

PALYNOLOGICAL STUDIES IN SOUTH GEORGIA: II. TWO PROFILES IN SPHAGNUM VALLEY, CUMBERLAND WEST BAY

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ABSTRACT. An analysis of pollen, spores and micro-fossils isolated from two post-glacial organic deposits in Sphagnum Valley, South Georgia, is presented. The sporomorph composition of peat and peat-clay sampled from profiles in the two contrasting valley bog communities indicate that many elements of the present vascular plant and bryophyte flora were flourishing in this part of the island at least 6650 years ago. These include the forb *Montia fontana* and the moss *Sphagnum fimbriatum*, the native status of which has thus been confirmed. Pollen of exotic taxa, mainly of southern South American provenance, is present throughout the profiles.

The sporomorph record throughout the profiles is dominated by grasses and the woody herb genus *Acaena*. Each group reaches peaks of maximum occurrence asynchronously and these, together with the presence of several less important taxa, have been interpreted as possibly indicating climatic fluctuations on the island. Peaks in grass pollen may reflect a cool or cool-wet climate while peaks in *Acaena* pollen may be indicative of warmer or drier conditions.

The vegetation of the sub-Antarctic island of South Georgia is well developed in most snow-free coastal areas and a range of closed plant communities extends to about 250 m altitude, although the most extensive and diverse vegetation is generally below 150 m, particularly on the north-east coast (Greene, 1964; Smith and Walton, 1975). The vascular flora is typical of the sub-Antarctic islands in possessing few native species (26 taxa listed by Greene and Walton, 1975) due to its isolation and cold oceanic climate and in particular to the low summer temperatures (Smith and Walton, 1975). Non-permafrost organic deposits several metres in depth are widespread but seldom extensive, and radiocarbon dates obtained for basal samples at several sites indicate that peat-forming plant communities were flourishing 9500 years ago, shortly after the end of the last major glaciation (Smith, 1979, 1981).

In order to determine the sequence of vegetational history on South Georgia and possibly relate any marked changes in floristic composition to climatic fluctuations, a detailed study was made (by C.J.B.) in 1972–73 of several organic deposits on the island (Fig. 1). Samples were taken from the surrounding surface litter and soil and at frequent intervals down a profile at each study site for subsequent palynological analysis in the UK. The results of two profiles in Sphagnum Valley are presented here; those for three profiles on the south side of King Edward Cove, two on Barff Peninsula and one on Annenkov Island are provided by Barrow (1983a,b). Pollen diagrams for the Sphagnum Valley and King Edward Cove sites have been compared and discussed by Barrow (1978).

The problems of palynological studies in sub-Antarctic islands were outlined by van Zinderen Bakker (1969, 1970). Depauperate vascular floras in which grass species predominate result in a low number of pollen and spore types of diagnostic value since Gramineae pollen varies little morphologically between species. All the South Georgia vascular flora occurs also in Tierra del Fuego, and most in the Falkland Islands, from where the island's flora most probably originated. There will therefore have been a continuous but variable sparse rain of pollen and spores over South

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Georgia which cannot be distinguished from the sporomorphs of the same taxa of local origin. Relatively few of the bryophyte species commonly produce sporophytes so their spore record in the past may also be poorly represented.

Isolated islands are generally not seriously affected by climatic changes which are experienced by major land masses due to the buffering effect of relatively stable conditions generated by the surrounding ocean. However, changes in the position of the Antarctic Convergence may have had a significant influence on the climate of South Georgia although there is no evidence that there have been major changes in its position during the Holocene (Sugden and Clapperton, 1977). Minor fluctuations, as indicated by glacial chronology, may not be reflected in floristic changes since glaciers are more sensitive to small changes in temperature and precipitation than most vegetation. Historical trends may be further masked since many of the island's phanerogams and cryptogams have wide ecological amplitudes (Smith and Walton, 1975) which can make pollen and spore diagrams difficult to interpret.

PAST RESEARCH

The only previous palynological investigations of Quaternary deposits from South Georgia were carried out by Cranwell (1963, 1964a,b, 1965, 1969), who examined peat samples from the Cumberland Bay–Stromness Bay area (collected by Dr S. W. Greene) and from Jason Island (Fig. 1) (collected by the late J. Smith), Falkland Islands Dependencies Survey (now British Antarctic Survey). Additional peat samples collected from Jason Island were examined for remains of Coleoptera by Coope (1963). Cranwell commented on the nature and micro-fossil content of these samples, referring in particular to pollen derived from South America. In some samples she recorded 0.5–1.0% of the total pollen sum per level as *Nothofagus fusca* agg., but she recorded no pollen of any other tree or shrub species except for occasional pollen of *Ephedra* spp.; spores of some native pteridophytes were isolated but none belonging to species which occur in South America but do not grow on South Georgia at present. There was considerable variation from one locality to another in the record of South American-derived grains. She isolated an interesting assemblage of micro-fossils and commented on a sparse but varied record of the island's native vascular plants. The presence of South American pollen in the peats of South Georgia emphasizes the possibility of wind-blown volcanic ash also being included. Cranwell (1969) commented on the occurrence of such ash in samples from the Cumberland Bay area, but it seems probable that, without petrological study, fine wind-blown dust of local fluvio-glacial or rockfall origin can easily be mistaken for volcanic ash (e.g. Gordon and others, 1978).

STUDY AREA

Following a general survey of the Cumberland Bay area, Sphagnum Valley was selected for close study because (a) it is extensively vegetated and has a wide range of plant communities, (b) there are numerous, relatively extensive, deep organic deposits, (c) the geomorphology is relatively simple and already mapped (Clapperton, 1971), and (d) a radiocarbon date indicated the presence of peat deposits at least 6500 ± 500 years old (Fergusson and Libbey, 1964).

Sphagnum Valley is a broad glaciated valley lying on the south side of Cumberland West Bay on the north-east coast of South Georgia (Fig. 1). From the shore, near Harpon Bay, it extends eastwards for 3.5 km, rising to c. 320 m below Echo Pass. The lower part of the valley is very wide and its seaward end opens into an extensive

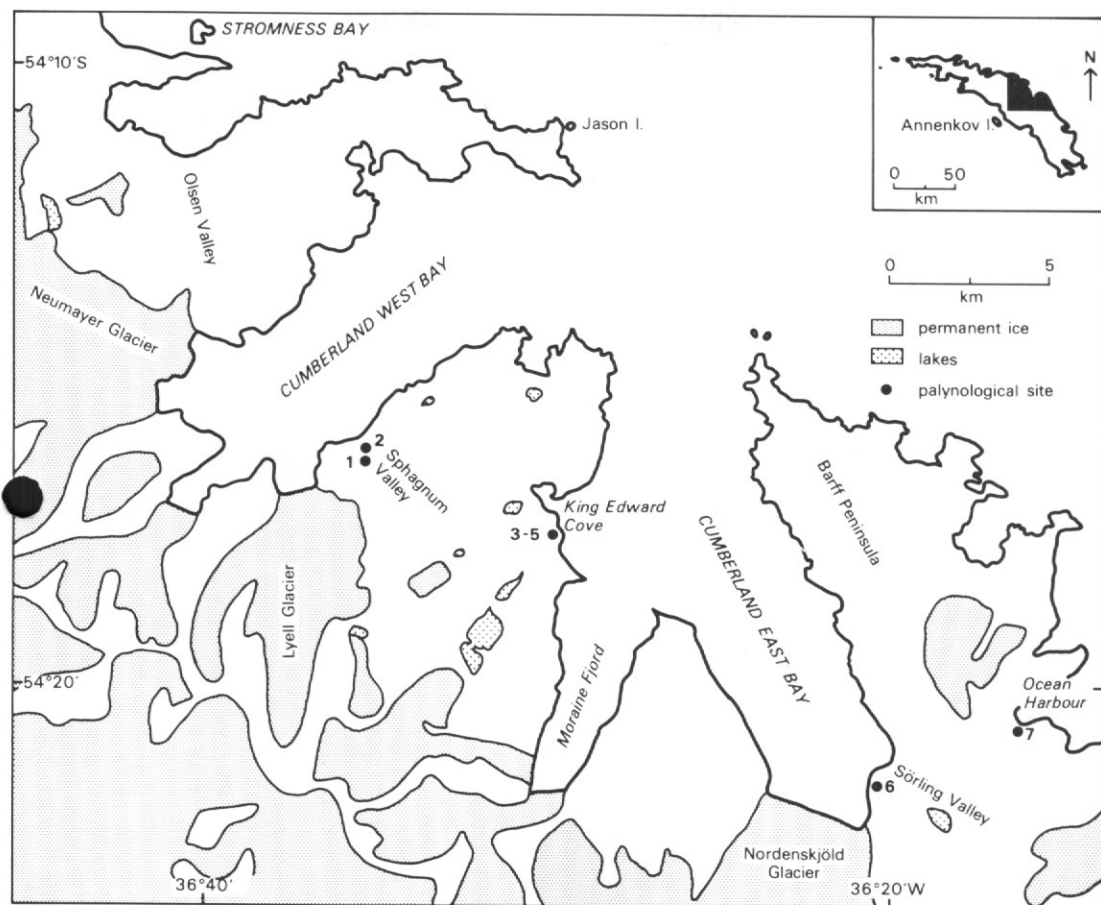


Fig. 1. Map of the Cumberland Bay region of South Georgia indicating location of palynological sites.

fluvio-glacial outwash plain. The main valley stream is joined by several tributaries, mainly from the hills to the north-east. The western boundary of the valley is a long high ridge with extensive scree, the west side of which flanks the Lyell Glacier.

The valley floor and lower slopes are extensively vegetated with a range of closed grassland (predominantly *Festuca contracta*, with *Poa flabellata* near the shore) and bog (predominantly the rush *Rostkovia magellanica*, and locally *Acaena magellanica*, and bryophytes) communities (Fig. 2). These merge into open fellfield on the drier, more windswept ridges, knolls and higher slopes, while the loose scree and stony glacial deposits in the upper reaches of the valley are virtually barren.

A *Rostkovia magellanica*-bryophyte mire complex (Site 1) and a wet *Acaena magellanica*-*Tortula robusta* mire (Site 2) (as classified by Smith, 1979, 1981) were selected for detailed sampling of organic deposits.

SITE DESCRIPTIONS

Site 1

The *Rostkovia* mire is situated about 0.75 km from the shore and about 100–150 m to the west of the main valley stream at an altitude of c. 30–70 m above sea level (Figs.



Fig. 2. Lower Sphagnum Valley looking north-west across Cumberland West Bay. The bog complex with Site 1 lies to the left of the sharp bend in the stream in the mid-left of the photograph and Site 2 lies across the ridge beyond the double bend in the stream in the centre of the photograph.

3 and 4). The mire lies in a broad shallow basin slightly above the meandering main stream of Sphagnum Valley which flows diagonally from south-east to north-west a little to the north of the basin. The basin opens into a small fluvial plain to the north but to the west, south and east it is flanked by slopes of morainic material forming a prominent low moraine ridge on the west side; according to Clapperton (1971) this material was deposited by an ice advance culminating about 5000–6000 years ago. Much of the area to the east and south is bordered by a rock bench, below which is an area of scree to the south. The site was surveyed by plane tabling and a vegetation map of the surrounding area was produced (Fig. 4). The sampling profile was situated towards the upper part of the mire at an altitude of 48 m. A 25-m² plot in each of the upper, middle and lower parts of the mire was sampled for surface deposition of sporomorphs and the present vegetation cover analysed.

The surface vegetation of this gently sloping mire is predominantly the rush *Rostkovia magellanica* (about 60% cover) with a closed understorey of mosses (mainly *Dicranoloma subimponens*, with frequent patches of *Drepanocladus uncinatus* and *Tortula robusta* and, in the wetter areas *Calliergon sarmentosum*, each achieving dominance over different parts of the mire and each, except *Dicranoloma*, being locally fertile). *Acaena magellanica*, *A. tenera*, *Festuca contracta*, *Galium antarcticum*, *Juncus scheuchzerioides*, *Montia fontana*, *Phleum alpinum*, *Ranunculus bitermatus* and, locally, *Deschampsia antarctica*, together with several additional species of mesic and hydric mosses (notably *Bartramia subsymmetrica*, *Chorisodontium aciphyllum*, *Conostomum pentastichum*, *Polytrichum alpestre*, *P. alpinum* and *Psilopilum trichodon*) and liverworts are sporadically associated.



(a)



(b)

Fig. 3. The *Rostkovia magellanica*-bryophyte bog complex in which Site 1 is situated. (a) Looking south up Sphagnum Valley; the Site 1 exposure appears as a scar in the centre of the photograph. (b) Looking north downhill from the study site.

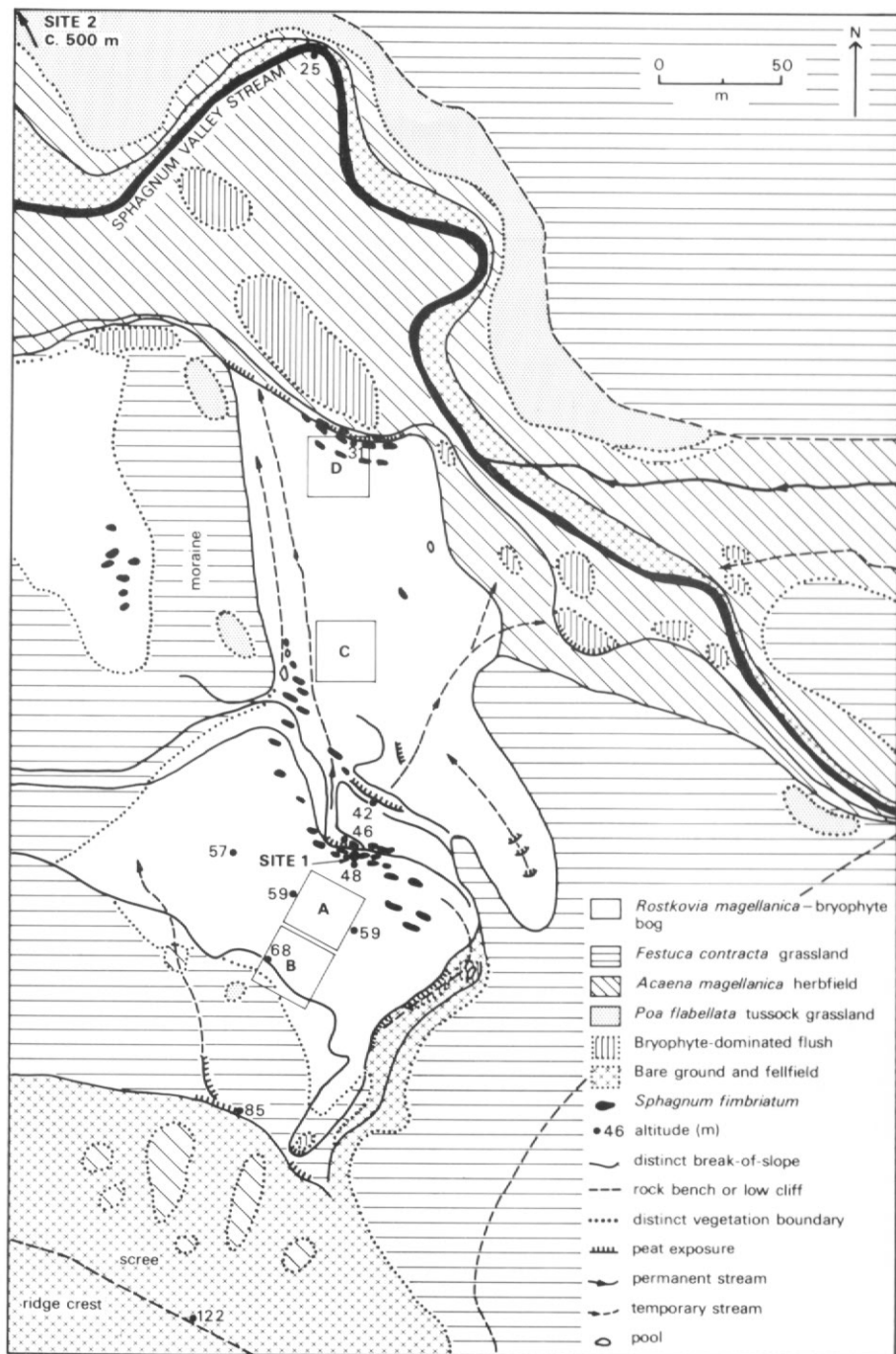


Fig. 4. The Sphagnum Valley bog complex indicating the major vegetation types and location of Site 1. Surface litter was sampled from Plots A-D.



Fig. 5. The Site 1 peat exposure in the *Rostkovia*-bryophyte bog. The lighter colour areas in the foreground and beyond the section are stands of *Sphagnum fimbriatum*.

Large crescentic hummocks of *Sphagnum fimbriatum* occur in several parts of the mire and were abundant around the position of the sample profile (Fig. 5). *Ophioglossum crotalophoroides* and *Uncinia meridensis* are rare but grow in a few drier areas close to the sampling site. The sloping ground rising from the bog to the west, south and east is dominated by dry *Festuca contracta* grassland with frequent *Acaena magellanica*, *Phleum alpinum*, bryophytes (of which only *Conostomum pentastichum* is commonly and abundantly fertile) and lichens. *Lycopodium magellanicum* occurs amongst sparse *Festuca* in one small site about 100 m east of the mire. A few small stands of *Poa flabellata* occur, mainly on the north-west moraine and flanking *Festuca* grassland to the north and north-east of the site. The valley floor adjacent to the stream is dominated by an *Acaena*-*Tortula* mire which becomes extensive on the fluvial plain due north of the site. Within this community, and also around the southern perimeter of the *Rostkovia* mire, are wet bryophyte flushes dominated by *Pohlia wahlenbergii*, *Philonotis acicularis*, *Bartramia subsymmetrica* (each commonly fertile), *Brachythecium* spp., and other hydric species. The scree slope to the south of the mire is partially colonized by dense *Acaena magellanica* and elsewhere by very open fellfield with sparse *A. tenera*, *Phleum* and *Deschampsia*; *Hymenophyllum falklandicum* occurs in crevices in the rock bench, while small cushion-forming xeric mosses (mainly species of *Grimmia* and *Racomitrium*) grow on the dry rock and boulder surfaces.

Peat accumulation is greatest towards the centre of the mire where the surface topography is slightly convex. Locally there are deep sink holes in the peat with subterranean channels draining spring melt water from the surface; otherwise there are no permanent surface streams although there are several small permanent pools.

Several peat exposures, caused by slippage or collapse of underground channels, occur within the bog and near its periphery. The Site 1 section was in one of these exposures near the middle of the mire (Fig. 5) and subterranean drainage is audible about 30 m up-slope of the sample profile. Samples with a visible organic content were taken from 3.17 m deep in this section, but below about 2.90–3.00 m the deposits are largely inorganic. The deepest recovery of samples with organic inclusions was from a depth of 3.74 m in a profile c. 25 m up-slope from the previous section.

Site 2

This mire lies about 0.5 km from the shore and 0.5 km to the north of Site 1 (see Figs. 2 and 4) at an altitude of about 9 m a.s.l. Because this subsidiary site was topographically and floristically simpler than Site 1 it was not plane tabled or mapped. It is situated at the southern end of an extensive upper raised beach area (Clapperton, 1971) and bordered on its southern side by a low cliff cut in a rock bench. The south-easterly continuation of this rock bench forms part of the boundary of Site 1 (Fig. 4). A small stream flows from a *Rostkovia* mire above the site, through a gully in the rock bench, then disappears into a sub-surface drainage channel through a small hole in the peat covering the upper raised beach.

Although most of the upper raised beach area is vegetated by wet *Rostkovia*-bryophyte mire, the sampling site close to the rock bench is wet mire dominated by dense *Acaena magellanica* with an understorey of *Tortula robusta*. In general, it is floristically much simpler than Site 1. The principal vascular species occurring close to the site are *Juncus scheuchzerioides*, *Montia fontana*, *Phleum alpinum*, *Ranunculus biternatus* and *Rostkovia magellanica* in the wetter areas; tussocks of *Poa flabellata* grow on the rock bench and *Festuca contracta* grassland, similar to that around much of Site 1, dominates the ridge immediately to the south of the cliff. The area of this mire is c. 100 m² and the peat depth averages about 2 m, grading into clay in the lowest 0.5 m. Samples were taken from three positions but only one has been analysed palynologically; the collection was from a stream exposure cleaned and extended downwards. The lowest level at which organic remains were visible was 2.32 m.

Stratigraphy of peat profiles

The stratigraphy of the sites is shown on the respective pollen diagrams (Figs. 9 and 10). Peat deposits examined in several sections in Sphagnum Valley appear to have developed *in situ* as semi-ombrogenous mires resting directly upon glacial or fluvio-glacial substrates which were exposed after the ice receded from the area. Although a radiocarbon date of 6650 ± 120 yr B.P. was determined for a sample of peat from 2.22 m depth in the Site 1 profile (Harkness, 1979), well above the totally inorganic deposits, Clapperton (1971) considered this glacial debris as having been deposited about 5000–6000 years ago. However, the authors believe that this material, lying well below the radiocarbon-dated organic material, may be 8000–9000 years old. The peat at Site 2 grades into clay which probably overlies fluvio-glacial outwash material or raised beach deposits, and is close to the level of the upper raised beach recognized by Clapperton (1971). Site 1 has a more varied stratigraphy than Site 2. Layers of clay, sand, gravel and stones of varying size and degree of sorting seem to be the result of phases of deposition (Fig. 6) due either to down-washing from largely unvegetated slopes above the mire complex during spring melt or short periods of extremely high rainfall (e.g. 215 mm of rain fell within 24 h in Cumberland East Bay on 4 April 1972 (Stone, 1974)), or, in the case of the finer material, to wind-transported dust. The less varied stratigraphy of Site 2 may



Fig. 6. Stratigraphy of the Site 1 section. The spade handle (bottom centre) is about 1 m above the base of the section. The knife is 20 cm in length.

reflect a constantly wet and more sheltered environment well away from sources of down-wash.

MATERIALS AND METHODS

Collection of material

After a preliminary survey of both study sites by examining exposures and probing organic deposits with a Hiller sampler or auger, sample cores were collected for analysis from several sections through the deeper deposits. However, only the samples from the deepest section at each site have been analysed in detail and are reported here. Each section was a natural peat exposure which was cut back to remove all weathered matter. Sampling was carried out during dry weather and all sample containers were thoroughly washed and rinsed with distilled water before use. Sixty-two samples from Site 1 and 46 samples from Site 2 were collected by pushing 22-ml plastic jars into the freshly cleaned face of the exposure at 5 cm intervals down a plumb-line; however, only 54 Site 1 samples contained adequate sporomorphs and only 23 (at 10 cm intervals) Site 2 samples were analysed. The jars were immediately sealed with air-tight lids, labelled and stored in their field moist

state at -10°C within four hours of collection to reduce chemical and physical change. Additional samples were collected in the same manner for radiocarbon dating.

To obtain an indication of present pollen and spore deposition in relation to the distribution and relative occurrence of local vegetation and to the influx of non-South Georgia sporomorphs, 20 surface litter samples (each of a few grams fresh weight) were collected at random from within each of four 25-m² plots in uniform vegetation along a transect from the north to the south of the Site 1 mire complex (see Fig. 2). The litter samples from each plot were amalgamated and sub-samples analysed using the same treatment and reagents as for the peat samples. Within each plot the mean percentage cover afforded by the principal plant species was estimated from ten randomly placed 1-m² quadrats.

Analytical procedure

Analyses were carried out in the UK, as far as possible during winter to reduce the risk of locally derived pollen and spore contaminants. All equipment and containers were cleaned with 'Decon 90' detergent, washed with hot water and rinsed with distilled water. By taking these precautions it was possible to overcome the problem of contamination by northern hemisphere species, which have affected the results of other workers (e.g. Hafsten, 1951, 1960; personal communication from D. M. Churchill). The removal of unsaturated soil colloids was achieved by the hydrolysis method of Faegri and Iversen (1975). Each sample, comprising 5–10 g of moist peat, was placed in a conical centrifuge tube to which was added 10 ml of 7% potassium hydroxide solution. The mixture was heated and stirred at 100°C for 2 min in a water bath, then centrifuged at 4000 r.p.m. for 4 min. The supernatant was decanted and the residue washed with distilled water, centrifuged and decanted again, and this procedure repeated two or more times, the supernatant being discarded until it was clear and free of the alkaline KOH. The residue left after each decantation was stirred well before and after the addition of each solution or distilled water wash. The residue was washed through clean copper gauze (625 holes cm⁻²) and the coarser fraction retained for examination of macro-fossils while the sieved solution was centrifuged and the supernatant decanted, leaving a sieved residue in the tube. This was washed first with 10% acetic acid, centrifuged and decanted, then with glacial acetic acid, and again centrifuged and decanted. The dehydrated organic residue was then subjected to acid hydrolysis to remove the cellulose.

An acetolysis mixture (Erdtman, 1960) was prepared immediately before use by adding 1 ml concentrated sulphuric acid to 9 ml of acetic anhydride; about 5 ml of this solution was added to each tube containing the sample residue and the mixture stirred while heating in a water bath, commencing at 70°C and rising to 100°C in not more than 2 min. The reaction was stopped by the addition of glacial acetic acid, the solution stirred, centrifuged and decanted.

Washing, stirring, centrifugation and decanting were repeated with glacial acetic acid, and twice with distilled water until the supernatant was clear, to remove all soluble cellulose acetate products of acetolysis. The removal of soluble silicates was necessary in twelve samples from Site 1. This was achieved by adding 40% hydrofluoric acid to each tube containing the sample solution, the quantity varying according to the amount of silica in the residue. It was then boiled in a water bath for 2–10 min, the mixture being stirred continuously with a glass rod. 5% hydrochloric acid, heated to 100°C , was added to the mixture before centrifuging (if necessary a few drops of 95% ethanol was added to reduce specific gravity). The residue was washed with 10% HCl at 100°C , centrifuged and decanted, then again washed until

the supernatant was clear. The residue was washed with distilled water twice to remove the acid.

Diatoms were isolated from selected samples at Site 1 using chemical techniques described by Evans (1968).

Microscopic examination and counting procedure

The material was examined using a Meopta S 13 microscope equipped with Nikon HKW $\times 15$ eyepieces, Nikon apochromatic $\times 100$ oil immersion objective and Meopta phase contrast stage and objectives $\times 10$, $\times 20$, $\times 40$. Most of the photography was with Nikon Apo $\times 40$. A Carl Zeiss automatic photomicroscope was used for difficult determinations, and could be linked by a Wild 'comparator-tube' to the Nikon apophot microscope to allow simultaneous viewing of fossil and reference pollen, displayed side-by-side in the one eyepiece.

Prepared slides were examined at random rather than counting those from one level to the next in series. Trends shown in the pollen diagrams should therefore not reflect any bias due to order of sample examination. Totals were recorded on an electric counter.

A count of 200 or more vascular pollen grains per sample was regarded as the desirable pollen sum; however, the pollen concentration at Sites 1 and 2 averaged only around 100 grains per sample (compared with 200 to over 500 grains per sample from other sites on the island). Ten or more (22×40 mm area) slides had to be examined to obtain this number of pollen grains. At Site 1 ten samples yielded very low counts and have been omitted from the pollen diagram.

The whole area of the cover-slip was examined at a magnification of $\times 150$, taking care that the edges of the cover-slip were not ignored (Brooks and Thomas, 1967). Each grain or micro-fossil encountered was identified at $\times 300$, $\times 600$ and if necessary $\times 1500$ magnification. Some samples were examined additionally for the presence of diatoms, but these were not recorded for all levels in the profiles.

Identification of sporomorpha

South Georgia pollen and spores are generally well preserved, and grains corroded or damaged beyond recognition are few. However, the pollen of *Juncus scheuchzerioides* and *Rostkovia magellanica* and spores of *Tortula robusta* do not preserve. Pollen and spores of the island's native vascular flora have been described and illustrated by Barrow (1976). Undetermined grains are recorded, the majority of which are tricolpate and probably derived from herb or shrub species of southern South American origin. Because of the unknown provenance and the lack of South American reference material most are not identified below family level but have been compared with descriptions and illustrations in several authoritative accounts of the region and other sub-Antarctic islands (e.g. Auer and others, 1955; Bellair, 1967; Cranwell, 1939, 1953; Heusser, 1966, 1971; Romero and Maronna, 1971; Schalke and van Zinderen Bakker, 1971; Villagrán, 1980).

Whenever identification is in any way uncertain the limits of confidence are indicated by the following notations (see also Benninghoff and Kapp, 1962):

- sim.: strong similarity to the taxon indicated, based on close resemblance to reference material;
- cf.: compares favourably with the representatives of that taxon known from literature published for southern South America, the Falkland Islands or the sub-Antarctic islands;

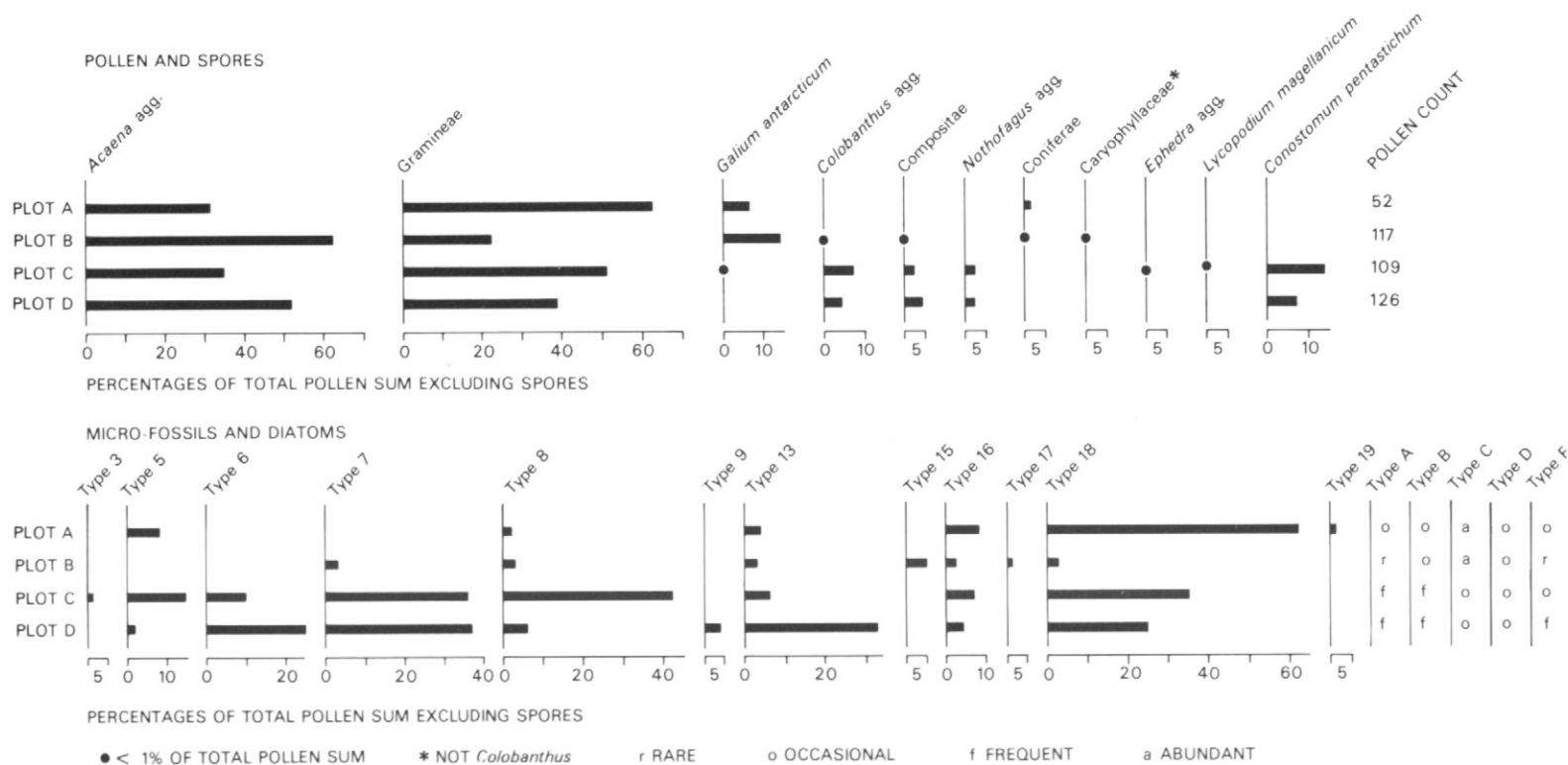


Fig. 7. Sporomorph and micro-fossil composition of surface samples from the Site 1 bog complex. (A key to the micro-fossil types is given in Fig. 8.)

agg.: closely related taxa which are difficult to separate are grouped together in a single aggregate category (e.g. the two species of *Acaena* plus their hybrid, the two species of *Colobanthus*, some species of *Nothofagus*, while the grasses have been aggregated as Gramineae).

Presentation of data

The analyses are presented as relative (percentage frequency) diagrams for each sporomorpha category at each sample depth, with pollen sums consisting of total vascular plant pollen but excluding all spores and unidentified micro-fossils. Thus, while the numbers of pollen grains of each vascular plant taxon are expressed as a percentage (the sum total being 100%), the numbers of cryptogam spores and micro-fossils of each taxon or type are given as a percentage of the total pollen count. For example, a sample may contain 250 pollen grains of which 150 (60%) are *Acaena* and 100 (40%) are Gramineae; however, there may in addition be 50 *Conostomum* spores (expressed as 20%) and 750 type 6 micro-fossils (expressed as 300%).

In the diagrams, percentages derived from a total pollen count of more than 100 grains are represented by solid bars and those from a total of less than 100 grains by open bars.

RESULTS

Present sporomorpha deposition

The principal plants occurring in the four surface sample plots at Site 1 were as follows:

Plot A was dominated by *Rostkovia magellanica* (c. 45% cover) and *Acaena magellanica* (30%) with *Festuca contracta* (20%) and *Phleum alpinum* (5%) being the main associates; *Galium antarcticum* and *Ranunculus bitermatus* were present as scattered plants. There was a virtually complete understorey of *Tortula robusta*.

Plot B was dominated by *Acaena* (80%) with small amounts of *Festuca* (10%), *Phleum* (5%) and *Rostkovia* (5%) and scattered plants of *Galium*. There was an almost complete understorey of *Tortula robusta*.

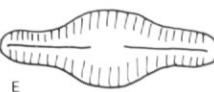
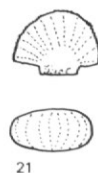
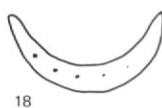
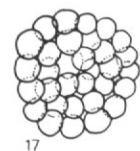
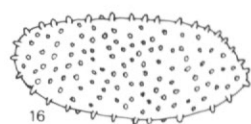
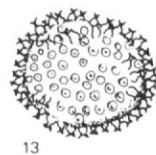
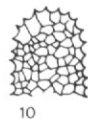
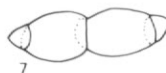
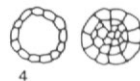
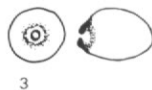
Plot C comprised dense (almost 100%) *Rostkovia* with only occasional *Acaena*. The bryophyte understorey was dominated by *Chorisodontium aciphyllum* and possibly *Dicranoloma subimponens*; *Sphagnum fimbriatum* occurred just outside the plot.

Plot D was also almost pure (c. 100%) *Rostkovia* but with occasional *Festuca* plants; *Sphagnum* occurred within the plot but not in the quadrats.

The results of the analysis of these are presented in Fig. 7. Gramineae and *Acaena* pollen comprised almost 90% of the total pollen count reflecting the present day dominance of these plants both near the site and also in the island's flora in general; several grains of South American provenance were also recorded. Various unidentifiable micro-fossils and diatoms were prominent, some of which were abundant; a key to the various types is given in Fig. 8.

Fossil sporomorpha record

The pollen and spore diagrams for Sites 1 and 2 are presented in Figs. 9 and 10, respectively. In general the sporomorpha represented in the samples analysed are those of species growing at present in the immediate vicinity of the sites. Large-scale fluctuations in actual numbers of pollen grains or spores of certain species may reflect significant changes in the composition of the flora and development of vegetation.



However, the presence of very low numbers representative of a particular species or the apparent absence of such evidence of species must be treated with caution. No woody remains, besides partly decomposed rhizomes of *Acaena magellanica*, sub-morainic peat, marine mollusc shells or bones were found in the profiles. Photomicrographs of sporomorphs from both sites are illustrated in Figs. 11–13.

Graminoids

The pollen of grass, together with that of the suffruticose herbs, *Acaena* spp., dominate both profiles as illustrated in the pollen diagrams (Figs. 9 and 10). Because of the morphological similarity of pollen grains of the various South Georgia grasses, all Gramineae have been amalgamated in each pollen histogram. However, graminoid pollen isolated from the two profiles (Fig. 11) includes occasional grains which are sufficiently diagnostic to suggest the presence of *Phleum alpinum* and *Poa flabellata*. *Poa flabellata*, with its large and often abundant inflorescences, each of which may have over 1 500 florets per panicle, produces a very large proportion of the grass pollen and must provide a heavy and fairly even 'rain' over all coastal parts of the island. Site 2 is fairly close to some dense stands of tussock grass, but Site 1 is

Fig. 8. Key to micro-fossil types recovered from South Georgia peat deposits. (Drawings not to scale; approximate largest dimensions given for each type.)

- Type 1. Alga or coccoid desmid, possibly *Volvox* (c. 12 μ m diameter).
- Type 2. Small ribbed ?spore, possibly fungal (c. 11 μ m diameter, 13 μ m long).
- Type 3. Monoaperturate micro-fossil, possibly fungal, or desmid, cf. *Oocystis* (c. 12 μ m diameter).
- Type 4. Globose ?fungal spore, possibly *Myxomycota*, *Scleroderma* or Ustilaginales (see Graham, 1962, 1971) (c. 12–14 μ m diameter).
- Type 5. Copepod ?spermatophore (see van Geel, 1972) (c. 10 μ m diameter).
- Type 6. Sub-reticulate ?fungal ascospore, often in groups of up to eight, probably Microthyriales (cf. *Microthyrium fuegianum*), or possibly Pleosporales (cf. *Pleospora* sp.) or Pyrenomyces; possibly parasitic on *Rostkovia magellanica*, or less likely on *Acaena magellanica*, *Poa flabellata* or other grasses (c. 40 μ m long).
- Type 7. Fungal ascospore (c. 40 μ m long).
- Type 8. Lichen or fungal spore, possibly *Buellia* (c. 20 μ m long).
- Type 9. Lichen or fungal spore (c. 20 μ m long).
- Type 10. Unidentified micro-fossil (c. 42 μ m diameter).
- Type 11. Unidentified micro-fossil (c. 80 μ m long).
- Type 12. Ribbed micro-fossil, possibly ciliate protozoan (c. 50 μ m long).
- Type 13. Tardigrade egg-case, possibly *Macrorbites* (c. 70–80 μ m diameter).
- Type 14. Desmid ?zygospore or diatom, possibly *Coscinodiscus* or *Stephanodiscus* (c. 19 μ m diameter).
- Type 15. Alga or foraminifera, possibly *Pandorina* (see Reinsch, 1980) (c. 100 μ m diameter).
- Type 16. Unidentified micro-fossil (c. 80 μ m long).
- Type 17. Unidentified micro-fossil (c. 110 μ m diameter).
- Type 18. Desmid, lunate form, possibly *Closterium* or *Dactyloccopsis* (see Fritsch, 1912; Holdgate, 1967, p. 106) (c. 55 μ m long).
- Type 19. Alga, possibly Chrysophyceae, cf. *Clericia* (see Frenguelli, 1955) or *Trachelomonas* (c. 14 μ m diameter).
- Type 20. Unidentified reniform ?desmid (c. 39 μ m long).
- Type 21. Desmid semicell, *Cosmarium* sp. (see Reinsch, 1980; Coesel, 1974) (c. 21 μ m diameter).
- Type 22. Unidentified micro-fossil, possibly dinoflagellate (see photograph by Cranwell, in Holdgate, 1967) (c. 120 μ m diameter).

DIATOMS

- Type A. *Pinnularia* sp. or *Fragillaria* sp. (c. 40 μ m long).
- Type B. *Eunotia* sp. (c. 12–30 μ m long).
- Type C. ?*Pinnularia borealis* (c. 25 μ m long).
- Type D. *Nitzschia* sp. (c. 40 μ m long).
- Type E. ?*Anomoeoneis* type (c. 45 μ m long).
- Type F. *Pinnularia* sp. or *Navicula* sp. (see Fritsch, 1912; Carlson, 1913) (up to c. 80 μ m long).

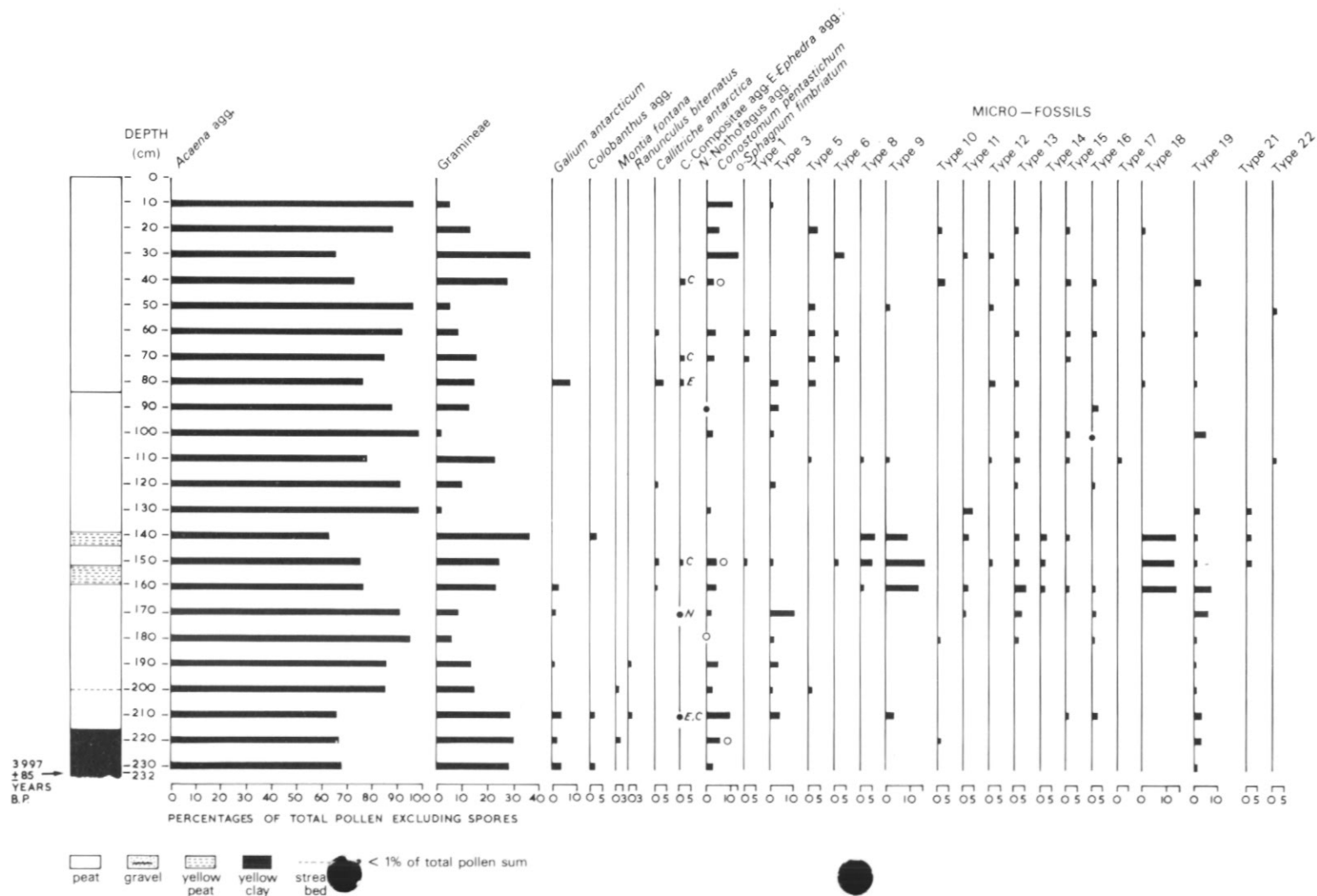


Fig. 10. Pollen diagram for Site 2, Sphagnum Valley. (A key to the micro-fossil types is given in Fig. 8.)

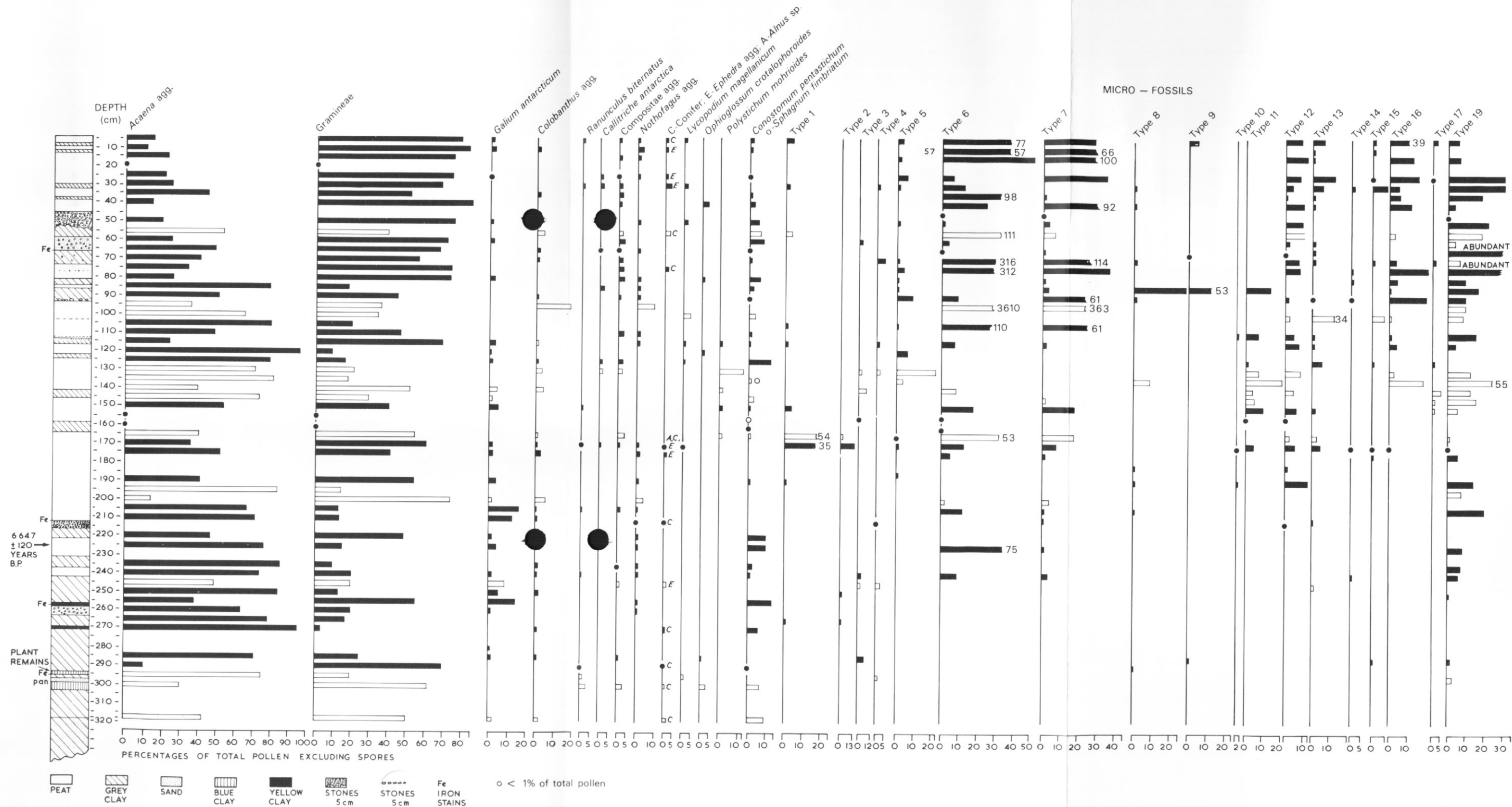


Fig. 9. Pollen diagram for Site 1, Sphagnum Valley. Open bars indicate a total of < 100 pollen grains isolated. (A key to the micro-fossil types is given in Fig. 8.)

c. 0.5 km from the nearest large stands. *Phleum alpinum* pollen is considerably more abundant at the latter site. *Festuca contracta* is generally cleistogamous and appears to release very little pollen (Tallowin and Smith, 1977) so that despite the abundance of this grass near the sites, little of the grass pollen in the samples is likely to be of this species. *Deschampsia antarctica* is not common in the immediate vicinity of the sites, but it is locally abundant near the shore and may, therefore, be one of the main contributors to the grass pollen sum in the samples. The nearest location of the only other native grass, *Alopecurus magellanicus*, is c. 6 km to the north-west of the sites. Although the naturalized alien grass *Poa annua* occurs near the shore its pollen is not likely to occur in the profiles as, despite being well established around the island, it is considered to be a relatively recent immigrant to South Georgia (Walton and Smith, 1973).

Of the rushes, both *Rostkovia magellanica* and *Juncus scheuchzerioides* are abundant at Site 1 and close to Site 2. However, they are commonly sterile in bogs and mires. In common with all Juncaceae, the pollen is delicate and is either not preserved in the peat or is destroyed during the treatment of peat samples, but flattened rhizome and shoot remains are visible to below 2.40 m at Site 1. The early existence of *Rostkovia* at Site 1 may further be inferred by the frequent occurrence of spores believed to belong to a fungus parasitic on the rush (Cranwell, 1964a, b, 1965, 1969). Although the sedge *Uncinia meridensis* occurs sporadically in the vicinity of Site 1, no pollen was isolated from either section. There is considerably greater and more irregular variation in the abundance of grass pollen at Site 1, where it reaches 90% of the total pollen at some levels, than at Site 2. At the latter site grass pollen does not fluctuate greatly in abundance and never exceeds 40% of the total pollen count per sample. This may reflect the closer proximity of *Poa flabellata*. Even at the base of the Site 1 profile (3.17 m), grass pollen comprises about 50% of the total pollen recovered.

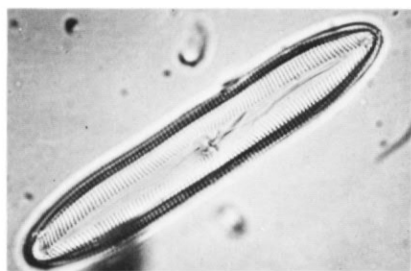
Suffruticose herbs

Large quantities of pollen belonging to the genus *Acaena* occur throughout both profiles (Figs. 9 and 10). Since pollen of *Acaena magellanica*, *A. tenera* and their hybrid intergrade morphologically (Barrow, 1976) it is possible to ascribe only a small proportion with confidence to a particular taxon. Consequently, all such grains obtained from the sections have been grouped as *Acaena* agg., although the great majority are almost certainly those of *A. magellanica*.

Acaena and Gramineae pollen dominate the total pollen sum with each reaching a peak at intervals down the profiles while the other is relatively low. In the samples from Site 2 the *Acaena* grains are never less than 60% of the total pollen counted in each sample, while in samples from Site 1 the *Acaena* sum is much more variable and falls well below 50% of the total pollen at many levels.

Forbs

Of the non-graminoid herbs, *Galium antarcticum* is represented most frequently in both sections and is the only forb to show distinct trends in the pollen diagrams. It is fairly common in small quantities in the *Festuca* grassland and drier mires dominated by *Acaena magellanica* and *Tortula robusta* near Site 1. In the Site 1 profile it shows two peaks exceeding 10% of the total pollen at 2.05 and 2.55 m, and it was isolated from the base of the profile at 3.17 m depth. In the profile from Site 2 it peaks once, at 80 cm depth, but otherwise occurs only below 1.60 m and is present at 2.30 m at the base of the profile.



a₁



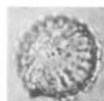
b₁



b₂



c



d₁



d₂



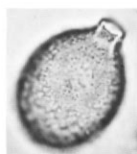
a₂



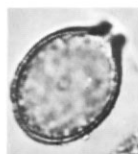
e



f



g₁



g₂



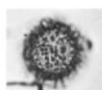
h



i₁



i₂



j₁



j₂



j₃



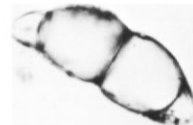
k



l



m



n



o₁



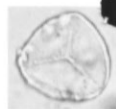
o₂



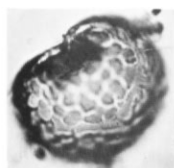
p



q₁



q₂



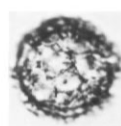
r₁



r₂



r₃

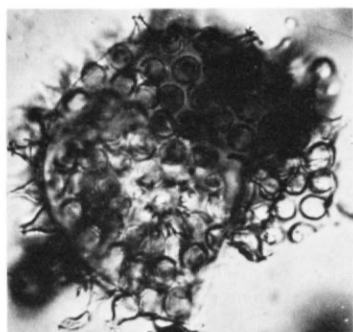
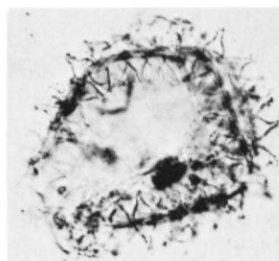
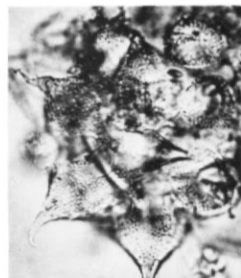


s

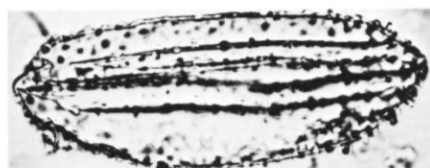
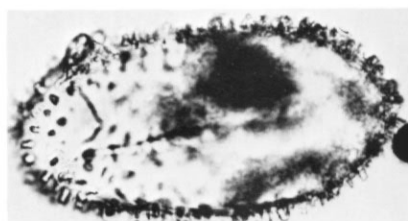
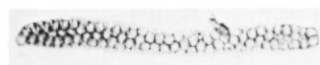
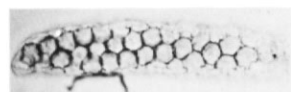
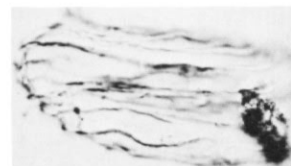
Periporate grains belonging to the genus *Colobanthus* occur sporadically throughout both sections, although *Colobanthus* spp. were not seen in the immediate vicinity. *C. quitensis* is frequent in the high rocky areas to the south and on the nearby outwash plain towards the shore, while both *C. quitensis* and *C. subulatus* are present near the coast in rocky situations. Although the former species would appear to be the more frequently occurring grain in these deposits, both species have been grouped together as their pollen is very similar. The only other species with *Colobanthus*-like grains which occurs on the island is the naturalized alien *Cerastium fontanum*, also belonging to Caryophyllaceae, but its grains are unlikely to be confused with those of *Colobanthus* on account of their larger size. Walton and Smith (1973) considered it to be a recent arrival on the island, occurring close to the former whaling stations, although it has been recorded from the headland between Mercer Bay and Harpon Bay about 3 km west of the sites. However, a few of the grains grouped as *Colobanthus* may be those of Caryophyllaceae derived from South America; Groot and others (1967) noted grains of this family to be common in sediments from the Argentine Basin, the closest site being about 250 km north-west of South Georgia.

Fig. 11. Algae, including diatoms and desmids, and fungal, lichen and bryophyte spores recovered from Sites 1 and 2, Sphagnum Valley.

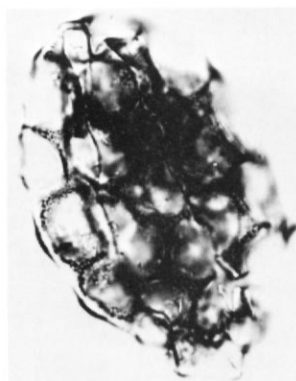
- a1. Diatom cf. *Pinnularia* or *Navicula* sp. (type F), valve view, mid focus (Site 1, 5 cm depth).
- a2. As a1 (Site 1, 1.55 m depth).
- b1. Diatom cf. *Pinnularia* or *Fragillaria* sp. (type A), valve view, mid focus (Site 1, surface litter).
- b2. As b1, girdle view, mid focus.
- c. Diatom cf. *Pinnularia borealis* (type C), valve view, mid focus (Site 1, surface litter).
- d1. Diatom cf. *Coscinodiscus* sp. or desmid zygospore (type 14), polar view, high focus (Site 1, 1.70 m depth) (see Bellinger, 1974).
- d2. As d1, polar view, mid focus (Site 2, 15 cm depth).
- e. Diatom cf. *Nitzschia* sp. (type D), valve view, mid focus (Site 1, 15 cm depth).
- f. Diatom cf. *Eunotia* sp. (type B), valve view, mid focus (Site 1, surface litter).
- g1. Alga (Chrysophyceae) cf. *Clericia* sp. (see Frenguelli, 1955) or Chitinozoa (type 19), oblique equatorial view, high focus (Site 1, 90 cm depth).
- g2. As g1, oblique equatorial view, mid focus.
- h. Desmid cf. *Closterium* sp. or *Dactyloccopsis* sp. (see Fritsch, 1912; Holdgate, 1967) (type 18), mid focus (Site 2, surface litter).
- i1. Desmid zygospore cf. *Cosmarium* sp. (see Coesel, 1974; Reinsch, 1890) (type 21), polar view, high focus (Site 2, 1.10 m depth).
- i2. As i1, polar view, mid focus.
- j1. Desmid? cf. *Volvox* (type 1), high focus (Site 2, 1.65 m depth).
- j2. As j1, mid focus.
- j3. As j1 aggregate, mid focus.
- k. Fungal spore with attached conidiophore, mid focus (Site 1, surface litter).
- l. Fungal or lichen spore, mid focus (Site 1, 2.85 m depth).
- m. Fungal or lichen (cf. *Buellia* sp.) spore (type 8), mid focus (Site 1, 85 cm depth).
- n. Fungal or lichen spore (type 7), mid focus (Site 1, 90 cm depth).
- o1. Sub-reticulate ascospore of fungus resembling *Microthyrium* cf. *fuegianum* or *Pleospora* sp., possibly parasitic on *Rostkovia magellanica*, *Acaena magellanica* or *Poa flabellata* (type 6), mid focus (Site 1, 90 cm depth).
- o2. As o1, high focus.
- p. Fungal material, mid focus (Site 1, 2.35 m depth).
- q1. Trilete bryophyte spore, *Sphagnum fimbriatum*, mid focus (Site 1, 1.35 m depth).
- q2. As q1, high focus (Site 1, 1.15 m depth).
- r1. Bryophyte spore, *Conostomum pentastichum*, high focus (Site 1, 5 cm depth).
- r2. As r1, high focus (Site 1, 3.00 m depth).
- r3. As r2, mid focus.
- s. Unidentified globose ?fungal spore cf. *Myxomycota*, *Scleroderma* or Ustilaginales (see Graham, 1962, 1971) (type 4), mid focus (Site 1, 1.85 m depth).

 a_1  a_2 

b

 c_1  c_2  d_1  d_2 

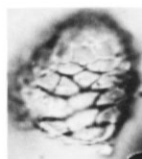
e

 j_1 

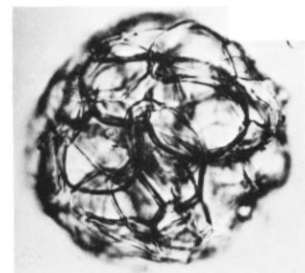
f



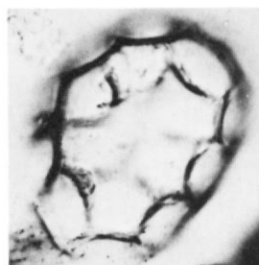
g



h



i

 j_2

0 50
μm

Ranunculus biternatus is widespread but scattered in wetter parts of the bog complex near Site 1 and present in the proximity of Site 2; *Callitriche antarctica* is frequent amongst stands of tussock grass on the raised beach but was not recorded at either site. Pollen of both species was low in quantity and erratic in occurrence in both profiles. *Montia fontana*, a species typical of flush and mire communities, was seen near both sites, but its pollen was isolated only from Site 2 deep in the profile at 2.00 and 2.20 m (see Fig. 10).

Pteridophytes

Although all six species of fern and the single species of clubmoss occurring on South Georgia are fertile, pteridophytes are generally poorly represented in the profiles. *Lycopodium magellanicum*, *Hymenophyllum falklandicum* and *Ophioglossum crotalophoroides* grow in small quantities close to Site 1, while *Polystichum mohrioides* is slightly more common but a little farther away. None of these species was seen near Site 2, and their spores are absent in samples from this site. *Blechnum penna-marina*, *Cystopteris fragilis* and *Grammitis kerguelensis* were not recorded near the sites, and no spores were recovered. The only known locality of *Blechnum* is in the vicinity of Husvik Harbour 10–12 km to the north-west.

At Site 1 (Fig. 10) the distinctive spores of *Lycopodium* are sporadic and scarce, but have been isolated down to 2.95 m; *Polystichum* spores showed a slight peak at 1.30 m depth, while *Ophioglossum* spores have been isolated from a considerable depth (3.00 m) also at Site 1.

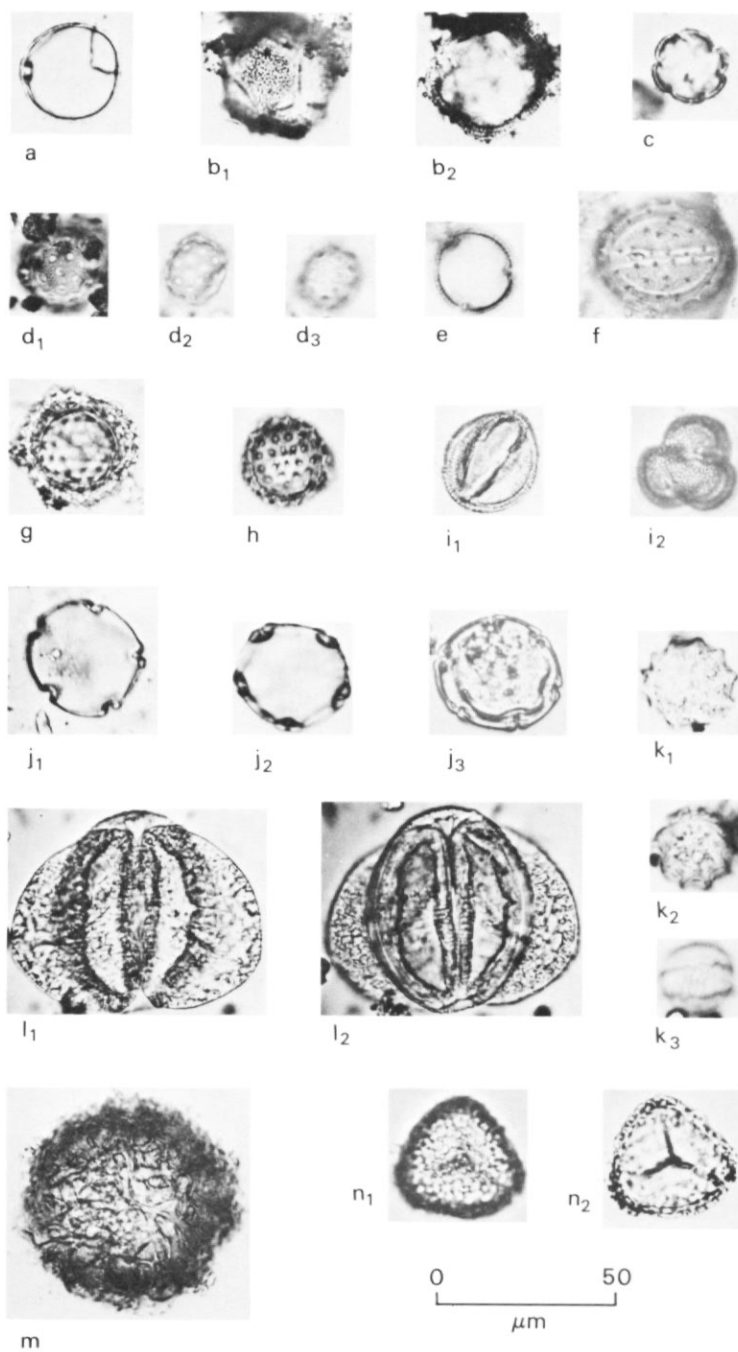
Bryophytes

In each section there occurred distinctive spores of *Conostomum pentastichum* (Fig. 13) a frequent moss in the more open *Festuca* grassland and on rock ledges close to the sites. Little is known of the fruiting cycle of the South Georgian Bartramiaceae but environmental variation may have a significant influence on sporophyte and spore production, particularly in a species with a wide ecological amplitude such as *C. pentastichum* (Longton, 1972). The occurrence of *Conostomum* spores at Site 2 provides an indication of trends; those in the Site 1 profile are a little more erratic but peaks may represent drier periods when *Festuca* grassland predominated, or merely conditions suitable for sexual reproduction.

Although *Sphagnum fimbriatum* is locally abundant in several widely separated *Rostkovia* bogs and mires around the island (Smith, 1981) it is probably most extensive in lower *Sphagnum* Valley. It has not been recorded with fruit on South Georgia, yet spores of *Sphagnum*, strongly resembling those of *S. fimbriatum*

Fig. 12. Invertebrates and unidentified micro-fossils recovered from Sites 1 and 2, Sphagnum Valley.

- a1. Tardigrade egg-case cf. *Macrobiotus* sp. (type 13), mid focus (Site 1, 1.15 m depth).
- a2. As a1, high focus (Site 2, 1.10 m depth).
- b. ?Tardigrade egg-case (type 15), high focus (Site 1, 30 cm depth).
- c1. Unidentified micro-fossil (type 16), mid focus (Site 1, 30 cm depth).
- c2. As c1, high focus (Site 1, 5 cm depth).
- d1. Unidentified micro-fossil, mid focus (Site 1, 1.65 m depth).
- d2. As d1, magnification $\times 2$.
- e. Unidentified micro-fossil (type 12), high focus (Site 1, 1.15 m depth).
- f. ?Copepod spermatophore (type 5), mid focus (Site 1, 50 cm depth).
- g. Unidentified dark brown monoaperturate micro-fossil with annulus around pore (type 3), mid focus (Site 1, 2.40 m depth).
- h. Unidentified micro-fossil (type 10), mid focus (Site 1, surface litter).
- i. Unidentified micro-fossil (type 17), high focus (Site 1, 30 cm depth).
- j1. As i1, mid-high focus.
- j2. Unidentified micro-fossil (type 11), high focus (Site 1, 1.65 m depth).



collected in the Falkland Islands, have been isolated from both profiles (Fig. 12). Since they appear to be concentrated at certain levels (more than 100 grains were counted at 1.55 m depth at Site 1 while other pollen grains and spores were very sparse), suggesting a local origin rather than long-distance transport, and possibly indicative of mild wet conditions favouring the production of sporophytes.

Spores of only a few other bryophyte species were recorded but none was abundant or positively identified. Occasional spores resembling those of *Pohlia* have been isolated but some commonly fertile genera (e.g. *Tortula* and *Polytrichum*) produce spores which are too small to be identified without the aid of electron microscopy.

Algae, fungi and lichens

A wide range of spores belonging to non-vascular cryptogams, excluding bryophytes, has been isolated from many of the peat samples. These are illustrated in Figs. 12 and 13, and their provisional determinations, referred to as micro-fossil type 1, 2, 3, etc., are also provided. These types include algae (mainly desmids and diatoms), spores and other material of fungi (especially basidiomycetes and ascomycetes) and the spores of lichens. The abundance of each micro-fossil type is expressed as a percentage of the vascular pollen sum in the pollen diagrams (Figs. 5 and 6), but it is difficult to interpret the trends in terms of possible environmental change.

Two types of desmid have been isolated and tentatively identified. The form described as micro-fossil type 18, which resembles either *Closterium* sp. or *Dactylocopsis* sp. (illustrated by Cranwell, in Holdgate, 1967), is abundant between 1.40 and 1.60 m at Site 2, but apparently absent from Site 1. The second (micro-fossil type 21) is the semicell of a desmid resembling a species of *Cosmarium* and has been isolated from samples from Site 2 only. Two other micro-fossils (types 1 and 14) may also be the remains of desmids, but this is uncertain.

Fig. 13. Pollen and spores of vascular plant taxa recovered from Sites 1 and 2, Sphagnum Valley.

- a. Gramineae cf. *Phleum alpinum*, mid focus (Site 1, 1.50 m depth).
- b1. *Montia fontana*, high focus (Site 2, 2.20 m depth).
- b2. As b1, mid focus.
- c. *Galium antarcticum*, polar view, mid focus (Site 2, 1.70 m depth).
- d1. Caryophyllaceae cf. *Colobanthus* sp., high focus (Site 2, 1.70 m depth).
- d2. As d1 (Site 2, 50 cm depth).
- d3. As d2, mid focus.
- e. Tricolpate grain cf. Compositae, polar view, mid focus (Site 1, surface litter).
- f. Compositae, equatorial view, high focus (Site 1, surface litter).
- g. Compositae, polar view, mid focus (Site 2, 1.70 m depth).
- h. Compositae, polar view, high focus (Site 1, surface litter).
- i1. Compositae, oblique equatorial view, mid focus (Site 2, 1.70 m depth).
- i2. As i1, semi-oblique polar view, high focus.
- j1. *Nothofagus fusca* agg., mid focus (Site 1, 5 cm depth).
- j2. As j1 (Site 1, 90 cm depth).
- j3. As j1 (Site 1, 1.70 m depth).
- k1. *Ephedra* cf. *fragilis* agg., polar view, mid focus (Site 2, 80 cm depth).
- k2. As k1, high focus.
- k3. As k1, equatorial view, mid focus.
- l1. *Podocarpus* sp., high focus (Site 1, 55 cm depth).
- l2. As l1, mid focus.
- m. *Polystichum mohrioides* with monolete scar on left side obscured, equatorial polar view, high focus (Site 1, 1.65 m depth).
- n1. *Lycopodium magellanicum*, distal surface, high focus (Site 1, 30 cm depth).
- n2. As n1, mid focus.

Diatoms were common in samples of surface litter collected in the bog complex in the vicinity of Site 1. Within these samples there appears to be some variation between drier sites and the wetter sources of litter lower down the valley side. In analyses of profile samples from the two sites some diatoms were sporadically isolated; type D (cf. *Nitzschia* sp.) was isolated from 1.55 m depth, and type A (cf. *Fragillaria* of *Pinnularia* sp.) from 2.50 m at Site 1.

Basidiomycetes and ascomycetes were scarce but present in the vicinity of both sites; however, collected specimens do not appear to be the source of the large ascospore with sub-reticulate sculpture (type 6), or the barely sculptured type 7 ascospore; the former is often exceedingly abundant at certain levels in Site 1 but rare in Site 2 and may be that of an endophytic 'fly-speck' fungus which parasitizes *Rostkovia magellanica* (*Microthyrium fuegianum*) (Dennis, 1968; Cranwell, 1969; personal communication from R. W. G. Dennis); however, it may possibly belong to a parasitic fungus that infects *Acaena magellanica*, *Poa flabellata* or other grasses (e.g. *Pleospora* sp.). Spore types 4, 7, 8 and 9 may be of either fungal or lichen origin.

In general, micro-fossil types, other than pollen and spores of higher plants, increase from about 2.30 m towards the surface in both sections. They are particularly abundant above 1.05 m at Site 1 and between 1.60 and 1.40 m at Site 2.

Sporomorpha not of South Georgian origin

The limited variety and quantity of the native pollen in the samples makes the recognition of material believed to have been transported from South America comparatively easy. The majority of these grains are those of *Nothofagus fusca* agg. (Fig. 11). Only one *Nothofagus* grain was recovered from the Site 2 samples, but 49 were isolated from samples at Site 1 and four from surface samples nearby. The variable representation of non-South Georgian pollen from site to site probably reflects the influence of local topographical features on air currents and hence on deposition since the long-distance 'fall-out' should be similar for sites only 0.5 km apart and within the same valley. Additional pollen in the two profiles includes species of Compositae (but excluding *Taraxacum officinale*, an alien established around the former whaling stations (Walton and Smith, 1973), *Podocarpus*, *Ephedra* and various unidentified sporomorpha, but there are no trilete or monolete fern spores. The absence of pteridophyte spores derived from species common in South America was also noted by Cranwell (1964a, b, 1969) although such spores have been isolated from sea-bed sediments in the Argentine Basin (Groot and Groot, 1964; Groot and others, 1967). It seems unlikely that any of these alien grains isolated in the present study are of northern hemisphere origin, with the possible exception of a single grain of *Alnus* (although Groot and others (1967) commented on the recovery from the Argentine Basin of *Alnus* possibly derived from South American sources as far south as 30°S). No pollen or spores of common European species has been recognized in any of the samples. A wide range of pollen and spore types probably of South American origin (predominantly *Nothofagus* spp., *Podocarpus* sp., *Ephedra* sp., Chenopodiaceae, Araliaceae, Compositae, Umbelliferae and Gramineae) have been isolated from a peat deposit on Signy Island, South Orkney Islands (Churchill, 1973).

Invertebrates

Various invertebrate animal fragments and micro-fossils have been isolated from the two sites, among the more easily identifiable being the egg-cases of a tardigrade resembling those of *Macrobiotus* sp. (Fig. 12). Fragments of mites and occasional beetle fragments have also been found in preparations from both sites. Beetle

fragments and mites have previously been recorded in a deep tussock grass peat deposit on Jason Island to the north of Cumberland Bay (Coope, 1963; Smith, 1981).

DISCUSSION

As environmental indicators pollen and spores in South Georgia peat deposits should be considered with caution, since many of the plant species have a wide ecological amplitude, at least with regard to their present distribution on the island. Attempts have previously been made to correlate elements of the pollen sum, recovered from other sub-Antarctic islands, with specific environmental conditions. Bellair-Roche (1973) considered *Acaena magellanica* and *Galium antarcticum* as indicators of a temperate climate on Iles Crozet. In their study of the Late Quaternary of Iles Kerguelen, Young and Schofield (1973) recognized *Acaena magellanica* as representative of a warm element, *Galium antarcticum* of a warm, perhaps dry element, and *Lycopodium magellanicum* as indicating a warm lowland element. Schalke and van Zinderen Bakker (1971) regarded *Acaena magellanica* and ferns, particularly *Polystichum marionense* (a species very similar to *P. mohrioides*), as typifying a lowland vegetation existing under warm conditions on Marion and Prince Edward Islands.

Of the two South Georgia profiles discussed here the pollen diagram for the Site 2 deposit indicates certain trends more clearly than that of the deeper Site 1 deposit. The pollen record of the former section is dominated by *Acaena* but does not fluctuate as much as the gramineous pollen. This pattern appears to reflect the present local distributions of vegetation, the study site being dominated by *A. magellanica* and partly surrounded by grassland; the grass pollen in this diagram (Fig. 10) probably derives from nearby stands of tussock grass (*Poa flabellata*). In samples from Site 1, the more variable and often more dominant grass curve may reflect the local preminence of species like *Phleum alpinum* (less likely *Festuca* or *Deschampsia*) in addition to the background pollen rain from tussock grass. It seems likely that a peak in the Gramineae curve would reflect a cool or cool-wet period while a peak in the *Acaena* curve may be indicative of a warm or dry climate. *Montia fontana* may indicate wet mire conditions, and *Galium antarcticum* seems, in Site 1 at least, to be correlated with an increase in *Acaena*. Young and Schofield (1973) noted in their studies on Iles Kerguelen that *G. antarcticum* tended to reach a peak later than other 'lowland' species.

Distinct trends shown by *Conostomum pentastichum* spores in the Site 2 profile may relate to the grass curve. At both sites the micro-fossil record is generally similar and suggestive of moist conditions.

The presence of *Sphagnum* spores in the profile may be a useful indicator of warm moist conditions. *S. fimbriatum* fruits in the Falklands Islands but, although locally abundant in the present flora of South Georgia, it is not known to be fertile, suggesting that climatic conditions are not optimal for sexual reproduction; nevertheless, spores of this moss were recovered from surface litter samples by C.J.B. during the 1972-3 summer. Although little is known about the occurrence of fungal spores in peats, van Geel (1972) considered that a high percentage of fungal spores and hyphae compared with pollen grains was an indication of moist conditions at the time of deposition. If the trends shown in the Site 1 profile, particularly for the type 6 fungal spores, occur in other localities it may be possible to interpret past conditions from the fungal record.

Although the sites are well separated and differ in local topography and peat conditions, they share general similarities in palynological results. It is suggested that

the two pollen diagrams reflect vegetational fluctuations at the local level due to some degree of environmental change resulting from climatic fluctuations during the deposition of organic matter.

The analyses of peat samples from the two sections and of surface litter have revealed the pollen and spores of most species currently growing in the vicinity of the sites, even several comparatively rare ones. With the exception of *Uncinia meriden-sis*, a generally infrequent sedge but which occurs close to Site 1, the major gaps in the record are mainly restricted to pteridophytes, particularly those of very restricted distribution and growing well away from the sites. There is no evidence of species existing on the island which are no longer components of the flora.

The palynological record of the Sphagnum Valley sites indicates that many of the present species have probably been present on South Georgia for at least 6500 years. *Acaena* sp., Gramineae, *Galium antarcticum*, *Colobanthus* sp., *Ranunculus biter-natus*, *Lycopodium magellanicum*, *Ophioglossum crotalophoroides* and the moss *Conostomum pentastichum* were all isolated below 2.35 m depth at Site 1 (radio-carbon dated as c. 6655 \pm 120 yr B.P.), and all but *Lycopodium* occurred between 3.00 and 3.20 m. The presence of *Montia fontana* pollen at Site 2 in a sample dated almost 4000 yr B.P. confirms the native status of this species. Moore (1963) suspected it may be a recent immigrant but Cranwell (1964a) found *Montia* to be one of the oldest members of the flora, recording pollen of two forms of this taxon. Similarly, the abundance of spores at various levels of the very localized moss *Sphagnum fimbriatum* suggest that it has been present on the island for at least 4000 years; it is not known to be fertile yet its spores occur even in surface litter near stands of the moss so it is presumed to occasionally reproduce sexually. Pollen of *Poa annua*, which may be distinguished from that of other South Georgia grasses (Barrow, 1976) was not recovered from deposits below the surface litter, suggesting that it is very probably an introduced species. It is the most widespread alien plant on the island and is frequent amongst the coastal vegetation near Sites 1 and 2. Walton and Smith (1973) considered it to have become established by multiple introductions around the island by sealers and whalers since about A.D. 1800.

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