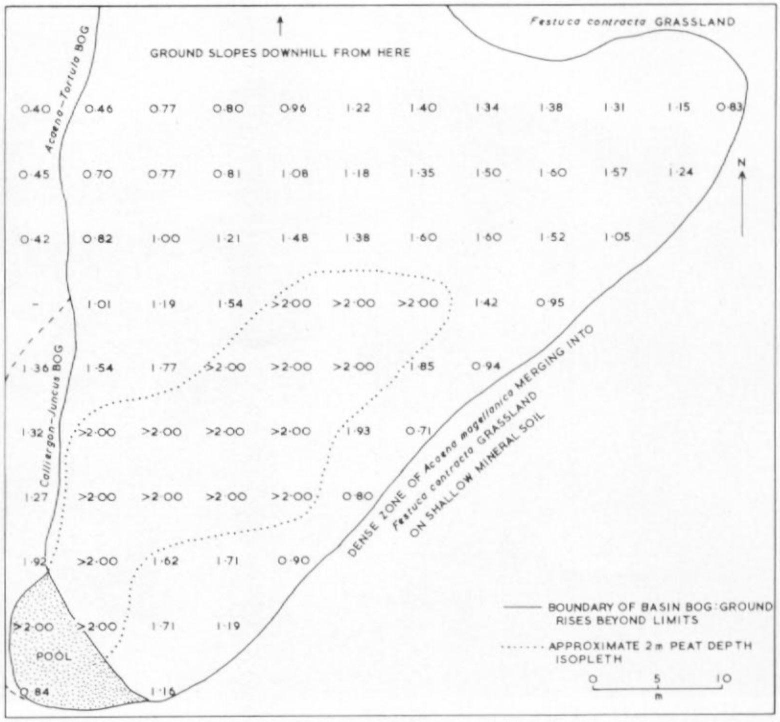

Fig. 9. Diagrammatic map of *Rostkovia–Chorisodontium–Polytrichum* basin bog, south side of King Edward Cove, showing peat depths (unpublished data of G. J. Lawson).

low compared with the other South Georgian organic deposits and they may be considered as ombrogenous oligo- to mesotrophic peats.

Tussock Peat

The principal climax vegetation type of South Georgia is *Poa flabellata* tussock grassland. This tall, robust pedestalled grass forms extensive stands on moist or wet coastal hillsides and raised beaches, and are typically inhabited by seals, penguins, burrowing petrels and albatrosses. In areas where the biotic influence is great, erosion of peat and soil between the tussocks may be considerable, leaving the individual plants raised by up to 2 m above the surrounding terrain on a pedestal of peat formed by *Poa* litter and roots (Fig. 13). On hillsides free from bird and seal activity, the individual plants are much smaller and the intervening spaces between tussocks are often occupied by discontinuous banks of *Chorisodontium aciphyllum* or *Polytrichum alpestre* (Fig. 3e). Here, a more uniform depth of fairly loose fibrous peat accumulates to 1.5 m or rarely 2.5 m but in one exceptional instance up to 5 m has been recorded on Jason Island (unpublished field notes of J. Smith). A schematized profile through this deposit is illustrated in Fig. 4c.

In seal-wallow areas, the water-table is at or near the surface during summer and pools of stagnant water between tussocks are often occupied by fur seals or groups of moulting elephant seals (Fig. 3e). In such situations the tussock pedestals are eroded and the peat is greatly enriched by excrement and urine, and pieces of moulted skin and hair become incorporated into the organic matter. However, the water-table on hillsides is low and biotic enrichment is localized around breeding colonies of birds (particularly gentoo penguins, prions and white-chinned

Fig. 10. *Deschampsia antarctica* bog adjacent to pools and surrounded by *Poa flabellata* tussock grassland. The low ridges, of unknown origin, are covered mainly by *Colobanthus quitensis*. Peat depth is *c*. 2 m "The Meadows", Bird Island.

petrels) and fur seals. Tussock peat tends to be acid with low calcium levels and may be categorized as a type of ombrogenous oligotrophic peat, becoming more mesotrophic where birds and seals raise the base status.

Ranker

A type of peat resembling tundra ranker (Kubiëna, 1953) sometimes forms beneath dense herbfield stands dominated by the deciduous woody herb *Acaena magellanica* and its understorey moss *Tortula robusta* on well-drained sheltered slopes, particularly in gullies on slopes near the shore (Fig. 14). The peat is seldom more than about 0.75 m deep and generally has a lower organic content than the other peat types. It differs from a true tundra ranker, and from other South Georgian peats, in having a very active micro-flora which results in rapid decomposition rates and consequently the accumulation of organic matter is reduced. Although the water-table is generally at least 30 cm below the surface, the substratum is flushed during the spring melt and the nutrient status is high, but this may be partly due to the rapid re-cycling of elements, resulting from the high rate of decomposition of the *Acaena* leaves which themselves have high element levels (Walton and Smith, 1980). The soil is somewhat intermediate between a true peat and the tundra brown soil which develops beneath *Festuca contracta* grassland (Smith and Walton, 1975). Calcium levels are high and the soil may be classed as a soligenous eutrophic peat similar to, but drier and less organic than, the *Acaena–Tortula* mire peat.

Distribution of Main Organic Deposits

All the peat-forming communities described above are widespread on the north-east and northern south-west side of South Georgia, particularly between Stromness Bay and Hound Bay,

Fig. 11. *Polytrichum alpestre* raised bog with scattered tussocks of *Poa flabellata* and *Festuca contracta*. Peat depth within the area delineated by white poles is *c*.2 m. The light-coloured vegetation towards the lower left is a *Deschampsia antarctica–Cephaloziella* sp. bog in a rock depression; peat depth is *c*.1 m. Maiviken, Cumberland West Bay.

where the greatest extent of snow-free terrain and most diverse vegetation occurs. Conversely, the sector of south-west coast between Holmestrand and Cape Disappointment has very little closed vegetation, besides tussock grassland, and peat deposits are nowhere very extensive or deep due to the small area or precipitous nature of the snow-free ground.

Beyond the central north-eastern sector, *Rostkovia* and *Juncus* bogs and mires are infrequent and generally occur in moraine and rock basins, and on wet fluvio-glacial outwash plains. Several large *Rostkovia* bogs occur in Bjornstadt Bay and Gold Harbour, while *Juncus* is the principal rush in bogs at Cape Vahsel. Some of the deepest (probably exceeding 2 m) and most extensive peat deposits on the south-west coast were recorded in *Rostkovia*–bryophyte bogs on the east side of Schlieper Bay, inland from the Samuel Islands and south-west of Shallop Cove, Queen Maud Bay. Similar but smaller *Rostkovia* bogs are frequent on north-west Annenkov Island, and they also occur north-east of Ducloz Head, Undine South Harbour. The distribution of *Rostkovia* bogs with locally dominant *Sphagnum fimbriatum* is indicated in Fig. 1. Although *Acaena magellanica* is abundant around the island, organic deposits formed solely by this vascular plant and *Tortula robusta* are seldom extensive. *Polytrichum alpestre* banks are mainly within the Stromness Bay–Hound Bay sector with particularly good development near the Husvik whaling station and on the south of Hound Bay, but they have scattered occurrences elsewhere on the southern part of the north-east coast and northern part of the south-west coast. Here also is the main distribution of *Chorisodontium aciphyllum* banks which typify hillsides free of tussock grass in those parts of the island with a higher rainfall than the central north-eastern area, notably coastal areas between the Willis Islands and Ice Fjord and between Capes Vahsel

Fig. 12. Hydrosere illustrating development of various bog types. A fringe of floating *Juncus scheuchzerioides, Deschampsia antarctica* and *Calliergon sarmentosum* extends up to 12 m from the lake shore in water up to 2 m deep; the outermost zone comprises *D. antarctica* (afloat) and *Callitriche antarctica* and *Drepanocladus* cf. *aduncus* (submerged). The dark band is *Rostkovia magellanica–Drepanocladus uncinatus*–liverwort bog merging into *R. magellanica–Chorisodontium aciphyllum* bog, where the peat has raised the vegetation above the level of free water. Beyond this is a raised light band of *Polytrichum alpestre* with *J. scheuchzerioides,* overlooked by a 2 m high raised bog of *P. alpestre* with scattered *Juncus, Festuca contracta* and *Poa flabellata*; total peat depth exceeds 3 m. A ridge of bedrock covered by tussock grass and *Festuca* rises above the bog behind. Maiviken, Cumberland West Bay.

and Disappointment. Also, in these wetter areas, swards of *Deschampsia antarctica* are more common and accumulate a substantial amount of peat; they are frequently associated with gentoo penguin rookeries. Tussock grassland (*Poa flabellata*) is widespread on raised beaches and hillsides in all snow-free coastal situations, producing a mantle of fibrous peat, but deep accumulations of tussock peat are seldom extensive.

Historical Development of the South Georgian Organic Deposits

During the early Wisconsin glacial maximum, the South Georgian ice-cap margin is believed to have extended as much as 80 km beyond the present coastline (Sugden and Clapperton, 1977). The island was probably completely covered by ice, with the exception of a few nunataks and cliff faces, until around 10 000 years B.P. (Clapperton and others, 1978).

With the recession of the ice, immigrant plants from southern South America probably took several hundred years to become established and develop closed communities capable of accumulating organic matter. The oldest radiocarbon date so far obtained for organic matter is 9 493 ± 370 years B.P. (Barrow, 1978; Harkness, 1979) from the basal layer of peat in a *Rostkovia–Tortula* mire overlying the multiple moraine complex on the south side of King Edward Cove. An almost identical date of 9 433 ± 120 years B.P. was determined for the base of a similar mire south-east of Dartmouth Point, also in Cumberland East Bay. This confirms that this area of the island was snow-free and that vegetation was well established here at least 9 500

Fig. 13. Tussock grass (*Poa flabellata*) on a raised beach. The pedestals of tussock peat are *c.* 1.75 m high. Coast north of Samuel Islands.

years ago. In Sphagnum Valley, Cumberland West Bay, the oldest date for the base of a peat deposit in a *Rostkovia–Tortula* mire is 6 647 ± 120 years B.P., while a thin layer of the moss *Calliergon sarmentosum* at the base of a *Polytrichum alpestre* "raised bog" at Maiviken, Cumberland West Bay, has been dated as 8 657 ± 45 years B.P.

Unfortunately, the dates obtained for peats from the Stromness Bay localities are not for basal levels, as the samples were collected to correlate the age at corresponding depths in different sites of the base, and hence the approximate date of establishment of bands of *Sphagnum fimbriatum*, an important peat-forming moss in temperate and tundra regions. Although of very restricted distribution on South Georgia, it would appear to have been a component of some mire communities for at least 3 600 years. While the moss has not been recorded with sporophytes on South Georgia, Barrow (1978) isolated spores of this species at depths estimated to be abo[illegible] 4 000 years old.

Radiocarbon dates for organic matter at various depths at a number of localities are given in Table III, and the relationship between age and depth of peat is illustrated in Fig. 15. Most samples were of peat in *Rostkovia–Juncus–Acaena–Tortula* mires, although the actual peat sampled may have been of a different origin depending on the stage of the succession and the dominant species growing at the time of formation. The increase in age with depth appears to be fairly linear, indicating a comparatively constant rate of accumulation and compression, and suggesting no major changes in the island's climate over the period of peat accumulation. Similarly, the dates for the base of the *Sphagnum* hummocks or buried layers in *Rostkovia–Juncus–Acaena–Tortula* mires lie within the same scatter of points at the "younger" end of the line. *Polytrichum–Chorisodontium* peat appears to have a similar rate of accumulation as the mire communities in which these turf-forming mosses are also the principal peat formers. *Poa flabellata* peat accumulates more rapidly than the bog or mire peats which, at corresponding

TABLE III. RADIOCARBON DATES FOR SEVERAL TYPES OF PEAT ON SOUTH GEORGIA

Surface vegetation/peat type	*Locality*	*Depth** (cm)	*Radiocarbon date* (years B.P. ± error)	*Sample number* (SRR series)†	*Comments*
Rostkovia–Tortula mire peat	Lower "Gun Hut Valley", Cumberland East Bay	38 }	391±70	30	Base of *Sphagnum* hummock
		101 }	2 335±50	31	
		38	227±25	32	Base of *Sphagnum* hummock
	"Gun Hut Valley", Cumberland East Bay	50	4 852±210	580	*c.* 1 m surface peat removed by stream erosion
		105	2 935±85	581	Surface peat exposed by stream erosion
		160	8 537±65	582	Base of peat deposit
		255–260	9 493±370	736	Base of "sink-hole" in peat deposit
	"Husvik Valley", Stromness Bay	51 }	657±72	33	Base of *Sphagnum* hummock
		76 }	1 092±55	34	
		38	564±70	35	Base of *Sphagnum* hummock
		51	1 084±65	36	
	North of Stromness whaling station, Stromness Bay	38 }	300±50	37	Base of *Sphagnum* hummock
		64 }	584±50	38	
	Sphagnum Valley, Cumberland West Bay	38 }	435±50	39	Base of *Sphagnum* hummock
		64 }	869±50	40	
		89 }	1 547±50	41	
		102 }	1 759±50	42	
		152 }	2 380±50	43	Previously dated as 2 500 ±800 (UCLA-658C)‡
		38 }	718±60	44	
		64 }	1 563±60	45	
		76 }	1 962±60	46	
		64 }	1 886±65	47	Base of buried layer of *Sphagnum* peat
		102–115 }	6 500±500	UCLA-658B‡	
		127 }	5 191±100	48	
		223	6 647±120	578	
		233	3 997±85	579	Surface peat exposed by stream erosion
	South side of Ocean Harbour, Barff Peninsula	143	3 591±100	584	Peat containing *Sphagnum*
	East side of Dartmouth Point peninsula, Cumberland East Bay	280 }	9 417±35	1165	Base of "sink-hole" in peat deposit
		300 }	9 433±120	1166	
Polytrichum alpestre "raised bog" peat	Between Poa Cove and Burnet Cove, Maiviken, Cumberland West Bay	50–55 }	422±55	1158	
		100 }	2 588±40	1160	
Poa flabellata tussock peat	Behind Grytviken whaling station, King Edward Cove, Cumberland East Bay	100	721±60	29	Base of former tussock pedestal now colonized by *Polytrichum alpestre*
	South side of Annenkov Island	150	1 007±160	585	Base of tussock pedestal
	Between Poa Cove and Burnet Cove, Cumberland West Bay	170–173	3 377±50	1161	Narrow layer of tussock leaves beneath *Polytrichum alpestre* "raised bog"
	Jason Island, Busen Peninsula	355	4 300±500	UCLA-658A‡	Base of deep accumulation of tussock peat
Calliergon sarmentosum–Drepanocladus cf. *uncinatus* mire peat	Between Poa Cove and Burnet Cove, Maiviken, Cumberland West Bay	174–176 }	7 543±40	1163	Narrow layer of *Drepanocladus*
		177–179 }	7 786±45	1164	Narrow layer of *Calliergon*
		180 }	8 657±45	1162	Narrow layer of *Calliergon*

* Depths linked by a bracket are from the same profile.
† Sample numbers are all preceded by the prefix SRR, the code of the Scottish Universities Research and Reactor Centre.
‡ Sample numbers prefixed by UCLA indicate dates provided by the University of Cambridge Quaternary Research Centre.

Fig. 14. Closed stand of *Acaena magellanica* with a partial understorey of *Tortula robusta* in a moist sheltered gulley. The moderately organic ranker type of soil is *c.* 50 cm deep. King Edward Cove, Cumberland East Bay.

depths, are considerably older. This is to be expected in view of the high productivity of tussock grass both above and below ground, and its large annual investment of dead foliage into the litter layer, in relation to that of the other grasses, rushes and bryophytes (Smith and Walton, 1975; Gunn, 1976). The potential peat production by the deciduous *Acaena magellanica* is largely negated by the rapid decomposition of its leaves (Walton, 1976).

Changes in the composition of the vegetation of many sites are evident from examination of macro-remains in the profiles and palynological analysis. Also, inhibition to peat accumulation may have occurred following temporary burial by mineral material deposited by wind or water, or the removal of the living vegetation by stream erosion. However, there is little evidence to suggest that there has been any large-scale re-advance of glaciers or the development of snowfields over lowland vegetated areas, although there has been considerable fluctuation in the positions of glacier snouts in many of the still sparsely vegetated valleys and in fjords, and ice-cap margins have also changed but without affecting the local vegetation significantly. An interesting exception is on the east side of the receding Nordenskjöld Glacier, Barff Peninsula, where a moraine 4 m high and about 400 m in front of the present snout is composed largely of folded peat, indicating that the glacier had advanced through a bog adjacent to the ice cliff. An extensive *Juncus–Calliergon* bog presently exists adjacent to the west side of this glacier south-east of Dartmouth Point but only a low fragmentary moraine lies beyond it; however, it is separated from the morainic debris adjacent to the glacier by a series of 1 m high "Swiss roll" moraine composed of living vegetation and the underlying peat and glacial till, suggesting a very recent minor forward surge by this side of the glacier (Fig. 7).

The maximum depth of organic matter which has accumulated beneath the principal peat-forming plant communities during the past *c.* 10 000 years is very variable throughout the long-

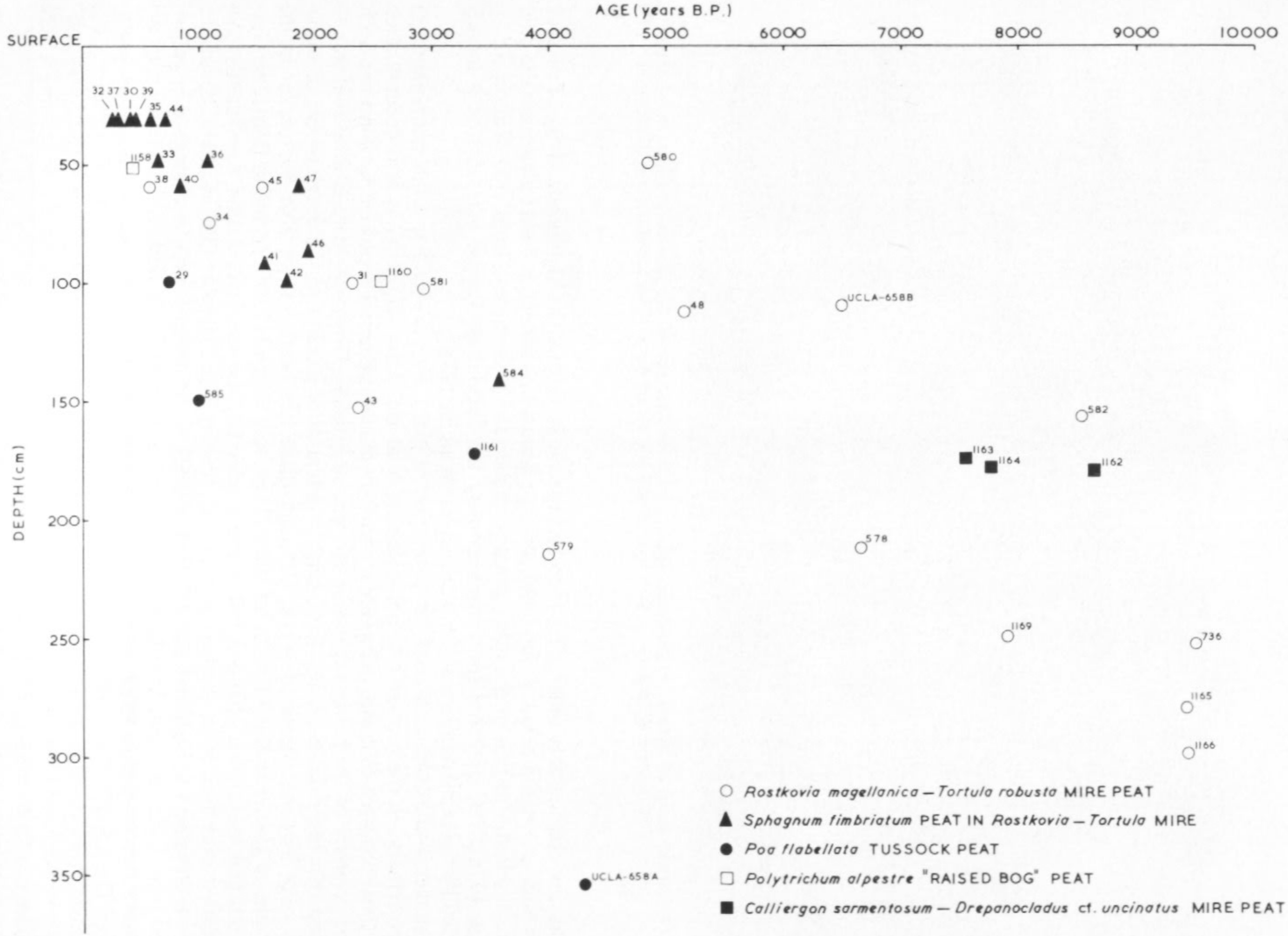

Fig. 15. Relationship between depth of peat and radiocarbon age of different peat types on South Georgia.

deglaciated areas. Few examples of continuous peat exceeding 3 m in depth have been located and profiles in shallower mire deposits generally have narrow bands of fine clayey material or even pebbles. Continuous peat accumulation has, however, occurred in basin bogs (mainly *Rostkovia–Chorisodontium–Polytrichum* stands) and in *Polytrichum alpestre* raised bogs. The occurrence of tussock peat up to *c.* 5 m deep (unpublished field notes of J. Smith) on Jason Island certainly seems exceptional. A natural cutting in a *Rostkovia*–mixed bryophyte mire on the north-facing slope behind the Grytviken whaling station is about 4 m in height but this depth has probably been accentuated by solifluction (Fig. 16). Peat samples taken from 350 and 460 cm below the top of the cutting gave radiocarbon dates of 5 415 $\pm$ 55 years B.P. (SRR-1167) and 8 737 $\pm$ 50 years B.P. (SRR-1168), respectively.

Palynological evidence provided by Barrow (1977, 1978, in press *a, b*) indicates that there has been no significant change in the composition of South Georgia's flora and vegetation during the past 9 500 years. Pollen and spores of several of the island's present flora were isolated from the oldest deposits. *Acaena* sp. (probably *A. magellanica*), *Colobanthus* sp., at least one species of grass and the moss *Conostomum pentastichum* were identified in a deposit dated at 9 493 $\pm$ 370 years B.P. in "Gun Hut Valley" on the south side of King Edward Cove, while at a nearby site in the same valley other species isolated from peat older than 8 500 years B.P. included more than one species of grass (probably including *Poa flabellata*), *Callitriche antarctica* (a typical associate of tussock grass stands), *Galium antarcticum, Lycopodium magellanicum* and macro-remains of *Rostkovia magellanica* (Barrow, 1978). The author located macro-remains of the hydrophytic moss *Calliergon sarmentosum* from a site at Maiviken, Cumberland West Bay, also within this radiocarbon age group. Fluctuations in the dominant pollen types (particularly Gramineae and *Acaena*) suggest minor variations in the climate which would have affected the

Fig. 16. Deep erosion cutting in a *Rostkovia magellanica–Tortula robusta* mire. There is at least 1 m of peat beneath the spade, which is *c.* 1.25 m high. Behind Grytviken whaling station, King Edward Cove, Cumberland East Bay.

extent of grassland, bog and herbfield ecosystems, but it is not yet clear whether these changes correlate with glaciological and geomorphological evidence of climatic change on the island during the past ten millennia.

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