VEGETATION OF THE ARTHUR HARBOUR–ARGENTINE ISLANDS REGION OF THE ANTARCTIC PENINSULA

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ABSTRACT. An account is presented of the terrestrial vegetation of a number of islands and headlands in the Arthur Harbour–Argentine Islands region of the Antarctic Peninsula, and the history of botanical work in the area is reviewed. The climate and topography of the region are briefly discussed.

The vegetation of the Argentine Islands received the most detailed survey and is considered separately to that of the more northerly region which incorporates the islands and headlands in the Arthur Harbour (Anvers Island) and Port Lockroy areas. Following a fairly critical examination of the species composition of the plant communities in relation to environmental features, it has been possible to classify the vegetation of the Arthur Harbour–Argentine Islands region according to the system recently applied to the South Orkney and South Shetland Islands. Several sociations are described for the first time and one new association has been recognized. Species lists giving percentage cover and percentage frequency or semi-quantitative assessments of frequency are presented for several of the sociations.

The vegetation is considered in relation to that of the South Orkney Islands and was found to be sparser, the communities being less complex as a result of a smaller diversity of habitats and a less frequent supply of available moisture. Finally, a brief description is provided of the vegetation of a number of localities on the mainland of the Graham Coast and of some of the offshore islands which were cursorily visited or observed from a distance.

WHILE small collections of plants and sporadic observations on the distribution of vegetation along the west coast of the Antarctic Peninsula have been made since the end of the nineteenth century, extensive botanical surveys and detailed ecological work have previously been very limited. This paper presents the results of observations on the plant ecology of several islands and headlands near or on the Danco and Graham Coasts of the west coast of the Antarctic Peninsula between lat. 64°46′ and 65°26′S. (Fig. 1), made between January 1964 and March 1967. The localities ranged from the islands and promontories in Arthur Harbour (Anvers Island) and north-west Bismark Strait to Goudier Island in Port Lockroy (Wiencke Island) south to Darboux Island and Cape Pérez on the Graham Coast. Within this region, the Argentine Islands received the most detailed study.

HISTORY OF BOTANICAL WORK

A summary of the expeditions on which botanical collections and observations have been made in the region of the Danco and Graham Coasts of the west coast of the Antarctic Peninsula is presented in Table I. The earliest collections were made by Racovitza during 1897–99 and, although this expedition did not explore farther than about lat. 65°S., a large number of plants was collected as far as Wiencke Island and the northern end of Lemaire Channel (lat. 65°05′S.). At that time the latter locality yielded the most southerly known bryophytes. A few lichens were already known from Victoria Land.

More extensive botanical work was undertaken south of Gerlache Strait by Turquet during the Expédition Antarctique Française (Table I). Collections of bryophytes and lichens were made at the south end of Wiencke Island, in Biscoe Bay at the south-east end of Anvers Island and on Booth and Hovgaard Islands off the north-west Graham Coast. The first occurrence of *Deschampsia antarctica* and *Colobanthus quitensis* in this region was reported by Turquet (1906), who noted both species growing together amongst mosses in Biscoe Bay, while the grass alone was found at Port Charcot on Booth Island.

During 1908–10, Gain made important collections of mosses and lichens from Port Lockroy (Wiencke Island) as far south as localities in northern Marguerite Bay when the range of the *Deschampsia* was extended to Petermann, Rasmussen and Berthelot Islands and both the *Deschampsia* and the *Colobanthus* were reported from Cape Pérez (Gain, 1910).

Gain made some brief comments on the general ecology of the vegetation of this region and further notes based on photographs were provided by Cardot (1913). Although only

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Fig. 1. The Danco and Graham Coasts with offshore islands including those extending from Arthur Harbour (Anvers Island) and Port Lockroy to the Argentine Islands and Collins Bay. The Danco Coast extends northward from Cape Renard, and the Graham Coast southward from that cape.

TABLE I. HISTORY OF BOTANICAL WORK IN THE ARTHUR HARBOUR–ARGENTINE ISLANDS REGION

Expedition and date	*Sites of botanical collections*	*Principal collector*	*Principal herbaria*	*References*
Belgian Antarctic Expedition, 1897–99	Gerlache Strait to north end of Lemaire Channel	E. M. Racovitza	Bruxelles, Jardin Botanique de l'Etat	Cardot (1900, 1901, 1908), Stephani (1901), Vainio (1903)
Expédition Antarctique Française, 1903–05	South end of Wiencke Island; Biscoe Bay at south-east end of Anvers Island; Booth and Hovgaard Islands	J. Turquet	Paris, Muséum National d'Histoire Naturelle, Laboratoire de Cryptogamie	Cardot (1906, 1907), Hue (1908), Turquet (1906)
Deuxième Expédition Antarctique Française, 1908–10	Port Lockroy, Wiencke Island to northern Marguerite Bay including Petermann, Argentine, Rasmussen and Berthelot Islands; Edge Hill, Capes Tuxen and Pérez on Graham Coast	M. L. Gain	Paris, Muséum National d'Histoire Naturelle, Laboratoire de Cryptogamie	Cardot (1911, 1913), Gain (1910), Hue (1915)
British Graham Land Expedition, 1934–37	Argentine Islands to Marguerite Bay	G. C. L. Bertram	London, British Museum (Nat. Hist.)	Bertram (1938), unpublished reports in Scott Polar Research Institute, Cambridge, and British Antarctic Survey Botanical Section
Operation Tabarin, 1944–45	Goudier, Wiencke and Doumer Islands	I. M. Lamb	London, British Museum (Nat. Hist.)	Lamb (1948), Lamb unpublished reports in British Antarctic Survey Botanical Section
Falkland Islands Dependencies Survey and British Antarctic Survey, 1946 onwards	Arthur Harbour to Argentine Islands	Various	Birmingham, British Antarctic Survey	Corner (1971), Gimingham and Smith (1970), Greene and Holtom (1971), Longton (1967)

Pohlia nutans and *Polytrichum alpestre* were collected on the Argentine Islands, Cardot described the *Polytrichum* banks as "une végétation bryologique vraiment luxuriante" and forming "une véritable petite *tundra*". On Petermann Island and Cape Pérez the mosses were said to form extensive "carpets" ("tapis") on the ground and on rocks while "sheets" ("plaques") of lichens covered the rock faces. From his examination of Gain's material, Cardot observed that mosses which grew in compact clumps or turves almost always formed an association of several species including hepatics; some species of *Andreaea*, *Grimmia*, *Bryum*, *Pohlia*, *Polytrichum* and *Drepanocladus uncinatus* also, at times, produced pure stands. He commented on the small cushion growth form of the Andreaeas, the extensive carpets of *Bryum* and the large hummocky clumps of *Polytrichum* and *Drepanocladus* and made the earliest reference to the deep *Polytrichum alpestre* turf which formed a sort of peat.

There was little further botanical activity in the region until it was visited during the British Graham Land Expedition of 1934–37, when some collections were made in the Argentine Islands, the most important revealing the presence of the grass and pearlwort. Botanical collections were also made in the Berthelot Islands. Although no detailed account of the botanical work was ever published, Bertram (1938) remarked on the luxuriance of the moss and lichen vegetation of the Argentine Islands and stated "that this region was botanically the richest in the whole Antarctic". He commented, in particular, on the development of a moss peat "3 feet in thickness, albeit permanently frozen except for the top few inches in summer". Observations were made on the insulating effect of snow on the temperature within the moss, results which also remain unpublished. Holdgate (1964*a*) mentioned that the expedition sowed "grass seeds" which germinated but did not become established.

It was not until 1944–45 that the first systematic botanical work was undertaken in this region, when Lamb (1948) made an intensive collection of the flora of Goudier, Wiencke and Doumer Islands, particularly of the lichens. He also provided notes on the ecology and distribution of the lichen associations of Goudier Island. As reported by Holdgate (1964*a*), Lamb also set up an experimental plot on this island in which he attempted to grow vascular species transplanted from the Falkland Islands.

Since 1954 numerous collections of the region's flora have been made by members of the Falkland Islands Dependencies and the British Antarctic Surveys. Reports on individual lichen and moss genera have been published in a number of recent taxonomic papers, notably by Lamb (1948, 1964, 1968), Lindsay (1969*a*, *b*, 1971*a*, *b*, *c*, *e*) and Greene and others (1970). However, the ecology of the vegetation of the Arthur Harbour–Argentine Islands region has not been described in detail, although Longton (1967) provided a very brief account of the vegetation in comparison with other regions of the maritime Antarctic. Follmann (1965) has described in some detail the ecology of an association of epipetric lichens, typified by the presence of *Ramalina terebrata*, which occurs in many regions of the maritime Antarctic, including the region discussed in this paper. The distribution, performance and ecology of the vascular plants in the Argentine Islands has been described by Corner (1971) and in neighbouring areas of this region by Greene and Holtom (1971).

Climate

The Arthur Harbour–Argentine Islands region has an oceanic Antarctic climate typical of the maritime Antarctic, as defined by Holdgate (1964*b*). Weather conditions do not differ considerably from those experienced in the South Orkney Islands about 550 km. farther north. However, in the more southerly region, air temperatures are slightly lower, there are fewer days of precipitation with a lower total rainfall equivalent, less cloud cover, fewer gales and generally lighter winds, while there is a higher sunshine record and a higher incidence of clear days. During winter there is usually extensive sea ice around the islands and along the coast of the mainland which persists almost continuously from April or May until November or December.

Synoptic meteorological records have been maintained in the Argentine Islands, on Winter Island, from 1947 to 1953, and on Galindez Island from 1954 until the present day. Some mean monthly data for these islands are presented in Table II, while a comparison of some mean annual data between the Argentine Islands and Goudier Island, about 60 km. to the

TABLE II. MEAN MONTHLY CLIMATIC DATA FOR THE ARGENTINE ISLANDS 1947–66

Month	*Air temperature* (° C) (20 years)		*Relative humidity* (per cent) (16–17 years)	*Wind speed* (m./sec.) (18 years)	*Daily sunshine* (hr.) (18–20 years)	*Precipitation* (*as rainfall equivalent*) (mm.) (5–9 years)
	Mean	*Range*				
January	0·2	1·8 to −1·4	85·4	2·8	3·7	18·2
February	−0·2	1·7 to −3·0	85·7	3·2	3·3	42·8
March	−1·2	0·9 to −3·6	86·1	3·9	2·0	38·5
April	−4·3	−0·5 to −14·0	85·8	3·9	1·3	40·2
May	−6·7	−1·4 to −13·8	84·4	3·8	0·7	19·7
June	−9·1	−1·9 to −17·8	85·3	4·1	0·2	26·1
July	−11·4	−5·6 to −20·1	85·3	4·0	0·5	18·2
August	−12·1	−3·9 to −17·6	86·1	4·1	1·5	19·7
September	−8·9	−4·7 to −13·4	86·6	4·8	2·0	29·3
October	−5·2	−2·5 to −8·4	87·4	5·4	2·4	20·9
November	−2·7	−1·0 to −6·7	85·3	3·9	3·6	23·2
December	−0·6	0·4 to −2·3	86·0	2·8	4·4	25·9*
Annual total	–	– –	–	–	777·0	322·7
Annual mean	−5·2	−1·9 to −8·1	85·9	3·9	2·1	–

* This figure does not take into account the 188·3 mm. precipitation recorded for December 1952.

Data taken from Pepper (1954) for the years 1947–50, from the *Falkland Islands Dependencies annual meteorological tables* for the years 1951–59, from the *British Antarctic annual meteorological tables* for the years 1960–63 and from the meteorological records maintained at the station for the years 1964–66.

The figures in brackets indicate the period of the records.

north-north-east, where meteorological records were obtained sporadically for only a few years, are given in Table III.

January is the only month when the mean air temperature is generally above freezing point, although in some years December, February and March may also have a mean above 0° C. While the mean for the coldest months (June to August) is only rarely below −15° C, sub-zero temperatures may occur at any time in the year and, for example, during a 61 day period from January to March 1965, there was frost on 75 per cent of the days; on the other hand, temperatures above freezing may be encountered occasionally during winter. The highest recorded temperature was 11·7° C in February 1960, while the lowest on record was −43·4° C in August 1958. However, there may be considerable variation in winter temperatures from year to year, as shown in Table II. Temperatures on Goudier Island, although recorded for only a short period, tended to be higher than at the Argentine Islands, presumably because of the influence of föhn winds and the amelioration effect of the surrounding mountains which shelter it from the open sea to the south-west. For example, the minimum temperature recorded on 31 August 1948 at Winter Island (Argentine Islands) was −35° C, while it was only −23·9° C at Goudier Island on the same day.

The principal wind direction at both stations is from the north to north-east blowing from the mainland of the Antarctic Peninsula. Wind velocity is greatest during winter, particularly in September and October, and least in December and January. Goudier Island has a higher

TABLE III. MEAN AND TOTAL ANNUAL CLIMATIC DATA FOR THE ARGENTINE ISLANDS AND GOUDIER ISLAND, 1945–66

Station and duration of meteorological records	*Air temperature* (° C)	*Wind speed* (m./sec.)	*Number of days of gale*	*Relative humidity* (per cent)	*Total sunshine* (hr.)	*Total precipitation (as rainfall equivalent)* (mm.)	*Number of days with snow or sleet*	*Number of days with rain or drizzle*	*Number of cloudy days*	*Number of clear days*
Argentine Islands,	−5·2	3·9	14	86	777	330	193	54	236	15
1947–66	(20 yr.)	(18 yr.)	(15 yr.)	(16 yr.)	(16 yr.)	(4 yr.)	(4 yr.)	(4 yr.)	(15 yr.)	(15 yr.)
Goudier Island,	−3·1	5·2	39	79	–	–	173	40	234	17
1945–50	(3 yr.)	(3 yr.)	(3 yr.)	(3 yr.)			(3 yr.)	(3 yr.)	(3 yr.)	(3 yr.)

Data taken from Pepper (1954) for the years 1945–50, from the *Falkland Islands Dependencies annual meteorological tables* for the years 1951–59, from the *British Antarctic annual meteorological tables* for the years 1960–63, and from the meteorological records maintained at Galindez Island for the years 1964–66. All stations were situated below 12 m. altitude. The figures in brackets indicate the period of the records.
Cloudy days are those on which the sum of the cloud cover for the 12.00, 18.00 and 24.00 hr. G.M.T. observations was $\geqslant$ 20 oktas.
Clear days are those on which the sum of the cloud cover for the 12.00, 18.00 and 24.00 hr. G.M.T. observations was $\leqslant$ 4 oktas.

mean wind speed and almost three times the number of gales experienced in the Argentine Islands. The more northerly station is situated close to Harbour and Thunder Glaciers on Wiencke Island and the funnelling effect produced by Neumayer and Peltier Channels generates very strong winds. Humidity is high throughout the year in the Argentine Islands but rather lower at Goudier Island. Precipitation, recorded as rainfall equivalent, is relatively high in the Argentine Islands but there is considerable monthly variation from year to year, e.g. 188·3 mm. fell in December 1952 while only 8·8 mm. were recorded for the same month in 1957. The number of days with precipitation, in one form or another, is less at Goudier Island. The high annual sunshine record may be one of the most important factors responsible for the extensive development of the vegetation in this region.

Topography

The majority of the localities visited in this region were small islands, seldom more than 60 m. in altitude, and in a few instances headlands on larger islands or on the mainland of the Graham Coast. However, certain islands which were not visited, but on which vegetation was observed, rise to over 1,000 m., e.g. Booth Island. Many of the low offshore islands have permanent ice caps, or *névé* domes (Linton, 1964) especially those in the Argentine Islands. According to Thomas (1963), these islands are *roches moutonnées* possessing rocky northern coasts rising steeply to a rock peak, to the south of which lies the bulk of the ice cover which terminates abruptly in a steep ice cliff on their south side. The ice caps which now cover these islands are relics of the original coastal ice shelf which has eroded the islands to their present shape. Snow- and ice-free areas are usually restricted to a coastal fringe and low-lying wave- or ice-cut platforms, particularly on the north side of the islands, coastal cliffs and occasional inland rock exposures. The islands in and near Arthur Harbour possess less permanent snow and ice, and are consequently more extensively vegetated. Most of the localities visited were well irrigated by melt streams in summer but large melt pools were scarce. All snow-free areas throughout this region have undergone considerable glacial erosion, although Holtedahl (1929) suggested that the straits separating the islands from the Graham Coast had been filled with permanent ice until relatively recently and that the reduced erosive power of the glaciers had resulted in the present immature topography.

The petrology of this sector of the Antarctic Peninsula has been described in detail by Hooper (1962), Elliot (1964) and Curtis (1966). Exposures are composed entirely of igneous rocks which may be separated into two broad groups, namely Jurassic andesites, tuffs and breccias, and rocks of the Andean Intrusive Suite including granites, granodiorites, diorites, gabbros, tonalites and associated hybrid types.

Aim and Methods of Study

The aim of the present work is to describe the vegetation of the Arthur Harbour–Argentine Islands area in terms of ecological units and to place these into the system of classification of terrestrial vegetation of the maritime Antarctic proposed by Gimingham and Smith (1970) and Smith (1972). A simplified version of this classification is given in Table IV.

Table IV. Classification of terrestrial plant communities of the Arthur Harbour–Argentine Islands region

A. Antarctic non-vascular cryptogam tundra formation
- 1. Fruticose lichen and moss cushion sub-formation
  - a. *Andreaea–Usnea* association
    - i. *Andreaea* sociation
    - ii. *Andreaea*–lichen sociation
    - iii. *Andreaea–Racomitrium austro-georgicum* sociation
    - iv. *Andreaea–Dicranoweisia grimmiacea–Usnea–Umbilicaria* sociation
    - v. *Andreaea–Grimmia–Usnea–Umbilicaria* sociation
    - vi. *Usnea–Himantormia lugubris* sociation
    - vii. *Usnea–Umbilicaria decussata–Alectoria* sociation
    - viii. *Usnea antarctica* sociation
    - ix. *Usnea fasciata* sociation
  - b. Bryophyte and lichen assemblages of rock micro-habitats
    - i. In siliceous rock crevices

Table IV *continued overleaf*

TABLE IV—*continued*

- c. *Tortula–Grimmia antarctici* association
  - i. *Tortula* sociation
  - ii. *Tortula conferta–Bryum* sociation

2. Crustose lichen sub-formation
   - a. *Verrucaria* association
     - i. *Verrucaria serpuloides* sociation
     - ii. *Verrucaria microspora–V. psychrophila* sociation
     - iii. *Verrucaria ceuthocarpa–V. tesselatula* sociation
     - iv. *Verrucaria elaeoplaca* sociation
   - b. *Caloplaca–Xanthoria* association
     - i. *Caloplaca* sociation
     - ii. *Xanthoria elegans* sociation
     - iii. *Xanthoria elegans–Haematomma erythromma–Mastodia tesselata* sociation
   - c. *Buellia–Lecanora–Lecidea* association
     - i. *Buellia–Lecanora–Lecidea* sociation

3. Moss turf sub-formation
   - a. *Polytrichum alpestre–Chorisodontium aciphyllum* association
     - i. *Polytrichum alpestre* sociation
     - ii. *Polytrichum alpestre*–lichen sociation
     - iii. *Chorisodontium aciphyllum* sociation
     - iv. *Chorisodontium aciphyllum*–lichen sociation
     - v. *Polytrichum alpestre–Chorisodontium aciphyllum* sociation
     - vi. *Polytrichum alpestre–Chorisodontium aciphyllum*–lichen sociation
   - b. *Polytrichum alpinum* association
     - i. *Polytrichum alpinum–Drepanocladus uncinatus* sociation
     - ii. *Polytrichum* sociation

4. Moss carpet sub-formation
   - a. *Brachythecium* cf. *antarcticum–Calliergon sarmentosum–Drepanocladus uncinatus* association
     - i. *Brachythecium* cf. *antarcticum* sociation
     - ii. *Drepanocladus uncinatus* sociation

5. Moss hummock sub-formation
   - a. *Bryum algens–Drepanocladus uncinatus* association
     - i. *Bryum algens–Drepanocladus uncinatus* sociation
     - ii. *Bryum algens* sociation
   - b. *Brachythecium austro-salebrosum* association
     - i. *Brachythecium austro-salebrosum* sociation

6. Alga sub-formation
   - a. *Prasiola crispa* association
     - i. *Prasiola crispa* sociation

7. Snow alga sub-formation

B. ANTARCTIC HERB TUNDRA FORMATION

1. Grass and cushion chamaephyte sub-formation
   - a. *Deschampsia antarctica–Colobanthus quitensis* association
     - i. *Deschampsia antarctica* sociation
     - ii. *Colobanthus quitensis* sociation
     - iii. *Deschampsia antarctica–Colobanthus quitensis* sociation

Where only the generic name is given, either the species is unknown or two or more species are involved. This classification is based on the classification of terrestrial plant communities of the South Orkney Islands given by Smith (1972).

Owing to recent taxonomic revision, *Omphalodiscus* has been transferred to *Umbilicaria*, while plants formerly referred to *Racomitrium* cf. *crispulum* are now considered to be *R. austro-georgicum*.

The nomenclature used throughout follows that of Smith (1972) but, owing to taxonomic revisions, the names of some associations and sociations have had to be revised (see Table IV for details). Where detailed studies of the plant communities were undertaken, their descriptions are supplemented by sociation tables with species lists and semi-quantitative or quantitative data.

A preliminary survey of the vegetation of each area showed that various community types

TABLE V. FREQUENCY ASSESSMENT OF SPECIES IN SEVERAL SOCIATIONS OF THE *Andreaea–Usnea* ASSOCIATION AND IN ROCK MICRO-HABITATS ON GALINDEZ ISLAND, ARGENTINE ISLANDS

Species	*Andreaea–Grimmia–Usnea–Umbilicaria sociation*					*Andreaea–Racomitrium austro-georgicum sociation*		*Andreaea–lichen sociation*	*Andreaea sociation*	*Usnea fasciata sociation*	*Crevice and ledge communities*		
	Stand 1	*Stand 2*	*Stand 3*	*Stand 4*	*Stand 5*	*Stand 6*	*Stand 7*	*Stand 8*	*Stand 9*	*Stand 10*	*Stand 11*	*Stand 12*	*Stand 13*
Mosses													
Andreaea depressinervis	–	–	–	–	–	o	–	–	–	–	–	o	–
Andreaea gainii	f	o	–	o	–	–	–	f	o	–	la	–	o
Andreaea regularis	a	la	f	la	o	a	a	a	a	–	–	–	o
Bartramia patens	o	o	o	–	–	–	–	o	o	–	f	–	o
Brachythecium cf. *antarcticum*	–	–	–	–	–	–	–	–	–	–	–	–	o
Brachythecium austro-salebrosum	–	–	–	–	–	–	–	–	–	–	o	–	o
Bryum algens	o	f	o	–	–	–	–	–	–	–	f	f	f
Ceratodon cf. *grossiretis*	o–f	o–f	–	o	–	–	–	o	o	–	–	–	f
Chorisodontium aciphyllum	o	–	–	–	–	–	–	–	–	–	–	–	r
Drepanocladus uncinatus	f	–	–	–	–	–	–	r	–	–	la	–	o
Grimmia antarctici	o	o	–	–	–	–	–	o	o	–	o	–	r
Grimmia cf. *donniana*	o	o–lf	lf	la	o	–	–	o–f	o	–	–	–	r
Hypnum sp.	–	–	–	–	–	r	–	–	–	–	r	–	r
Pohlia cruda var. *imbricata*	o	f	–	–	–	o	–	r	–	–	la	–	o
Pohlia nutans	f	lf	o	o	o	–	–	f	o	–	o	f	f
Mielichhoferia austro-georgica	–	–	–	–	–	–	–	–	–	–	lf	–	–
Polytrichum alpestre	–	–	–	o	o	o	–	–	–	–	–	f	–
Polytrichum alpinum	o	o	–	–	–	–	–	o	–	–	o	o	r
Racomitrium austro-georgicum	–	–	–	–	–	a	a	o	–	–	–	–	–
Sarconeurum glaciale	–	–	–	–	–	–	–	–	–	–	o	–	–
Tortula conferta	–	–	–	–	–	–	–	–	–	–	f	o	–
Hepatics													
Barbilophozia hatcheri	f	f	–	–	–	–	–	o	o–f	–	f	–	f
Cephaloziella varians	o	o	–	–	–	r	–	o	o	–	o	–	f
Lichens													
Acarospora macrocyclos	–	o	–	–	–	–	–	–	–	–	–	–	–
Alectoria minuscula	–	o	o	r	–	–	–	o	–	r	–	–	–
Alectoria pubescens	f	f	la	r	–	f	–	o–f	–	r	–	–	–
Biatorella antarctica	–	o	–	–	–	–	–	–	–	–	o	–	r
Buellia spp.	f	f	a	f–a	f	o	a	o	f	f	o	–	o
Caloplaca sp.	–	–	–	–	–	–	–	–	–	–	lf	–	–
Catillaria corymbosa	–	–	–	–	–	–	–	–	–	–	r	r	–
Cladonia furcata (incl. *C. balfourii* and *C. chlorophaea*)	f	–	–	–	–	–	–	f	o	o	o	f	r
Cladonia metacorallifera	o	–	–	–	–	–	–	o	–	o	–	–	r
Cornicularia epiphorella	o	o	–	–	–	–	–	r	–	–	–	–	r
Cystocoleus niger	o	–	–	–	–	–	–	r	–	–	–	–	o
Lecanora aspidophora	–	–	o	o	–	–	–	r	–	–	–	–	–
Lecidea dicksonii	–	r	r	r	–	–	–	r	–	–	–	–	–
Lecidea sp.	–	–	f	–	–	–	–	o	–	–	–	–	–
Lepraria sp.	–	–	–	–	–	–	–	–	–	–	–	o	r
Mastodia tesselata	–	–	–	–	–	–	–	–	–	–	f	–	–
Ochrolechia antarctica	–	r	o	r	–	–	–	r	–	r	–	–	r
Ochrolechia frigida	la	f	–	f	–	f	a	f	f	f	f	–	f
Parmelia saxatilis	f	f	–	–	–	–	–	–	–	–	–	–	r
Peltigera spuria	–	–	–	–	–	–	–	–	–	–	lf	–	–
Physcia caesia	–	–	o	–	–	–	–	–	–	–	o–f	–	–
Physconia muscigena	–	–	–	–	–	–	–	–	–	–	–	la	–
Psoroma follmannii	f	–	–	–	–	–	–	–	–	–	–	–	r
Rhizocarpon geographicum	o	o–la	–	f	–	–	–	o	r	–	–	–	r
Sphaerophorus globosus	–	–	–	–	–	–	–	f	–	o–f	–	–	–
Stereocaulon alpinum	–	–	–	–	–	–	–	o	r	–	–	lf	r
Umbilicaria antarctica	f	f–a	la	–	–	–	–	r	–	–	o	–	–
Umbilicaria decussata	–	o–f	f	–	–	–	–	–	–	–	–	–	–
Umbilicaria propagulifera	f	f	la	f	a	–	–	–	–	–	–	–	–
Usnea antarctica	f	o	la	f	f–a	–	–	f	r	f	o–f	–	r
Usnea fasciata	–	o	–	r	o	–	–	f	–	a	–	–	–
Verrucaria elaeoplaca	–	–	–	–	–	–	–	–	–	–	r	–	r
Unidentified crustose species	f	f	o	o	o	f	f	r	r	o	o	f	o
Alga													
Prasiola crispa	lf	–	o	–	–	–	–	–	–	–	–	–	o

Frequency assessment according to the scale: a, abundant; f, frequent; o, occasional; r, rare; with the prefix l, locally, e.g. la = locally abundant.

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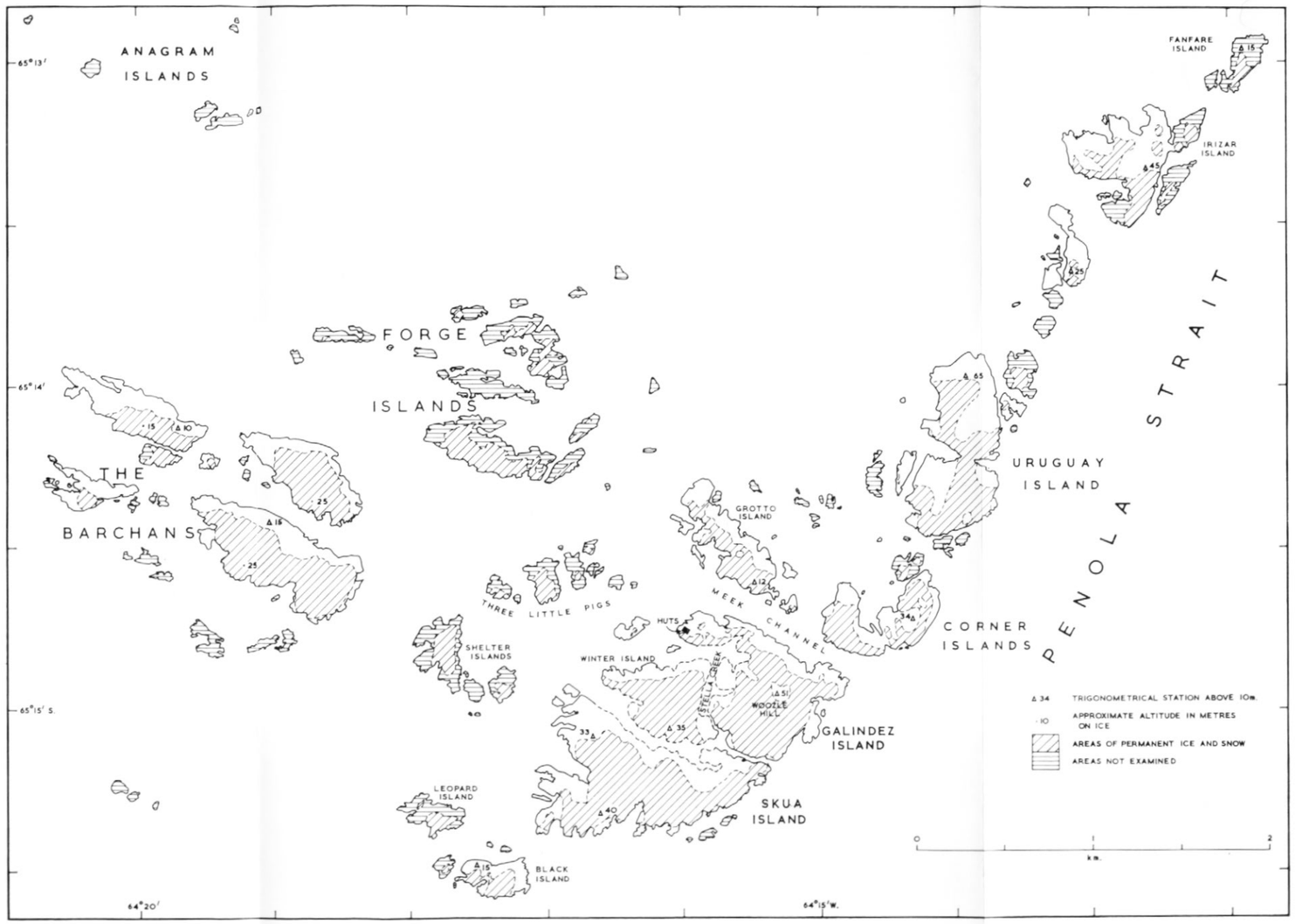

Fig. 2. The Argentine Islands showing areas examined botanically.

were recognizable and comparable with those described for Signy Island (Smith, 1972). In the most homogeneous stands, 20 quadrats measuring 20 cm. by 20 cm. were placed randomly within an area of *c.* 25–50 m.^{2} and within each the cover abundance of every species was estimated. From these data the mean percentage cover and frequency of each species was calculated for the community as a whole and presented as a quantitative species list. In less uniform or very open stands, semi-quantitative frequency estimates were collated for each species. In a few instances the pH of fresh soils from certain terricolous stands was determined using a glass electrode and pH meter. When all the results were available, it was found possible to allocate most assemblages to an existing unit of the classification, but some new communities were described and incorporated into the hierarchical system.

Occasional observations on the vegetation of nearby islands were made by one of the authors (R.I.L.S.) from R.R.S. *John Biscoe* at a distance of up to *c.* 400 m. and these have provided some indication of the extent of vegetation on these islands.

Vegetation of the Argentine Islands

The Argentine Islands are a group of small, low ice-capped islands lying from 6–12 km. west of the Graham Coast and separated from the mainland by Penola Strait (Fig. 2). The largest of this group is Skua Island (1·2 km. by 0·8 km.) and the highest point is on Uruguay Island (65 m.). Geologically, the Argentine Islands fall into two groups. Those to the east, i.e. the Irizar Island group, Uruguay, Grotto, Corner, Galindez, Winter, Skua, Three Little Pigs, Shelter, Leopard and Black Islands, are all composed of older breccias, tuffs and andesites belonging to the Upper Jurassic Volcanic Group. However, the western group of islands, i.e. Anagram and Forge Islands and The Barchans, are younger and are composed of gabbroic and granodioritic rocks of the Andean Intrusive Suite (Elliot, 1964). This major difference in rock type was clearly reflected in the distribution and development of vegetation. Although both geological groups of islands possessed approximately the same proportion of snow-free ground, there was surprisingly little vegetation and far fewer species have been recorded on the relatively more oceanic and wind-swept western group. By contrast, the apparently more sheltered eastern group was well vegetated and supported locally extensive stands representative of a wide variety of cryptogamic community types. The most widespread development of vegetation was largely restricted to the northern and western sides of the islands where there was most snow-free ground during summer. There were no extensive screes or areas of glacial detritus and accumulations of soil were scarce and seldom deep. There were also no shingle beaches while coastal rocks and offshore skerries were not widespread.

Fruticose lichen and moss cushion sub-formation

Most rock surfaces, with the exception of those close to the shore, and dry wind-swept stony ground were colonized by varying densities of bushy fruticose and foliose lichens (species of *Usnea* and *Umbilicaria*) with frequent crustose species associated, and small compact cushion-forming mosses (particularly species of *Andreaea*, *Grimmia* and *Racomitrium*). Occasionally closed stands of these mosses and lichens covered sheltered rock faces moistened by trickling melt water.

Although communities of the *Andreaea–Usnea* association (Table V) were the most widespread in the Argentine Islands, the number of sociations represented was low, there being considerably fewer than have been described for the South Orkney Islands (Smith, 1972). There were some interesting differences between the species composition and species occurrence in these communities in the two island groups. For instance, on Signy Island, base-rich habitats are frequent in which certain species typical of the *Tortula–Grimmia antarctici* association were distinctly calcicole in their requirements and rarely associate with calcifuge species of the *Andreaea–Usnea* association. However, in the Argentine Islands, *Grimmia antarctici* was commonly found with these latter genera on relatively acid rocks and soil. Some lichens show a difference in habitat preference between the South Orkney Islands and the Argentine Islands. *Cornicularia epiphorella* is a comparatively rare associate of *Polytrichum alpestre–Chorisodontium aciphyllum* banks on Signy Island, but on Galindez Island it frequently occurred amongst species of *Usnea* and cushion-forming mosses on dry rock surfaces. The

ecological amplitude of *Usnea antarctica* appears to become progressively narrower with increasing latitude and, while this lichen may predominate in a wide range of habitats on Signy Island, e.g. moss banks, eroded peat, soil, gravel, stones, rock and even imported wood, in the Argentine Islands area it was almost entirely restricted to rock habitats.

The Argentine Islands and neighbouring areas possessed several species, rare or unknown elsewhere in the maritime Antarctic, which were frequent associates in the *Andreaea–Usnea* sociations. *Grimmia* cf. *donniana* and *Polytrichum piliferum*, species unknown in the South Orkney Islands, but which are widespread on South Georgia and recorded from a number of localities in the South Shetland Islands and farther south, were fairly common plants in some *Andreaea*- and *Usnea*-dominated communities in the Argentine Islands area, the former species occurring on rock. *P. piliferum* was commonest on the capes of the Graham Coast, where it occurred on gravelly soil, but it appeared to be absent from the Argentine Islands and most of the other islands visited. Another unusual species commonly occurring in these islands was *Umbilicaria propagulifera*, a species almost entirely restricted to the Danco and Graham Coasts and offshore islands (Lindsay, 1969*b*). Similarly, a species of *Cetraria*, unknown elsewhere in the Antarctic or on South Georgia was occasionally associated with species of *Usnea* in saxicolous communities of the *Andreaea–Usnea* association on Galindez and Skua Islands. In contrast, some species appeared to be near the southern limit of their geographical distribution in the Argentine Islands. Thus *Himantormia lugubris*, a species which is common in many calcifuge rock communities in the South Orkney Islands, was found in only one locality in the Irizar Island group. *Dicranoweisia grimmiacea* is also common in the South Orkney Islands but it was a very scarce associate in the Argentine Islands. Both species were, however, locally frequent on the islands in Arthur Harbour. *Cornicularia epiphorella* is not known south of the Argentine Islands (Lindsay, 1969*a*).

Areas of stony ground interspersed with pockets of soil supported small open stands of a mixed *Andreaea*–lichen sociation in which species of *Andreaea*, *Alectoria*, *Cladonia*, *Usnea*, *Grimmia antarctici*, *Ochrolechia frigida*, *Pohlia nutans*, *Polytrichum alpinum*, *Sphaerophorus globosus* and numerous unidentified crustose species were abundant (Table V). *Polytrichum juniperinum* was also noted in this sociation on Uruguay Island. Damp sheltered rock faces were occasionally covered by closed stands of *Andreaea regularis* or, less commonly, by *A. gainii* with scattered cushions of *Bartramia patens*, *Ceratodon* cf. *grossiretis*, *Pohlia nutans*, *Grimmia antarctici*, *G.* cf. *donniana* and several epiphytic crustose lichens, particularly *Ochrolechia frigida* and a species of *Buellia*. *Prasiola crispa* was also sometimes present.

On exposed sloping rocks not far from the shores of Galindez and Skua Islands, an *Andreaea–Racomitrium austro-georgicum* sociation was locally prominent. Here small cushions of the *Racomitrium* were abundant and occasionally co-dominant with *Andreaea regularis*, and numerous crustose lichens were associated (Table V). This sociation is rare in the South Orkney Islands where it tends to develop on stony slopes and screes on moist sheltered hillsides rather than on continuous rock surfaces (Smith, 1972).

Species of *Usnea* were generally associated with other cryptogams and did not appear to form the dense stands known from the South Orkney and South Shetland Islands, although *U. antarctica* was often abundant on wind-swept rock outcrops, while *U. fasciata* was similarly common particularly in slightly more sheltered situations on the westernmost of the Corner Islands, the north-east of Uruguay Island and the southern island of the Irizar Island group. Throughout the Argentine Islands a mixed community occurred in which species of *Usnea* combined with species of *Andreaea*, *Grimmia* and *Umbilicaria* to form a recurring assemblage with a fairly constant species composition. Although the existence of this sociation was indicated by its inclusion in the classification of the terrestrial vegetation of the maritime Antarctic given by Gimingham and Smith (1970), it is described here for the first time.

Andreaea–Grimmia–Usnea–Umbilicaria sociation (Table V). Predominant species: *Andreaea gainii*, *Andreaea regularis*, *Grimmia* cf. *donniana*, *Umbilicaria antarctica*, *Umbilicaria propagulifera*, *Usnea antarctica* and numerous epipetric crustose lichens. Habitat: dry wind-swept rock surfaces and the damp sheltered walls of gullies, usually with a northerly aspect. Altitudinal range: 2–50 m.

This lichen-dominant sociation was common in most gently sloping to vertical exposed

rock surfaces, although on the more sheltered sides of gullies the bryophyte components and *Umbilicaria antarctica* tended to become more prominent. In the most wind-swept situations the predominant species was *Usnea antarctica* with *Alectoria minuscula*, *A. pubescens*, *Andreaea regularis*, *Grimmia* cf. *donniana*, *Ochrolechia frigida*, *Rhizocarpon geographicum*, *Umbilicaria antarctica*, *U. decussata*, *U. propagulifera*, *Usnea fasciata* and numerous unidentified crustose lichens all locally abundant. Where there was some degree of shelter or moisture, the contribution afforded by the bryophytes increased, small cushions of *Bryum algens*, *Ceratodon* cf. *grossiretis* and *Pohlia mutans* becoming important associates of the Andreaeas and *Grimmia* cf. *donniana*. *Grimmia antarctici* was also locally frequent. *Parmelia saxatilis*, *Umbilicaria antarctica* and *U. propagulifera* were the predominant lichens, while *Barbilophozia hatcheri*, *Cephaloziella varians* and *Prasiola crispa* were also occasionally present on the wetter moss-dominated rocks.

Mixed assemblages in rock micro-habitats were widespread in the Argentine Islands wherever there were rock faces. On account of the acidic nature of the substratum, all such crevice and ledge communities were composed of calcifuge species, although some mildly calcicolous species were present where there was local flushing. A wide variety of short turf- and cushion-forming mosses and occasionally mats of other species, hepatics, crustose and foliose lichens, were prominent wherever this type of habitat prevailed (Table V).

The principal genera represented in these habitats were *Andreaea*, *Bartramia*, *Bryum*, *Ceratodon*, *Grimmia* and *Pohlia*, while *Drepanocladus uncinatus*, *Barbilophozia hatcheri*, *Cephaloziella varians* and occasionally species of *Brachythecium* were abundant in the damper situations, while small mats of a species of *Hypnum* were also sometimes present. Various crustose lichens were usually present, while species of *Cladonia*, *Parmelia saxatilis* and *Stereocaulon alpinum* occurred on the ledges and sometimes *Umbilicaria antarctica* and *Usnea antarctica* festooned the wider vertical fissures. The black felt-like *Cystocoleus niger* was occasionally seen amongst species of *Andreaea* or below the larger lichens.

Several species considered as rare along the west coast of the Antarctic Peninsula occurred in crevices and on ledges on the low cliffs above the north and west sides of many of the eastern group of islands. Thus scattered cushions of *Mielichhoferia austro-georgica* and *Sarconeurum glaciale* and small mats of a species of *Hypnum* were associated with the more frequent species of *Andreaea*, *Bartramia patens*, *Bryum algens*, *Grimmia antarctici* and *Tortula conferta* and various crustose and foliose lichens including species of *Caloplaca*, *Physcia* and *Xanthoria* and the rare *Parmelia gerlachei* and *Peltigera spuria*. Slightly farther inland other species, rare in the Argentine Islands, were recorded in moist crevices, e.g. species of *Amblystegiella*, *Dicranoweisia*, ? *Pseudoleskea*, *Lophozia* and *Metzgeria*.

The only calcareous habitats in the Argentine Islands occurred locally in rock depressions near the shore where Dominican gulls (*Larus dominicanus*) had deposited limpet shells, particularly near their nests. In places these accumulations had weathered to form a calcareous shell soil, 10–20 cm. deep, with a pH ranging from 6·0 to 7·6. Such situations were colonized by small open stands representative of the *Tortula–Grimmia antarctici* association. Although *Grimmia antarctici* was a rare associate, these communities belonged to the *Tortula* sociation in which *Tortula conferta*, *T.* cf. *grossiretis* together with *Brachythecium austro-salebrosum*, *Bryum algens*, *Ceratodon* cf. *grossiretis* and *Drepanocladus uncinatus* predominated. *Caloplaca* cf. *murorum* was often abundant on the shells, while small plants of *Deschampsia antarctica* were occasionally rooted amongst them.

Crustose lichen sub-formation

The more exposed rock faces around the shores of the Argentine Islands, and more locally inland where rock outcrops were used as bird perches, were frequently colonized by stands of crustose lichens. These communities, belonging to the *Caloplaca–Xanthoria* association, were usually most extensive on the north- and west-facing sea cliffs. As most rocks at sea-level were susceptible to sea-ice abrasion, the typical *Verrucaria* zone was only seldom encountered. Black species of *Verrucaria*, including *V. maura*, and possibly also *V. psychrophila*, occasionally colonized rocks from a little below high-water mark to about 1 m. above that level. Above this were mixed stands dominated by species of *Caloplaca* and *Xanthoria elegans* with *Haematomma*

erythromma, *Mastodia tesselata*, *Lecidea atrobrunnea*, *Physcia* cf. *caesia* and several unidentified crustose species frequently associated. *Parmelia gerlachei* was abundant on one cliff on Galindez Island at the north-east of Stella Creek. Although *Pottia austro-georgica* is a regular associate, in rock crevices and on ledges, of the *Caloplaca–Xanthoria* association in the South Orkney and South Shetland Islands, it was not recorded from the Argentine Islands where its niche appeared to be occupied by *Sarconeurum glaciale*. Similarly, *Orthotrichum crassifolium* is locally abundant in some hygrohaline *Caloplaca* communities in the South Orkney Islands, but this species was only a rare associate on the north-east side of Uruguay Island.

Farther inland this association was represented by small stands of a *Xanthoria elegans–Haematomma erythromma–Mastodia tesselata* sociation, a community which has been reported by Lindsay (1971*d*) from several of the South Shetland Islands. It was included by Smith (1972) in the *Xanthoria elegans* sociation for fragmentary stands on Signy Island. Its presence on Goudier Island can be inferred from Lamb (1948). Its occurrence in the Argentine Islands can now be confirmed and the sociation is described here for the first time.

Xanthoria elegans–Haematomma erythromma–Mastodia tesselata sociation. Predominant species: *Buellia coniops*, *Buellia russa*, *Mastodia tesselata*, *Haematomma erythromma*, *Rinodina petermannii*, *Xanthoria elegans*. Habitat: exposed outcrops, boulders and rock fragments used as bird perches and near bird colonies; influenced by nitrogenous drainage. Altitudinal range: 2–50 m.

This sociation occurred as small stands usually on rock outcrops and boulders close to the nests of gulls and skuas using these habitats as perches. The local nitrogen enrichment permitted a variety of ornithocoprophilous crustose and foliose lichens to form a recurring community dominated by *Haematomma erythromma* and *Xanthoria elegans*, while *Mastodia tesselata* was almost always present in small quantities near the shore, particularly in the fine fissures of the horizontal or gently sloping rock. However, *H. erythromma* may frequently be sparse, while *M. tesselata* occasionally predominated in the more sheltered situations and may afford almost closed cover. Several species of *Buellia* were generally also present, of which *B. coniops*, *B. latemarginata* and *B. russa* were the most prominent, while *Acarospora macrocyclos*, *Rinodina petermnanii*, *Lecania brialmontii* and *Xanthoria candelaria* were frequent associates with *Bacidia stipata* and *Catillaria corymbosa* occasionally present. In other regions of the maritime Antarctic, *Ramalina terebrata* and *Caloplaca regalis* may be prominent associates in this type of community and give rise to the *Xanthoria elegans–Haematomma erythromma–Caloplaca regalis* sociation, the *Xanthoria elegans–Ramalina terebrata* sociation or the *Haematomma erythromma–Ramalina terebrata* sociation.

Elsewhere, on the more inland rocks, where there was little influence from birds, stands of more nitrophobous species of *Buellia*, *Lecidea* and *Lecanora aspidophora* constituted the *Buellia–Lecanora–Lecidea* association, although these frequently merged with certain *Usnea*- and *Umbilicaria*-dominated communities in which small cushion-forming mosses were also associated.

Moss turf sub-formation

A number of the eastern Argentine Islands possessed some of the largest and deepest banks of the *Polytrichum alpestre–Chorisodontium aciphyllum* association south of the South Orkney Islands, these being the most conspicuous closed plant communities on the islands. The most extensive was about 530 m.^{2}, situated on the west side of Galindez Island, while only a single very small stand was seen in the western group of islands, on the largest of The Barchans. The moss turf developed over rock surfaces or less frequently over large rocks on steep or gentle slopes and occasionally on broad ledges with a northerly aspect. Some of these banks exceeded 1 m. in depth and were permanently frozen below *c.* 20 cm. Stands of varying dimensions occurred from close to high-water mark in sheltered bays to *c.* 60 m. on Uruguay Island, the highest point in the Argentine Islands. Locally, some of the peat banks were penetrated by the burrows of nesting Wilson's petrels (*Oceanites oceanicus*) but the birds did not appear to be a cause of serious erosion.

Where banks had developed on steep rock slopes the surface of the turf was stepped due,

presumably, to slumping or solifluction within the upper layer of unfrozen peat during periods of thaw. Large open cracks often break the surface of the moss turf at the back of each step where it has pulled away from the step above. On less steep slopes the surfaces of the banks were more even and less disrupted by frost action and there was little accumulation of snow in winter because of their relatively exposed positions on the islands, although shallow snow cover persisted for 7–8 months until early December. Where snow was completely removed by strong winds the surfaces of the banks became coated with ice. In summer, strong winds and frost action occasionally dislodged large pieces of turf on the down-hill side of banks situated on steep rocky ground. Sometimes melt water also caused some erosion of the margins of the moss banks, particularly those adjacent to the drainage channels on Woozle Hill, Galindez Island.

Unlike the peat banks in the South Orkney and South Shetland Islands, those in the Argentine Islands are formed predominantly by *Polytrichum alpestre* (Table VI), while

TABLE VI. PERCENTAGE COVER AND PERCENTAGE FREQUENCY OF SPECIES IN TWO SOCIATIONS OF THE *Polytrichum alpestre–Chorisodontium aciphyllum* ASSOCIATION ON GALINDEZ ISLAND, ARGENTINE ISLANDS

Species	*Polytrichum alpestre–lichen sociation*			*Polytrichum alpestre–Chorisodontium aciphyllum–lichen sociation*
	Stand 1	*Stand 2*	*Stand 3*	*Stand 4*
Mosses				
Chorisodontium aciphyllum	–	–	+; 30	49;100
Drepanocladus uncinatus	–	<1; 10	–	–
Pohlia nutans	4; 90	17;100	19;100	5;100
Polytrichum alpestre	61;100	37;100	51;100	41;100
Hepatics				
Barbilophozia hatcheri	<1; 50	<1; 40	<1; 60	<1; 70
Cephaloziella varians	6;100	3; 70	7;100	3;100
Lichens				
Buellia cf. *punctata*	3; 90	12;100	2; 70	2; 40
Cladonia metacorallifera	4;100	9;100	4; 90	3; 60
Cladona furcata	1; 60	2; 70	2; 80	2; 60
Cladonia sp.	1; 50	1; 10	–	3; 90
Lecidea sp.	–	–	–	1; 10
Ochrolechia frigida	19;100	30;100	18;100	6; 70
Sphaerophorus globosus	14;100	–	–	–
Usnea antarctica	–	–	<1; 20	–
Fungus				
Basidiomycete	<1; 20	<1; 20	–	<1; 40

+ Indicates the presence of a species close to but just outside a quadrat.
– Indicates the absence of a species.
The figure before the semi-colon is that of percentage cover; that following the semi-colon is percentage frequency.
All cover data are means derived from 20 quadrats of 20 cm. by 20 cm. in each stand.

Chorisodontium aciphyllum is abundant in very few banks although it is often present in small quantities amongst the *Polytrichum*. The scarcity of the *Chorisodontium* is probably due to the lack of ground water, since it has been noted (Smith, 1972) that this moss dominated the wetter habitats where this association was represented. The largest stand of almost pure *Chorisodontium aciphyllum* turf, measuring only *c.* 15 m.^{2}, occurred in a steep gully on the north-east side of Uruguay Island. *Pohlia nutans* was a constant associate in most turf communities and in some stands provided considerable cover, while *Barbilophozia hatcheri* and *Cephaloziella varians* were almost always present, particularly in the fissures of the peat. Colonies of small basidiomycete fungi commonly occurred late in the summer amongst the living shoots of the turf-forming mosses. The steeper *Polytrichum alpestre* banks were often heavily encrusted with *Ochrolechia frigida*, *Buellia* cf. *punctata* and *Rinodina turfacea*. Of the macro-lichens, *Sphaerophorus globosus* occasionally provided high cover but it was also often absent. Several grossly malformed species of *Cladonia*, chiefly *C. furcata* and *C. metacorallifera*, were frequent and on the more exposed banks these had an almost crustose growth form. *Usnea antarctica* was a rare epiphyte and other fruticose lichens such as species of *Alectoria* and *Cornicularia*, which are common associates on *Polytrichum–Chorisodontium* banks in the South Orkney Islands, appeared to be absent or very rare in the Argentine Islands. A single occurrence of *Cornicularia aculeata*, recorded on the pure *Chorisodontium aciphyllum* bank on Uruguay Island, represents the southernmost known locality for this species (Lindsay, 1969*a*).

In a few places on Galindez Island, where a continuous *Polytrichum alpestre* bank had developed over a level rock terrace and extended down an adjacent slope, erosion had removed most of the turf on the level substratum, leaving numerous isolated hummocky *P. alpestre* turves *c.* 30 cm. in height and up to 1 m. in diameter. The vertical sides of these mounds were often moribund and colonized by *Pohlia nutans* and *Barbilophozia hatcheri*, while the eroding crests were encrusted with lichens. The intervening peaty soil supported a closed stand of *Drepanocladus uncinatus* with frequent *Pohlia nutans*.

The *Polytrichum alpinum* association was not well developed and small open stands dominated by *P. alpinum* occurred sparingly near the shores and on broad rock ledges where it was usually associated with shallow mats or carpets of *Drepanocladus uncinatus*. The following species were recorded on a damp wide ledge, *c.* 2–3 m. above high-water mark on the north side of Galindez Island:

Brachythecium austro-salebrosum	o	*Barbilophozia hatcheri*	
Ceratodon cf. *grossiretis*	o		
Drepanocladus uncinatus	f	*Cladonia metacorallifera*	o
Polytrichum alpinum	a	*Psoroma folmannii*	o

Moss carpet sub-formation

This sub-formation is dependent on a permanent supply of moisture but habitats of this nature were infrequent in the Argentine Islands. There were few melt streams and pools on any of the islands and stands of the carpet-forming *Brachythecium* cf. *antarcticum–Calliergon sarmentosum–Drepanocladus uncinatus* association were largely restricted to depressions where there was an accumulation of soil and moisture. These communities were commonest at low altitudes and extended to near sea-level. Moist gravelly ground was usually dominated by pure stands of *Drepanocladus uncinatus*, although *Pohlia nutans* was also frequently associated. These mosses were frequently parasitized by small white circular colonies of the ascomycetous fungus *Thyronectria antarctica* var. *hyperantarctica* which has been reported from Signy Island by Smith (1972) and described by Hawksworth (1973). Where the substratum was wetter, a short form of *Brachythecium* cf. *antarcticum* or occasionally *Brachythecium austro-salebrosum* predominated. *Calliergon sarmentosum*, common in stands of this association in the South Orkney and South Shetland Islands, was apparently absent. In a few situations, colonies of *Pohlia nutans*, normally a short cushion- or turf-forming species, coalesced to such an extent as to produce a modified carpet habit affording cover over several square metres. The composition of three stands representative of this association is given in Table VII.

TABLE VII. PERCENTAGE COVER AND PERCENTAGE FREQUENCY OF SPECIES IN THREE COMMUNITIES OF THE *Brachythecium* cf. *antarcticum–Calliergon sarmentosum–Drepanocladus uncinatus* ASSOCIATION ON GALINDEZ ISLAND, ARGENTINE ISLANDS

Species	*Brachythecium* cf. *antarcticum* sociation	*Drepanocladus uncinatus* sociation Soil pH 4·4, 5·0	*Brachythecium* cf. *antarcticum–Pohlia nutans community** Soil pH 3·9, 4·25
Mosses			
Brachythecium cf. *antarcticum*	94;100	–	51;100
Brachythecium austro-salebrosum	1; 15	4; 50	–
Bryum algens	–	2; 25	–
Ceratodon cf. *grossiretis*	–	1; 20	–
Drepanocladus uncinatus	7;100	91;100	6; 70
Pohlia nutans	<1; 20	3; 40	38; 90
Polytrichum alpinum	–	<1; 20	–
Hepatic			
Cephaloziella varians	–	1; 35	8;100
Lichen			
Psoroma follmannii	–	<1; 30	–
Alga			
Prasiola crispa	<1; 15	1; 30	–

All data were estimated as in Table VI.
* This community has not been recognized as a sociation since stands were seldom extensive and the cover and frequency of its component species was not uniform.

The habitats occupied by these communities were covered by deep snow from the onset of winter until early or mid-summer, in some instances for up to 10 months. During the summer of 1964-65 a greater area of ground became snow-free than in the two previous summers and the recession of some snow banks revealed small carpets of a brown moribund species of *Brachythecium* and *Bryum* coated with grey, red and purple filamentous algae. However, several of these apparently dying moss shoots produced new growth during the season.

Moss hummock sub-formation

Large cushion-forming mosses of the genera *Brachythecium* and *Bryum* were nowhere extensive. Small stands of the *Brachythecium austro-salebrosum* association were occasionally seen on wet sloping rock faces, ledges or depressions near the shore, while the *Bryum–Drepanocladus uncinatus* association was more widespread, particularly in damp hollows.

Alga and snow alga sub-formations

No stands of *Prasiola crispa* were observed, although the alga was frequently associated with bryophytes in wet situations and rock crevices. Elsewhere in the maritime Antarctic, the alga is particularly abundant in and near penguin rookeries, and the absence of any breeding colonies of these birds in the Argentine Islands probably accounts for the lack of *Prasiola*-dominated stands. The only dense colony of birds was of blue-eyed shags (*Phalacrocorax atriceps*) on Uruguay Island where *Prasiola crispa* was one of the few species noted, although it occurred only very sparsely.

The transient snow alga association occurred in small pinkish patches on the ice caps of several of the islands as well as on some offshore tabular icebergs.

Grass and cushion chamaephyte sub-formation

Although the two vascular plants were recorded on many of the islands of the eastern Argentine Islands (Corner, 1971), they did not develop distinct stands, since they were always associated with an abundance of cryptogams. *Deschampsia antarctica* had a wide distribution in coastal areas and occasionally farther inland on Irizar and Uruguay Islands, the largest island between these and the nearest island to the south-west side of Uruguay Island, Corner Island, the island between it and Grotto Island, Galindez, Winter, Skua and Black Islands, Yalour Islands, lying *c.* 2·4 km. east of Uruguay Island (Greene and Holtom, 1971), and a single plant on the north side of the largest of The Barchans. The grass occurred almost always as small tufts, seldom larger than 15 cm. across, although it did produce inflorescences abundantly. One of the largest stands of *Deschampsia antarctica* occurred in a small rock depression filled with gravel and base-rich soil produced from decomposed limpet shells (pH 6·8), *c.* 50 m. inland from Stella Creek at the north-west side of Galindez Island, at an altitude of *c.* 16 m. The stand was *c.* 1 m. by 1 m. and the following species were recorded with the percentage cover indicated:

Deschampsia antarctica	60	*Acarospora macrocyclos*	5
Bryum algens	5	*Buellia* sp.	5
Ceratodon cf. *grossiretis*	5	*Cladonia furcata*	5
Drepanocladus uncinatus	20	*Cladonia metacorallifera*	5
Pohlia nutans	5	*Ochrolechia frigida*	5
Polytrichum alpinum	10		

Colobanthus quitensis was also associated with various cryptogams but it had a considerably more restricted range than *Deschampsia antarctica* (Corner, 1971), being recorded as scattered cushions in two stands on the north side of the island south of Irizar Island, three stands on the south-west of Skua Island and a single locality on the north coast of Galindez Island.

Vegetation of Islands in the Arthur Harbour Area and Port Lockroy

The vegetation of a number of islands and headlands in and near Arthur Harbour (Fig. 3), a bay approximately midway along the south-west coast of Anvers Island, was studied briefly in 1964 and 1967. Goudier Island, situated in Port Lockroy (Wiencke Island) on the east side of Neumayer Channel, was also examined in 1967. These islands differ from the Argentine Islands in that they have no ice cap and relatively small areas of permanent snow and ice, which are mainly on the south sides of the larger islands. They are very rocky and some of those in Arthur Harbour have steep slopes rising to over 40 m. with 60 m. being reached on Hermit Island. Litchfield and Hermit Islands are the two largest islands in Arthur Harbour and received the greatest attention botanically. The largest of the Outcast Islands, *c.* 5 km. south-west of the coast of Anvers Island was the farthest offshore locality visited. The promontories on the north and south sides of Arthur Harbour, namely Norsel and Bonaparte Points, were also inspected, as well as the small promontory on which Palmer station is situated. Similarly, Lécuyer and Jougla Points, to the south-east of Goudier Island, were cursorily examined.

The Arthur Harbour area is subjected to strong south-westerly winds blowing across the open ocean, while Goudier Island lies in the path of north-easterly winds funnelling down Neumayer Channel. There are also frequent catabatic winds originating in the high mountains north of the Marr Ice Piedmont on Anvers Island, and the mountains to the north of Port Lockroy on Wiencke Island.

Because of the extensive area of snow-free terrain in summer, there is a wide range of habitats available for plant colonization. A large proportion of the islands and rocky headlands of Anvers Island are well-vegetated, except where there are colonies of sea birds, particularly Adélie penguins (*Pygoscelis adeliae*) and cormorants as on Litchfield, Humble and Cormorant Islands. The vegetation of Goudier Island is sparse and dominated by crustose

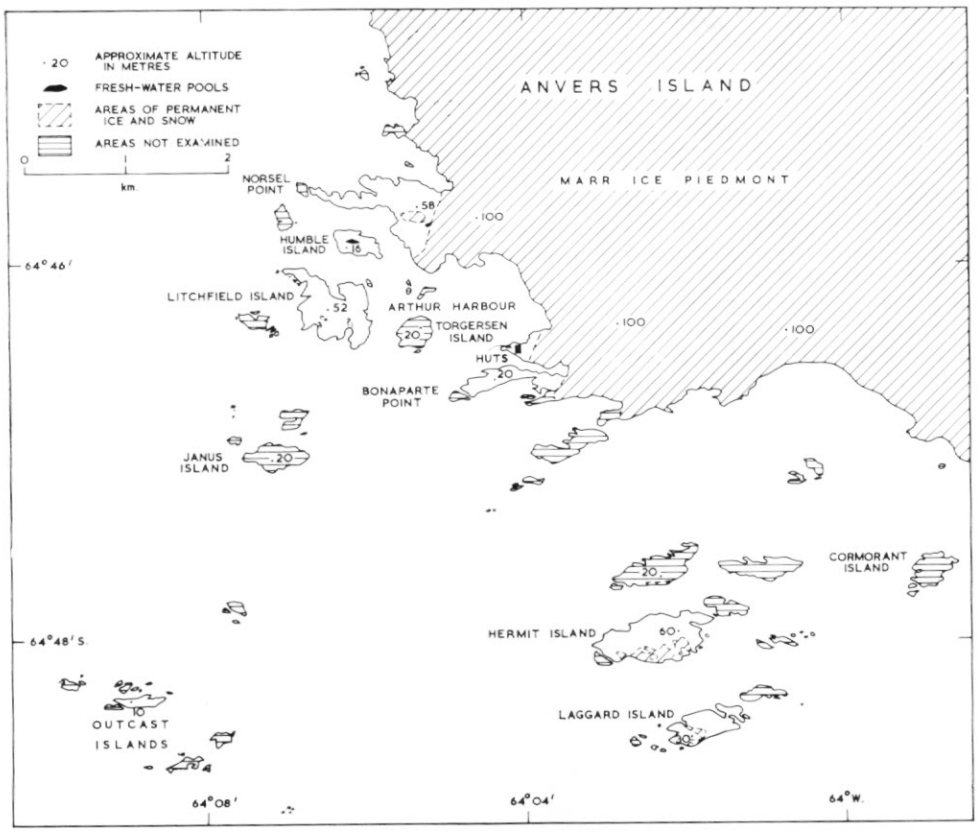

Fig. 3. The Arthur Harbour area of south-western Anvers Island showing areas examined botanically.

lichens. The ecology of these predominantly pyrenocarp lichen communities has been briefly described by Lamb (1948).

Fruticose lichen and moss cushion sub-formation

Communities of this sub-formation were frequent on most rock surfaces and stony ground in the Arthur Harbour area only, with small cushion-forming mosses predominating in the more sheltered north-facing situations and fruticose and crustose lichens occurring where the habitats were drier and more exposed.

Several species which were frequent associates in these communities in the Argentine Islands appeared to be absent from the Arthur Harbour area. The most noticeable of these were *Alectoria minuscula*, *Cornicularia epiphorella*, *Grimmia* cf. *donniana*, *Racomitrium austro-georgicum* and *Umbilicaria propagulifera*, while on Goudier Island no species of hepatic nor of the genera *Alectoria*, *Andreaea*, *Grimmia* or *Umbilicaria* was recorded. *Usnea fasciata*, *Himantormia lugubris* and *Dicranoweisia grimmiacea* were also not seen, although all are known to occur nearby on Wiencke Island (Lamb, 1964; Greene and others, 1970). It is interesting to note that I. M. Lamb collected *Grimmia* cf. *donniana* on Goudier Island in 1944 but the moss no longer appears to exist there. However, the *Himantormia* and *Dicrano-weisia*, which were rare in the Argentine Islands, were frequent in communities of the *Andreaea–Usnea* association on the islands in Arthur Harbour.

The *Andreaea–Usnea* association was common on Litchfield, Laggard and Hermit Islands and to a lesser extent near Norsel and Bonaparte Points, although bryophytes were seldom dominant. Coalesced cushions of species of *Andreaea* rarely exceeded 15 cm. across. As with

these communities in the Argentine Islands, *Ceratodon* cf. *grossiretis*, *Grimmia antarctici* and *Pohlia nutans* were frequently associated with species of *Andreaea* while *Dicranoweisia grimmiacea* was occasionally present also. The turf-forming mosses *Polytrichum alpinum*, *P. alpestre* and *Chorisodontium aciphyllum* were typical associates on broad soil-covered ledges.

The *Usnea–Himantormia lugubris* and *Usnea antarctica* sociations were frequent on many wind-swept rock surfaces, while the *Andreaea–Dicranoweisia grimmiacea–Usnea–Umbilicaria* sociation occurred on the more sheltered north-facing inland cliffs. The composition of two stands of this latter sociation on Hermit Island is given in Table VIII. The stand on the vertical face was situated near the shore and close to bird perches which accounted for the occurrence of several nitrophilous lichen species typical of coastal rock communities, e.g. species of *Caloplaca*, *Haematomma* and *Xanthoria*.

Rock crevices and narrow ledges on the Arthur Harbour islands possessed a wide variety of bryophytes and occasional lichens, including several species considered as mildly to strongly calcicolous in more northerly regions, e.g. *Bryum argenteum* and *Tortula* cf. *grossiretis*. *Deschampsia antarctica* and *Colobanthus quitensis* were occasionally present in such habitats where there was adequate moisture, shelter and a northerly aspect. Species recorded in two rock micro-habitats on Hermit Island are listed in Table VIII. On Goudier Island, few rock crevices were colonized and only *Bryum algens* and *Pohlia cruda* var. *imbricata* were seen in the moister fissures.

Small stands representative of the *Tortula–Grimmia antarctici* association occurred where there were accumulations of limpet shells near the nests of gulls. Here the substratum was highly calcareous and several calcicolous species predominated. The mean pH of four fresh samples of such shell soil on Goudier Island was 7·7 (ranging from 7·6 to 8·0). A composite list of species recorded in several of these habitats on Hermit Island is given in Table VIII. Elsewhere, on Hermit Island and occasionally on Laggard Island, ledges on north-facing cliffs subjected to some degree of flushing supported small stands dominated by coalesced cushions of *Tortula* cf. *grossiretis* and *Bryum algens* with *Brachythecium austro-salebrosum* and *Leptogium puberulum* usually associated. It is of interest to note that I. M. Lamb (personal communication) recorded a single "introduced seedling coming up spontaneously in shelly detritus soil" on Goudier Island in January 1945. The plant had at least five leaves and has been identified from a photograph as a species of *Matricaria*.

One of the most frequently occurring bryophyte-dominated communities on Goudier Island was also referable to the *Tortula–Grimmia antarctici* association. These small open assemblages occurred on pockets of mineral soil (pH of two samples: 5·5 and 5·6) in rock depressions and comprised scattered cushions or short turves of *Bryum algens*, *Ceratodon* cf. *grossiretis*, *Pohlia nutans*, *Tortula conferta* and *T.* cf. *grossiretis* intermixed with small mats of short *Drepanocladus uncinatus*. Thalli of *Usnea antarctica*, *Leptogium puberulum*, grossly malformed species of *Cladonia* and occasional encrustations of other lichens were also usually present.

Crustose lichen sub-formation

Rock and cliff faces, especially those near the shore, of most islands and headlands in the Arthur Harbour–Port Lockroy area, supported stands typical of the *Caloplaca–Xanthoria* association. Near high-water mark, species of *Verrucaria* were locally abundant while species of *Buellia*, *Caloplaca*, *Haematomma erythromma*, *Mastodia tesselata*, *Rinodina petermanii* and *Xanthoria elegans* were prominent at slightly higher levels on the rocks. Several of the islands were strongly influenced by birds, and rocks used as perches by gulls, terns and skuas were colonized by stands dominated by *H. erythromma* and *X. elegans* with associated nitrophilous species.

On Goudier Island diffuse nitrophilous crustose lichen assemblages colonized much of the polished granodiorite and basalt dykes, although *Usnea antarctica*, *Rhizocarpon geographicum* and occasionally other nitrophobous species occurred on the higher parts of the island.

From the observations of one of the authors (R.I.L.S.) on Goudier Island and between Lécuyer and Jougla Points on Wiencke Island, and with the aid of photographs and notes

TABLE VIII. FREQUENCY ASSESSMENT OF SPECIES IN SEVERAL COMMUNITIES OF THE FRUTICOSE LICHEN AND MOSS CUSHION SUB-FORMATION ON HERMIT ISLAND

Species	*Andreaea–Dicranoweisia grimmiacea–Usnea–Umbilicaria* sociation		*Mixed bryophyte and lichen assemblages of rock micro-habitats*		*Tortula–lichen community**
	On dry vertical rock	*On dry horizontal rock*	*In moist crevice*	*On flushed ledge*	*On limpet shells and gravel*
Mosses					
Amblystegiella cf. *densissima*	–	–	r	–	–
Andreaea depressinervis	–	f	–	–	–
Andreaea gainii	1f	f	o	–	–
Andreaea regularis	1f	o	–	–	–
Bartramia patens	–	–	o	r	–
Brachythecium austro-salebrosum	–	–	o	f	–
Bryum algens	–	–	f	f-a	f
Bryum argenteum	–	–	r	–	–
Ceratodon cf. *grossiretis*	o	–	o	o	f
Drepanocladus uncinatus	–	o	o	f–la	–
Grimmia antarctici	o	f	o	–	r
Pohlia cruda var. *imbricata*	–	–	f	o	–
Pohlia nutans	–	f	–	–	–
Polytrichum alpestre	–	o	–	–	–
Polytrichum alpinum	–	o	–	–	–
? *Pseudoleskea* sp.	–	–	o	–	–
Sarconeurum glaciale	–	–	r	–	–
Tortula conferta	–	–	o	r	f
Tortula cf. *grossiretis*	–		o	f–a	o
Hepatics					
Barbilophozia hatcheri	–	–	–	o	–
Cephaloziella varians	–	o	r	o	–
Lichens					
Acarospora macrocyclos	–	–	–	–	o–f
Alectoria pubescens	f	f	–	–	–
Biatorella antarctica	f	–	–	–	–
Buellia spp.	f–a	f–a	–	–	–

TABLE VIII—*continued overleaf.*

TABLE VIII—*continued.*

Species	*Andreaea–Dicranoweisia grimmiacea–Usnea–Umbilicaria sociation*		*Mixed bryophyte and lichen assemblages of rock micro-habitats*		*Tortula–lichen community**
	On dry vertical rock	*On dry horizontal rock*	*In moist crevice*	*On flushed ledge*	*On limpet shells and gravel*
Caloplaca sp.	1f	–	–	–	f–a
Cladonia furcata	–	o	–	o	–
Cladonia metacorallifera	–	o	–	r	–
Haematomma erythromma	o	–	–	–	1f
Himantormia lugubris	o	o	–	–	–
Lecania brialmontii	1f	–	–	–	–
Lecanora aspidophora	f	f	–	–	–
Leptogium puberulum	–	–	r	o	–
Massalongia carnosa	o	–	–	–	–
Mastodia tesselata	–	–	–	–	1f
Parmelia saxatilis	o	o	–	–	–
Physcia caesia	1f	–	–	–	1f
Psoroma follmannii	–	–	–	o	–
Rhizocarpon geographicum	f	f	–	–	–
Rinodina sp.	o	–	–	–	–
Sphaerophorus globosus	–	f	–	–	–
Umbilicaria antarctica	f	o	–	–	–
Umbilicaria decussata	r	–	–	–	–
Usnea antarctica	f–a	f–a	–	–	–
Usnea fasciata	o–f	o–f	–	–	–
Xanthoria candelaria	f	–	–	–	–
Xanthoria elegans	1f	–	–	–	r
Alga					
Prasiola crispa	–	–	o	o	r
Vascular plants					
Colobanthus quitensis	–	–	–	o	–
Deschampsia antarctica	–	–	o	o	–

* This community has not been recognized as a sociation since stands were seldom extensive and the cover and frequency of its component species was not uniform.

Abbreviations as for Table V.

provided by I. M. Lamb, it has been possible to distinguish several sociations within the *Caloplaca–Xanthoria* association, but no quantitative data are available to describe them in detail. Within and a little above the hygrohaline zone a distinct *Caloplaca* sociation was locally well represented, in which one or more species of *Caloplaca* predominated above the *Verrucaria*-dominated sociations (see below). The smooth granodiorite surfaces around and below bird perches were extensively colonized by stands of the *Xanthoria elegans–Haematomma erythromma–Mastodia tesselata* sociation (p. 100) with *M. tesselata* frequently predominating and locally providing up to 90 per cent cover over small areas of rock. However, it was noted that the actual perches frequented by gulls, skuas, sheathbills, etc., were generally devoid of vegetation, with the exception of scattered thalli of species of *Buellia*, particularly *B. latemarginata*. This was presumably due to the effects of excessive trampling and dunging. Similarly, Lamb noted that localized patches of apparently more acidic rock were avoided by most lichens and occurred as barren surfaces within certain comparatively dense stands. On the more sheltered rock faces below bird perches, *Lecania brialmontii*, *Lecanora aspidophora*, *Rinodina petermannii* and *Xanthoria candelaria* were frequent associates in this sociation. In some situations the cushion-shaped thalli of *Lecania brialmontii* were locally dominant over several square metres of rock. Elsewhere on rocks frequently used as bird perches, heterogeneous stands covering many square metres were dominated by nitrophilous species of *Buellia* (notably *B. augusta*, *B. inordinata*, *B. isabelina*, *B. latemarginata* and *B. anisomera*—the latter a frequent epiphyte on *B. russa*—while *B. coniops*, *B. granulosa* and *B. subpedicellata* occupied slightly less nitrophilous situations), *Lecanora aspidophora* and *L. atra*, *Huea grisea*, *Rinodina petermanii* and scattered colonies of *Lecidea placodiiformis* and other species of *Lecidea*.

Loose stones in rock depressions, which Lamb noted were deeply covered by snow throughout winter, supported diffuse stands containing *Acarospora macrocyclos*, *Huea cerussata*, *Lecania brialmontii*, *L. racovitzae* and several species of *Buellia*. It is of interest to note that in such hollows there were often accumulations of almost spherical colonies of detached thalli of *Lecania brialmontii*. Lamb (unpublished notes) has noted that these lichen nodules, which were originally attached to rock surfaces, can be blown by strong winds for long distances over land or sea ice to neighbouring islands.

Within the littoral zone, on Goudier Island, several species of *Verrucaria* were widespread and locally abundant, particularly on the more sheltered eastern and south-eastern sides. It was clear that these stands consisted of a number of definable sociations and, while sometimes comprising only a single species, other genera were rarely associated. In recent descriptions of the vegetation of the maritime Antarctic (e.g. Gimingham and Smith, 1970; Lindsay, 1971*d*; Smith, 1972), a *Verrucaria* sociation was included within the *Caloplaca–Xanthoria* association. However, from the intensive study of the *Verrucaria*-dominated communities on Goudier Island by Lamb (1948), together with observations by one of the authors (R.I.L.S.) and discussions with I. M. Lamb and D. C. Lindsay, it is proposed to erect a *Verrucaria* association in which several sociations dominated by one or more species of *Verrucaria* may be recognized. This association is widespread in most coastal areas throughout the maritime Antarctic, and a brief description of its sociations is provided below, following the procedure of Smith (1972). However, there are still too few data on the phytosociology of these lichens and future revision may be necessary.

Verrucaria association. Coastal rocks from a little below the lower spring-tide level to *c.* 1–3 m. above high-water mark in most areas of the maritime Antarctic are colonized by locally extensive continuous or diffuse stands formed almost entirely by species of the genus *Verrucaria*. Two groups of maritime species of *Verrucaria* may be recognized, namely, those occurring in the salt-spray or hygrohaline zone and those occupying habitats in or below the intertidal or hydrohaline zone (Lamb, 1948). One common hydrophilous species which extends inland, *V. elaeoplaca*, forms small discontinuous stands on stones and rock surfaces soaked by nitrogenous melt water. The distribution of the halophilous stands on coastal rocks in the littoral zone appears to be governed largely by the degree of exposure to rough seas and the scouring action of brash and fast ice in the vicinity of tide cracks. In more sheltered situations there is often a well-defined series of crustose lichen zones related to the exposure

and salinity of the habitat, with the upper *Verrucaria*-dominated stands commonly intergrading with one or more *Caloplaca*-dominated sociations.

Verrucaria serpuloides sociation. Predominant species: *Verrucaria serpuloides.* Habitat: rocks "below the level of the lowest spring tides and therefore permanently submerged" (Lamb, 1948). Also in intertidal rock pools. Altitudinal range: 0–1·5 m. (−10 m.) below the lowest low-water level.

Lamb (1948) described *Verrucaria serpuloides* as an obligate submarine lichen of the middle hydrohaline zone remaining consistently below the lowest low-tide level and he stated that it is the only known marine lichen which passes its entire existence submerged. *V. serpuloides* has been collected down to a depth of 10 m. at Gamma Island in the Melchior Archipelago (Lamb, 1970), and on Goudier Island he described it as forming an "association" with an encrusting calcareous alga (? *Lithophyllum* sp.). The upper margin of these black stands frequently formed a distinctive "trim line" coinciding with the surface of water in pools.

Verrucaria microspora–Verrucaria psychrophila sociation. Predominant species: *Verrucaria microspora* and *V. psychrophila.* Habitat: rocks in the intertidal zone. Altitudinal range: 0–2 m. above low-water level.

These two species occupying the upper hydrohaline or intertidal zone have been grouped together to constitute this sociation characteristic of intertidal rocks, although they were not always associated, and each also formed pure stands. Lindsay (1971*d*) described *V. psychrophila* as forming an extensive zone around the high-water level in the South Shetland Islands, while similar stands have been noted in the South Orkney Islands (Smith, 1972).

Verrucaria ceuthocarpa–Verrucaria tesselatula sociation. Predominant species: *Verrucaria ceuthocarpa* and *V. tesselatula.* Habitat: rocks in the salt-spray zone just above high-water level. Generally encrusted with salt-water ice in winter. Altitudinal range: 0·5–2 m. above high-water mark.

According to Lamb (1948), these species are characteristic of the lower hygrohaline or salt-spray zone. Of the principal components of this sociation, only *Verrucaria ceuthocarpa* was recorded on Goudier Island where it formed locally extensive open encrustations on rocks subjected to regular deposits of sea spray. Farther north in the South Shetland Islands (Lindsay, 1971*d*) and in the South Orkney Islands (Smith, 1972), this species formed mixed stands with *V. tesselatula* in similar habitats. According to Lindsay, *V. ceuthocarpa* occupied the more exposed parts of headlands and cliffs, while *V. tesselatula* appeared to prefer slightly sheltered situations. On Goudier Island, *V. dispartita* was also frequent in this habitat but is not known in the more northerly localities (Lamb, 1948). *V. maura* was also associated in these stands in the South Orkney Islands (Smith, 1972). This sociation commonly integrated with a *Caloplaca* sociation in which *C. cirrochrooides* usually predominated.

Verrucaria elaeoplaca sociation. Predominant species: *Verrucaria elaeoplaca.* Habitat: rocks and stones intermittently irrigated by nitrogenous melt water. Altitudinal range: *c.* 3–35 m.

Verrucaria elaeoplaca forms small stands on rocks from close to the shore to several hundred metres inland in most regions of the maritime Antarctic. It was characteristic of stones in melt-water channels and pools, and rock surfaces soaked by snow melt enriched with nitrogen from bird excrement, and was thus typical of wet stony conditions in and near penguin colonies (e.g. on Lécuyer and Jougla Points, Wiencke Island) and close to colonies or perches of gulls, skuas and cliff-breeding petrels. On Goudier Island, *V. elaeoplaca* occurred only as small diffuse stands in rock channels, the margins of melt pools and occasional sloping rock surfaces which received irregular soakings of nitrogenous melt water. Where the habitat appeared to be less influenced biotically, the *Verrucaria* was replaced locally by *Staurothele gelida.*

Moss turf sub-formation

Banks of the tall turf-forming mosses, *Polytrichum alpestre* and *Chorisodontium aciphyllum*, were frequent on the north-facing slopes of the larger islands in Arthur Harbour (particularly

Litchfield, Hermit and Laggard Islands) and near Norsel Point. As with the *Polytrichum alpestre–Chorisodontium aciphyllum* association in the Argentine Islands, these stands were dominated by *P. alpestre*, while *C. aciphyllum* was only a casual associate and occasionally absent. The only extensive pure *Chorisodontium aciphyllum* bank noted was on a moist slope on the north side of Litchfield Island although small banks of a few square metres occurred on the other islands. On Litchfield and Hermit Islands there were *Polytrichum*-dominated banks of *c.* 400 m.^{2} with a peat depth reaching *c.* 1 m. on the down-hill sides of the banks. Smaller banks occurred to near the summits of these islands.

Pohlia nutans was the principal moss associate, while the hepatics *Barbilophozia hatcheri* and *Cephaloziella varians* were almost always present and occasionally formed thin mats over moribund *Polytrichum alpestre* and on the sides of fissures in the peat. Small basidiomycete fungi were also occasionally present amongst the moss shoots. Moist depressions in the banks were colonized by *Drepanocladus uncinatus* but this species seldom invaded stands of the turf-forming moss. Epiphytic lichens varied in their cover abundance but they were generally more frequent where the banks were more exposed. Species of *Cladonia*, *Sphaerophorus globosus* and encrustations of *Ochrolechia frigida* were locally abundant, while *Cornicularia aculeata*, *Stereocaulon alpinum* and *Usnea antarctica* were rare. An analysis of two sociations is given in Table IX.

Polytrichum alpinum did not form extensive stands and these were generally restricted to broad rock ledges and moist stony soil which had accumulated below rock faces. Open stands

TABLE IX. PERCENTAGE COVER AND PERCENTAGE FREQUENCY OF SPECIES IN TWO SOCIATIONS OF THE *Polytrichum alpestre–Chorisodontium aciphyllum* ASSOCIATION ON HERMIT ISLAND

Species	*Polytrichum alpestre–Chorisodontium aciphyllum -lichen sociation*	*Polytrichum alpestre–lichen sociation*
Mosses		
Chorisodontium aciphyllum	11;100	–
Pohlia nutans	9; 90	4; 85
Polytrichum alpestre	56;100	84;100
Hepatics		
Barbilophozia hatcheri	–	1; 40
Cephaloziella varians	5;100	4;100
Lichens		
Cornicularia aculeata	–	1; 10
Cladonia metacorallifera	3; 90	1; 60
Cladonia furcata	4;100	3; 80
Cladonia sp. (? *C. chlorophaea*)	1; 40	1; 15
Ochrolechia frigida	7; 80	9; 90
Sphaerophorus globosus	17;100	2; 35
Stereocaulon alpinum	–	+; 10
Usnea antarctica	–	+; 10
Fungus		
Basidiomycete	–	<1; 20

All data were estimated as in Table VI.

of *P. alpinum* were also noted around colonies of giant petrels on Litchfield and Hermit Islands, where the species was accompanied by *Bryum algens*, *Ceratodon* cf. *grossiretis*, *Drepanocladus uncinatus*, *Pohlia nutans* and species of *Cladonia*. Near the former Palmer station south-east of Norsel Point, large circular stands of *Polytrichum alpinum* and *P. juniperinum* occurred on dry gravelly soil, with species of *Bryum*, *Ceratodon*, *Drepanocladus*, *Pohlia* and *Cladonia* again in association, together with scattered shoots of *Polytrichum piliferum* and *Brachythecium austro-salebrosum*. Where the substratum was damper, shallow *Polytrichum alpestre–Chorisodontium aciphyllum* banks replaced the other turf-forming mosses.

No species of *Polytrichum* or *Chorisodontium aciphyllum* were seen on Goudier Island, although *P. alpinum* has been recorded from there (Greene and others, 1970). However, it was observed in small scattered colonies near Lécuyer Point on Wiencke Island but the two taller turf-forming mosses, *P. alpestre* and *C. aciphyllum*, appeared to be absent.

Moss carpet sub-formation

Small stands of the *Brachythecium* cf. *antarcticum–Calliergon sarmentosum–Drepanocladus uncinatus* association were frequent wherever the substratum was moist, although there were few melt pools and streams to permit extensive development of these carpet-forming communities. In the Arthur Harbour area, the drier more gravelly soils supported pure stands of *Drepanocladus uncinatus*, frequently with a mat growth form which became more carpet-like as the habitat became wetter. In these latter situations *Brachythecium* cf. *antarcticum* usually predominated, but both species were often intermixed and were frequently infected by white circular hyphal colonies of an ascomycete fungus (*Thyronectria antarctica* var. *hyperantarctica*). *Pohlia nutans* was frequently present and in the drier habitats it became more extensive and small colonies of this short turf-forming moss coalesced to produce a carpet-like growth form. *Calliergon sarmentosum* was not recorded. The largest pure stand of the *Drepanocladus*, measuring about 10 m. by 15 m., was seen on Hermit Island.

On Goudier Island this sub-formation was restricted to small closed stands of *Drepanocladus uncinatus*, usually with *Bryum algens* associated, occurring wherever there was some degree of moisture. Larger mixed stands of *Brachythecium* cf. *antarcticum* and *D. uncinatus* occurred along the margins of melt streams and in wet hollows near a gentoo penguin (*Pygoscelis papua*) rookery on Jougla Point, Wiencke Island.

Moss hummock sub-formation

This sub-formation shows an increasing tendency to become less clearly defined with increasing latitude along the west coast of the Antarctic Peninsula. Stands of the *Bryum–Drepanocladus uncinatus* association on Signy Island occupy flushed habitats where the principal mosses develop a distinctive large cushion growth form which produces a hummocky surface where cushions coalesce. However, suitable habitats become increasingly scarce farther south and the component species of this association tend to occupy considerably drier and less base-rich habitats. *Drepanocladus uncinatus* develops a more typical mat or carpet growth form, while *Bryum algens* produces shorter and more compact cushions more typical of its performance in the *Tortula–Grimmia antarctici* association and in crevice communities.

While the *Bryum–Drepanocladus uncinatus* association is commonly represented in damp or mildly flushed areas and the margins of melt streams in most western coastal areas of the Antarctic Peninsula, the more extensive stands are less uniform in composition and the large hummocky growth form of the predominant species is no longer prevalent. Such stands appear, therefore, to incorporate characteristics of several associations and indeed sub-formations. Depending on the habitat, these stands in the Arthur Harbour area may resemble more closely sociations typical of the *Brachythecium* cf. *antarcticum–Calliergon sarmentosum–Drepanocladus uncinatus* association in which *D. uncinatus* was dominant or those of the *Tortula-Grimmia antarctici* association in which small cushions of *Bryum algens* predominated with *Brachythecium austro-salebrosum*, *Drepanocladus uncinatus*, *Tortula conferta* and *T.* cf. *grossiretis* as frequent associates. Occasionally, in suitable habitats, *Colobanthus quitensis* and *Deschampsia antarctica* were also present in association with these bryophytes, as was a small basidiomycete fungus which occurred on all the islands visited, including Goudier Island.

Elsewhere, on moist pockets of soil enriched by accumulations of limpet shells deposited

by gulls or irrigated by run-off from bird perches, small stands of the *Bryum–Drepanocladus uncinatus* association prevailed. These closely resembled stands of the *Tortula–Grimmia antarctici* association occupying similar base-rich habitats, but in which the *Bryum* and the *Drepanocladus* were the predominant species. These habitats were most frequent on Outcast and Goudier Islands where small stands, often barely 1 m. across, dominated by *D. uncinatus* with *B. algens* as the chief associate, were widespread. *Ceratodon* cf. *grossiretis*, *Pohlia nutans*, *Tortula conferta*, *T.* cf. *grossiretis* and *Prasiola crispa* were also usually present. Table X gives

TABLE X. FREQUENCY ASSESSMENT OF SPECIES RECORDED IN THE *Bryum–Drepanocladus uncinatus* ASSOCIATION ON HERMIT, LAGGARD AND GOUDIER ISLANDS

Species	*Hermit and Laggard Islands*	*Goudier Island*
Mosses		
Brachythecium austro-salebrosum	1f	o
Bryum algens	o–a	1a
Bryum sp.	–	o
Ceratodon cf. *grossiretis*	f	o
Drepanocladus uncinatus	a	1a
Pohlia cruda var. *imbricata*	o	–
Pohlia nutans	1f	o
Tortula conferta	o	r
Tortula cf. *grossiretis*	o	–
Hepatics		
Barbilophozia hatcheri	1f	–
Cephaloziella varians	1f	–
Lichens		
Acarospora macrocyclos	r	o
Caloplaca sp.	–	o
Cladonia sp.	o	–
Leptogium puberulum	o	–
Psoroma follmannii	f	o
Staurothele gelida	–	r
Unidentified crustose species	f	–
Alga		
Prasiola crispa	o	o
Vascular plants		
Colobanthus quitensis	o	–
Deschampsia antarctica	o–1a	–

Abbreviations as for Table V.

a composite list of species and their relative frequency of occurrence in this association on Hermit, Laggard and Goudier Islands.

The *Brachythecium austro-salebrosum* association was represented only in the Arthur Harbour area where small stands of isolated or coalesced large cushions of this moss occurred on moist north-facing rock faces and ledges. It was, however, more often incorporated in stands of the *Bryum–Drepanocladus uncinatus* association in similar habitats.

Alga and snow alga sub-formations

Although *Prasiola crispa* occurred sparsely in most damp habitats where it was associated with various bryophytes, the alga formed stands in only a few localities. These were best developed in the vicinity of the penguin colonies on Litchfield and Humble Islands and also at Jougla Point close to Goudier Island. Small areas of red discoloration caused by snow algae were noted on the Marr Ice Piedmont (Anvers Island) and the glaciers bordering Port Lockroy.

Grass and cushion chamaephyte sub-formation

Deschampsia antarctica and *Colobanthus quitensis* were present only as associates in various cryptogamic communities and were not seen to coalesce to form definable stands. In the Arthur Harbour area both species were commoner and more widely distributed than in the Argentine Islands.

Deschampsia antarctica was locally common on the northern sides of Laggard, Hermit, Litchfield and Humble Islands, and was also widespread near Norsel and Bonaparte Points. It is also known to occur on an unnamed promontory in Biscoe Bay (Turquet, 1906) and on an unnamed island between Anvers Island and Port Lockroy (Greene and Holtom, 1971). *Colobanthus quitensis* had a similar distribution, with the exception of Humble Island and the latter unnamed island, but it was nowhere abundant. The largest open stand of *C. quitensis* with associated cryptogams on the north-east side of Litchfield Island measured about 9 m. by 2 m. Both vascular plants occurred in moist soil-filled depressions and on rock ledges, although in the vicinity of Norsel and Bonaparte Points the ground was stonier and drier, and the plants were small and yellowish but most had inflorescences. On Hermit Island the grass was an associate in open bryophyte and lichen communities from near sea-level (1·5 m.) to the summit (*c.* 60 m.), while *Colobanthus quitensis* reached only *c.* 35 m. The species most typically associated with the flowering plants were those of the *Bryum–Drepanocladus uncinatus* association such as have been listed above.

Although neither vascular plant occurred on Goudier Island, *Deschampsia antarctica* has been reported from Lécuyer Point (Wiencke Island) (Greene and Holtom, 1971).

Notes on Other Areas

A few islands close to the Graham Coast and several localities on the mainland were visited in 1964–65 and the vegetation cursorily examined and collections of plants made. In addition, rock exposures on a number of other islands as well as the scattered localities along the coast of the mainland were observed at a distance of several hundred metres from a ship, and the presence of stands of vegetation recorded, although it was seldom possible to identify accurately the community types represented.

Islands near the Graham Coast

Wauwermans Islands. Some of this group of islands in Bismark Strait were observed from a distance of 0·2–0·5 km. The low-lying islands in this archipelago are similar in topography to those of the Argentine Islands and most possess dome-shaped ice caps and little exposed rock. The most prominent vegetation was the *Caloplaca–Xanthoria* association on low-lying rocks, while species of *Usnea* were also noted at higher altitudes. Small stands of moss were visible near the shore on the northern sides of a few of the islands. Those with a light green colour were probably dominated by *Drepanocladus uncinatus* and by shallow *Polytrichum alpestre–Chorisodontium aciphyllum* banks, whereas the blackish vegetation on rocks was most likely to be stands of *Andreaea* spp.

Booth and Hovgaard Islands. These mountainous islands lie in the north-east sector of the Wilhelm Archipelago. Observations were restricted to the north and east coasts where stands of the *Caloplaca–Xanthoria* association were locally extensive near sea-level on rocks on both islands. Species of *Usnea* occurred on dry wind-swept rock faces to over 300 m. on Booth Island. Moist rocks on both islands supported small stands dominated by species of *Andreaea*, while the others were colonized by large yellow-green cushions of *Brachythecium austro-salebrosum* and possibly also of *Drepanocladus uncinatus*. Turquet collected a number of mosses on these islands, including species of *Andreaea*, *Brachythecium*, *Bryum*, *Drepanocladus*, *Grimmia*, *Pohlia* and *Polytrichum* (Cardot, 1908). *Deschampsia antarctica* was also reported from Booth Island (Turquet, 1906).

Petermann Island. This island lies between the Argentine Islands and Hovgaard Island and, although heavily ice-capped, abundant vegetation was seen to extend to over 100 m. at the northern end. The most conspicuous feature was extensive *Polytrichum alpestre–Chorisodontium aciphyllum* banks, almost 1 m. in depth, on north-facing slopes and broad ledges. These banks were considerably larger than those in the Argentine Islands, although their species composition was virtually identical. The moss carpet sub-formation was represented by mixed and pure stands formed by *Brachythecium* cf. *antarcticum* and *Drepanocladus uncinatus* which occupied the wetter situations. Open stands of the *Andreaea–Usnea* association occupied most of the more exposed and drier rocky terrain. Here species of *Andreaea*, *Dicranoweisia*, *Umbilicaria* and *Usnea* were locally abundant, while *Cornicularia epiphorella* was noted amongst the latter on a cliff at the northern end. *Himantormia lugubris*, which was collected by Gain in 1909, was not observed on the island.

A wide variety of bryophytes was recorded in moist flushed rock crevices in a cliff at the northern end of the island. These included species of *Amblystegiella*, *Grimmia*, *Metzgeria* and *Plagiothecium*, together with *Bartramia patens*, *Bryum argenteum*, *Pohlia cruda* var. *imbricata*, *P. nutans* and *Sarconeurum glaciale*. *Deschampsia antarctica* was frequent on ledges and rocky slopes, while *Colobanthus quitensis* was seen in only a single stand where it was relatively abundant. Sea cliffs had locally extensive stands of the *Caloplaca–Xanthoria* association.

Berthelot Islands. Only the largest of this group of islands, to the north-west of Collins Bay, was visited in November 1964 when much of the vegetation was still snow-covered. Extensive stands of the *Polytrichum alpestre–Chorisodontium aciphyllum* association extended along the north side of the island and to an altitude of *c.* 125 m. Banks of these mosses were also noted on much of Green Island to the north-west of the main island. On drier gravelly detritus, *Polytrichum alpinum* and *P. piliferum* were common. No stands of the moss carpet sub-formation were visible since all depressions and level ground were still covered by snow. Large cushions of *Bryum algens* and *Brachythecium austro-salebrosum* were present on wet ground below a high cliff. The *Andreaea–Usnea* association was widespread and represented by sociations similar to those seen in the Argentine Islands. *Bryum argenteum* and *Cystocoleus niger* occurred on dry rock surfaces, while *Grimmia* cf. *apocarpa* and *Peltigera spuria* grew on sheltered ledges. A species of *Metzgeria* and *Pohlia cruda* var. *imbricata* were recorded in several moist crevices, together with numerous other bryophytes. *Colobanthus quitensis* was infrequent and not seen above 30 m. but *Deschampsia antarctica* was locally common on the north coast and was observed up to 125 m. The grass has also been collected on Green Island (Greene and Holtom, 1971).

Darboux and Somerville Islands. Darboux Island, situated south-west of Collins Bay, was observed from a short distance offshore. Several small *Polytrichum alpestre–Chorisodontium aciphyllum* banks were prominent. However, *Deschampsia antarctica* was collected near the nest of a Dominican gull at 6 m. a.s.l. on a small islet close to the north-west side of Darboux Island. The grass has also been collected on Somerville Island (Greene and Holtom, 1971), a small ice-capped island in Grandidier Channel north-west of Darboux Island. *Andreaea regularis* and *Pohlia nutans* have been recorded on that island (Greene and others, 1970), as well as several other species of moss and lichen, while species of *Cladonia*, *Usnea* and *Umbilicaria* have also been collected there (personal communication from D. C. Lindsay).

Localities on the Graham Coast

Edge Hill. Edge Hill rises precipitously from Penola Strait to an altitude of 291 m. The south and east sides are extensively covered by permanent snow and ice but vegetation is widespread on the snow-free north and west slopes. Banks of *Polytrichum alpestre* with scattered *Chorisodontium aciphyllum* and other typical associates were conspicuous features ascending almost to the summit. Large banks occurred on sheltered slopes and broad ledges and where the turf had grown over the edge of the ledges, large pieces had broken off and lay on the sea ice below.

The *Andreaea–Usnea* association was well represented and several uncommon bryophytes occupied the damper crevices at low altitudes, including *Amblystegiella* cf. *densissima*, *Didymodon gelidus* and *Sarconeurum glaciale*. *Polytrichum alpinum* and *P. piliferum* were frequent on dry gravelly substrata, while *Dicranoweisia grimmiacea* was recorded in association with species of *Andreaea*. Wet rocks and hollows at low altitudes supported small stands of *Drepanocladus uncinatus* and *Brachythecium austro-salebrosum*. Scattered tufts of *Deschampsia antarctica* were seen up to *c.* 155 m.

Vegetation was also locally extensive on the rocky headland *c.* 1·5 km. south-south-west of Edge Hill. This cape is formed by a ridge extending westwards from Mount Mill and a little to the north of Rasmussen Island. Locally extensive stands of the moss turf sub-formation ascended to over 300 m. and *Deschampsia antarctica* was seen both near sea-level and at *c.* 60 m

Cape Tuxen and Mount Demaria. Cape Tuxen, with Mount Demaria to its south-east, is due east of the southernmost of the Argentine Islands. The cape is largely snow-free on its west and north sides in summer and consequently supported extensive open vegetation. The moss turf sub-formation was widespread and shallow banks of the *Polytrichum alpestre–Chorisodontium aciphyllum* association ascended to *c.* 340 m. As on Edge Hill, *Polytrichum alpinum* and *P. piliferum* were frequent on drier ground up to 310 m. Species of *Cladonia*, *Sphaerophorus globosus*, *Ochrolechia frigida*, *Pohlia nutans*, *Barbilophozia hatcheri*, *Cephaloziella varians* and *Usnea antarctica* were frequent associates with the principal mosses.

Most exposed rocks and stony ground were extensively colonized by open stands of the *Andreaea–Usnea* association, with *Andreaea regularis* recorded at over 370 m. on both rock and soil, and *A. gainii*, *Grimmia antarctici*, *G.* cf. *donniana*, *Pohlia nutans* and the hepatics *Barbilophozia hatcheri* and *Cephaloziella varians* all occurring above 310 m. *Bartramia patens*, *Dicranoweisia grimmiacea*, *Usnea antarctica*, *U. fasciata* and numerous crustose lichens were also frequent associates on the dry rocks, while *Racomitrium austro-georgicum* was collected at *c.* 100 m. by Gain (Cardot, 1913). The more gravelly substrata were sparsely colonized by short cushion mosses and species of *Cladonia*, *Sphaerophorus globosus* and *Stereocaulon alpinum*. Crevices supported diverse assemblages on north-facing cliffs. Rare species such as *Didymodon gelidus*, *Distichium capillaceum*, *Peltigera rufescens* and a species of *Metzgeria* were restricted to these moist habitats. Cliffs near the shore were variably colonized by stands of *Caloplaca* spp. and other halophilous and nitrophilous epipetric species.

Due to the absence of wet habitats, the moss carpet sub-formation was reduced to a few small stands dominated by *Drepanocladus uncinatus* and *Brachythecium austro-salebrosum* while *Leptogium puberulum* was an occasional associate. *Deschampsia antarctica* was not abundant but scattered tufts occurred as high as 185 m., one of the highest records for the grass in the Antarctic botanical zone (Greene and Holtom, 1971).

Cape Pérez. This headland lies on the south side of Collins Bay and most of the snow-free areas are situated above the steep coastal cliffs. Once again, vegetation was best developed on the north- and west-facing slopes and banks of the *Polytrichum alpestre–Chorisodontium aciphyllum* association were observed above some precipitous crags. *Polytrichum alpinum* and *P. piliferum* were also frequent as associates in other communities. Open stands of the *Andreaea–Usnea* association predominated on exposed rocks, while the crustose lichen sub-formation was widespread near sea-level. Crevices supported a variety of bryophytes and occasional lichens, of which *Brachythecium austro-salebrosum*, *Bryum algens*, *Pohlia cruda* var. *imbricata* and *Peltigera rufescens* were regularly present, while *Bryum argenteum* and a species of *Hypnum* were rare associates. *Pottia charcotii* was collected by Gain (Cardot, 1913) from a rock crevice,

the only record for this genus in this region of the maritime Antarctic. Wet ledges were locally colonized by small stands dominated by *Brachythecium austro-salebrosum* and *Drepanocladus uncinatus* with *Leptogium puberulum* and *Deschampsia antarctica* occasionally associated. The grass was frequent up to *c.* 30 m.

Mount Mill, Mount Balch and Mount Boland. These peaks, situated *c.* 1·2, 4 and 8 km. inland respectively, rise to between 700 and 1,300 m. Although they were visited in September, many north- and west-facing rock surfaces were snow-free. A scree slope on the east side of the col between Mount Mill and Mount Balch, at over 300 m., supported a well-developed *Usnea–Umbilicaria–Alectoria* sociation. This community, comprising principally *Usnea antarctica*, *Umbilicaria decussata*, *Alectoria minuscula* and *A. pubescens*, has been reported previously only from Blaiklock and Horseshoe Islands in the north of Marguerite Bay (Gimingham and Smith, 1970). No bryophytes were recorded and the higher rock faces did not appear to be colonized by lichens.

The coarse granitic outcrops on Mount Boland appeared to be devoid of vegetation, although patches of reddish brown discolouration on a rock surface at 775 m. may have been colonies of *Lecidea dicksonii*.

Coast between Deloncle Bay and Girard Bay

A number of snow-free cliffs and ledges along the east coast of Lemaire Channel possessed locally extensive stands of mosses and lichens, although these were only observed from several hundred metres offshore. Stands of greenish moss (possibly including *Drepanocladus uncinatus*) and blackish moss (*Andreaea* spp.) and small banks of *Polytrichum alpestre* were noted near Loubat Point on the north side of Deloncle Bay. It is possible that it was near here that Racovitza collected a number of moss species in 1898 "à l'entrée du chenal de Lemaire; roches au milieu d'un glacier, alt. 50 mètres" (Cardot, 1901, 1908). Extensive stands of green and blackish moss also occurred on wet rock surfaces on the south side of Girard Bay, while assemblages dominated by greenish grey species of *Usnea* and orange encrustations of species of *Caloplaca* or *Xanthoria* were also locally prominent.

Discussion

From the foregoing account of the vegetation of the Arthur Harbour–Argentine Islands region, it is clear that many of the terrestrial plant communities of this sector of the Antarctic Peninsula bear a close similarity to those of the South Orkney Islands (Smith, 1972) and South Shetland Islands (Lindsay, 1971*d*; Allison and Smith, 1973). But as a result of the narrower range of habitat types, the increased aridity and decreased length of the growing season with respect to air temperature in the more southerly region there is a decline in the number of individual species, in the diversity and complexity of the plant assemblages, and in the spatial distribution and extent of these communities. As with the vegetation of the South Orkney and South Shetland Islands, the development and species composition of communities in this more southerly region are related primarily to such environmental factors as moisture availability, type and stability of substratum, exposure to wind and aspect. Longton (1967) also commented on the progressive restriction of habitats southward along the west coast of the Antarctic Peninsula with a consequent reduction of closed bryophyte cover which tends to become increasingly dependent upon moisture availability. Despite the small area of snow-free terrain in the Arthur Harbour–Argentine Islands region, vegetation is as well developed here as anywhere in the maritime Antarctic. Most of the habitats available for plant colonization support stands ranging from small, closed monospecific communities to locally extensive and relatively complex open assemblages of mosses and lichens.

A characteristic feature of communities in the South Orkney Islands is that many have clearly defined boundaries, usually related to micro-environmental factors, and therefore exist as discrete classifiable units (Smith, 1972). Although ecotones are frequent between adjacent sociations, these generally form narrow assemblages of variable species composition and growth form. Unlike the accepted sociations, these heterogeneous stands are seldom

uniformly recurrent and consequently are difficult to classify. One of the major differences between the two is that in the Arthur Harbour–Argentine Islands region environmental variation tends to be less clearly demarcated, ecotones are frequently extensive and the existence of widespread floristic gradients suggests that the units of vegetation comprise numerous noda in a continuous network of variation, with the more uniform and better-developed communities occupying the habitats with the most stable environmental conditions. Nonetheless, it has been possible to classify readily the vegetation of this area at least to the association level, and frequently to the sociation level.

Another principal difference between the vegetation of the Arthur Harbour–Argentine Islands region and that of the more northerly island groups is the limitation, in the more southerly region, of communities of the *Tortula–Grimmia antarctici*, *Bryum–Drepanocladus uncinatus* and *Brachythecium austro-salebrosum* associations to restricted locally base-rich habitats which are usually close to bird colonies or on accumulations of shells deposited by gulls. The widespread outcrops of marble and amphibolite on Signy Island and the lavas and tuffs on certain of the South Shetland Islands provide base-rich habitats for extensive calcicolous and flush communities.

There are several notable phytosociological similarities between the two regions, perhaps the most prominent being the widespread occurrence of the *Polytrichum alpestre–Chorisodontium aciphyllum* association in both regions. Several sociations in the *Andreaea–Usnea*, *Caloplaca–Xanthoria*, and *Brachythecium* cf. *antarcticum–Calliergon sarmentosum–Drepanocladus uncinatas* associations occupy precisely the same habitats and comprise the same species as their counterparts in the South Orkney and South Shetland Islands. However, a number of sociations are described for the first time, since they have not previously been reported, while an important new association has been recognized, incorporating the *Verrucaria*-dominated communities of coastal rocks. These assemblages had previously been grouped together by Gimingham and Smith (1970) and Smith (1972) as a *Verrucaria* sociation within the *Caloplaca–Xanthoria* association, as there had been insufficient data available to permit a more critical treatment of these crustose lichen communities.

Possibly correlated with the decrease in vegetational diversity is the greater ecological amplitude in the higher latitudes of a number of prominent and widespread species, particularly mosses. This is most noticeable in the fruticose lichen and moss cushion sub-formation and the moss hummock sub-formation. On Signy Island, where there is an exceptionally wide range of habitat types by Antarctic standards, many species tend to have specific environmental requirements, particularly with regard to edaphic factors. Hence, certain groups of bryophytes and lichens with similar preferences and tolerances associate to form distinct assemblages which recur wherever the same combination of environmental conditions prevail. Thus, on Signy Island sociations of the *Andreaea–Usnea* association tend to be restricted to the more acidic, often dry and wind-swept habitats, while those of the *Tortula–Grimmia antarctici* association occur in similar situations on base-rich rock and soil. The *Bryum algens–Drepanocladus uncinatus* association is barely represented on Signy Island but it appears to be incorporated in the stands of the *Tortula–Grimmia antarctici* association or even in the *Bryum algens* or *Bryum algens–Drepanocladus uncinatus–Tortula excelsa* sociations of flushed habitats (Smith, 1972). The predominant genera represented in these assemblages, i.e. *Andreaea*, *Bryum*, *Drepanocladus*, *Grimmia*, *Tortula* and *Usnea*, include some of the most widespread species in the maritime Antarctic tolerating the broadest spectrum of environmental conditions. On Signy Island, many species appear to have specific edaphic requirements and those with similar demands tend to associate to form distinct sociations typical of a particular habitat regime. However, as the diversity of habitats becomes more restricted and conditions become more extreme for plant growth in the more southerly region, several of these species tend to combine to produce new or heterogeneous communities. These intermediate stands are sometimes inconsistent in species composition and are difficult to classify since they represent ecotonal assemblages corresponding to environmental gradients.

In the Argentine Islands and neighbouring localities, where the rock types and derived soils are not particularly base-rich, calcifuge genera such as *Andreaea*, *Racomitrium*, *Umbilicaria* and *Usnea* commonly associated with the genera *Bryum*, *Grimmia* and *Tortula*, which on Signy Island tend to be typical calcicoles. Similarly, the *Bryum algens–Drepanocladus*

uncinatus component of the calcicolous *Tortula–Grimmia antarctici* or *Bryum algens* flush communities of Signy Island occurred in a much wider range of habitats farther south, where it became one of the commonest but seldom extensive sociations. These situations vary from comparatively acidic soils to pockets of calcareous shell soil and from dry to moderately wet conditions.

Another major difference in species composition between communities in the northern sector of the maritime Antarctic and the Arthur Harbour–Argentine Islands region is to be seen in the composition of the *Polytrichum alpestre–Chorisodontium aciphyllum* banks. In the more southerly localities, *P. alpestre* is the predominant turf-forming moss with *C. aciphyllum* seldom abundant and frequently absent, whereas in the South Shetland and South Orkney Islands, *C. aciphyllum* is the principal peat producer and *P. alpestre* is often absent. This variation in the performance of these two species throughout their range in the maritime Antarctic has been attributed to the availability of water, with *P. alpestre* increasing where the substratum becomes drier (Longton, 1967; Gimingham and Smith, 1970). A further difference is that the living surface of the more northerly moss banks is regularly colonized by epiphytic crustose and fruticose lichens of the genera *Alectoria*, *Buellia*, *Cladonia*, *Cornicularia*, *Ochrolechia*, *Sphaerophorus*, *Stereocaulon* and *Usnea*. However, in the Arthur Harbour–Argentine Islands region the fruticose species are restricted to malformed encrusting thalli of species of *Cladonia*, *Sphaerophorus globosus* and very rarely *Cornicularia aculeata* and *Usnea antarctica*. On the other hand, *Ochrolechia frigida* is often very abundant especially on the more exposed banks.

A number of species recorded in the Argentine Islands area appear to be at or near the southern limit of their geographical distribution, e.g. *Chorisodontium aciphyllum*, *Mielichhoferia austro-georgica*, *Cornicularia aculeata*, *C. epiphorella* and *Himantormia lugubris*. It is also of interest to note that neither *Caloplaca regalis* nor *Ramalina terebrata* were encountered in the Arthur Harbour–Argentine Islands region, although they are commonly associated in many northern coastal regions of the maritime Antarctic and also sporadically from the region of southern Anvers Island to southern Marguerite Bay (Follmann, 1965).

The reasons for the rarity or absence of certain species are attributed to their intolerance of the prevailing environmental conditions and to a lesser extent to the absence of specific habitats and the inability of propagules either to reach this area from farther north or to become established and colonize suitable habitats should they succeed in doing so. Despite the broader ecological amplitude of certain groups of species at the community level, a number of mosses and lichens, particularly fruticose species, have a considerably narrower ecological amplitude in the southern localities than in the more northerly sector of the maritime Antarctic. *Usnea antarctica* occurs commonly in a wide range of sociations both as a lithophyte and as an epiphyte on turf- and cushion-forming mosses and also colonizes gravelly soil and alien timber in the South Orkney Islands (Smith, 1972). In 1967 one of the authors (R.I.L.S.) observed the species growing abundantly on a wooden building and the deck of an old boat in the ruined whaling station on Deception Island. Farther south, however, it is almost entirely restricted to rock habitats. Several prominent species which appear to be at or near the southern limit of their geographical range in the Argentine Islands area are usually restricted to one type of habitat or occur within a single community type, whereas farther north they may occupy a variety of habitats and be components of several sociations, e.g. *Chorisodontium aciphyllum* and the fruticose lichens *Cornicularia aculeata*, *C. epiphorella*, *Himantormia lugubris* and *Sphaerophorus globosus*.

It is of interest to note that in the Argentine Islands several mosses produce sporophytes which have been seen only very rarely or not at all in the South Orkney Islands. These included *Bryum algens*, *Drepanocladus uncinatus*, *Pohlia cruda* var. *imbricata*, *P. nutans* and *Tortula* cf. *grossiretis*, while *Grimmia* cf. *donniana* and *Mielichhoferia austro-georgica*, although apparently absent from the South Orkney Islands, were also abundantly fertile here. The only known Antarctic locality where *Polytrichum alpestre* has been recorded with sporophytes was near Norsel Point in Arthur Harbour (Longton, 1972). Male inflorescences of both *P. alpinum* and *P. piliferum* were widespread and those of the latter species were noted at *c.* 250 m. at Cape Tuxen. Some lichens also exhibited increased fertility in this area, for instance most of the few collections of apotheciate *Usnea antarctica* have been collected in

the Argentine Islands (Lamb, 1964; Lindsay, 1969*a*), while *Ochrolechia frigida* is abundantly fertile throughout the Arthur Harbour–Argentine Islands region (Lindsay, 1971*e*). It is suggested that the reproductive success of these and numerous more commonly fruiting species in this region, in comparison with the northern sector of the maritime Antarctic, is due largely to the increased duration of sunshine combined with a reasonably favourable, if short, growing season and a non-limiting supply of moisture, at least in the majority of habitats occupied by the species concerned.

No detailed observations were made on the dynamics of the vegetation, but it was clear that pattern within and between communities was nowhere as well developed as that reported by Smith (1972) in the South Orkney Islands or by Lindsay (1971*d*) and Allison and Smith (1973) in the South Shetland Islands. This is largely due to the considerably narrower range of environmental gradients and to the shallower and much less extensive soil or fine debris and wet habitats. The various forms of frost action on ground habitats and consequently on the vegetation, which are characteristic features of environmental pattern farther north in the maritime Antarctic, were virtually absent from the localities examined in the Arthur Harbour–Argentine Islands region.

The most pronounced form of environmental pattern is exhibited by the altitudinal zonation of certain groups of lichens, particularly near sea-level. The zoned crustose lichen communities typical of coastal rocks in most regions of the maritime Antarctic are well represented only in the more sheltered localities. The best examples were seen on Goudier Island, some islands in Arthur Harbour and nearby promontories and islets, where distinct sociations dominated by one or more species of *Verrucaria* and to a lesser extent of *Caloplaca*, occupied specific habitats related to the degree of submergence by sea-water or of exposure to sea spray. Beyond the immediate influence of the sea, the uppermost of the halophilous communities intergrade with more "montane" assemblages even at low altitudes or with nitrophilous communities in the vicinity of bird perches or penguin rookeries and breeding colonies of other sea birds.

A close examination of plant colonization on two rock exposures protruding from ice cliffs in the Argentine Islands (Corner and Smith, 1973), has provided evidence to suggest that there has been some degree of ice recession in these islands within recent times. Although this retreat is only *c.* 1–2 m., it tends to contradict the findings of recent glaciological investigations (Thomas, 1963; Sadler, 1968). At both localities, one on Galindez Island and the other on the easternmost of the Corner Islands, the rock adjacent to the present ice edge was light in colour, devoid of any vegetation and usually clearly demarcated by a trim line beyond which pioneer plant colonists have become established. The number and size of these lichen and moss colonies increased progressively farther from the trim line, suggesting that plant colonization has kept pace with the rate of ice recession. Also with increasing distance from the trim line a succession of pioneer colonists could be traced as the habitat and micro-climate became modified away from the permanent ice. Similar trim lines have been observed at the foot of rock faces rising from permanent ice in a number of localities both on islands and on the mainland between Anvers Island and the Argentine Islands.

I. M. Lamb (personal communication) has indicated that certain changes have taken place in the predominantly lichen vegetation on Goudier Island during a period of 20 years, but he does not consider a modification of the climate to be the causal factor. Lamb has stated that, on re-visiting the island in 1965, it was "quite apparent that it [i.e. the lichen vegetation] had very considerably diminished since I first saw it in 1944, and I am sure that many of the species had totally disappeared". He considers that these changes had resulted from human activities and stated that "Already in 1945, when I left Port Lockroy after a year's sojourn . . . , the lichen vegetation on Goudier Island had been seriously disturbed by careless housekeeping, mainly by the scattering of coal ashes and garbage out of the house over the surrounding rocks. The beautiful mosaic of *Buellia russa* on granodiorite faces near the house . . . had been totally exterminated by coal ash by the time I left the following year." However, when one of the authors (R.I.L.S.) visited the island in 1967, it was noted that accumulations of coal ash had been partially re-colonized by scattered colonies of moss, chiefly *Bryum algens*, *Ceratodon* cf. *grossiretis* and *Drepanocladus uncinatus*, while occasional thalli of *Prasiola crispa* and a species of *Cladonia* had also become established. The apparent disappearance of *Grimmia* cf. *donniana*

and *Polytrichum alpinum* from Goudier Island provides further evidence of floristic changes within recent times.

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